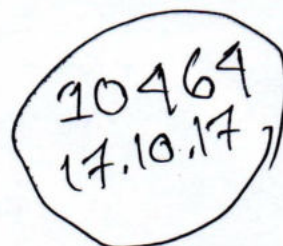


**INCIDENCE AND CONTROL OF THRIPS TABACI (THYSANOPTERA:
THRIPIDAE) ON ONION USING NEEM LEAF EXTRACTS**

A THESIS

BY



MD. HABIBUR RAHMAN

Registration No. 1505190

Semester: July-December, 2016



MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY



DEPARTMENT OF ENTOMOLOGY

**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
UNIVERSITY, DINAJPUR**

DECEMBER, 2016

**INCIDENCE AND CONTROL OF THRIPS TABACI (THYSANOPTERA:
THRIPIDAE) ON ONION USING NEEM LEAF EXTRACTS**

A THESIS

BY

MD. HABIBUR RAHMAN

Registration No. 1505190

Semester: July-December, 2016

*Submitted to the Department of Entomology
Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfillment of the requirements for the degree of*

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY



**DEPARTMENT OF ENTOMOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
UNIVERSITY, DINAJPUR**

DECEMBER, 2016

**INCIDENCE AND CONTROL OF THRIPS TABACI (THYSANOPTERA:
THRIPIDAE) ON ONION USING NEEM LEAF EXTRACTS**

A THESIS

BY

MD. HABIBUR RAHMAN

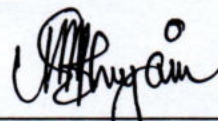
Registration No. 1505190

Semester: July-December, 2016

Approved as to style and content by



Professor Dr. Md. Alamgir Hossain
Supervisor



Dr. Md. Mosharof Hossain Bhuyain
Co-supervisor



Professor Dr. Hasan Fuad El Taj
Chairman, Examination Committee
and
Chairman of the Department

**DEPARTMENT OF ENTOMOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
UNIVERSITY, DINAJPUR**

DECEMBER, 2016

**Dedicated
To My
Beloved Parents**

ACKNOWLEDGEMENT

“Alhamdulillah”-All compliments and thanks are due to the Glorified, “Allah ta-ala” the creator of the heavens and the earth. Who is the most kind, the most merciful and grant me the power and ability to complete the research work and this manuscript successfully for the degree of Master of Science (MS) in Entomology.

The author feels proud to express his profound respect, deepest sense of gratitude, heartfelt appreciation to his honorable teacher and research supervisor, Professor Dr. Md. Alamgir Hossain, Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his constant inspiration, scholastic guidance, invaluable suggestion during the conduct of this research and for his constructive criticism and hearted cooperation, and affectionate feeling during preparation of the manuscript.

The author expresses his deep sense of gratitude and heartiest appreciation to his co-supervisor Dr. Mohammad Mosharof Hossain Bhuyain, Associate professor, Department of Entomology, HSTU, Dinajpur for his kind help, co-operation and valuable advice during the progress of the work.

It is also a great pleasure for the author to express hearty appreciation and regard to all honourable teachers of the Department of Entomology, HSTU, Dinajpur for their encouragement and valuable intimation during the research work.

Finally, the author expresses his indebtedness and profound respect to his beloved parents, brother Harun-Ur-Rashid for their best wishes, co-operation and continuous encouragement during this study.

The author

ABSTRACT

The experiment was conducted to study the incidence of onion thrips, *Thrips tabaci* (Lindeman) in field conditions and mortality also tested using three different solvent (acetone, petroleum benzene and distilled water) extracts of neem leaf powder in the laboratory of the Department of Entomology, HSTU, Dinajpur during the period from November, 2015 to April, 2016. Results showed that the highest number of thrips was observed at the end of March, 2016 while the lowest was 3.93 due to heavily rainfall on 29 March, 2016. The average number of nymphs per plant was 4.91 when plant height was 39.49 cm then the number of nymphs increased up to 20.37 when the plant height was 42.78 cm. The maximum number of thrips (20.37) was observed at the end of March, 2016 when the mean number of leaves per plant was 4.11. The number of thrips per plant was negatively correlated with leaves per plant and plant height. Weather parameters (temperature, humidity and rainfall) had great influence on incidence of onion thrips population. In case of temperature, thrips population gradually increased with increasing average temperature at a certain level. On the other hand, thrips population decreased with increasing relative humidity and rainfall (cm). Among the tested extracts, acetone extract of neem leaf powder provided the highest mortality (33.67%) while the extract with distilled water caused the lowest mortality (12.33%). In case of control treatment, no mortality of thrips was found. The lowest LD₅₀ values of acetone extract of neem leaf powder at 1, 2, 3, 4 and 5 HAT indicated that acetone extract possessed the highest toxic effects. Acetone extract was highly toxic to nymphs of onion thrips and which provided 100% mortality within 5 hours after exposure. The LT₅₀ (h) values of acetone extract (1.56) provided best performance among the tested extract. It is revealed from the results that plant height, number of leaves and weather parameters have influence on incidence of onion thrips population. It is also revealed that acetone extract of neem leaf powder performed well to check the *T. tabaci* infestation.

CONTENTS

CHAPTER	TITLE	PAGE NO.
	ACKNOWLEDGEMENT	i
	ABSTRACT	ii
	CONTENTS	iii-iv
	LIST OF TABLES	v
	LIST OF FIGURES	vi
	LIST OF PLATES	vii
	LIST OF APPENDICES	viii-ix
CHAPTER I	INTRODUCTION	1-3
CHAPTER II	REVIEW OF LITERATURE	4-18
2.1	Systematic position	4
2.2	Natural history of thrips	4
2.3	Distribution	5
2.4	Morphology of thrips	5
2.5	Seasonal distribution of thrips	6
2.6	Biology of <i>T. tabaci</i>	7
2.7	Eggs	8
2.8	Larvae	8
2.9	Pupae	8
2.10	Adults	9
2.11	Nature of damage	9
2.12	Management	12
2.12.1	Cultural manipulation	12
2.12.2	Biological control	14
2.12.3	Onion thrips insect pest management by using botanicals	15
2.12.4	Neem	16
CHAPTER III	MATERIALS AND METHODS	19-28
3.1	Location of the experimental plot	19
3.2	Soil	19
3.3	Climate	19
3.4	Land preparation	20
3.5	Application of manures and fertilizers	20
3.6	Experimental design and layout	21
3.7	Seeds used for experiment	21
3.8	Collection of onion seedling	22
3.9	Transplanting date of onion seedling	22
3.10	Transplanting procedure	22
3.11	Intercultural operation	22
3.11.1	Irrigation	22
3.11.2	Gap filling	22
3.11.3	Weeding and mulching	23

CONTENTS (Contd.)

CHAPTER	TITLE	PAGE NO.
3.12	Treatments of the Experiment	23
3.13	Data Collection	23
3.13.1	Field data	24
3.13.1.1	Counting of onion thrips number per plant	24
3.13.1.2	Plant height (cm)	24
3.13.1.3	Number of leaves per plant	24
3.14	Harvesting	25
3.15	Cleaning, drying and storing	25
3.15.1	Laboratory data	25
3.15.1.1	Preparation of neem leaf extracts	25
3.15.1.2	Preparation of different dosage	26
3.15.1.3	Test of neem leaf extracts on onion thrips	27
3.15.1.4	By residue on substrate	27
3.15.1.5	Mortality test of onion thrips	28
3.16	Statistical analysis	28
CHAPTER IV	RESULTS AND DISCUSSION	29-44
4.1	Incidence of onion thrips	29
4.2	Relationship between numbers of onion thrips with plant height	29
4.3	Relationship between numbers of onion thrips with leaves per plant	31
4.4	Effect of weather parameters on onion thrips	32
4.5	Probit analysis	35
4.5.1	Performance of solvent extracts against onion thrips	35
4.5.2	Performance of doses against onion thrips	36
4.5.3	Probit analysis for toxic effect	38
4.5.4	Probit regression lines	39
4.5.6	Lethal effects of neem leaf powder extracts on onion thrips	43
CHAPTER V	SUMMARY AND CONCLUSION	45-46
	REFERENCES	47-62
	APPENDICES	63-72

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1	Effect of neem leaf extracts against onion thrips at different HAT(Interaction of solvents of neem leaf powder and time)	37
2	Toxic effect of different doses of different solvent extracts against onion thrips, <i>T. tabaci</i> at different HAT (Interaction of doses and time)	37
3	Interaction effects of three solvents extracts of neem leaf powder and dose on onion thrips, <i>T. tabaci</i> at different HAT (Interaction of solvents of neem and time)	38
4	Relative toxicity (by probit analysis) of different solvents extracts of neem leaf powder against onion thrips, <i>T. tabaci</i> after 1, 2, 3, 4 and 5 HAT	40
5	Statistical comparison of the lethal effects of three different solvents extracts of neem leaf powder on onion nymphs (n=15)	44

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1	Graph showing the average number of nymphs at different dates of observation period	30
2	Graph showing the relationship between the number of onion thrips and plant height (cm)	31
3	Graph showing relationship between the number of onion thrips and leaf per plant	32
4	Relationship between mean numbers of onion thrips with average temperature	33
5	Relationship between mean numbers of onion thrips with average relative humidity	34
6	Relationship between mean numbers of onion thrips with total rainfall	35
7	Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against <i>T. tabaci</i> at 1 HAT	41
8	Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against <i>T. tabaci</i> at 2 HAT	41
9	Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against <i>T. tabaci</i> at 3 HAT	42
10	Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against <i>T. tabaci</i> at 4 HAT	42
11	Relationship between probit mortality and log doses of different solvent extracts of neem leaf powder against <i>T. tabaci</i> at 5 HAT	43
12	Proportion surviving of onion thrips nymph to various exposure times (hours) at 1.5 ml dose level. Here, the elaboration of the legend is: AE = Acetone extract; PBE = Petroleum benzene extract; DWE = Distilled water extract of neem leaf powder, and DW = Distilled water (Control).	44

LIST OF APPENDICES

APPENDIX NO.	TITLE	PAGE NO.
1	Experimental location in the map of Agro-Ecological Zones of Bangladesh	63
2	Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Nashipur; Dinajpur-5200.	64
3	Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site.	65
4	ANOVA table of the toxic effect of different solvent extracts of neem leaf powder against the nymph of <i>Thrips tabaci</i> at 1 HAT.	65
5	ANOVA table of the toxic effect of different solvent extracts against the nymph of <i>Thrips tabaci</i> at 2 HAT.	65
6	ANOVA table of the toxic effect of different solvent extracts against the nymph of <i>Thrips tabaci</i> at 3 HAT.	66
7	ANOVA table of the toxic effect of different solvent extracts against the nymph of <i>Thrips tabaci</i> at 4 HAT.	66
8	ANOVA table of the toxic effect of different solvent extracts against the nymph of <i>Thrips tabaci</i> at 5 HAT.	66
9	ANOVA table of the effect of day on onion thrips number per plant.	67
10	ANOVA table of the effect of plant height on onion thrips number per plant.	67
11	ANOVA table of the effect of leaf per plant on onion thrips number.	67
12	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in acetone solvent at 1 HAT.	68
13	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in acetone solvent at 2 HAT	68
14	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in acetone solvent at 3 HAT	68
15	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in acetone solvent at 4 HAT	69
16	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in acetone solvent at 5 HAT	69
17	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in petroleum benzene solvent at 1 HAT.	69
18	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in petroleum benzene solvent at 2 HAT.	70

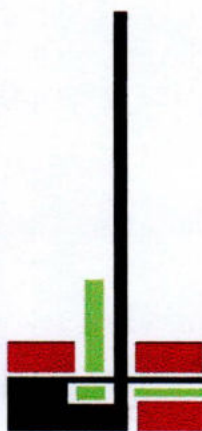
LIST OF APPENDICES (Contd.)

