EVALUATION OF THE REPELLENT EFFECTS OF DIFFERENT BOTANICAL EXTRACTS ON TOMATO INSECTS

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CERTIFICATE

This is to certify that the thesis entitled **"Evaluation of the repellent effects of different botanical extracts on tomato insects"** submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Department of Agricultural Chemistry, embodies the result of a piece of bona-fide research work carried out by **MD. ABU SAYED**, Registration **No. 10-04026** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2016 to March 2017 for the evaluation of the repellent effects of different botanical extracts on tomato insects.BARI tomato 15 was used as test crop. There were 7 treatment *viz*. i) Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval, ii) Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval, iii) Neem oil @ 3.0 ml L^{-1} of water at 5 days interval, iv) Neem oil @ 3.0 ml L^{-1} of water at 10 days interval, v) Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval, vi) Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval and vii) control (no repellant)was used for the experiment. The present study showed significant effect to control insects effectively. The lowest incidence of whitefly, jassid, aphid and leaf miners plant^{-1} (16.31, 1.60, 16.70 and 3.12 respectively) presence by number were found more effective with (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where control treatment gave the highest incidence (35.44, 4.10, 30.67 and 5.62 respectively). Treatment of T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) also showed highest percent reduction whitefly, jassid, aphid and leaf miners plant^{-1} over control (53.98, 60.98, 46.55 and 44.48% respectively). The highest plant height (105.66 cm), number of branches plant^{-1} (7.44), number of healthy fruits plant^{-1} (37.41), weight of healthy fruits plant^{-1} (1516.29 g), healthy fruit yield ha^{-1} (60.65 t) and total fruit yield ha^{-1} (65.55 t) also achieved by Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where control treatment gave the lowest performance with these parameters. Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval and Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval treatment also gave better performance in respect to control treatment. In terms of eco-friendly management, it was found that botanical antimicrobials derived from plants are currently recognized as biodegradable, systemic, eco-friendly and non-toxic to mammals and are thus considered safe. Botanical products are environmentally safe, less hazardous, economic and easily available.

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
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
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

Chapter I
Introduction

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the important vegetables in Bangladesh as well as many countries of the world. It is one of the most widely grown vegetables in the world. It is grown on more than 5 million ha with a production nearly 129 million tons including Bangladesh (Srinivasan, 2010). It is cultivated in almost all home gardens and also in the field for its adaptability to wide range of soil and climate in Bangladesh. It ranks next to potato and sweet potato in respect of vegetables production in the world (Hossain *et al.*, 2010). At present 6.85% area is under tomato cultivation both in winter and summer and it ranks fourth in respect of production and third in respect of area in Bangladesh (BBS, 2006). The total production of tomato in Bangladesh was about 232000 tons from 24700 hectares of land with an average yield of 9.39 t ha^{-1} (BBS, 2011). The yield of the tomato in Bangladesh is very low as compared to those of some advanced countries (Sharfuddin and Siddique, 1985). Tomato is a major source of vitamins and minerals. It contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). It also contains high levels of a vitamins A and C, as well as the carotenoid phytochemical lycopene (Milind *et al.*, 2011). It is a nutritious and delicious vegetables used in salads, soups, and processed into stable products like ketchup, sauce, marmalade, chutney and juice paste, powder and other products (Ahmed, 1976).

The low yield of tomato in Bangladesh however is not an indication of low yield potentially of this crop, but of the fact that the low yield may be attributed to a number of reasons *viz.*, unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper irrigation facilities. Tomato is susceptible to insect attack from seedling to fruiting stage. All parts of the plant including leaves, stems, flowers and fruits are subjected to attack. This crop is attacked by different species of insect pests in Bangladesh. These are tomato fruit worm, tomato aphid, stink bugs and leaffooted bugs, homworms, silver leaf, whitefly etc. Among them tomato fruit borer (*Helicoverpa armigera)* is one of the major pests of tomato (Haque, 1995). Damage by this pest may be up to 85-93.7% (Tewari, 1984).

The tobacco whitefly (*Bemisia tabaci*) has been reported to be the most serious pest of tomato all over the world (Basu, 1995). The whitefly causes damage to the plant by direct feeding and transmission of virus. Leaf miner populations were significantly correlated with leaf injury, whereby an increase of one leaf miner adult corresponds to 1.76% leaf injury, and an increase of one leaf miner larva corresponds to a 3.06% leaf injury. An increase in leaf injury by leaf miner adult and larva decreases yield by 0.26% and 0.87%, respectively (Oloan *et al.* 2003).

In Bangladesh, very few research works have been done only on pesticide approaches for the management of tomato insect pests. The research work, cultural control, mechanical control, biological control by utilizing parasitoid and pathogens, development of resistant varieties, sex pheromone, and use of botanical insecticides are scantly.

Use of chemical to control a pest and disease is the most popular means to farmers till now. However, application of precise dose of the chemical to the field is a difficult job for them. Indiscriminate and long time use of chemical affect the soil health. Harmful chemical substances enter into the food chain that ultimately causes serious health hazards. Eco-friendly management of plant diseases such as use of botanical extracts has a great chance to save the beneficial soil microorganisms. Most of the botanical extracts also cost effective and readily available near to the fanners in timely. As a result botanical pesticides are becoming popular day by day. Now a days, these are using against many insects.

Use of botanical extract against pest control is however a modern approach to insect pest management is and it has drawn a special attention of the Entomologist all over the world. In Bangladesh, only a few attempts have been made to evaluate botanical extracts against insect pests (Karim, 1994). Botanical products are environmentally safe, less hazardous, economic and easily available. Biopesticides are natural plant products that belong to the so called secondary metabolites, which include alkaloids, terpenoids, phenolics, and minor secondary chemicals. Plants are rich source of bioactive organic chemicals. It is estimated that the plants may contain as many as 4000,000 secondary metabolites (Mamun, 2011). Many researchers reported botanical extracts having pesticide properties and thus having potential to be used against many insect pests. It would help to avoid environmental pollution caused by chemicals and thus become most rewarding one in our existing socio-economic conditions and environmental threat.

In view of the aforesaid perspective, the present research work was undertaken to evaluate the possible repellent effects of three indigenous plants *viz.*, neem leaf extract, neem oil and garlic extracts against insect pest control of tomato.

In light of the above back ground, the present piece of research work has been undertaken with the following objectives-

i. To know the effectiveness of different botanical extracts utilized against different insect pests of tomato;
ii. To know the effect of different botanical extracts on yield and yield contributing characters of tomato;
iii. To observed eco-friendly sustainable agriculture

Chapter II
Review of literature

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. Agriculture has had to face the destructive activities of numerous pests like fungi, weeds and insects from time immemorial, leading to radical decrease in yields. With the advent of chemical pesticides, this crisis was resolved to a great extent. The indiscriminate use of pesticides has created several problems, which came to limelight. Use of botanicals and bio-pesticides offer a good alternative to manage the insect pests and diseases in an eco-friendly way. Available literatures related to the present study are reviewed in this section. The review of literature in terms of repellent effect of different botanical extract in tomato insects cited here with suitable headings-

2.1 Efficacy of botanical extracts

Some concerns, especially environmental ones, lead the researchers to find new avenues of insect control in agriculture. Considering negative effects of synthetic pesticides especially on non-target organisms caused a general perception that natural compounds are better products or Generally Regarded As Safe (GRAS) (Scott *et al.*, 2003).

The use of plant extracts (botanical insecticides) to protect crops and stored products is as old as crop protection. Indeed, prior to the development and commercial success of synthetic insecticides beginning in the 1940s, botanical insecticides were major weapons in the farmer's arsenal against crop pests (Isman, 2008). Three major types of botanical insecticides are being used for insect control including pyrethrum, rotenone and neem along with three others in limited use (Isman, 2006).

2.1.1 Pyrethrum

Pyrethrum is an oleoresin extracted from the dried flowers of the pyrethrum daisy, Tanacetum cinerariaefolium (Asteraceae) that its active ingredients are three esters of chrysanthemic acid and three esters of pyrethric acid (Isman, 2006).
The insecticidal action of the pyrethrins is characterized by a rapid knockdown effect, particularly in flying insects, and hyperactivity and convulsions in most insects. These symptoms are the result of the neurotoxic action of the pyrethrins, which block voltage-gated sodium channels in nerve axons (Isman, 2006.

Pyrethrum is powdered, dried flower head of the pyrethrum daisy, Tanacetum cinerariaefolium and pyrethrins active compound from pyrethrum with six related insecticidal compounds which occur naturally (Henn and Weinzierl, 1989). There is pyrethrin I and pyrethrin II. The compounds related to pyrethrin I contain methyl group (-CH_3) and the compound related to pyrethrin II contain -CO_2CH_3 group (Khater, 2012 and Aerts and Mordue, 1997).

Pyrethrins are axonic poisons and have an insect repellent effect when present in little amount (Henn and Weinzierl, 1989). They are harmful to fish, but are less toxic to mammals and birds than many synthetic insecticides.

Pyrethrins degrade easily when is exposed to the environment moisture, air and the sunlight (Khater, 2012). The half-life of pyrethrins in the environment and field-grown bell pepper fruit is 2 hours or less (Henn and Weinzierl, 1989).

2.1.2 Neem (Azadirachtin)

Azadirachtin is an extraction from Indian neem tree, Azadirachta indicahas that has two profound effects on insects (Schmutter, 2002). Azadirachtin, apart from its antifeedant effects on insects, inhibited the synthesis and release of ecdysteroids from the prothoracic gland resulting incomplete ecdysis in immature insects and sterility in adult females (Isman, 2006).

Neem tree is under the Meliaceae family possessing bitter triterpenoids (Aerts and Mordue, 1997). The active compound in the neem is azadirachtin which is found in the leaves, and also concentrated in the seeds. It is a bitter, complex chemical compound which belongs to the limonoid group and it show strong biological activities among various insect pests (Khalil, 2013). This compound is a feeding deterrent and growth regulator (Khater, 2012).

This compound can affect about 200 species of insects by acting as antifeedant and growth disruptor. Khalil, (2013) revealed that azadirachtin has a toxicity and fascinating effect on insects (LD_{50} (*S. littoralis*), 15 μg/g). It has very low toxicity to mammals whereby the LD50 in rats is greater than 3540 mg/kg which make it practically non-toxic to mammals and also has been reported to be non mutagenic (Aerts and Mordue, 1997). Azadirachtin has been found to degrade rapidly under environmental factors such as UV radiation in sunlight, heat, air moisture, acidity and enzymes present in foliar surfaces (Khalil, 2013). The half-life of azadirachtin has been found to be between 48 minutes and 3.98 days under Ultraviolet (UV) light and sunlight and 2.47 days on leaf surface (Henn and Weinzierl, 1989 and Khater, 2012).

2.1.3 Rotenone

Rotenone is a type of isoflavonoids extracted from the roots or rhizomes of the tropical legumes like Derris, Lonchocarpus, and Tephrosia (Isman, 2006). Rotenone is a mitochondrial poison by blocking the electron transport chain leading to inhibition of energy production (Hollingworth *et al.*, 1994).