APPENDIX NO.	TITLE	PAGE NO.
19	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in petroleum benzene solvent at 3 HAT.	70
20	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in petroleum benzene solvent at 4 HAT.	70
21	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in petroleum benzene solvent at 5 HAT.	71
22	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in distilled water solvent at 1 HAT.	71
23	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in distilled water solvent at 2 HAT.	71
24	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in distilled water solvent at 3 HAT.	72
25	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in distilled water solvent at 4 HAT.	72
26	Doses mortality data of nymph of <i>Thrips tabaci</i> treated with neem leaf extract in distilled water solvent at 5 HAT.	72



Chapter I

Introduction



INTRODUCTION

Onion (*Allium cepa* L.), the kitchen of queen is an important spice crop in Bangladesh. In Bangladesh, it ranks first in production (989000 MT) and second in area (125101 ha) among the spices and it covers almost 36% of the total areas under spices (BBS, 2013). The mean yield of onion in Bangladesh is very low (4 t/ha) compared to world average of 18.21 t/ha (FAO, 2004). During winter, it is widely cultivated all over the country. Its cultivation is concentrated in the greater districts of Faridpur, Pabna, Rajshahi, Jessor, Mymensingh, Comilla and Rangpur. Although production of onion is increasing day by day, but in a land hungry country like Bangladesh, it may not be possible to meet the domestic demand due to increase in population. There is an acute shortage of onion in relation to its requirement. Every year, Bangladesh has to import a big amount of onion from neighbouring and other countries to meet up its demand. The high demand of onion can only be met by increasing its production vertically. Farm level yield of onion is very low compared to their recommended yield.

It is appreciated for its pungency due to presence of a volatile oily substance known as allyl propyl disulphide. It has manifold uses such as spices, vegetable, salad, dressing etc. It is used in cooking (soups, sauces, dried fish, sandwich, meat etc.) as much for flavoring materials. Onion contains protein, fat, vit.-A, vit.-B, iron and calcium. It has many medicinal properties and is applied on bruises and wounds. It also relieves head sensation and insect bites. Onions are also rich in flavonoids and alkenyl cysteine sulfoxides which play a part in preventing heart disease and other ailments in humans (Javadzedah *et al.*, 2009; Havey *et al.*, 2004 and Gareth *et al.*, 2002).

The high demand of onion can only be met by increasing its production vertically. Among the major factors limiting onion production the insect pests and diseases are

major threats. Onion plant in field are attacked by a number of insect i.e. *Thrips tabaci* and cut worms (*Agrotis sp.*) etc. in worldwide (Muendo and Tschirley, 2004; Rabinowitch and Currah, 2002). Amid those, onion thrips is the most important insect pest of onions. It is considered to be the most economically important pest of onion worldwide (Trdan *et al.*, 2005) is responsible for causing considerable reduction in yield (Trdan *et al.*, 2005; Nawrocka, 2003 and Brewster, 1994). This insect causes significant economic losses, by reducing yields up to 60% (Fournier *et al.*, 1995). In Kenya, thrips can cause up to 59% loss in yield (Waiganjo *et al.*, 2011). It has also effect on onion seed production. Thrips damage to young onions is more devastating than on larger plants late in the growing season; however, thrips feeding opens up the onion to secondary infections.

Therefore it is important to protect the onions from thrips from the attack during growing season. At present, pest control measures mostly rely on synthetic insecticides in Bangladesh. But chemical measures suffer so many serious drawbacks (Cooper *et al.*, 2007). Their extensive uses causes pest resurgence and outbreak of secondary pests, creates phytotoxicity, residues in foods and feeds (Luckman and Metcalf 1978, 2004; Martin *et al.*, 2003; Ashamo 2004; Nas, 2004 and Burkett-Cadena *et al.*, 2008). Moreover, continuous use of insecticides leads to hazardous effect on pollinators, natural enemies e.g. predators, parasitoids and also caused the environmental pollution (Saxena, 1992; Nagarare and More, 1998; Hossain, 2001).

Researchers and scientists all over the world are now trying to adopt alternatives of insecticides to controlling onion thrips. Among the various alternatives, use of plant based materials, i.e., botanicals stands top most position to protect insect pests. They become promising grain protectants by offering many advantages in comparing to insecticides, such as, host specific, non-toxic to mammals and beneficial organisms, less

prone to insect resistance, readily biodegradable and less expensive (Kavitha *et al.*, 2008).

They have less environmental impact and benefit our agricultural sector. Besides these, botanicals are cheaper, easy to process and raw materials are available at farmer' level. Among the compounds from neem plant, azadirachtin plays a vital role in insect pest management. It has proved its pest controlling efficacy against several insect pests in field (Saxena *et al.*, 1981). Neem based insecticides also proved as a potential antifeedant, growth retardant and having adverse effects in the longevity of insect pests (Barman, 1993). Keeping these in view, the present research work was therefore planned and designed with the following objectives.

Objectives

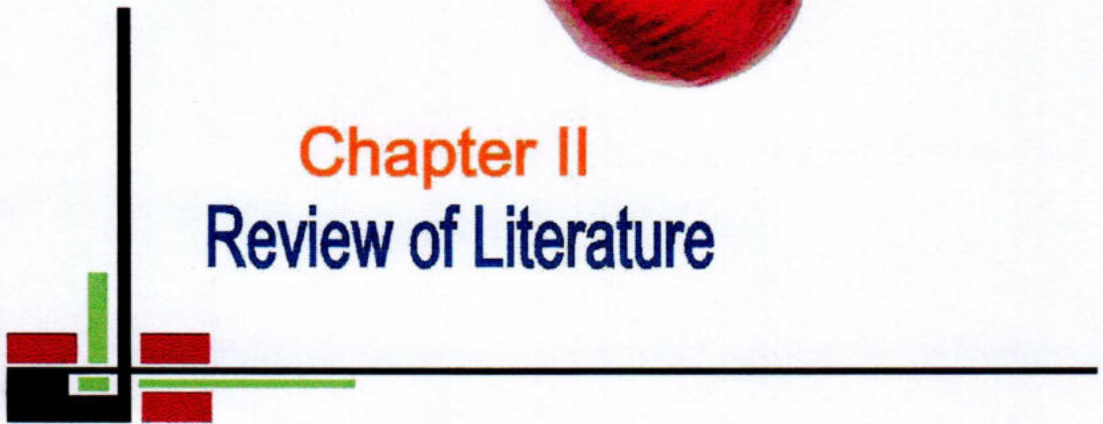
Considering the above points the experiment have been undertaken to fulfill the following objectives:

- To identify the incidence of onion thrips.
- To determine the effect of neem leaf extracts on nymph mortality of onion thrips.



Chapter II

Review of Literature



REVIEW OF LITERATURE

Onion thrips (*Thrips tabaci* Lindeman) is one of the major destructive insect pests of onion. In most seasons, damage by thrips to newly emerging onion plant happens to a greater or lesser degree. Attacks are more severe during periods of slow growth and in particular on stony soils. Thrips first appear in most vegetable fields in mid-to-late June and have numerous overlapping generations throughout the summer months. The biology, distribution, nature of damage, host range, effective control measures and various other substantial works has been done globally on this pest. The available literature on onion thrips that is relevant to these studies has been reviewed in this manuscript to explore the possibilities for successful management of this pest.

2.1 Systematic position

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Family: Thripidae

Genus: *Thrips*

Species: *T. tabaci* (Foster *et al.*, 2010)

2.2 Natural history of thrips

Thrips are believed to have descended from a mycetophilic ancestor during the Mesozoic, (Grimaldi *et al.*, 2004) and many groups still feed upon and inadvertently redistribute fungal spores, but most research has focused on those species feeding on or in association with economically significant crops. Some thrips are predatory, but the majorities are phytophagous insects feeding on pollen and the chloroplasts harvest

from the outer layer of plant epidermal and mesophyll cells (Heming *et al.*, 1993 and Kirk, 1995). These species are minute organisms that prefer to feed within the tightly packed apical buds of new growth. Feeding usually occurs along the main vein or ribs of leaves and petals (Lewis, 1973). Flower-feeding thrips may be responsible for pollination while feeding, (Derksen, 2009) but their most obvious contribution to their ecosystem remains the damage they can cause during feeding. This impact may fall across a broad selection of prey items, as there is considerable breadth in host affinity across the order, and even within a species, varying degrees of fidelity to a described host remain (Mound, 2005). Family Thripidae is particularly notorious for members with broad host ranges, and the majority of pest thrips come from this family (Bailey, 1940). While poorly documented, chemical communication is believed to be important to the group (Blum, 1991). Anal secretions are produced in the hindgut (Derksen, 2009) and released along the posterior setae as predator deterrents (Lewis, 1973). Some Phlaeothripidae, such as genera *Kladothrips* and *Oncothrips* form eusocial groups similar to ant colonies, with reproductive queens and nonproductive soldier castes. Many thrips form galls on plants when feeding or laying their eggs.

2.3 Distribution

Thrips is widely distributed in China, Iran, Korea, India, Indonesia, Sri Lanka, Philippines, Fiji (Reitz *et al.*, 2011; Tang *et al.*, 2002).

2.4 Morphology of thrips

Mound and Palmer (1981) indicated the following characters for *Thrips* genus-group: Antennae 8- segmented, ocellar setae pair I present; median metanotal setae at anterior margin; metanotal spinula absent; tergite VIII with postero marginal comb usually interrupted; and sternal discal setae absent. The males of two species, including *T.*

tabaci, are easily known by an array of short, spear-shaped setae ventrally on the abdomen. A further problem is recognition of the plant species on which these thrips can maintain a population. These thrips are highly vagile, and the females that predominate in all populations and land on many plants on which they cannot breed (Mound, 2013). Ratios of larvae per adult female of each thrips species of less than and greater than one were considered indicative of declining and increasing populations, respectively (Northfield *et al.*, 2008). Thripidae females use their saw like ovipositor to make an incision into plant tissue and then the egg is embedded into the incision (Lewis, 1973).

2.5 Seasonal distribution of thrips

According to Kranz *et al.*, (1977), the number of thrips on a crop can increase rapidly in dry weather and decrease rapidly after rain. They found that large number of thrips attacking a crop at the seedling stage. However, once established and growing vigorously, most plants could tolerate feeding damage. Adults and nymphs were present from February to harvest (April or May) with peak abundance in early April (Edelson *et al.*, 1986). Reuda and Shelton (2003) reported that at the end of the season, however, thrips might not be able to survive in abundance because there is not sufficient green vegetation in the surrounding areas, as April and May being the driest months of the year. They added that from June-September heavy rains maintained thrips population at low levels in native vegetation where they were not treated, i.e. living on wild flora. Earlier studies conducted on the insect pest were done in Zaria (Sub-humid zone of Nigeria) by Raheja (1973) which reported that population of thrips gradually built up and reached a peak 50 days after transplanting. Also Kisha (1977) found that few thrips were present on onion crop until mid-February when there was a sudden increase in numbers to peak levels during the first week of April, after which the numbers declined.

There has been no study conducted on the seasonal abundance on the insect in this agro ecology (Dry Sub-humid) where bulk of the crop is produced. Bakr *et al.*, (2004) conducted an experiment in the field against thrips population. They showed that during kharif season, the thrips catching ranged from 21.2-66.5. The white traps caught the highest number of thrips (297.4) followed by blue traps (227.6). In general, thrips infestation appeared from the first week of the crop, which progressively and significantly increased in successive crop stages up to 6 weeks.

In New York, four to six generations of onion thrips occur during the season (Narayansamy, 2013). The number of generations completed depends on temperature. For example, at a constant temperature of 68° F, only one complete generation would occur in the onion crop. In contrast, two complete generations would occur at a constant temperature of 77° F and four generations at a constant temperature of 86° F. At 86° F, a single female could be responsible for the production of nearly 16 million thrips over a two-month period, which is 76,000 times more than would be produced during the same period at 68° F and 588 times more than would be produced at 86° F (Kendall and Capinera, 1987).

2.6 Biology of *T. tabaci*

Onion thrips can complete their life cycle in as little as two weeks or as long as one month Uckland *et al.*, (2013). In New York, onion thrips populations may consist entirely of females that do not need to mate in order to lay fertile eggs (parthenogenesis). Other populations may include males and females and mating may occur (sexual reproduction). Regardless of the mode of reproduction, females lay eggs in onion leaves. Eggs hatch shortly after they are laid and small larvae begin feeding. Dai *et al.*, (2009) studied that there are only two instars and after the second completes

its development, it moves into the soil and becomes a pre-pupa. The pre-pupal stage transforms into a pupa and remains in the soil. Neither the pre-pupa nor the pupa feeds. Adults generally emerge from the soil five to seven days later and initiate another generation stated by Diaz-Montano *et al.*, (2010).

2.7 Eggs

Females have an ovipositor with saw-like structure that helps to make an incision in plant tissue for egg laying. Eggs are placed singly just under the epidermis of succulent leaf, stem or bulb tissue and flower. Eggs are elliptical, approximately 1/125 inch in length. They are whitish at deposition and change to an orange tint as development continues. Hatching occurs in 4-5 days in Hawaii (Arrieche *et al.*, 2006 and Bagheri *et al.*, 2002). Hatching occurred in 2.82 ± 1.33 days in laboratory conditions.

2.8 Larvae

Larvae are whitish to yellowish. There are two larval stages and besides the adults they are the only damaging stages. Larval development is completed in about 9 days. L1 development was completed in about 1.95 ± 1.42 days and L2 was 4.12 ± 0.92 respectively (Lewis, 1973).

2.9 Pupae

There are two non-feeding stages called the prepupa and pupa. They do not feed and occur primarily in the soil. Combined pre-pupal and pupal development is completed in 4-7 days. They occurred primarily in the soil. Combined pre-pupal and pupal development is completed in 1.03 ± 1.44 and 1.97 ± 0.91 days (MacIntyre-Allen, 2005).

2.10 Adults

Nault and Shelton (2010) reported that adults are 1/25 inch long. Their body color ranges from pale yellow to dark brown; wings are unbanded and dirty gray. In Hawaii, this species has a darker form during the rainy season. Males are wingless and exceedingly rare. Females live for about two to three weeks and each can lay about 80 eggs. Adults were about 0.9 mm long. Their body color ranged from pale yellow to light brown; males were exceedingly rare. Adult development was completed in about 14.4 ± 3.13 days. Females live for 12 to 17 days and each of them could lay about 26.82 ± 5.56 eggs. The egg was inserted by the female in soft plant tissue; it was slightly protuberant and visible to the unaided eye (Reitz, 1999).

2.11 Nature of damage

Onion crop is attacked by several insects such as onion thrips, *T. tabaci* Lindeman; onion fly, *Delia antique* Meign; cutworm, *Agrotis epsilon* Hufnagel, tobacco leaf eating caterpillar, *Spodoptera litura* Fabricius and gram pod borer, *Helicoverpa armigera* (Hubner). Among the insect pests, onion thrips (*Thrips tabaci*) is a major pest and reported to be most serious on onion (Shock, 2009). *T. tabaci* (L.) feeds on sap from leaf epidermal cells, which become air-filled and thereby exhibit silvery sheen that is characteristics of damage by this insect (Jones and Jones, 1974). Infested leaves may become twisted. Young onion plants are more susceptible and may be killed by heavy thrips attack (Lewis, 1973). Raheja (1973) observed that damage by thrips in early stages of crop growth would seem to be more important and is likely to result in substantial reduction in yield. Anon (2004) found that large number of thrips kill onion seedlings, while damage to older plants by thrips may cause crops to mature early and subsequently reduce yields. This symptom was typically associated with the presence of



specks of black trays. Flower petals might also become discolored and deformed. In the open, populations might be very large during hot, dry weather (Lewis, 1997). Onion thrips preferred to feed on the young plant tissue on the newest emerged leaves. When the leaf grew, the previous damage produced by the thrips enlarged, leaving empty spaces in the surface of the leaf. The appearance of the damage was silvery patches. When damage was severe, these small patches could occupy most of the surface of the leaf and the plant could not adequately photosynthesis. The plant lost more water than normal through the damaged tissues and plant pathogens penetrate the injured plant easily. This pest is also important as a vector of tomato spotted wilt virus (TSWV). Only the larvae can acquire the virus (Shelton and North, 1987; Waterhouse, 1987; Zawirska, 1980; Lockwood, 1956). Mostly in glasshouses, *T. tabaci* colonies could be very large and they could often cause very severe direct and indirect damage (Lewis, 1997). Lewis (1973) observed that time of sowing and harvesting crops can also reduce the severity of injury. Kisha (1977) stated that early transplanted onions were usually well established before attack began in mid-February of 1970-71 and Kisha (1977) added that a mean number of 5-10 nymphs/plant be adopted as a critical level at which commencement of control measures can be made. However, Edelson *et al.*, (1989) noted that insecticide applications were initiated when populations of thrips increased above one thrips/plant. If left unsprayed such a population would reach peak levels soon afterwards. The possible reason why this occurred was the parthenogenesis nature of thrips (Shelton *et al.*, 1982). Adesiyun (1981, 1982) found that damage caused by shoot flies to sorghum planted early in the season was low and insignificant and this low population was on the scanty vegetation during the dry season. Reuda and Shelton (2003) reported that at the end of the season, however, thrips might not be able to survive in abundance because there is not sufficient green vegetation in the surrounding

areas, April and May being the driest months of the year. They added that from June-September heavy rains maintained thrips population at low levels in native vegetation where they were not treated.

Onions are most sensitive to thrips injury during the rapid bulb enlargement phase that occurs in dry season particularly during irrigation season November to early June in Ethiopia. Yield reduction due to reduced bulb size is the primary crop loss caused by onion thrips. Accelerated plant maturity and senescence due to thrips injury may truncate the bulb growth period. Following harvest and during storage, thrips may continue to feed on onion bulbs, causing scars that reduce quality and aesthetic appearance of bulbs. *Thrips tabaci* feeding damage results in leaf tissue silverying and photosynthesis reduction, leading to bulb size reduction and yield loss (Childers, 1997).

The characteristic symptom of attack is a silvery sheen of the attacked plant tissue, and white or silvery patches and streaks on leaves. Affected tissue will dry up when the damage is severe. Damaged leaves may become papery and distorted. Infested terminals lose their color, roll, and drop leaves prematurely. Moreover, *T. tabaci* has been identified as the main vector of an emerging tospovirus, the Iris Yellow Spot Virus (IYSV), which is correlated to bulb size reduction in western states (Gent *et al.*, 2004).

Total and marketable bulb yield were determined at physiological maturity (Gachu *et al.*, 2012). Feeding by thrips causes tiny scars on leaves and fruit, called stippling, and can stunt growth. Damaged leaves may become papery and distorted. Infested terminals may discolor, become rolled and drop leaves prematurely.

2.12 Management

Insecticide use is the major tactic used to manage thrips. However, resistance to insecticides and the lack of highly efficacious products has made control difficult. In New York, we have documented widespread resistance to lambdacyhalothrin (Warrior) and in some thrips population's low levels of resistance to methomyl (Lannate LV). Consequently, it is critical to identify new products for thrips control (Shock *et al.*, 2012).