It is a relatively low toxicity insecticide for use in gardens but is highly toxic to fish and is sometimes used to eliminate unwanted fish from lakes Hinson (2000). It occurs naturally in the seeds, stems, leaves and the roots of plants in fabaceae family. It was the first described member of the family of chemical compounds known as rotenoids (Khater, 2012).

Rotenone is rapidly broken down by sunlight which is both an advantage and disadvantage (Hinson, 2000). Since it breaks down rapidly, it does not accumulate in the environment and less harmful to non-target organisms (Henn and Weinzierl, 1989). However, it must be re-applied at short intervals and is usually applied in the early morning or in the evening to avoid degradation of it by sunlight (El-Wakeil, 2013). In water, the rate of decomposition depends upon several factors, including temperature, pH, turbidity of water and sunlight. The half life of rotenone is four days (El-Wakeil, 2013 and Khater, 2012). The half-life of rotenone in natural waters ranges from half a day at 24°C to 3.5 days at 0°C (Henn and Weinzierl, 1989).

2.1.4 Garlic

Garlic extracts have been shown to be effective at controlling several foliar fungal pathogens (Lozano *et al.*, 2000; Quarnstrom, 1992; Raghavaiah and Jayaramaiah, 1987; Singh et al., 1995). Extracts of garlic have also been demonstrated to have antifungal properties against some soilborne fungi. Russell and Mussa (1977) found that a crude juice extract of crushed garlic cloves inhibited in vitro growth of *Fusarium solani* f.sp. *phaseoli* and provided adequate in vivo control of root rot of 'Seafare' common bean (*Phaseolus vulgaris*) when applied as a seed treatment. Singh et al. (1979) observed that when seeds of gram (*Cicer arietinum*) were treated with an aqueous garlic leaf extract, the resulting seedlings, when placed in soil infested with *Fusarium oxysporum* f.sp. *ciceri* and *Sclerotinia sclerotiorum*, were wilt-free, whereas untreated seeds resulted in seedlings with wilt symptoms. Singh and Singh (1980) also found that garlic oil suppressed sclerotial formation by *Rhizoctonia solani* and killed the organism when hyphal discs were exposed to the oil in a petri plate assay. They concluded that the inhibition of sclerotia was in part the result of the inhibition of hyphal growth. Singh et al. (1990) found that ajoene, a compound isolated from garlic, inhibited spore formation in several pathogenic fungi in culture. Singh et al. (1992) reported that at higher concentrations, ajoene inhibited mycelial growth, sporangium formation, and zoospore germination of *Phytophthora drechsleri* f.sp. *cajani* in culture. Bianchi *et al.*(1997) conducted ultra structural studies of hyphae of phytopathogenic fungi treated with micronized garlic powder and observed that the garlic powder strongly inhibited hyphal development with changes in cytoplasm, cell walls, and cell membranes. However, Mercado and Rodriguez (2001) treated two soil borne phytopathogens (*R. solani* and *Myrothecium roridum*) with a garlic compound called "Garlic Barrier" and found little effectiveness in reducing populations of either pathogen in culture.

2.2 Mode of action of active compounds from botanical pesticides

2.2.1 Mode of Action of Pyrethrins

Pyrethrins attack the nervous systems of all insects and act like pyrethroids and DDT (Henn and Weinzierl, 1989). Axonic poison substances affect the electrical transmission of the impulses along the axon (Khater, 2012). During their mode of action pyrethrins upset the sodium and potassium ion exchange process in insect nerve fibers and interfere the normal transmission of nerve impulses (Henn and Weinzierl, 1989). Pyrethrins delay the closure of voltage-gated sodium ion channels in the nerve cells of insects, resulting in repeated and extended nerve firings (Khater, 2012). This hyperexcitation causes the death of the insect due to loss of motor coordination and paralysis. Sometimes insect pests may develop resistance to pyrethrum (Henn and Weinzierl, 1989). Piperonyl butoxide is paired with pyrethrin to prevent resistance by insect pests. It is synergist compound. Together, these two compounds prevent detoxification in the insect, ensuring insect death. Synergists make pyrethrin more effective, allowing lower doses to be effective (Henn and Weinzierl, 1989). Pyrethrins are effective pesticides because they selectively target insects rather than mammals due to higher insect nerve sensitivity, smaller insect body size, lower mammalian skin absorption, and more efficient mammalian hepatic metabolism (Henn and Weinzierl, 1989).

2.2.2 Mode of Action of Azadirachtin

Azadirachtin displays strong antifeedant effects on chemoreceptors of the insects and discourage the insect pests to consume the plant (Khalil, 2013). If the insect pest continues in consuming crops sprayed with neem tree extracts, the azadirachtin blocks peptide hormone release, which results in severe growth defects and molting abnormalities (Aerts and Mordue, 1997 and Mordue and Blackwell, 1993). Finally, azadirachtin has a damaging effect on the tissues including the muscles, fat and gut of most of the insect (Aerts and Mordue, 1997).

2.2.3 Mode of Action of Rotenone

Rotenone delay the electron transport chain in mitochondria of the insect pests and it is a contact and stomach poison (El-Wakeil, 2013 and Belmain *et al.*, 2012). It inhibits the transfer of electrons from iron-sulfur centers in complex I to ubiquinone and interferes with Nicotinamide adenine dinucleotide hydride (NADH) during the creation of usable cellular energy Adenosine triphosphate (ATP) (Belmain *et al.*, 2012). In that case, Complex I is unable to pass through its electron to Complex Q, creating a back-up of electrons within the mitochondrial matrix. During this limiting process, cellular oxygen is reduced to the radical which is a reactive species. This reactive species can damage Deoxyribonucleic acid (DNA) and other components of the mitochondria (Hinson, 2000).

2.2.3 Mode of Action of Garlic Extract

Garlic extracts have been widely reported to be repellent to a number of invertebrate species (Rahman and Motoyama, 2000 ; Auger et al. 2002; Inyang and Emo-sairue, 2005) and/or to act as an antifeedant (Chiam *et al.*, 1999) and it was hypothesized here that sub-strates containing allicin would deter *M. domestica* females from ovipositing into it. This premise was borne-out, albeit at concentrations well above those required to eliminate larval development and it was more clearly manifested when adults were provided with a choice of oviposition sites, results that demon- strated the capacity of *M. domestica* to discriminate between suitable and non-suitable oviposition sites.This element of the work also provided evidence that relatively high levels of allicin may deter adult flies from feeding on such treated substrates, or if they do feed upon them, results in toxic quantities being ingested. Whilst the two potential causes of the high mortality in the high dose no-choice tests need to be separated, the result indicates a potentially useful additional activity against filth feeding flies if it is translatable to a real world situation. Feed upon them, results in toxic quantities being ingested.

2.3 Role of botanicals as repellent

Abtew *et al*. (2015) evaluated to propose an alternative to chemical control, the repellency of 24 plant extracts was evaluated against adult female thrips of *Megalurothrips sjostedti* in the laboratory. *Megalurothrips sjostedti* is an important pest of cowpea (*Vigna unguiculata* L.) in Africa. The results showed highly significant differences in repellency among extract type, concentration and their interactions. It was identified that *Piper nigrum*, *Cinnamomum zeylanicum*, *Cinnamomum cassia* was strong repellents. Repellency of the extracts increased with the concentration suggesting that the behavioral response of *M. sjostedti* was dose-dependent. Mono- and sesquiterpene hydrocarbon compounds from seven highly repellent extracts were identified by gas chromatography-mass spectrometry (GC/MS). The use of repellent extracts could be useful in developing integrated pest management strategies for thrips on legume crops.

Sharma (2015) tested ethanolic plant extracts of *Citrullus colocynthis* (Tumba), *Tephrosia purpurea* (Sarpfonk) and *Balanites aegypticaa* (Hingotaa) for their repellent effect against stored grain pest *Triboilum castaneum* (red flour beetle) under the laboratory conditions. The results revealed that all the tested plant materials had repellent effects at different concentrations against the test insect. Ethanolic extract of Citrullus showed maximum repellency (0) @ 5% concentration for 90 minutes followed by Citrullus + Balanites (0.06), Tephrosia (0.12), Tephrosia + Balanites (0.32), Balanites (0.46) and Tephrosia + Citrullus (0.46).

Rupp *et al.* (2015) conducted a study to evaluate the action of vegetable extracts and essential oils on *S. oryzae* in the adult phase in stored wheat, through the assessment of toxic effect on exposed individuals to wheat grains treated. They found that the natural products of plants come as an alternative ecologically more compatible in substitution to the synthetic insecticides. The extracts of *P. nigrum* were obtained through the maceration of the grains with acetone and methanol and the essential oils of *Ocimum basilicum* and *Eucalyptus globulus* acquired of specialized companies. To study the toxic effects of the extracts on adults of *S. oryzae*, six concentrations were tested (50; 25; 12.5; 6.25; 3.125 and 1.5625 %) of each extract, in 40 g of wheat previously disinfectant, containing 20 adults of *S.oryzae* of 0-72 h of age. The same conditions were repeated for the experiments with essential oils of *O. basilicum* and *E. globulus*, where each portion received oil 0.1mL in 40 g of wheat. The insects dead were counted in each experiment, being discarded after each evaluation. The extracts of *P. nigrum* didn't control in an effective way the *S. oryzae* in the different concentrations. The other essential oils provided quite promising results, and the insecticide activity was reached by the three essential oils, being emphasized the oil of *E. globulus* with 100% of mortality, *O. basilicum* and *M. piperita*, species that it has been proven as botanical insecticide potentials being proceeded, because the secondary metabolics of plants have been used as pesticides or models for synthetic pesticides.

Sagheer *et al.* (2014) assessed acetone based plant extracts of *Nigella sativa*, *Syzygium aromaticum* and *Trachyspermum ammi* was assessed against the stored pest of processed commodities, *Tribolium castaneum*. Periodic analysis for the repellence, by impregnating half-filter paper disc and at various concentrations (5, 10, 15%), was done. Trials showed significant repellent effects as *T. ammi* (76.67%) followed by *S. aromaticum* (76.54%) and *N. sativa* (64.32%). Overall, the *T. ammi* extracts were proved to be more repellent followed by *S. aromaticum* and *N. sativa*. Results suggest a safer potential of these natural extracts toward disturbing the biology and invasion of stored product pest, *T. castaneum*. Results also indicate a definite potential of these extracts towards incorporation of these extracts in pest management programs and towards optimizing food security through utilizing them as bio-pesticides.

Chauhan *et al.* (2013) conducted an experiment with three botanical pesticides, Neem (*Aazadirachta indica*) leaves extract, *Acacia catechu* leaf and bark extract, *Carica papaya* seed extract and three chemical pesticides Indocarb 15 SC, 0.006%, @ 30 ai/ha, 200ml/g/ha, Fipronil 5EC 0.005%, 25-50g ai/ha, 500 ml/g/ha and Endosulfan 35 EC, 0.05-0.07%, 250-500 ai/ha 700-1004 ml/g/h against larvae of the noctuids *Helicoverpa armigera* on field tomato under both laboratory and field conditions. The maximum mean mortality was obtained in Endosulfan, Indocarb and Fipronil treatments under laboratory conditions followed by NSE (Neem Seed Extract-2.5%, 10%) and AcLE (Acacia Leaf Extract-5%). Repellency test through square dip experiments showed that the significant difference was recorded amongst the different treatments for mean mortality of *Helicoverpa armigera* larvae. Statistically significant mean mortality was observed from larvae allowed to feed on square dipped in Neem seed extract 2.5-10% followed by Carica papaya seed extract-2.5% , while other treatments were not found significant. During larval immersion method Carica papaya seed extract (2.5-10%) was again proved to be most significant followed by Acacia bark extract (5-10%) concentrations. However, Endosulphan was found superior than botanicals in both square dip and larval immersion methods.