2.12.1 Cultural manipulation

Plant health adherence through removal of volunteer onion plants and weeds around the cultivated fields and crop rotation would be useful in minimizing thrips populations in onion field (Waiganjo *et al.*, 2008). Gachu *et al.*, (2012) reported that intercropping onion with spider plant and carrot reduced thrips population by up to 45.2% and 21.6%, respectively. Other intercropping systems which have significantly reduced thrips population and plant infestation include leek with clover (Belder *et al.*, 2000) leek with carrot, and clover with French bean (Kucharczyk and Legutowska, 2002).

Intercropping of various plant species has also been investigated to compare reductions in colonization rates of onion thrips and overall reductions in yield (Trdan *et al.*, 2006). Mulching has also been reported to reduce thrips infestation considerably (Jensen *et al.*, 2002). The potential for kaolin was as a deterrent to oviposition and feeding of onion thrips on onions (Larentzaki *et al.*, 2007). The effect of intercropping on thrips population densities and damage depends, among other factors, on the selection of plants species. A mixed cropping habitat is likely to encourage thrips predators, as has been shown for the minute pirate bugs; *Oriustritis discolor* (Parella and Lewis, 1997).

Ellis and Bradley (1992) reported that blue sticky traps are good for monitoring thrips population and also reported the pest could be well controlled; if the crop debris is destroyed properly. Parella and Murphy (1996) used sticky traps to monitor thrips. Rateaver and Rateaver (1993) reported that soil fertility management affects thrips infestation and damage. Lack of adequate soil calcium may invite higher population of thrips. Use of fertilizer not only affects the nutritive value of plants but also impacts the insect pest densities (Cantisano, 1999).

Soil fertility management may also affect thrips infestation and damage. According to one source, a lack of adequate soil calcium may invite higher populations of thrips (Rateaver and Rateaver, 1993). Another writer suggests that nutritional balance can reduce thrips attack. High nitrate levels will invite thrips, and the effects of excessive nitrate are compounded by shortages of potassium, sulfur, boron, and manganese. Foliar applications of soluble calcium and kelp will balance the excess nitrogen. These nutrient levels can be monitored on a weekly basis, using plant tissue analysis, to make accurate adjustments (Anon, 1992). The use of cover crops can affect the number of overwintering thrips. Oats is a better choice, but requires later fall planting than rye or wheat a factor that constrains its use as a cover crop in colder regions (Quarles, 1990). Drought stress increases the susceptibility of onions to thrips damage. Adequate irrigation throughout the growing season is a critical factor in minimizing damage of thrips (Fournier *et al.*, 1995). The fact that thrips are color-sensitive suggests that colored mulches may be effective in their control. Louisiana researchers conducted a study to see whether aluminum coated mulch would repel the pest (Antignus, 1996). The reflective mulch repelled 33 to 68% of the thrips. Ultraviolet-absorbing plastics used to build walk-in field tunnels have proved effective in protecting crops from western flower thrips (Ludger and Jean, 2005). Mulching with wood shavings can be

used as a strategy to improve onion yield and bulb size under the agro ecological settings of the area of Mersan (Ludger and Jean, 2005). Regarding thrips population cultural management, the farmers are much interested in the outcome thus 30 cm inter row spacing with 20 cm plant-to-plant distance is recommended for commercial farming of onion (Muhammad *et al.*, 2003). *T. tabaci* can be effectively managed by early planting/transplanting with bulb yields (Ibrahim and Adesiyun, 2008).

2.12.2 Biological control

There are many beneficial organisms prey to harm onion thrips. Some of these include ladybird beetles, minute pirate bugs, ground beetles, lacewings, hover flies, predatory mites, and spiders (Hoffmann *et al.*, 1996). Some authors observed that the effect of *Beauveria bassiana* against the onion thrips was significantly increased after 3 days where as the effect of *Metarhizium* against the onion thrips was prolonged unlikely decreasing trend resulting unsatisfactory control of the pest (Shiberu, 2013).

Beauveria bassiana was most effective when used early at economic threshold level, before large thrips populations have built up. The influence of temperature on the infection process is very important. According to them, the temperature at which

Metarhizium infecting adult thrips is about 23°C and decreases in temperature of 3 to 5°C increase the time to death of the insect about a day. *Beauveria bassiana* species is used as a contact myco-insecticide but survives a relatively short period of time when exposed on a leaf surface. The killing capacity of this fungus at 3rd, 5th, and 7th day was 46.18, 54.31 and 60.67%, respectively thrips population (Shiberu, 2013).

Neil *et al.*, (2004) reported that *Beauveria* infection can kill the insect from 3 to 7 days, leaving a while mass of spores which can spread to other insects. Some authors observed that the effect of *Beauveria bassiana* against the onion thrips was significantly

increased after 3 days whereas the effect of *Metarhizium anisopliae* against the onion thrips was prolonged unlikely decreasing trend resulting unsatisfactory control of the pest (Shiberu, 2013). *Beauveria bassiana* was most effective when used early at economic threshold level, before large thrips populations have built up. In field trials conducted at the experiment shores of Lake Victoria, Kenya, applications of 2% or 3% neem seed extract (NSE) @ 200 l/ha with a knapsack sprayer at 38, 47 and 51 days after emergence (DE) of the cowpea crop or 5%, 10% or 20% NSE sprayed @ 10 l/ha with an ultra-low-volume applicator at 31, 39 and 49 DE often significantly reduced the number of larvae of the flower thrips, *Megalurothrips usitatus* (Trybom), in cowpea flowers recorded 2 days after each treatment. Also fewer adults occurred in flowers at 51 DE in plots sprayed with 5%, 10% or 20% NSE. Cowpea grain yield was significantly higher in plots sprayed with 20% NSE than in untreated control plots and was comparable to the grain yield obtained in plots sprayed thrice with cypermethrin. Because of the low cost of NSE treatment, the net gain was often more when the crop was sprayed with NSE than with cypermethrin. Also, grain quality was superior in neem treated plots than in untreated or cypermethrin treated plots (Kidiavai, 2009).

2.12.3 Onion thrips insect pest management by using botanicals

Botanical pesticides are the most cost effective and environmentally safe inputs in integrated pest management (IPM) strategies. There are about 3000 plants and trees with insecticidal and repellent properties in the world, and India is home to about 70% of this floral wealth (Nazrussalam *et al.*, 2008). The neem seed kernel extracts, neem oil, extracts from the leaves and barks have all been used since ancient times to keep scores of insect pests away. A number of commercial neem-based insecticides are now available and they have displaced several toxic chemical insecticides. The extracts are of particular value in controlling the sucking and chewing pests.

2.12.4 Neem

Scientific name : *Azadirachta indica*

Family : Meliaceae

Neem is a perennial tree, 15-20m in height with a straight trunk; leaves are simple, number of leaflets 9-15, opposite, sub-opposite or alternate, lanceolate, acuminate or sub falcate. Flowers are white, Fruit (Drupe) oblong (Rice *et al.*, 2007). Neem is well-known for its medicinal properties. The main active component is azadirachtin, which is famous for its toxic, antifeedant and growth regulating effects on insects (Saxena *et al.*, 2004). A variety of preparations based on Neem extracts have been tested against stored product insects. Azadirachtin rich commercial "Margosan-O" is already produced in developing countries for controlling pests. (Jacobson, 2004). Neem derivatives have been demonstrated as repellents, antifeedants, growth inhibitors and chemosterilant (Butterworth and Morgan, 1968; Leuschner, 1972; Steets, 1976). Singh and Srivastava (1985) found that alcohol extract of neem oil, *Azadirachta indica* (5%) reduced oviposition of *B. cucurbitae* on bittergourd completely and its 20% concentration was highly effective to inhibit oviposition of *B. zonata* on guava. Stark *et al.*, (1990) studied the effect of Azadirachtin on metamorphosis, longevity and reproduction of *Ceratitis capitata*, *B. cucurbitae* and *B. dorsalis*. Gupta and Pathak (2009) reported that the efficacy of some indigenous neem products, insecticides and their admixture' were tested at Research Farm of College of Agriculture, Tikamgarh during kharif 2003-2005. The results indicated that admixture treatments, neem seed kernel extract (NSKE) (in cow urine), 3% + dimethoate, 0.03% and neem oil, 0.5% + dimethoate, 0.03% not only reduced the incidence of onion thrips and yellow mosaic but also of pod borer. These treatments gave maximum grain yield of 935 and 902 kg ha⁻¹, net profit of Rs 3934 and

Rs 3320 ha⁻¹ with incremental cost benefit ratio of 11.2 and 10.9, respectively. In a laboratory study, Butler and Rao (1990) reported that 0.5% sprays of 3 commercial neem oil formulation namely Neemguard, Newark, Neempon to single eggplant leaves against onion thrips resulted 97% fewer eggs and 87% fewer immature compared to those on untreated leaves. The crude extracts and active principles isolated from number of other plants have anti feedant, insecticidal, hormonal and repellants properties (Jayaraj, 1988). Plant products play an important role in evolving an ecologically sound and environmentally acceptable pest management system. Grainage *et al.*, (1985) reported that neem is the major source of antifeedant principles and the seed contain a number of toxic terpenoids. The ether extract of *Tribulus terrestris* L. had juvenilising effects on cutworm (*Spodoptera litura*) and pod borer (*Heliothis armigera*), respectively (Gunasekaran and Chelliah, 1985). Treatment of Triflumuron, a moult inhibitor against thrips nymphs or pupae reduced the adult emergence (Radwan *et al.*, 1985). Visalakshimi *et al.*, (2005) reported that application of neem effectively reduced the oviposition of *H. armigera* throughout the crop period. Among various IPM components (neem 0.06%, HaNPV 250 L/ha, bird perches one/plot, endosulfan 0.07%), neem and HaNPV found as effective as endosulfan in the terms of reduction larval population and pod damage, further, endosulfan comparatively found toxic to natural enemies present in chickpea eco-system. Jeyakumar and Gupta (1999) reported neem seed kernel extract (NSKE) reduced the oviposition of *H. armigera* in a dose dependent manner during the exposure periods of 0-24 h and 24-48 h and showed oviposition deterrency effect. Reduction of oviposition was highest (60.9%) with 10% NSKE. The hatchability of the laid eggs was also affected on NSKE treated surface. Akhauri and Yadav (1999) observed that aqueous extracts of neem seed kernel and green castor leaves each at 5 and 10 per cent concentration, neem and mahua oils and mangraila

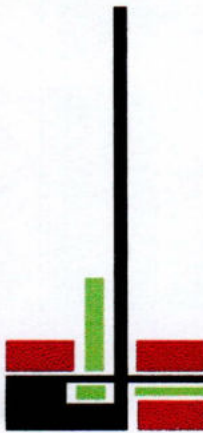
(*Nigella sativa* L.) seed extract in water each at 2 per cent concentration, were effective in controlling *Melanagromyza obtusa*, *Apion clavipes* Gerst and *H. armigera*.