Akpotu and Adebote (2013) evaluated the efficacies of the oils of five plant seed extract namely: *Albizia lebbeck*, *Anacardium occidentale*, *Citrullus colocynthis*, *Citrullus vulgaris* and *Khaya senegalensis* at 0.46, 1.38 and 4.13ml per 17g smoke-dried *Clarias gariepinus* for the control of *Dermestes maculatus* larvae. Each of the five oils caused significantly high ($p<0.05$) repellency on the larvae of the beetle at all concentrations when compared to the control.

Paul and Sohkhlet (2012) observed over 30 decades a number of natural plant products have been considered for use as insect anti-feedants and repellents in the agriculture. Plants are able to synthesize a broad range of different chemical compounds called secondary metabolites, with many of them as promising new sources of natural pesticides. With an experiment, Paul and Sohkhlet (2012) studied the queous extracts of four locally available plants namely, *Artemisia vulgaris*, *Datura arborea*, *Nicotiana tobacum* and *Zanthoxylum alatum* were prepared, and their feeding deterrence, repellent action, and mortality affects on the *Pieris brassiceae* larvae. Discernable effects were recorded at 20 mg kg^{-1}, and at higher concentrations of 50 mg/kg, 100 mg/kg and 150 mg/kg, the intensity of the effects gradually increased. Among the four extracts, *Z. alatum* was the most potent as a feeding deterrent and repellent, and also caused the highest mortality of *Pieris brassiceae* larvae. *Datura aborea* was seen to exhibit Insect growth regulating (IGR) activity in causing late pupation of the larvae. All the results exhibited significant differences in feeding deterrence, repellent action, mortality, and late pupation when compared with the non-treated controls.

Ikeura (2012) initiated to develop a botanical insecticide against *Pieris rapae* larvae; it was assessed the effect of 7 kinds of herb (rosemary, spearmint, eucalyptus, sage, chili pepper, chives and tansy) extracts as feeding repellents against *P. rapae* larvae. The cabbage white butterfly, *P. rapae*, *crucivora Boisduval*, is a serious pest to *Brassicaca* species such as cabbage, cauliflower and broccoli, and its larvae damage the host plant leaves when feeding. The repellent rate of rosemary, spearmint, eucalyptus, sage, chili pepper, chives and tansy was 75, 72, 64, 59, 40, 40 and 36%, respectively. These results clarified that of the tested herbs, rosemary and spearmint volatile extracts have a notable feeding repellent effect against *P. rapae* larvae.

Sharma *et al.* (2011) tested the aqueous extract of eight plant species, namely *Azadirachta indica*, *Melia azedarach*, *Lantana camara*, *Cannabis sativa*, *Nerium indicum*, *Eucalyptus sp.*, *Ricinus communis* and *Solanum nigrum* for repellent effects against *Pieris brassicae*. The ethanol extracts of potential plants were further tested for their biological activity against the test insect. The aqueous extracts of *A. indica* and *M. azedarach* resulted in statistically higher repellent effect repelling 2.2-50.4 and 4.4-52.6 per cent second instar larvae of *P. brassicae* respectively. In case of ethanol extract also seed extracts of *A. indica* and *M. azedarach* were highly effective against *P. brassicae* giving statistically higher repellent (15.1 and 13% respectively) effects as compared to other plant extracts. In general repellent effect was dose dependent and diminished with the passage of time.

Bakhashwain and Bakhashwain (2010) tested five natural ethanolic plant extracts of *Rhazya stricta*, *Caralluma tuberculata*, *Capparis spinosa*, *Marrubium vulgare* and *Argemone ochroleuca* were tested in the laboratory for their insecticidal and repellent effectiveness saw-toothed grain beetle,*Oryzaephilus surinamensis* (L.). Four concentrations of each plant extract, 200, 400,600 and 800 ppm were tested. The repellent action of the previous plant extracts was studied. All of these extract showed remarkable toxicities. Results showed that complete mortality of *O. surinamensis* was achieved by *C. tuberculata* and *R. stricta* at the concentration of 800 ppm for both larvae and adult beetles. The rest of plant extracts increased mortality with increasing of concentrations. Of five plant extracts, the effect of *C. tuberculata* and *R. stricta* were relatively more pronounced with LC_{50} values of 203, 970 and 244, 245 ppm, respectively, two days from treatment. Corresponding LC_{50} values after six days exposure for larva, values were 114, 615 and 117, 775. As for adult, the LC_{50}s values after 2 days were 210.062 and 238.563. After 6days, LC_{50}s were 123.295 and 127.182 respectively. Moreover, *R. stricta* and *C. tuberculata* exhibited high repellency 100% and 90.08% at concentration of 800 ppm against *O. surinamensis* adults.

Rehman *et al.* (2009) evaluated repellent and oviposition deterrent effects of 'sweetflag' *Acorus calamus* L., 'tumba' *Citrullus colocynthis* L., 'turmeric' *Curcuma longa* L., 'kuth' *Saussurea lappa*, 'balchar' *Valeriana jatamansi*, and 'harmal' *Peganum harmala* L. extracts each in petroleum ether, acetone and ethanol at 2% concentration against peach fruit fly *Bactrocera zonata* in a free choice bioassay. Petroleum ether extract of *C. longa*, ethanol and acetone extracts of *P. harmala* were the most promising repellents against Peach fruit fly. Acetone extract of *P. harmala*, ethanol extract of *V. jatamansi* and petroleum ether extract of *S. lappa* also showed effective oviposition deterrence. *C. colocynthis* suppressed the overall egg laying.

Shah *et al.* (2008) performed the experiment at Bangladesh Agricultural University (BAU), Mymensingh. Leaves of six indigenous plants viz., *Typhonium trilobatum*, *Cleome viscosa*, *Cassia occidentalis*, *Pongamia pinnata*, *Mesua ferrea*, and *Trewia nudiflora* were extracted using acetone, ethanol and water solvents. These extracts were evaluated for their repellent effect against *Oryzaephilus surinamensis* (L.) at 2.5, 5.0, 7.5, and 10.0% concentrations. Extracts of water solvent showed higher repellent effect than that of others except ethanol extract of *M. ferrea*. Considering mean repellency rate, extracts of three solvents of all six plants were in the same repellency class i.e. class II except water extract of *P. pinnata* (class III). It was found that the rate of repellency increased with the increase of dose level. At 10.0% dose level all plant extracts showed the highest repellency rate and were in repellency class III.

Jovanovi *et al.* (2007) conducted studies to evaluate the effect of the ethanol extracts from five aromatic medicinal plants against the bean weevil, *Acanthoscelides obtectus*. The extracts were tested for potential to protect stored legume seeds in terms of their repellency, toxicity and reduction of F_1 progeny. Significant insecticidal activity was exhibited only by the 100% concentrated extracts from *Urtica dioica* L. and *Taraxacum officinale* L., whereas both 100 and 30% extracts from these plants were effective in repellency and reduction of F_1 progeny. Although the extract form *Achillea millefolium* L. (100%) was ineffective in insecticidal activity, it provided a good level of repellency and reduction of F_1 progeny. Extracts from *Sambucus nigra* L. and *Juglans regia* L. were ineffective in all conducted bioassays.

Yang *et al.* (2004) found that at a dose of 0.1 mg/cm^2, the repellency of extracts of *Cinnamomum cassia* bark (91%), *Naidostichys chinensis* rhrzome (81%o), *Paeonia suffruticosa* root bark (80%, and *Cinnamomum camphora* steam distillate (94%) was comparable to N-diethyl-z-toluamide (deet) (82%). The duration of the effectiveness for extracts from *C. cassia* bark and *N. chinensis* rhizome was comparable to deet and lasted for 1 h. Relatively short duration of repellency was observed in *P. suffruticosa* root bark extract and *C. camphora* steam distillate. The plants described merit further study as potential mosquito repellent agents.

2.7 Use of biopesticides in crop production

Biopesticides are derivatives of natural products including plants, microorganisms and animals and they manage pests in a non-toxic manner (Mizubuti *et al.*, 2007; Kumar, 2015; Mishra *et al.*, 2015). These products are important because unlike the synthetic pesticides they are easily degradable, they are non-toxic to humans and the environment, they are target specific, are easily available and do not have residual effects on produce (Kimani, 2014; Kumar, 2015; Srijita, 2015). In addition, biopesticides offer solutions to pest resistance, environmental and water body pollution, public concerns about food safety and improves agricultural productivity (Mishra *et al.*, 2015).

Farmers have used crushed leaves of African marigold to control nematodes while other damaging diseases have been controlled by use of biological agents from micro-organisms and plant origin. Late blight of potato and Fusarium wilt of different legumes, have been successfully controlled by microbial pesticides (Karimi *et al.*, 2012; Islam *et al.*, 2012). Chemical companies have come up with different formulations of the biological and are available for purchase by farmers (Islam *et al.*, 2012).

Biopesticides used in agriculture include microorganisms such as bacteria, fungi, viruses and protozoa and botanicals such as neem, garlic, pyrethrum and turmeric among others (Bautista-Banos *et al.*, 2003; Goufo *et al.*, 2008; Kimani, 2014). Bacteria species such as Bacillus, fungal species such as Trichoderma and Beauveria, and plant species such as neem (*Azadirachta indica*) and turmeric (*Curcuma longa*) have been used in Botanicals include essential oils and plant extracts. While essential oils are volatile aromatichydrophobic liquids from plant parts and mainly include terpenoids, plant extracts are dried plant parts obtained by filtration and evaporation and mainly consist of phenols, alkaloids, tannins and saponins and these give them the antifungal characteristics (Mizubuti *et al.*, 2007; Vidyasagar and Tabassum, 2013).

Different plant families have different bioactive compounds and thus exhibit varied modes of action. Neem from the Meliaceae family for instance, affects the reproductive and digestive system of the pests, garlic from the Liliaceae family has compounds that affect the neurosystem of insects while turmeric and ginger from the Zingibereaceae family has aromatic compounds that affect the morphology of the hyphae and mycelia structure of the fungal pathogen (Jahromi et al., 2012; Vidyasagar and Tabassum, 2013). management of plant pests and diseases (Mishra et al., 2015; Dunham, 2016).

Plant extracts have been used in management of pests and disease both under controlled and field conditions and have been reported to be as effective as the synthetic counter parts (Goufo *et al.*,2008; Nashwa and Abo-Elyousr, 2012; Al-Samarrai *et al.*, 2012; Al-Samarrai *et al.*, 2013). Reports on efficacy of biopesticides in pest and disease management are an indication that they have potential to replace the synthetics and can be incorporated in the crop management systems (Nashwa, 2011; Chethana *et al.*, 2012; Islam *et al.*, 2012; Karimi *et al.*, 2012; Fountain and Warren, 2013; Gonzalez, 2013; Raja, 2014; Wafula *et al.*, 2014).

Biopesticides have the capacity to balance between environmental safety and enhanced agricultural productivity (Kumar, 2015). From the recent concerns about food safety and food quality, increased demand for residue-free crop produce, increased organic food markets and for easier market registration and access, farmers ought to be trained on the necessity to embrace biocontrol of pests and diseases (Michel, 2015). This will help them to overcome the issues of pest resistance, genetic variations in plant populations, reduction of beneficial species, environmental and water pollution and food poisoning which will improve the quality and safety of their produce (Mishra *et al.*, 2015; Srijita, 2015). In turn, they will reduce the rate of interception and product rejection in the lucrative markets which will attract even more buyers for their produce. This boosts the agricultural productivity and economic level of the producing country (Srijita, 2015).

Biological agents have helped flower farms reduce the use of conventional pesticides by at least 50% (Casswell, 2015). Kenya is one of the leading producers of the natural pesticide, pyrethrin,which is a broad spectrum insecticide (Infonet-Biovision, 2015). The product is exported to developed countries: USA (60%), Europe (35%) and Africa (5%) are used (Birech *et al*., 2006). Kenya has the potential to utilize the botanicals from neem (*Azadirachta indica*), pyrethrum (*Chrysanthemum cinerariaeofolium*) and other plants to manage pests and diseases in horticulture (Infonet-Biovision, 2015).

Rahman *et al*. (2014) tested the efficiency of four botanicals viz., mahogany oil, mahogany seed extract, tobacco leaf extract, neem seed kernel extract along with one synthetic chemical, cypermethrin against *Helicoverpa armigera*. The lowest fruit infestation, both by number and weight, was observed in neem seed kernel extract (27.15%, 22.29%) treated plot which was statistically similar to tobacco leaf extract (27.71%, 23.31%) treated plot and cypermethrin (28.87%, 25.44%) treated fruits. While no significant difference was found among mahogany oil, mahogany seed extract and control treatments. Percent infestation reduction over control was the highest in neem seed kernel extract (30.08%) followed by tobacco leaf extract (28.68%). The highest yield (18.14 t/ha) and the highest MBCR (2.99) were also obtained from neem seed kernel extract treated fruits.

Gopalakrishnan (2011) evaluated the efficacy of washings of herbal vermicompost (called biowash; viz. Annona, Chrysanthemum, Datura, Jatropha, Neem, Parthenium, Pongamia, Tridax and Vitax) and plant growth promoting (PGP) bacteria [viz. Bacillus subtilis (BCB-19), Bacillus megaterium (SB-9), *Serratia mercescens* (HIB-28) and *Pseudomonas spp*. (SB-21)] and fungus (*Metarhizium anisopliae*) against *Helicoverpa armigera*. When the feed was treated with crude biowash for healthy larvae (4-day old), 42 and 86% mortality and 32 and 71% weight reduction over control was reported for *H. armigera*. When healthy larvae were treated with PGP bacteria and fungus, the mortality rate varied between 59 and 73%, with 55 and 92% weight reduction over control on H. armigera. It was therefore concluded that the aforementioned six botanicals and five entomopathogens has great potential in the management of *Helicoverpa armigera*.

Suradkar and Ukey (2015) reported that least fruit damage was experienced due to the treatment with endosulfan 0.05 percent, followed by the treatment of NSE 5% alternated with Blk @ 1000 ml/ha and the treatments with other neem based materials. All treatments performed well than untreated control. The highest fruit yield of 86.49 q/ha was obtained due to the treatment with endosulfan 0.05% followed by other neem based treatments.

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important as pest control properties like seed kernels of neem, *Azadiracta indica*, *Pongamia glabra*, leaves of tobacco, *Nicotiana tabacum* and *indiara*, a neem based herbal product, against *Helicoverpa armigera* on chickpea cv. I.C.C.V.5 for its management in Rabi seasons of 1993-96 at College of Agriculture, Nagpur, Maharashtra, India. The results revealed that the crop treated with the leaf extract of *N. tabacum* 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.

Ju *et al.* (2000) tested six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest, *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 pHs 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 (2002) screened methanol extracts of selected plants namely *Anisomeles malabarica*, *Ocimum canum*, *O. basilicum*, *Euphorbia hirta*, *E. heterophylla*, *Vitex negundo*, *Tagetes indica* and *Parthenium hysterophorus* for their insecticidal activity against the fourth instar larvae of *Helicoverpa 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 extracts in 2 per cent test concentration (48 h) except *E. heterophylla* which recorded 47.3 per cent mortality in 2 per cent concentration. Among the plant extracts tested V. negundo is found to show higher rate of mortality (82.5%) at 2 per cent concentration.

Usman *et al.* (2012) investigated the effficiency of *Trichogramma chilonis*. *T. chilonis* in combination with *Chrysoperla carnea* and neem extract against tomato fruit worm, *Helicoverpa armigera* were carried out at the Research Farm of Agricultural University, Peshawar, Pakistan during summer 2009. Treatment having trichocard having 300 parasitized eggs in combination with chrysoperla and neem extract is the most promising for effective management of *H. armigera* on tomato.

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 fruit set per plant (32.47, 32.10 and 32.00). The highest cost-benefit ratios were obtained with NLE, OGBE and CFE (1:51, 1:50 and 1:47).

Ali *et al.* (2009) conducted an experiment at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to explore the effective and eco-friendly management practice(s) among seven combinations of some cultural, mechanical, botanical and chemical practices along with one untreated control applied on the susceptible variety BARI Tomato-2 against tomato fruit borer, *Halicoverpa armigera* (Hubner). Among the seven treatments, the botanical based treatment (T_6) comprising the spraying of neem oil @ 3 ml/L of water at 7 days interval along with plants supported with bamboo stick performed best in reducing 79.51 and 75.59% the fruit infestation over control by number and weight and contributed to maximum fruit yield (85.55 t/ha), which increased 26.76% yield over control. Based on the economic analysis of the treatments, T_6 contributed the maximum benefit cost ratio which also produced maximum yield.

2.8 Insect pest control by botanicals

Al-mazraawi and Ateyyat (2009) evaluated the toxicity and repellent activities of aqueous extracts of nine medicinal plants on different life stages of the sweet potato whitefly, *Bemisia tabaci*. Extracts of *Ruta chalepensis*, *Peganum harmala* and *Alkanna strigosa* were effective in reducing the numbers of *Bemisia tabaci* immatures similar to the reduction observed in the imidacloprid treatment. These three extracts were not detrimental on parasitoid, *Eretmocerus mundus*. In addition, the plant extracts *Urtica pilulifera* and *T. capita* were repellent to *Bemisia tabaci* adults. These results indicated that the extracts from the plants *R. chalepensis, P. harmala* and *A. strigosa* could act as a potential management source for natural product for *Bemisia tabaci*.

Chavan *et al*. (2015) reported that spraying of NSKE 5% @ 2 kg/ha, neem oil @ 2.5 L/ha and azadirachtin 3000 ppm @ 2.5 L/ha was most effective against whitefly and leaf miner of 20 days after transplanting.

Abou-Fakhr Hammad *et al*. (2001) experienced that extracts of callus and different age classes of *Melia azadirachta* leaves and fruits have repellent activity of 58.9±67.7% and significantly decrease the oviposition rate of the insect without affecting the adult whitefly emergence in comparison with the control.

Mukhtar *et al*. (2013) conducted field studies to evaluate three management techniques on controlling whitefly (*Bemisia tabaci Genn*) in tomato fields. Field evaluation was managed for two successive growing seasons (winter 2002/03 and 2003/04). Severity and infection rate of tomato yellow leaf curl begomovirus (TYLCV) as well as tomato yield were the criteria of evaluation. The techniques used were a) Sumicidin (insecticide), b) Neem (*Azadirachta indica*) seed oil c) Neem seed extract. Disease incidence was significantly reduced in both previous seasons.

TYLCV severity degree was also significantly reduced in 2002/03 season. TYLCV incidence was reduced when using applications of Neem-seed oil followed by Neem-seed extract in both seasons. Tomato yield was highest (8.4 t/ha) during 2002/03 when using Neem oil followed by Neem extract (7.7 t/ha) and Sumicidin application (4.8 t/ha). Tomato yield was highest (9.4 t/ha) during 2003/04 season when using Neem oil application followed by Neem extract application (9.2 t/ ha) and Sumicidin (6.0 t/ha).

Kuldeep *et al.* (2009) tested eight neem based formulations against whitefly causing leaf curl disease in tomato, nimbacidine proved most promising in minimizing the leaf curl incidence (08.33 and 08.73 %) in both years followed by Neemazal, Neemgold, RD-9-Repelin, Bioneem, Neemark, Neemta-2100 and Achook. Achook was least effective (23.13 and 23.64 % leaf curl incidence), however it was significantly superior over untreated control. The highest leaf curl incidence was recorded in untreated control, which was as high as 35.12 and 36.31 % during both years.

Abou-Fakhr Hammad *et al.* (2000) performed the host preference bioassays for adults of the sweetpotato whitefly with leaves of the neem, tomato, cucumber and bean. Fruit and leaf extracts of neem were tested against adults of the sweet potato whitefly. Fruit extracts were tested against eggs, first and second instar nymphs, and pupae of the insect. Results of the host preference bioassays indicated a significantly lower number of live insects on leaves of the neem leaves of bean, cucumber, and tomato after 24 h. This indicates that *Melia azadirachta* is not a good host for the whitefly. Adults significantly more repelled from tomato plants treated with the undiluted extracts when compared to the control after 72 h. Thus *Melia azadirachta* extracts were found to be repellent to the whitefly adults, while the fruit extracts have shown a significant detrimental effect against early nymphal instars.

Rehman *et al.* (2015) conducted an experiment to investigate the comparative efficacy of neem leaf extracts and lambdacyhalothrin against whitefly and jassid in okra field. They grew four okra cultivars (Sabz pari, Sada bahar, Pus a sawani, Arka and Anamika) treating with five neem oil concentrations (1, 2, 3, 4 and 5 percent) and a synthetic insecticide (Lambdacyhalothrin 2.5EC) @ 330 mL acre−1 to evaluate efficacy effects on targeted insects population. Distilled water was used as control. Results showed that Lambdacyhalothrin and neem oil @ 4 and 5% concentrations were equally effective in controlling jassid and had same impact on yield of okra plant.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted for evaluating of the repellent effects of different botanical extracts on tomato insects during the period from October 2016 to March 2017. This chapter provides a brief description of plant materials, experimental site, soil type, weather condition, land preparation, fertilizer application, experimental design layout, collection of data, method of intercultural operations, fruit harvesting and statistical analysis etc. under the following headings:

3.1. Location of the experimental field

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23°46′ N and longitude 90°23′E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of the department Entomology, SAU.

3.2. Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year.

3.3. Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28).

3.4. Land preparation

The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 21 equal plots (3m×2m) with plot to plot distance of 1 m and block to block distance was 0.5 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment was followed immediately after land preparation.