Butani and Mittal (1993) studied the efficacy of neem seed kernel suspension and several conventional insecticides against *H. armigera* and reported that all the tested insecticides significantly reduced the pest population and neem seed kernel suspension being equally effective. Sarode *et al.*, (1994) studied the efficacy of different doses of neem seed kernel extract (NSKE) for the management of pod borer. It was found two sprays of NSKE 6% at 7 days interval provided significantly high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%) and suggested that it may be used in managing *H. armigera*. Oils of plant origin such as neem seed oil (Puri *et al.*, 1991; Haq, 2011), soybean oil (Haq, 2011), cotton seed oil (Haq, 2011), have been tested against onion thrips and the results were encouraging.



Chapter III

Materials and Methods



MATERIALS AND METHODS

This chapter deals with the materials and methods those were used conducting the study. It consists of a short description of location of the experimental plot, characteristics of soil, climate, material used, treatments, layout and design of the experiment, land preparation, sowing and gap filling, after cares, harvesting, and collection of data. These are described below under the headings and sub-headings:

3.1 Location of the experimental plot

The experiment was conducted in the Central Farm of Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from November, 2015 to April, 2016.

3.2 Soil

The soil was silty clay in texture having 50.8% sand, 32.4% silt and 16.8% clay and the pH was 6.13. Textural class of the soil was loamy. The physio-chemical properties of the soil are presented in Appendix II. The experimental site belongs to the Old Himalayan Piedmont Plain Agro Ecological Zone (AEZ-1) as shown in Appendix I. The experimental site was a medium high land.

3.3 Climate

The climate of the experimental site was under the sub-tropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). There was no rainfall during the month of November and December, little rain in January and February. The average maximum temperature during the period of experiment was 33.8°C and the average minimum temperature was 13°C.

Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Weather Observatory (Synoptic), Rajbati, Dinajpur and presented in Appendix III.

3.4 Land preparation

The experimental field was ploughed with power tiller. After ploughing the field was left to nature for 10 days for sun and nature to work upon. Subsequent cross ploughing was done followed by laddering to make the land level. Then the soil clods were broken by a wooden hammer and all weeds, stubbles and residues were removed from the field. Later, Cow dung @ 10 ton/ha and chemical fertilizer like Urea, Triple Super Phosphate (TSP) and Murate of Potash (MP) was mixed with soil during final land preparation. Finally the land was properly leveled before seed sowing and plots were prepared as per the experimental design.

3.5 Application of manures and fertilizers

The entire quantity of the well-decomposed cow dung was applied just after opening of the land. The experimental field was fertilized with Nitrogen (in the form of Urea), Phosphorus (in the form of Triple Super Phosphate -TSP), Potassium (in the form of Murate of Potash -MP), Sulfur (in the form of Gypsum), Zink (in the form of ZnO) and Boron (in the form of Boric powder). As per the treatment, whole quantity of TSP, MP, Gypsum, ZnO, Boric powder and one fourth of Urea were applied at final plot preparation. The rest of the urea was applied later in three installments on 40, 60 and 80 days after planting.

Fertilizer was applied as per recommended doses (BARI, 2006). Applied doses of chemical fertilizers were as follows:

Element Fertilizer		Fertilizer dose (kg/ha)	Fertilizer applied during final land preparation	Rest installments (Urea) (kg/ 30m ² land)		
				1 st	2 nd	3 rd
N	Urea	320	0.24	0.24	0.24	0.24
P	TSP	415	1.245	-	-	-
K	MP	168	0.504	-	-	-
S	Gypsum	100	0.30	-	-	-
Zn	ZnO	5	0.015	-	-	-
B	Boric powder	5	0.015	-	-	-
	Manure	10,000	30	-	-	-

3.6 Experimental design and layout

The experimental plots were arranged in Randomized Complete Block Design (RCBD) with three (3) replications. The experiment details were given bellow:

- Total plot area : 30 m²
- Number of plot : 12
- Plot size : 0.72 m²
- Block to block distance : 0.8 m
- Plot to plot distance : 0.4 m
- Plot to boundary distance (lengthwise) : 0.4 m
- Plot to boundary distance (breadthwise) : 0.2 m
- Plant to plant spacing : 0.15 m
- Row to row spacing : 0.24 m

3.7 Seeds used for experiment

The experimental material was the bulb of "Taherpuri onion" which is a cherished local Cultivar. The bulb was used as seed material. Bulbs were selected from storage. After harvest the tops were removed along with roots. The bulbs were cured in the shady place and were placed in storage at ambient conditions.

3.8 Collection of onion seedling

Seedlings of onion were collected from Horticulture Centre, Dinajpur.

3.9 Transplanting date of onion seedling

Uniform seedlings were transplanted uniformly in the experimental plot in 30th November, 2015.

3.10 Transplanting procedure

Before transplantation, the top of seedlings leaves, at length of 10 to 12 cm from the base was cut with a sharp knife; the roots were also cut at 2cm from the base (a usual practice followed by farmers which may help decreased transpiration and faster root development). Bulbs were set upright at a depth of 2.5cm (Asaduzzaman *et al.*, 2012). The prepared seedling was transplanted, as per design and spacing in the evening and watered on the next following days up to establishment of seedling. A good number of seedlings were transplanted at the border for later use as gap fillers.

3.11 Intercultural operation

3.11.1 Irrigation

Irrigation was given as per requirement of the land with regular intervals. First irrigation was given after a days of transplanting and continued up to harvesting of crop. Water cane with perforated mouth piece was used for soft discharged of water. Irrigation was generally followed the each weeding of the crops.

3.11.2 Gap filling

The dead or sick seedlings were replaced by healthy seedlings within a week after transplantation. The damaged plants were also replaced by border plant through gap filling.

3.11.3 Weeding and mulching

Weeding is the most important aspect in respect of onion production. First weeding was done by hand picking at 20 days after transplanting (DAT). Subsequent three weeding were followed by irrigation with "khurpi". At the same time, some soils were put into the bed along with rows from the drain for making the root zone of onion plants strong enough. The common weeds were *Cynodon dactylon* L. (Durba grass), *Cyperus rotundus* L. (Mutha) etc. Weeding was done carefully keeping the delicate plants undisturbed. Mulching was done to keep the crop for better soil aeration and conserve soil moisture.

3.12 Treatments of the Experiment

Four treatment combinations were tested in this experiment.

T₁= Acetone extract of neem leaf powder.

T₂= Petroleum Benzene extract of neem leaf powder.

T₃= Distilled Water extract of neem leaf powder.

T₄= Distilled water (Control).

3.13 Data Collection

In general, data were collected at various stages of plant growth and development, during harvest and also after post-harvest operation.

3.13.1 Field data

For data collection ten plants per plot were randomly selected and tagged. Collection of data was started from vegetative stage up to harvesting. Data were collected and

recorded on number of onion thrips at 3 months after transplanting from thrips infested plants by direct counting. Field data were collected in respect of following parameters.

3.13.1.1 Counting of onion thrips number per plant

Data were collected and recorded on number of onion thrips at 3 days intervals during the observation periods. Numbers of thrips were counted from the selected plants by direct counting with the help of magnifying glass. Seven observations were taken in this case.



Plate 1. Counting of onion thrips number per plant

3.13.1.2 Plant height (cm)

Plant height was measured from the ground level up to the tip of the longest leaf. Average plant height was determined from 10 randomly selected plants at 40, 50, 60, 70, 80, 90 and 100 DAT in centimeter (cm) using a wooden meter scale.

3.13.1.3 Number of leaves per plant

The number of leaves was recorded from 10 randomly selected plants at 40, 50, 60, 70, 80, 90 and 100 DAT by direct counting.

3.14 Harvesting

The bulbs of the onions were harvested 120 days after transplanting in the main field when the leaves were appeared to dry and also the necks were fallen down on the ground and thus the when the scale leaves were easily peeled out by hand rubbing.

3.15 Cleaning, drying and storing

The bulbs were harvested with necks and after harvesting the necks were cut down with sharp knife and then dried by spreading in the open sunlight on brown paper until those reached the safe moisture content. After putting the bulbs in 15 polyethylene bags according to plot these were kept in dry and cool place at room temperature for laboratory test.

3.15.1 Laboratory data

3.15.1.1 Preparation of neem leaf extracts

Leaves of neem plant (Fig.1) were collected and kept in the laboratory for air drying followed by one day sun drying before making powder. After drying they were made powdered by an electric grinder and passed through a 60-mesh sieve to get fine powder. 10 grams of leaf powder were then separately mixed with 30 ml of different solvents (acetone, petroleum benzene and distilled water), stirred for 30 minutes and left stand for next 24 hours. The mixture was filtered through a fine cloth and again through what man no.1 filter paper. The filtrates were taken into round bottom flasks and condensed by evaporation of solvent in a water bath at 45°, 70° and 80° C temperature for acetone, petroleum benzene and water extracts, respectively to make it 10 ml which was used as stock solution.



Plate 2. Collected leaf of neem

3.15.1.2 Preparation of different dosage

From the stock solution, three concentrations (10%, 20% and 30%) of neem leaf extract were prepared with acetone, petroleum benzene and distilled water. For 10% concentration of neem leaf extract, 0.5ml neem leaf extract was mixed with 4.5 ml acetone, petroleum benzene and distilled water, respectively. For 20% concentration of neem leaf extract, 1.0 ml neem leaf extract was mixed with 4.0 ml acetone, petroleum benzene and distilled water, respectively. Similarly, for 30% concentration of neem leaf extract, 1.5 ml neem leaf extract was mixed with 3.5 ml acetone, petroleum benzene and distilled water, respectively. In case of control treatment only 5ml distilled water was used.



Plate 3. Preparation of different doses of neem leaf extract with different solvents

3.15.1.3 Test of neem leaf extracts on onion thrips

Neem leaf extracts were put on each petridish according to doses and 5 onion thrips was taken on every petridish.



Plate 4. Test of neem leaf extracts on onion thrips

3.15.1.4 By residue on substrate

The bottom of petri dishes (5.0 D × 1.3 H cm) was made residual film layered by pouring each of three different solvent extracts of neem leaf powder (1.0 ml/petri dish) taken from the 10% stock solution and dried for 1 hour. A control group was made with distilled water and assessed in the same manner stated above. Five unknown age of onion thrips nymphs collected from the field directly was then placed in each petri dish whose lid had single hole for ventilation and covered by thrips proof mesh with botanicals residue and incubated in the room temperature under laboratory condition without food sources. Mortality of nymphs was recorded every hour. A total of 15 thrips were tested for each solvent extract.

3.15.1.5 Mortality test of onion thrips

Mortality of onion thrips was determined by observing death time on petridish by keeping 5 onion thrips in each petridish. The data were collected every after one hour from each petridish until all the insect death.

3.16 Statistical analysis

Data regarding various characteristics under study collected from the experiment were statistically analyzed by the computer using the statistical package program MSTAT- C developed by Russel (1986). The means for all the treatments were calculated and the analysis of variance was performed by the 'F' variance test. Finally, the significance of difference between pair of means was performed by the least significant difference (LSD) test (Gomez and Gomez, 1984).



Chapter IV

Results and Discussion



RESULTS AND DISCUSSION

4.1 Incidence of onion thrips

The seasonal population of onion thrips is significantly ($P < 0.05$) different at different days after transplanting which is presented in figure 1. Among the dates, it shows thrips population was started to build up from mid-March and increase gradually up to end of this month (27.03.2016). The highest number of thrips was observed at the end of March 2016. After then population number sharply declined and came to 3.925 due to heavily showering. The results of present findings are similar with Liu (2004) who reported that in the Lower Rio Grande Valley (LRGV) of south Texas the incidence of *T. tabaci* were first present on onion plants in early February, increased in numbers gradually, and peaked in abundance in late March and early April. Mandal *et al.*, (2016) reported that the lower population of *Thrips tabaci* was recorded during 3rd week of March to last week of June and higher population level was maintained during last week of November to 3rd week of January in West Bengal, India. Our results contradict with their results due to variation in wide range of environmental conditions. Again, Waiganjo *et al.*, (2008) cited that thrips occurred in the onion field and infested onions in all the crop seasons. However, there was significant ($P < 0.05$) variation in thrips numbers between the crop seasons. The results of the present finding are comparable with Kranz *et al.*, (1977). They cited that the highest population of thrips was observed at the seedling stage. They also reported that the number of thrips on crop increased rapidly in dry weather and decreased rapidly after rain.

4.2 Relationship between numbers of onion thrips with plant height

The seasonal population of thrips due to plant height was significantly different ($P < 0.05$) at different days after transplanting which is presented in figure 2. Among the

plant height, it shows thrips population was recorded maximum at the end of March when plant height was 42.78 cm and then the population declined suddenly and came to 3.925 per plant due to rainfall. The average number of nymphs per plant was 4.909 when plant height was 39.49 cm and then the average number of nymph was increasing up to 20.37 when the height of plant (42.78 cm) was also increasing with days. The plant height was positively correlated with the increasing number of nymph of onion thrips which was significant ($P < 0.05$).

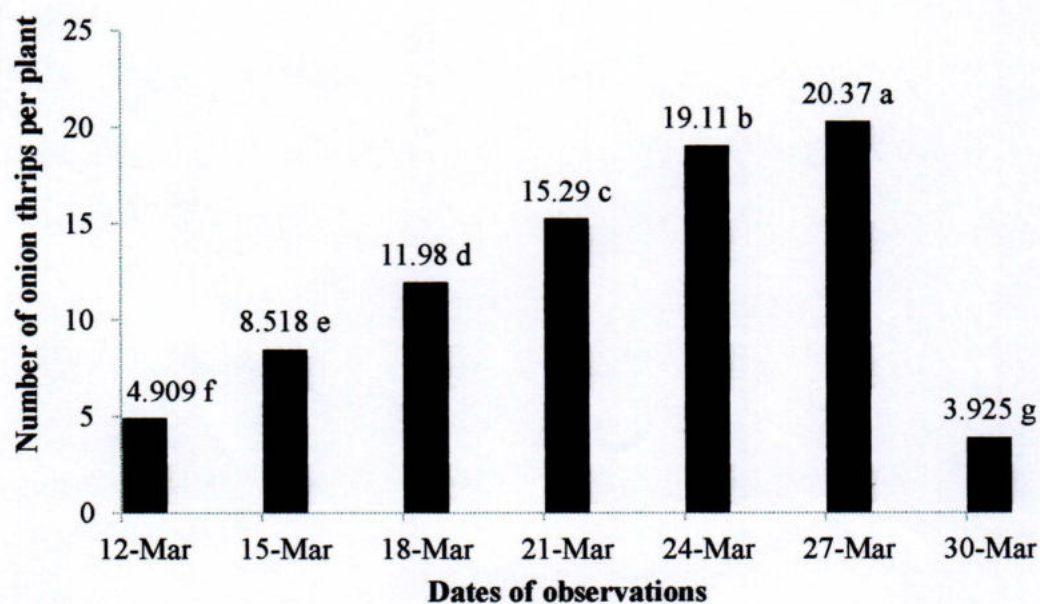


Figure 1. Graph showing the average number of nymphs at different dates of observation period

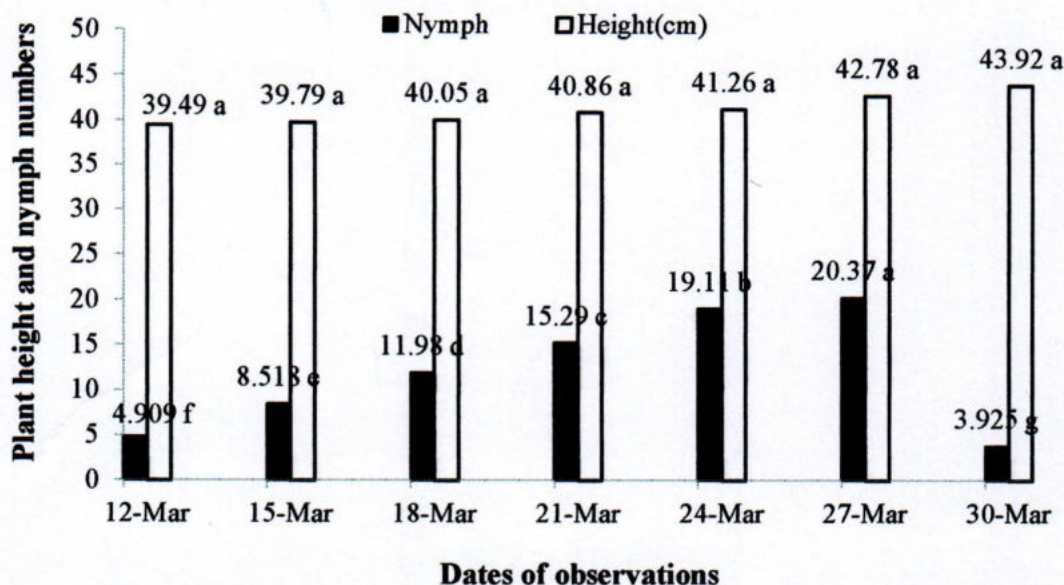


Figure 2. Graph showing the relationship between the number of onion thrips and plant height (cm)

4.3 Relationship between numbers of onion thrips with leaves per plant

The seasonal population of thrips was non-significantly ($p > 0.05$) different with leaves per plant at indicated days after transplanting which is presented in figure 3. Among the dates, it shows thrips population builds up from mid-March when average number of leaves per plant was 4.08 and increases gradually up to end of this month (27.03.2016) when average number of leaves per plant was 4.11. The maximum number of thrips (20.37) was observed at the end of March 2016 when average number of leaves per plant was 4.11. After then thrips population sharply declined and came to 3.93 at 30.03.2016 due to rainfall. The plant height was negatively correlated with leaves per plant. But plant height and leaves per plant were negatively correlated with the number of thrips per plant. Duranti and Cuocolo (1989) reported that slight increase in the number of leaves due to application of mulch in onion at that time population of thrips also high.

4.4 Effect of weather parameters on onion thrips

The relationship between onion thrips with average temperature, rainfall and humidity is presented in Figures 4-6. In case of temperature, onion thrips population gradually increased with increasing average temperature but decreased at temperature 25.65° C. Average temperature and population of onion thrips showed a negative correlation with each other ($r = 0.188$) (Figure 4). The co-efficient of determination ($r^2 = 0.0352$) revealed that 3.52% variation in the population of onion thrips accrued by the variation in mean temperature.

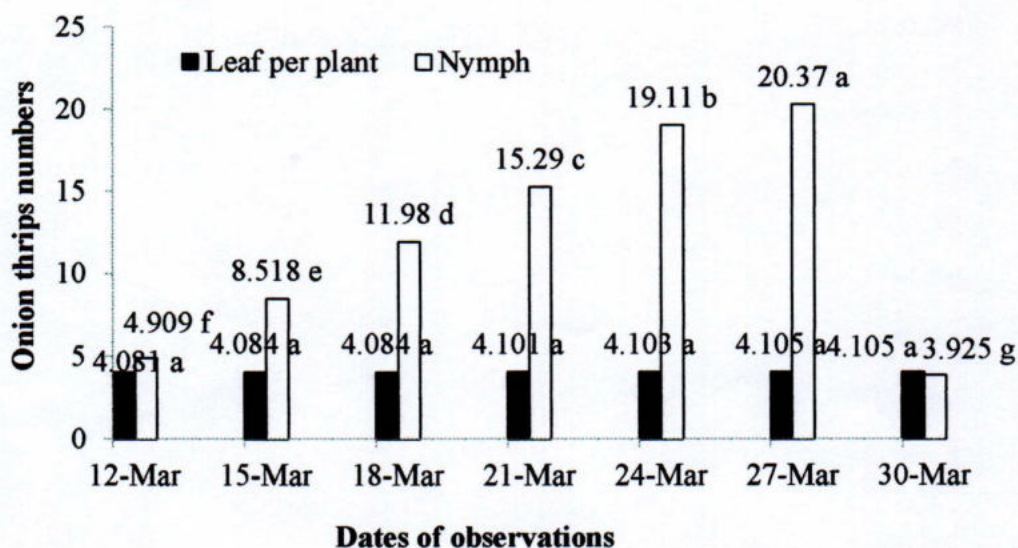


Figure 3. Graph showing relationship between the number of onion thrips and leaf per plant