3.5. Manure and fertilizer

Recommended fertilizers were applied at the rate of 450 kg urea, 250 kg triple super phosphate (TSP) and 260 kg muriate of potash (MoP) and cowdung 10 ton per hectare as source of nitrogen, phosphorus and potassium, respectively. Urea was applied into 3 equal split doses at 10, 25 and 40 days after transplanting the seedlings respectively after planting of seedling. Cowdung and TSP were applied during final land preparation. MP was applied during final land preparation @ 100 kg ha^{-1}. The remaining MP was applied 25 and 40 days after planting of seedling at equal dose of 80 kg ha^{-1} (BARI, 2015).

3.6. Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 7 unit plots. The size of the unit plot was 3 m×2 m. The block to block and plot-to-plot distance was 0.5m and 1m, respectively.

3.6. Collection of seed and raising seedling

The seeds of selected tomato variety BARI-15 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing seeds, the germination test was done and found 90% germination for all varieties. Seeds were then directly sown in the 1st October, 2016 in seedbed containing a mixture of equal proportion well decomposed cowdung. After sowing of seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

3.7 Treatments

Comparative effectiveness of the following seven treatments in reducing the insect pest complex of tomato (BARI tomato-2 variety) was evaluated:

1) T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
2) T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
3) T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
4) T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
5) T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
6) T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
7) T_7 = Control

3.9 Transplanting

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. At the time of uprooting, care was taken so that root damage become minimum and some soil remained with the roots. Thirty days-old healthy seedlings were transplanted at the spacing of 70 cm × 50 cm in the experimental plots on 29 November 2016. Light irrigation was given immediately after transplanting around each seedling for their better establishment. The transplanting seedlings were shaded for five days with the help of white polythene to protect them from scorching sunlight. Watering was done up to five days until they became capable of establishing on their own root system.

3.10 Cultural practices

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. Each plant was provided by bamboo stick on about 1.0 m height from ground level for additional support and to allow normal creeping. Weeding and mulching in the plot were done, whenever necessary.

3.11 Intercultural operations

3.11.1 Gap filling

Very few seedlings were found damaged after transplanting and new seedlings from the same stock were replaced.

3.11.2 Weeding

The plants were kept under careful observation. Three times weeding were done during cropping period, viz. 1st December, 15th December and 1st January, for proper growth and development of the plants.

3.11.3 Spading

After each irrigation soils of each plot were pulverized by spade for easy aeration.

3.11.4 Irrigation

Irrigation was given by according to the crop need to ensure proper growth and development.

3.11.5 Earthing up

Earthing up was done by taking the soil from the space between the rows on 2nd January 2017.

3.11.6 Plant protection

Few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Seven 80WP was dusted to the soil before irrigation to controlled mole crickets and cut worms. Some of the plants were infected by alternaria leaf spot disease. Rovral 50 WP @ 20 g per 10 litre of water was sprayed to prevent the spread of the disease.

3.11.7 Harvesting

Fruits were harvested at 3-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 15 February, 2017 and was continued up to 15 March, 2017.

3.12 Data collection

Five plants were selected randomly from each plot for data collection. Data on the following parameters were recorded from the sample plants during the course of experiment.

1) Plant height (cm)
2) Number of branches plant^{-1}
3) Healthy fruit yield (t ha^{-1})
4) Infested fruit yield (t ha^{-1})
5) Total fruit yield (t ha^{-1})
6) Incidence of insects plant^{-1}
7) Number of infested leaves plant^{-1}
8) Number of fruit borer infested fruits plant^{-1}
9) Number of infested fruits plant^{-1}
10) Weight of healthy fruits plant^{-1} (g)
11) Weight of infested fruits plant^{-1} (g)

3.13 Procedures of recording data

3.13.1 Plant height

The height of plant was recorded in centimeter (cm) during harvest by using a meter scale. The height was measured from the ground level to the tip of thegrowing point of an individual plant. Mean value of the 5 selected plants was calculated for each unit plot.

3.13.2 Number of branches

Number of branch per plant was counted at harvest from 5 plants and mean value was calculated

3.13.3 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.

3.13.4 Fruit yield

The data on the number of healthy, infested and deformed fruits for each treatment from whole plot along with their number and weight were recorded at each harvest. The healthy, infested and deformed fruit yields in ton per ha were counted. Sum of the marketable yield, infested and deformed fruit yield finally expressed as the total yield in ton per ha.

3.13.5 Incidence of insect

For recording data on whitefly, jassid, aphid and leaf miner, of 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 in situ at an interval of 10 days commencing from vegetative to ripening stage and counted the number of whitefly, jassid, aphid and leaf miner up to the last harvesting of the fruit. The following observations were considered during the recording data on incidence of insect plant^{-1}

1) Number of infested leaves plant^{-1}
2) Number of fruit borer infested fruits plant^{-1}
3) Number of infested fruits plant^{-1}

4) Weight of healthy fruits $plant^{-1}$ (g)
5) Weight of infested fruits $plant^{-1}$ (g)

3.13.6 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 spotted 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. 13.7 Number of total fruits per plant

Fruits of selected plants of each replication were counted and then the average number of fruits for each plant was determined.

3.13.8 Number of healthy fruits per plant

The number of fresh or healthy fruits of selected plants was counted and then the average number of fruits for each plant was determined.

3.13.9 Reduction of fruit infestation over control

The number and weight of infested and total fruit for each treated plot and untreated control plot were recorded and the percent reduction of fruit infestation in number and weight was calculated using the following formula:

$$\text{Percent infestation reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.14 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance for different treatments. The analysis of variance was performed by using MSTAT Program. The significance of the difference among the treatment means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to evaluate the repellent effect of different botanical extract in tomato insects. The analysis of variance (ANOVA) of the data on fruit infestation and different yield contributing characters of different tomato varieties are given in Appendix IV-XI. The results have been presented, discussed and possible interpretations have been given under the following sub-headings:

4.1 Number of white fly plant^{-1}

Significant variation was observed for number of white fly plant^{-1} influenced by different botanical treatments (Table 1 and Appendix V). It was found that the lowest number of white fly plant^{-1} (16.31) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval). The highest incidence of white fly (35.44) was found from control treatment (T_7) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval and T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

In terms of % decrease of white fly plant^{-1} over control, the best performance (53.98%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest effectiveness to control white fly plant^{-1} by number (30.08%) was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 1).Similar results was observed by Chavan *et al.* (2015) and they reported that spraying of NSKE 5% @ 2 kg/ha, neem oil @ 2.5 lit/ha and azadirachtin 3000 ppm @ 2.5 lit/ha was most effective against whitefly of 20 days after transplanting. Supported results were also observed by Al-mazra'awi and Ateyyat (2009) and Rehman *et al.* (2015).

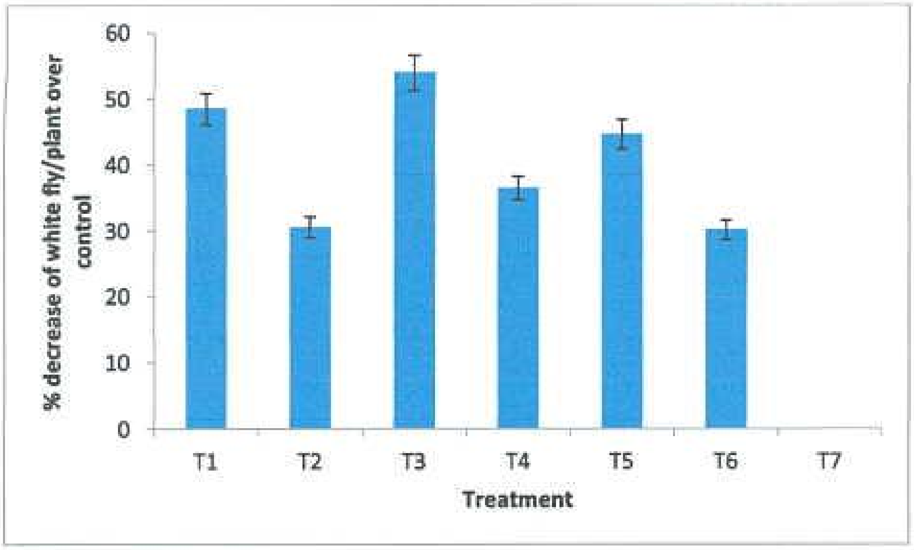

Fig. 1.Decrease of white fly plant^{-1} (%) over control by different botanical treatments in tomato

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.2 Number of jassid plant^{-1}

Significant variation was found for number of jassidplant^{-1} influenced by different botanical treatments (Table 1 and Appendix V). It was found that the lowest number of jassid plant^{-1}(1.60) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval). The highest presence of jassid (4.10) was found from control treatment (T_7) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval and T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

In terms of % decrease of jassid plant^{-1} over control, the best performance (60.98%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest effectiveness to control jassid plant^{-1} by number (28.54%) was obtained from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 2).Rehman *et al.* (2015) observed that neem oil @ 4 and 5% concentrations were effective in controlling jassid.

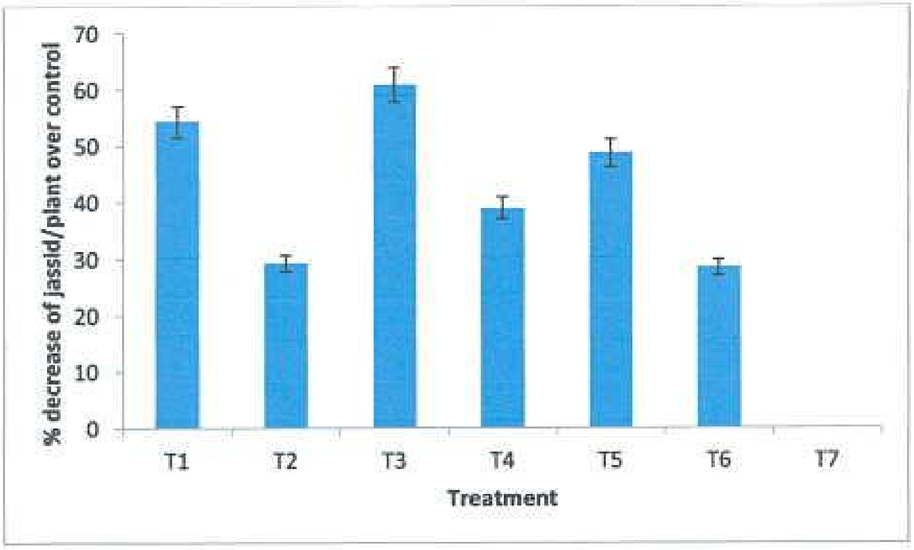

Fig. 2. Decrease of jassid plant^{-1} (%) over control by different botanical treatments in tomato

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.3 Number of aphid plant^{-1}

Significant variation was observed for number of aphid plant^{-1} influenced by different botanical treatments (Table 1 and Appendix V). Results revealed that the lowest number of aphid plant^{-1} (16.42) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) which was statistical with T_5 (Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval). The highest number of aphid plant^{-1} (30.67) was found from control treatment (T_7) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval and T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

In terms of % decrease of aphid plant^{-1} over control, the best performance (46.55%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest effectiveness to control aphid plant^{-1} by number (35.87%) was observed from T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 3).

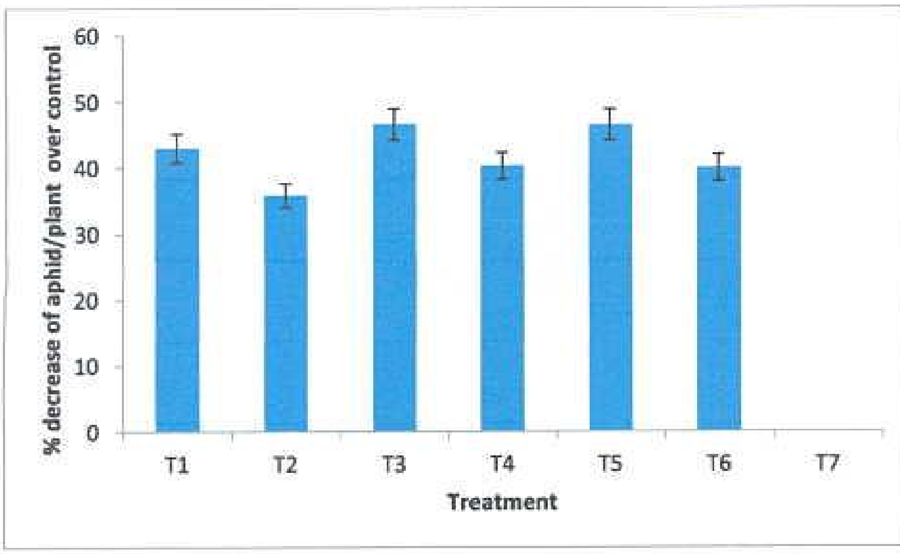

Fig. 3. Decrease of aphid plant^{-1} (%) over control by different botanical treatments in tomato

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.4 Number of leaf miners plant^{-1}

Significant variation was observed for number of leaf miners plant^{-1} influenced by different botanical treatments (Table 1 and Appendix V). Results revealed that the lowest number of leaf miners plant^{-1} (3.12) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval),T_5 and $T_4$where the highest number of leaf miners plant^{-1} (5.62) was found from control treatment (T_7) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval and T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

In terms of % decrease of leaf miners plant^{-1} over control, the best performance (46.55%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance to control leaf miners plant^{-1} by number (29.89%) was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 4).

Chavan *et al.*, (2015) reported that spraying of NSKE 5% @ 2 kg/ha, neem oil @ 2.5 L/ha and azadirachtin 3000 ppm @ 2.5 L/ha was most effective against leaf miner of 20 days after transplanting.

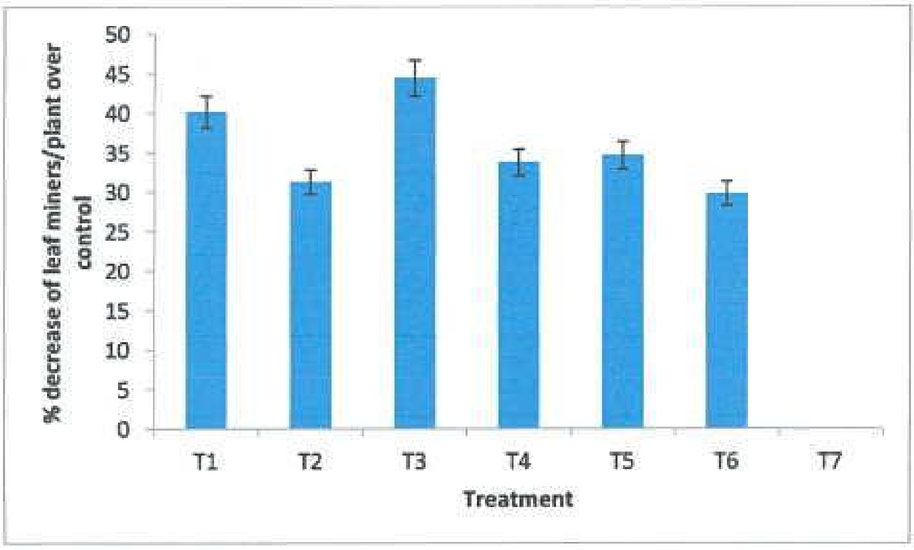

Fig. 4. % Decrease of leaf miners plant^{-1} (%) over control by different botanical treatments in tomato

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

Table 1. Incidence of different insect pest on infested plant of tomato under different botanical treatments during crop cultivation

Treatments	Incidence of insect pest complex of tomato by number			
	No. of white fly plant^{-1}	No. of jassid plant^{-1}	No. of aphid plant^{-1}	No. of leaf miners plant^{-1}
T_1	18.24 de	1.87 d	17.48 d	3.36 d
T_2	24.62 b	2.90 b	19.67 b	3.86 b
T_3	16.31 f	1.60 e	16.42 e	3.12 e
T_4	22.52 c	2.50 c	18.32 c	3.72 c
T_5	19.62 d	2.10 d	16.70 e	3.67 c
T_6	24.78 b	2.93 b	18.40 c	3.94 b
T_7	35.44 a	4.10 a	30.67 a	5.62 a
$LSD_{0.05}$	1.116	0.253	0.314	0.113
CV (%)	7.318	6.227	8.476	6.514

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.5 Number of infested leaves plant^{-1}

Number of infested leaves plant^{-1} was significantly influenced by different botanical treatments (Table 2 and Appendix VI). Results indicated that the lowest number of infested leaves plant^{-1} (7.18) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) which was statistically identical with T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the highest number of infested leaves plant^{-1} (24.10) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % decrease of leaf infestation over control, the best performance (70.21%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance to control number of infested leaves plant^{-1} (31.62%) was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 5).

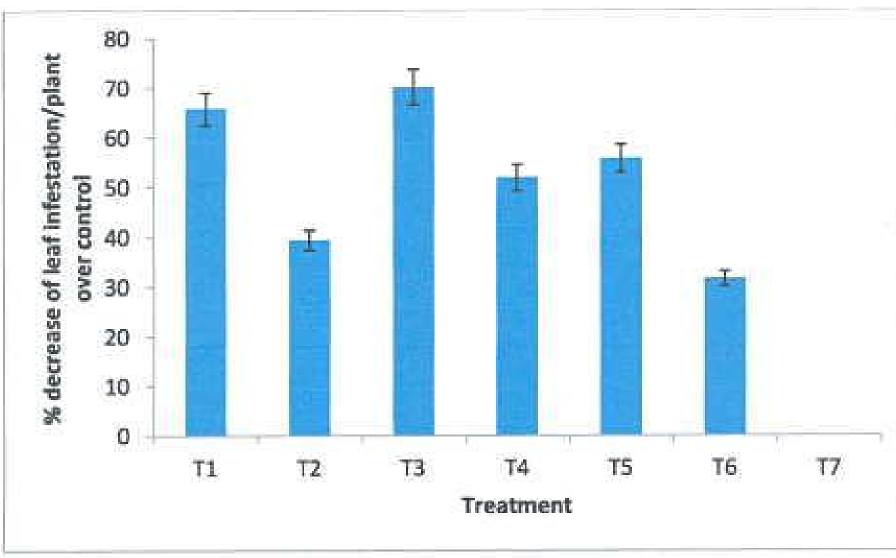

Fig. 5. Decrease of leaf infestation plant^{-1} (%) over control by different botanicals treatment in tomato by number

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.6 Number of fruit borer infested fruits plant^{-1}

Number of fruit borer infested fruits plant^{-1} was significantly influenced by different botanical treatments (Table 2 and Appendix VI). Results signified that the lowest number of fruit borer infested fruits plant^{-1} (4.62) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the highest number of fruit borer infested fruits plant^{-1} (11.70) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % decrease of fruit borer infested fruits plant^{-1} over control, the best performance (60.51%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance to control fruit borer infested fruits plant^{-1} (39.15%) was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 6).

It was also found that botanicals had repellent effect to control fruit borer of tomato. Bihari and Narayan (2010) and Ali *et al.* (2009) observed botanicals also more effect to control tomato fruit borer.

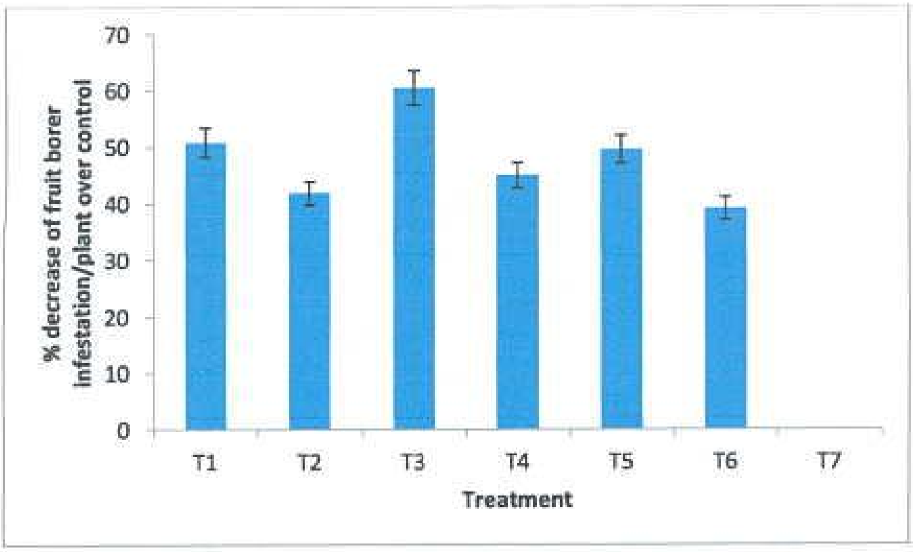

Fig. 6. Decrease of fruit borer infestation plant^{-1} (%) over control by different botanicals treatment in tomato by number

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

Table 2. Effect of different botanicals treatment on leaf and fruit borer infestation in tomato by number during crop cultivation

Treatments	Leaf and fruit infestation by insect pest complexl of tomato by number	
	Number of infested leaves plant^{-1}	Number of fruit borer infested fruits plant^{-1}
T_1	8.24 e	5.75 f
T_2	14.60 c	6.80 c
T_3	7.18 e	4.62 g
T_4	11.57 d	6.44 d
T_5	10.66 d	5.90 e
T_6	16.48 b	7.12 b
T_7	24.10 a	11.70 a
$LSD_{0.05}$	1.187	0.226
CV (%)	8.89	6.74

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.7 Plant height

Plant heightwas significantly influenced by different botanical treatments (Table 3 and Appendix VII). Results signified that the highest plant height(105.66 cm) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) and T_5 (Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval) where the lowest plant height (87.60 cm) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) and T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % increase of plant height over control, the best performance (20.62%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (4.93%) on plant height was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

4.8 Number of branches plant^{-1}

Number of branches plant^{-1} tomato was significantly influenced by different botanical treatments (Table 3 and Appendix VII). Results signified that the highest Number of branches plant^{-1} (7.44) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) whichwas statistically identical with T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) and closely followed by T_4 (Neem oil @ 3.0 ml L^{-1} of water at 10 days interval) where the lowest number of branches plant^{-1} (4.68) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) and T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % increase of Number of branches plant^{-1}, the best performance (58.97%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (9.40%) on plant height was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

Table 3: Effect of botanicals on growth and yield contributing parameters of tomato

Treatments	Growth parameters affected by insect pest complex of tomato			
	Plant height (cm)	% increase of plant height plant^{-1} over control	Number of branches plant^{-1}	% increase of branches number plant^{-1} over control
T_1	100.71 b	14.97	6.90 a	47.44
T_2	92.38 d	5.46	5.40 d	15.38
T_3	105.66 a	20.62	7.44 a	58.97
T_4	96.80 c	10.50	5.19 ab	10.90
T_5	99.50 b	13.58	6.32 c	35.04
T_6	91.92 d	4.93	5.12 d	9.40
T_7	87.60 e	--	4.68 e	--
$LSD_{0.05}$	2.741	--	0.588	--
CV (%)	9.531	--	5.229	--

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.9 Number of healthy fruits plant^{-1}

Number of healthy fruits plant^{-1} tomato was significantly influenced by different botanical treatments (Table 4 and Appendix VIII). Results indicated that the highest Number of healthy fruits plant^{-1} (37.41) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5

kg L^{-1} of water at 5 days interval) where the lowest Number of healthy fruits plant^{-1} (4.68) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % increase of Number of healthy fruits plant^{-1}, the best performance (118.26%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (40.26%) on healthy fruits was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 7).