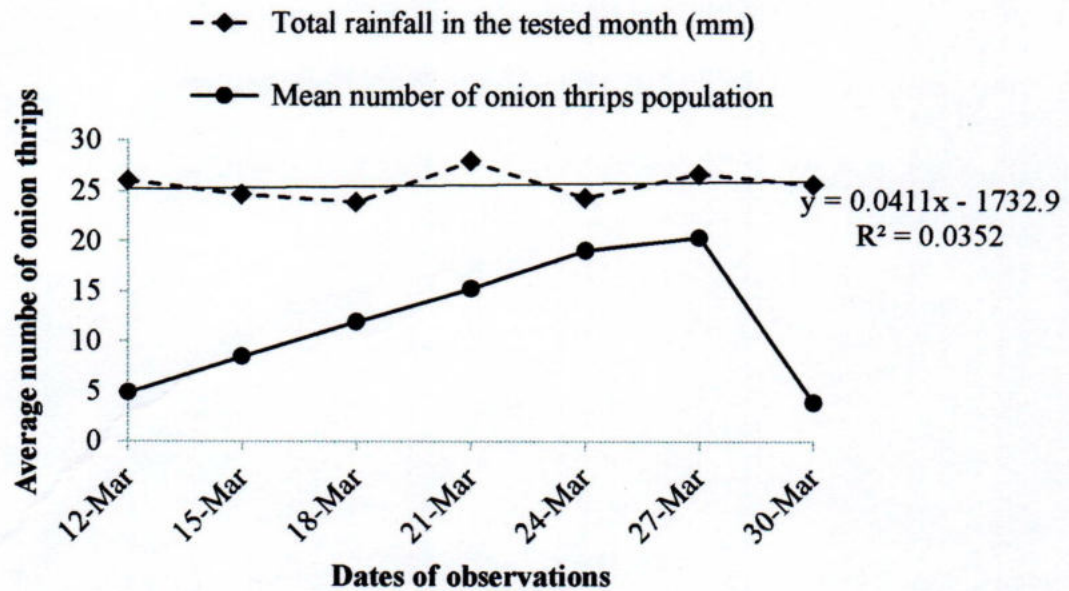


Figure 4. Relationship between mean numbers of onion thrips with average temperature

In case of relative humidity, onion thrips population increased with decreasing relative humidity. Relative humidity and population of onion thrips showed a negative correlation ($r = 0.504$) (Figure 5). The coefficient of determination ($r^2 = 0.2538$) revealed that 25.38% variation in the population of onion thrips accrued by the variation in the relative humidity.

Alimousavi *et al.*, (2007) and Bergant *et al.*, (2005) also find that *Thrips tabaci* is a very prolific species and can have overlapping generations under conducive environmental conditions especially at high temperatures. Mandal *et al.*, (2016) stated that thrips population had a significant positive correlation with temperature difference and relative humidity (maximum) while significant negative correlation with temperature (maximum, minimum and average). This indicates that activity of thrips population increase with the rise of relative humidity and population decrease with the rise of temperature.

In case of rainfall, onion thrips population decreased rapidly with increasing total rainfall. The total rainfall and population of onion thrips showed a negative correlation ($r = 0.327$) (Figure 6.) The coefficient of determination ($r^2 = 0.1069$) revealed that 10.69% variation in the population of onion thrips accrued by the variation in the total rainfall. The results of the present findings are similar with those of Waiganjo *et al.*, (2008) who experienced that dry weather (30.3 mm rainfall) with moderately high temperatures (15.6-28.2°C) increased seasonal thrips numbers, while wet season (391mm rainfall) with moderately high relative humidity was negatively correlated with thrips numbers. Sederatian *et al.*, (2010) who found that rainfall, relative humidity and minimum air temperature were negatively correlated with the thrips population. Again, similar result was found by Karar *et al.*, (2014) who stated effect of weather factors on thrips colonization depicted that heavy rainfall and low temperature had negative correlation with thrips abundance.

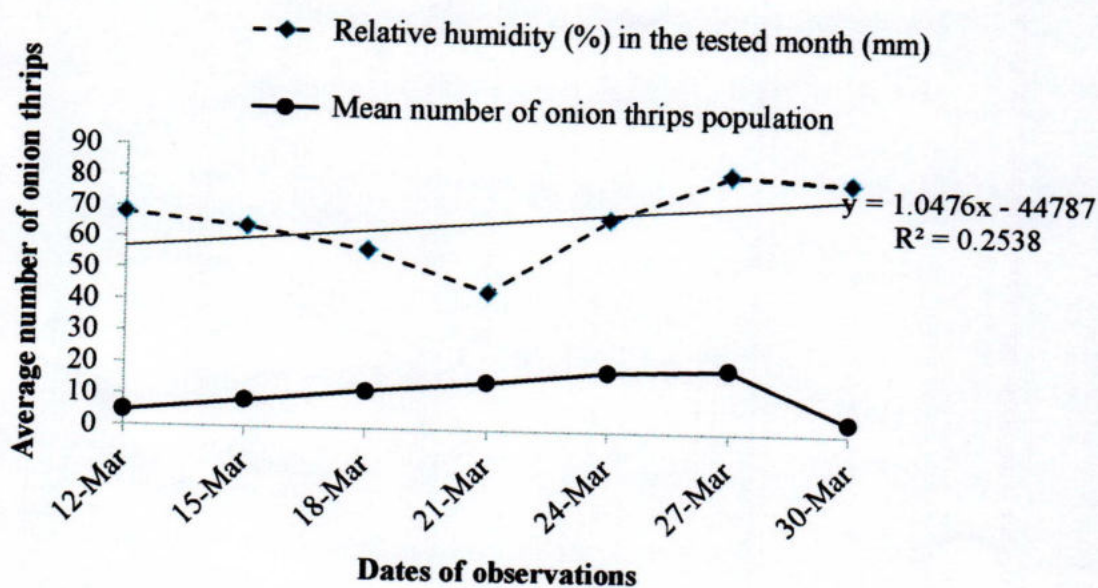


Figure 5. Relationship between mean numbers of onion thrips with average relative humidity

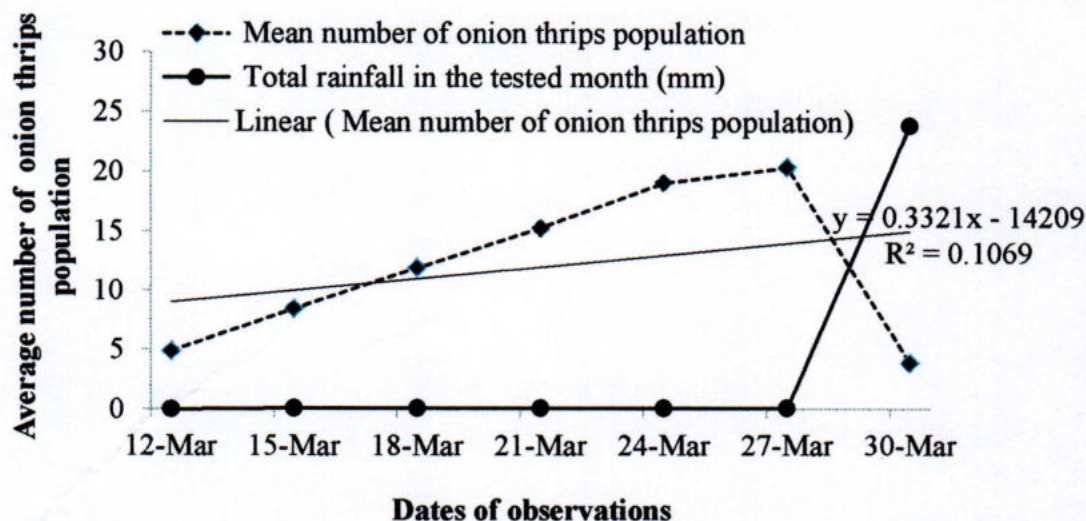


Figure 6. Relationship between mean numbers of onion thrips with total rainfall

4.5 Probit analysis

The efficacy of neem leaf powder using three different solvents namely acetone, petroleum benzene and distilled water against onion thrips, *T. tabaci* was evaluated in the laboratory conditions. The results of the experiments are presented and discussed under the following subheadings.

4.5.1 Performance of solvent extracts against onion thrips

Toxicity effect of tested neem leaf powder extracted with three different solvents against onion thrips is presented in Table 1. Among the solvent extracts, acetone showed the maximum (1.96 %) mortality while the distilled water showed the minimum (1.78 %) against the thrips at different observation periods. The moderate toxicity comes from petroleum benzene extract of neem leaf powder. The order of toxicity of three solvents extract against the onion thrips were found as acetone > petroleum benzene > distilled water. The mortality of insect showed significant differences while compared among the treatments ($df = 3, p < 0.05$). However, the death of nymphs was

increased with the increasing of time. Botanical extracts of garlic gave effective thrips control which was stated by Mandal *et al.*, (2016).

4.5.2 Performance of doses against onion thrips

The toxic effect of diverse doses of three solvents of neem leaf extracts on *Thrips tabaci* at different HAT is presented in Table 2. The doses showed significant differences in insect mortality ($df = 3, p < 0.05$). The highest mortality (2.32 %) was observed at the maximum dose of 1.5 ml while the lowest (0.85 %) was found in minimum (0.50 ml) dose. The mortality also directly proportional to the dose levels of three solvents of neem leaf extracts. In the control treatment, all nymphs were alive up to five hour where distilled water was used. The interaction effects of neem leaf extracts, dose and time are presented in Table 3. The mortality of insect showed significant differences ($df = 6, p < 0.05$) while treated with various doses of neem leaf extracts with solvents at different hours of intervals. The maximum mortality (3.47 %) was observed on acetone extract of neem followed by petroleum benzene (2.93%). On the contrary, the minimum mortality (2.40 %) estimated on Distilled water at maximum dose (1.5 ml). However, comparing the various doses among the solvents of neem leaf extracts, acetone also caused the highest mortality. From the above findings it is resulted that among the tested neem leaf extracts, acetone was the most effective on the mortality of the onion thrips.

Table 1. Effect of neem leaf extracts against onion thrips at different HAT (Interaction of solvents of neem leaf powder and time)

Treatments (solvent Extracts of neem leaf powder)	Insect mortality (%)					Average mortality
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT	
Acetone	13.33 a	26.67 a	38.33 a	43.33 a	46.67 a	33.67 a
Petroleum benzene	6.67 ab	18.33 b	26.67 b	36.67 a	40.00 a	25.67 b
Distilled water	0.00 b	3.33 c	11.67 b	20.00 b	26.67 b	12.33 b
Control	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b
P-value	0.0077	0.00	0.00	0.00	0.00	0.0001
CV (%)	141.42	50.68	34.51	30.00	23.34	27.77
LSD	7.94	6.88	7.43	8.43	7.43	5.59

Means followed by column the same letters did not differ significantly at 5% level by DMRT.