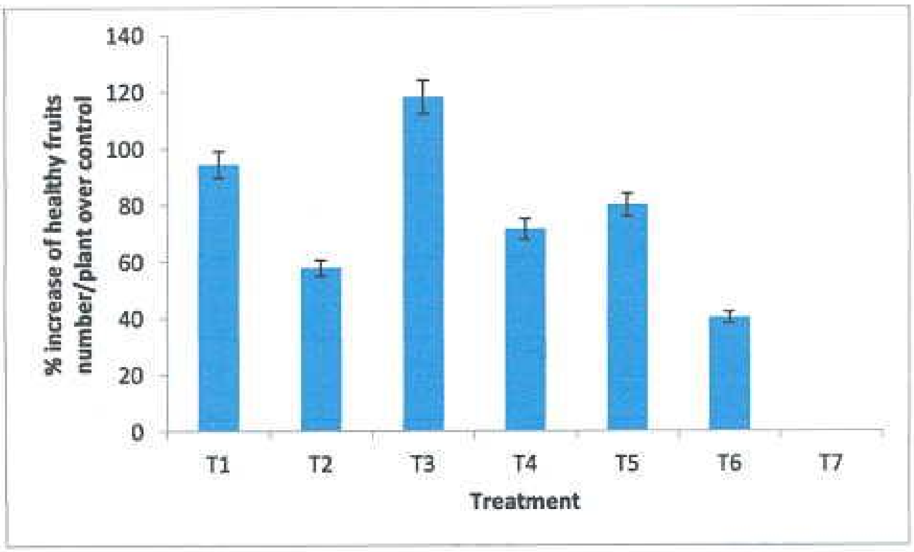

Fig. 7. Increase of healthy fruits number plant^{-1} (%) over control by different botanicals treatment in tomato by number

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.10 Number of infested fruits plant^{-1}

Number of infested fruits plant^{-1} tomato was significantly influenced by different botanical treatments (Table 4 and Appendix VIII). Results signified that the lowest Number of infested fruits plant^{-1} (5.12) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the highest Number of infested fruits plant^{-1} (15.52) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % decrease on Number of infested fruits plant^{-1}, the best performance (67.01%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (17.78%) on infested fruits was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval) (Fig. 8).

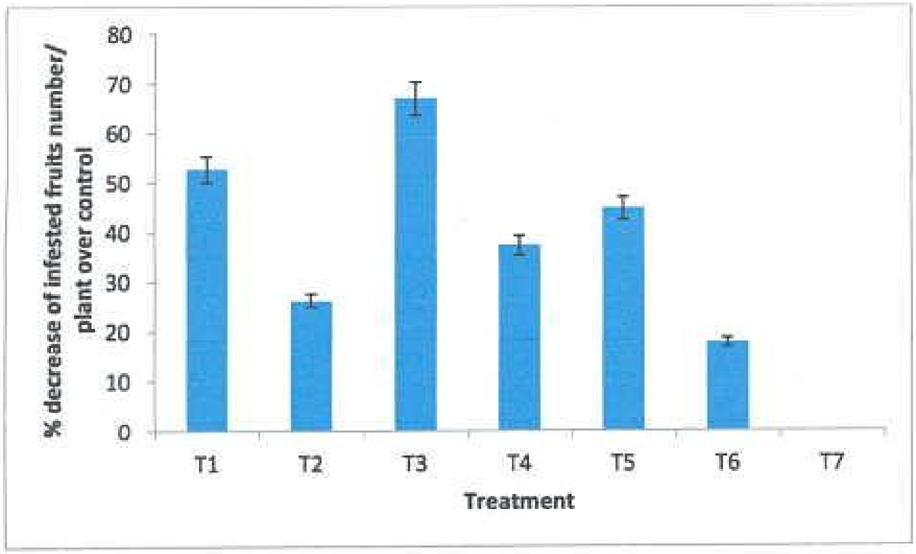

Fig. 8. Decrease of infested fruits number plant^{-1} (%) over control by different botanicals treatment in tomato by number

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

Table 4: Effect of botanicals on yield contributing parameters by number affected by insect pest complex of tomato

Treatments	Yield contributing parameters affected by insect pest complex of tomato	
	No. of healthy fruits plant^{-1}	No. of infested fruits plant^{-1}
T_1	33.34 b	7.33 e
T_2	27.05 d	11.45 b
T_3	37.41 a	5.12 f
T_4	29.41 c	9.71 c
T_5	30.86 c	8.56 cd
T_6	24.04 e	12.76 b
T_7	17.14 f	15.52 a
$LSD_{0.05}$	0.685	0.614
CV (%)	8.224	6.227

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.11 Weight of healthy fruits plant^{-1} (g)

Weight of healthy fruits plant^{-1} tomato was significantly influenced by different botanical treatments (Table 5 and Appendix IX). Results signified that the highest weight of healthy fruits plant^{-1} (1516.29 g) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the lowest weight of healthy fruits plant^{-1} (604.35 g) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % increase on weight of healthy fruits plant^{-1}, the best performance (150.90%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (56.26%) on healthy fruits weight was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

4.12 Weight of infested fruits plant^{-1}

Weight of infested fruits plant^{-1} tomato was significantly influenced by different botanical treatments (Table 5 and Appendix IX). Results signified that the lowest weight of infested fruits plant^{-1} (122.46 g) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the highest weight of infested fruits plant^{-1} (481.90 g) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Considering % decrease on weight of infested fruits plant^{-1}, the best performance (74.59%) was achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where the lowest performance (11.26%) on infested fruits weight was observed from T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval) followed by T_2 (Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval).

Table 5: Effect of botanicals on yield contributing parameters by weight affected by insect pest complex of tomato

Treatments	Yield contributing parameters affected by insect pest complex of tomato			
	Weight of healthy fruits $plant^{-1}$ (g)	% increase of healthy fruits weight $plant^{-1}$ over control	Weight of infested fruits $plant^{-1}$ (g)	% decrease of infested fruits weight $plant^{-1}$ over control
T_1	1350.85 b	123.52	215.65 f	55.25
T_2	1030.71 e	70.55	359.29 c	25.44
T_3	1516.29 a	150.90	122.46 g	74.59
T_4	1157.94 d	91.60	304.06 d	36.90
T_5	1245.98 c	106.17	266.77 e	44.64
T_6	944.35 f	56.26	427.65 b	11.26
T_7	604.35 g	--	481.90 a	--
$LSD_{0.05}$	14.569	--	5.216	--
CV (%)	11.261	--	10.552	--

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

4.13 Healthy fruit yield

Healthy fruits yield (ton ha^{-1})tomato was influenced significantly by different botanical treatments (Table 6 and Appendix 10). Results showed that the highest healthy fruits yield ha^{-1} (60.65 t) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the lowest healthy fruits yield ha^{-1} (24.17 t) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

4.14 Infested fruit yield

Infested fruits yield (ton ha^{-1})tomato was influenced significantly by different botanical treatments (Table 6 and Appendix X). Results showed that the lowest infested fruits yield ha^{-1} (4.90 t) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the highest infested fruits yield ha^{-1} (19.28 t) was found from control treatment (T_7) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

4.15 Total fruit yield

Total fruits yield (ton ha^{-1})tomato was influenced significantly by different botanical treatments (Table 6 and Appendix X). Results showed that the highest total fruit yield ha^{-1} (65.55 t) was observed with T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) followed by T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) where the lowest total fruits yield ha^{-1} (43.45 t) was found from control treatment (T_0) followed by T_6 (Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval).

Table 6: Effect of botanicals on yield parameters affected by insect pest complex of tomato

Treatments	Yield contributing parameters affected by insect pest complex of tomato		
	Healthy fruit yield (t ha^{-1})	Infested fruit yield (t ha^{-1})	Total fruit yield (t ha^{-1})
T_1	54.03 b	8.63 f	62.66 b
T_2	41.23 e	14.37 c	55.60 e
T_3	60.65 a	4.90 g	65.55 a
T_4	46.32 d	12.16 d	58.48 d
T_5	49.84 c	10.67 e	60.51 c
T_6	37.77 f	17.11 b	54.88 f
T_7	24.17 g	19.28 a	43.45 g
$LSD_{0.05}$	2.169	1.314	0.688
CV (%)	7.428	8.319	7.344

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval
T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval
T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval
T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval
T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval
T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval
T_7 = Control

Chapter V

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2016 to March 2017 for the evaluation of the repellent effect of different botanical extract in tomato insects. The experiment consisted of control measures with botanical methods. BARI tomato 15 was used as test crop. There were 7 treatment *viz.* (i) T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval, (ii) T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval, (iii) T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval, (iv) T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval, (v) T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval, (vi) T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval and (vii) T_7 = Control were used for the experiment.

Data were recorded on presence of insect pest, leaf infestation and fruit infestation in tomato, growth and yield parameters of tomato. Results revealed that significant variation was found in number of whitefly, jassid, aphid and leaf miners plant^{-1}.

Different botanicals used under the present study showed significant effect to control insects effectively. It was found that the lowest whitefly, jassid, aphid and leaf miners plant^{-1} incidence (16.31, 1.60, 16.70 and 3.12 respectively) by number were found with the treatment of T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where control treatment gave the highest incidence (35.44, 4.10, 30.67 and 5.62 respectively). Treatment of T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) also showed highest percent reduction whitefly, jassid, aphid and leaf miners plant^{-1} over control (53.98, 60.98, 46.55 and 44.48% respectively).

Similarly, in terms of leaf and fruit infestation by insect pest complex of tomato by number, T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) gave the best performance i.e. lowest leaf and fruit infestation by number (7.18 and 4.62 respectively) where control treatment gave the highest leaf and fruit infestation by number (24.10and 11.70respectively). Treatment T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) and T_5 (Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval) also gave better performance for number leaf and fruit infestation by number.

Considering growth and yield parameters, the highest plant height (105.66 cm), number of branches plant^{-1} (7.44), number of healthy fruits plant^{-1} (37.41), weight of healthy fruits plant^{-1} (1516.29 g), healthy fruit yield ha^{-1} (60.65 t) and total fruit yield ha^{-1} (65.55 t) also achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) where control treatment gave the lowest performance with these parameters. Treatment T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) and T_5 (Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval) also showed promising results compared to control treatment. In terms of percent increase of healthy fruits over control by number (118.26%) and weight (150.90%) were also achieved by T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval).

From the above summary, it can be concluded that, the highest performance on different growth, yield and yield contributing parameters in terms of insect pest infestation of tomato, T_3 (Neem oil @ 3.0 ml L^{-1} of water at 5 days interval) was the best as compared to control where T_1 (Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval) and T_5 (Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval) also gave better performance.

Again, it was observed that botanical antimicrobials derived from plants are currently recognized as biodegradable, systemic, eco-friendly and non-toxic to mammals and are thus considered safe. Their modes of action against pests are diverse. Botanical products are environmentally safe, less hazardous, economic and easily available. Biopesticides are natural plant products that belong to the so called secondary metabolites, which include alkaloids, terpenoids, phenolics, and minor secondary chemicals. Plants are rich source of bioactive organic chemicals. It is estimated that the plants may contain as many as 4000,000 secondary metabolites (Mamun, 2011). So, it can be assumed that insect pest management through botanical extracts is an eco-friendly management which is safe for crop production regarding human health issue and also environment.

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Appendices

APPENDICES

Appendix I: Experimental site showing in the map under the present study

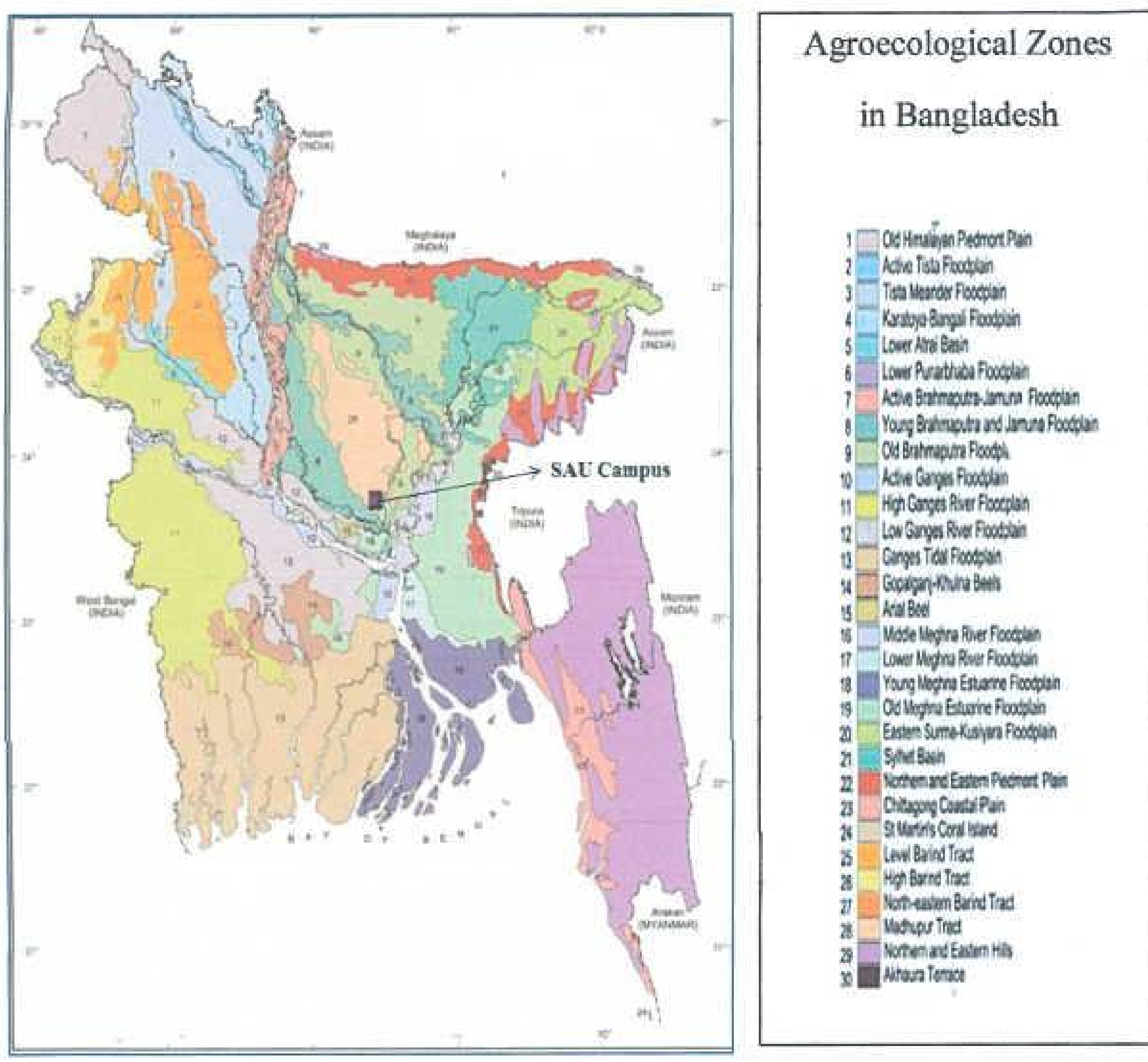


Fig. 1. Map of Bangladesh remarked with study area

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2016 to March 2017

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
2016	October	33.1	18.0	25.6	77	130	5.4
2016	November	32.0	15.0	23.5	67	14	7.8
2016	December	28.2	13.5	20.9	79	8	3.8
2017	January	24.5	11.5	18.0	72	6	5.7
2017	February	33.1	12.9	23.0	55	10	8.1
2017	March	35.4	15.3	25.35	58	12	8.3

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

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
p^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (µ gm/gm)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV. Layout of the experiment field

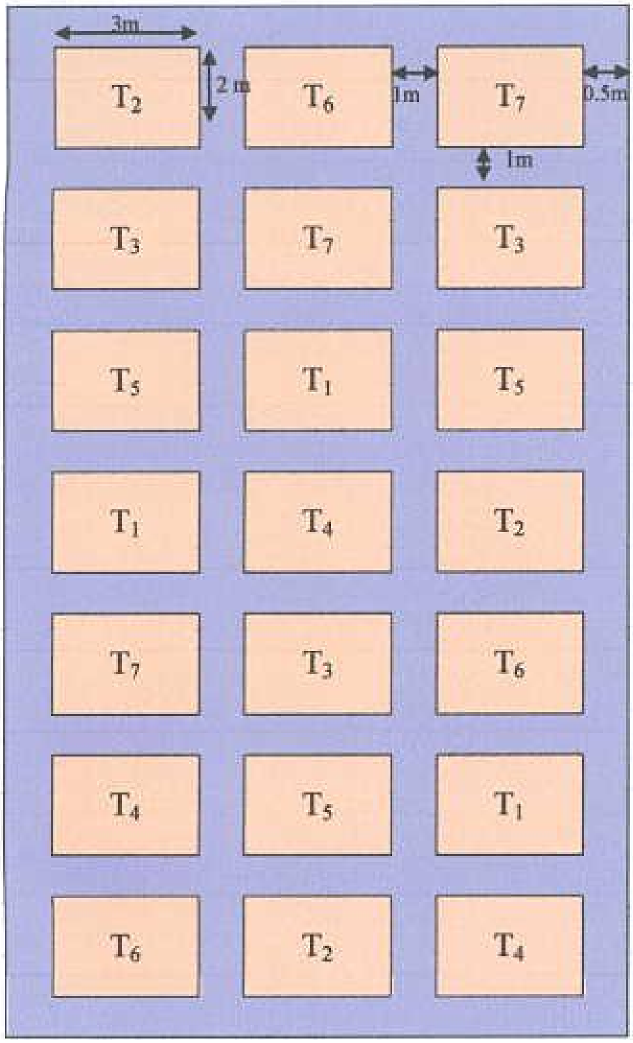
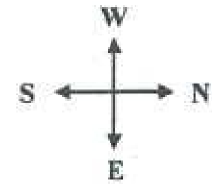


Fig. 9. Layout of the experimental plot

LEGEND



Layout:

Plot size: 3 m × 2 m

Plot spacing: 1 m

Between block: 0.5 m

Treatments:

T_1 = Neem leaf extract @ 0.5 kg L^{-1} of water at 5 days interval

T_2 = Neem leaf extract @ 0.5 kg L^{-1} of water at 10 days interval

T_3 = Neem oil @ 3.0 ml L^{-1} of water at 5 days interval

T_4 = Neem oil @ 3.0 ml L^{-1} of water at 10 days interval

T_5 = Garlic extract @ 0.5 kg L^{-1} of water at 5 days interval

T_6 = Garlic extract @ 0.5 kg L^{-1} of water at 10 days interval

T_7 = Control

Appendix V. Incidence of different insect pest on infested plant of tomato under different botanical treatments during crop duration

Source of variation	Degrees of freedom	Mean square			
		No. of white fly plant^{-1}	No. of jassid plant^{-1}	No. of aphid plant^{-1}	No. of leaf miners plant^{-1}
Replication	2	0.730	0.061	1.047	0.012
Factor A	6	17.243*	4.246**	17.356*	5.559*
AB	12	0.808	0.114	2.526	0.312

Appendix VI. Effect of different botanicals treatment on leaf and fruit borer infestation in tomato by number during crop duration

Source of variation	Degrees of freedom	Mean square	
		Number of infested leaves plant^{-1}	Number of fruit borer infested fruits plant^{-1}
Replication	2	0.214	0.315
Factor A	6	12.328*	16.327**
Factor B	12	0.127	0.539

Appendix VII. Effect of botanicals on yield parameters affected by insect pest complex of tomato

Source of variation	Degrees of freedom	Mean square	
		Plant height (cm)	Number of branches plant^{-1}
Replication	2	0.426	1.114
Factor A	6	16.578*	20.347*
Factor B	12	1.286	1.758

Appendix VIII. Effect of botanicals on yield contributing parameters by weight affected by insect pest complex of tomato

Source of variation	Degrees of freedom	Mean square)	
		No. of healthy fruits plant^{-1}	No. of infested fruits plant^{-1}
Replication	2	0.044	0.217
Factor A	6	14.527*	17.539**
Factor B	12	0.384	0.488

Appendix IX. Effect of botanicals on yield contributing parameters by number affected by insect pest complex of tomato

Source of variation	Degrees of freedom	Mean square	
		Weight of healthy fruits plant^{-1} (g)	Weight of infested fruits plant^{-1} (g)
Replication	2	0.387	0.529
Factor A	6	12.667*	18.389*
Factor B	12	0.412	1.314

Appendix X. Effect of botanicals on growth and yield contributing parameters of tomato

Source of variation	Degrees of freedom	Mean square		
		Healthy fruit yield (t ha^{-1})	Infested fruit yield (t ha^{-1})	Total fruit yield (t ha^{-1})
Replication	2	0.142	0.377	1.473
Factor A	6	22.569*	18.539**	24.557*
Factor B	12	1.344	1.218	2.419