HAT = Hours after treatment.

Table 2. Toxic effect of different doses of different solvent extracts against onion thrips, *T. tabaci* at different HAT (Interaction of doses and time)

Treatments	Insect mortality (%)					Average mortality
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT	
1.50	17.78 a	35.56 a	48.89 a	60.00 a	66.67 a	45.78 a
Petroleum benzene	8.89 ab	22.22 b	33.33 b	42.22 b	48.89 b	31.11 b
Distilled water	0.00 b	6.67 c	20.00 c	31.11 c	35.56 c	18.67 c
Control	0.00 b	0.00 c	0.00 d	0.00 d	0.00 d	0.00 d
P-value	0.0012	0.00	0.00	0.00	0.00	0.00
CV (%)	141.42	50.68	34.51	30.00	23.34	27.77
LSD	9.17	7.94	8.58	9.73	8.58	2.21

Means in a column followed by the same letter(s) did not differ significantly at 5% level of probability by DMRT.

HAT =Hours after treatment.

Table 3. Interaction effects of three solvents extracts of neem leaf powder and dose on onion thrips, *T. tabaci* at different HAT (Interaction of solvents of neem and time)

Treatments (solvent extract of neem leaf powder)	Doses (mL ⁻¹)	Insect mortality (%)					Average mortality
		1 HAT	2 HAT	3 HAT	4 HAT	5 HAT	
Acetone	1.50	33.33 a	60.00 a	73.33 a	80.00 a	80.00 a	50.67 a
	1.00	20.00 ab	33.33 b	53.33 b	53.33 bc	60.00 bc	33.33 bc
	0.50	0.00 c	13.33 cd	26.67 cd	40.00 cde	46.67 cd	18.67 de
Petroleum Benzene	1.50	20.00 ab	40.00 b	53.33 b	66.67 ab	73.33 ab	50.66 ab
	1.00	6.67 bc	26.67 bc	33.33 c	46.67 cd	53.33 c	33.33 de
	0.50	0.00 c	6.67 d	20.00 cd	33.33 de	33.33 de	18.67 ef
Distilled water	1.50	0.00 c	6.67 d	20.00 cd	33.33 def	46.67 cd	21.33 bc
	1.00	0.00 c	6.67 d	13.33 de	26.67 ef	33.33 de	16.00 de
	0.50	0.00 c	0.00 d	13.33 de	20.00 f	26.67 e	12.00 ef
P-value	0.35	0.003	0.003	0.012	0.0002	0.0002	0.39
CV%	104.74	141.42	50.68	34.51	30.00	24.97	104.74
LSD	0.93	15.89	13.76	14.86	16.85	14.86	15.24

Means followed by column the same letters did not differ significantly at 5% level by DMRT.

HAT =Hours after treatment.

4.5.3 Probit analysis for toxic effect

The results of the probit analysis for the estimation of LD₅₀ values and their 95% fiducially limits at 1, 2, 3, 4 and 5 HAT for the mortality of onion thrips are presented in Table 4. The LD₅₀ values of acetone (2.75 mg), petroleum benzene (3.66 mg), and distilled water (6.21 mg) at 1 HAT indicated that acetone extracted neem leaf provided the most toxicity followed by petroleum benzene while distilled water was the least toxic. Acetone was also performed the highest toxicity as compared the LD₅₀ values at 2 (1.59 mg), 3 (1.24 mg), 4 (1.00 mg) and 5 (0.72 mg) HAT. The chi-square values of three solvents of neem leaf extracts at different HAT were insignificant at 5% level of probability and did not show any heterogeneity of the mortality data. From the probit

results it is found that all the tested solvents of neem leaf extracts would be effective for controlling onion thrips.

4.5.4 Probit regression lines

The probit regression lines for the effect of tested three solvents of neem leaf extracts against onion thrips are presented in figure 7, 8, 9, 10 and 11. The insect mortality rate presented positive correlation with doses in all cases. The probit regression lines for the effects of tested three solvents of neem leaf extracts against onion thrips showed a clear linear relationship between probit mortality and their log doses. The calculated probit regression equation lines for the efficacy of different neem leaf extracts at 1 HAT were $Y = 3.2437x + 1.348$, $Y = 2.9673x + 1.4963$ and $Y = 2.2273x + 1.9388$ for acetone, petroleum benzene and distilled water, respectively (Fig. 7). Among the three lines, the regression line for acetone showed the highest probit mortality while distilled water showed the lowest probit mortality. The calculated probit regression equations of three different neem leaf extracts at 2 HAT were $Y = 1.5771x + 3.0752$, $Y = 1.7777x + 2.653$ and $Y = 1.095x + 3.094$ for acetone, petroleum benzene and distilled water, respectively (Fig. 8). The probit regression lines for three solvent extracts of neem leaf powder against onion thrips at 3 HAT are given in figure 9. The regression equations were $Y = 1.7383x + 2.7841$, $Y = 1.7224x + 2.6627$ and $Y = 1.3945x + 2.7469$. At 4 HAT the probit regression equations were calculated as $Y = 1.013x + 5.088$, $Y = 1.777x + 3.920$ and $Y = 1.744x + 3.640$ (Fig.10). At 5 HAT the probit regression equations were also calculated as $Y = 1.013x + 5.088$, $Y = 1.777x + 3.920$ and $Y = 1.744x + 3.640$ (Fig.11). Comparing among the regression lines at 1, 2, 3, 4 and 5 HAT it is found that, the regression line for acetone also showed the highest probit mortality and distilled water showed the lowest probit mortality. The probit regression lines became steeper as doses increased because the adult insects were treated with more toxins for the same period at higher doses.

Table 4. Relative toxicity (by probit analysis) of different solvents extracts of neem leaf powder against onion thrips, *T. tabaci* after 1, 2, 3, 4 and 5 HAT

Treatments (solvent extracts of neem leaf powder)	No. of insect used	LD 50 values (%)	95 % fiducially limits		χ^2 values
			Lower	Upper	
1 HAT					
Acetone	45	2.76	0.78	9.61	1.50
Petroleum benzene	45	3.63	0.55	23.91	1.08
Distilled water	45	6.27	0.18	214.04	1.05
2 HAT					
Acetone	45	1.58	0.42	5.99	4.48
Petroleum benzene	45	1.87	0.65	4.07	0.69
Distilled water	45	2.34	0.72	7.61	0.32
3 HAT					
Acetone	45	1.23	0.91	1.67	3.06
Petroleum benzene	45	1.15	0.80	1.66	0.96
Distilled water	45	1.60	0.67	3.83	5.81
4 HAT					
Acetone	45	1.0	0.61	2.39	5.05
Petroleum benzene	45	1.07	0.69	1.45	0.94
Distilled water	45	1.21	0.69	1.64	0.79
5 HAT					
Acetone	45	0.83	0.47	1.94	7.45
Petroleum benzene	45	0.96	0.76	1.28	0.83
Distilled water	45	0.96	0.54	1.26	0.19

HAT = Hours after treatment

Values were based on three concentrations, three replications of 10 insects each. χ^2 = Goodness of fit

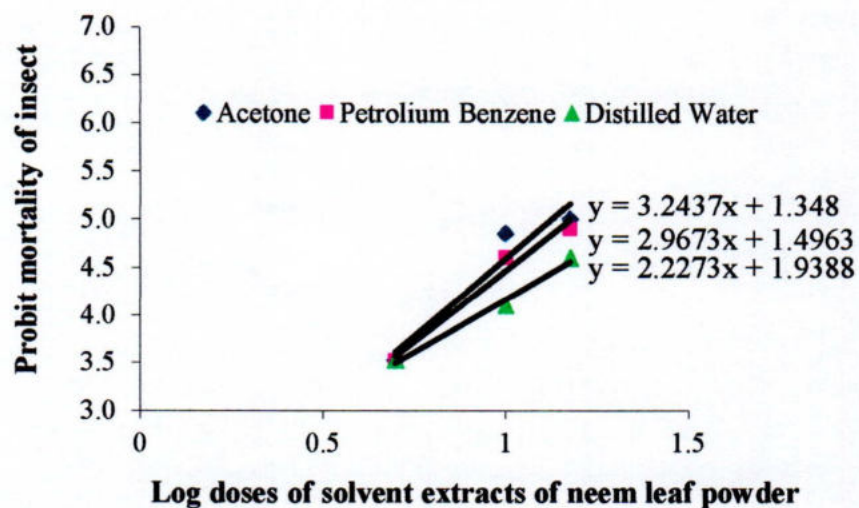


Figure 7. Relationship between probit mortality and log doses of different solvent extracts of neem leaf powder against *T. tabaci* at 1 HAT

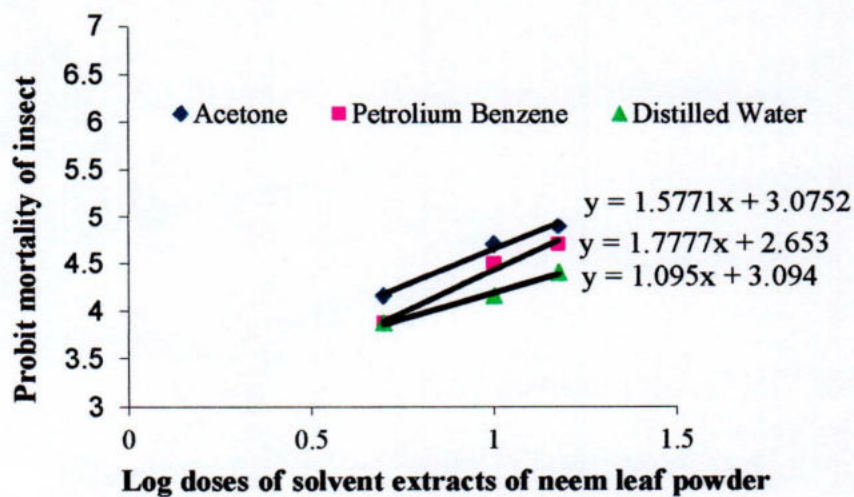


Figure 8. Relationship between probit mortality and log doses of different solvent extracts of neem leaf powder against *T. tabaci* at 2 HAT

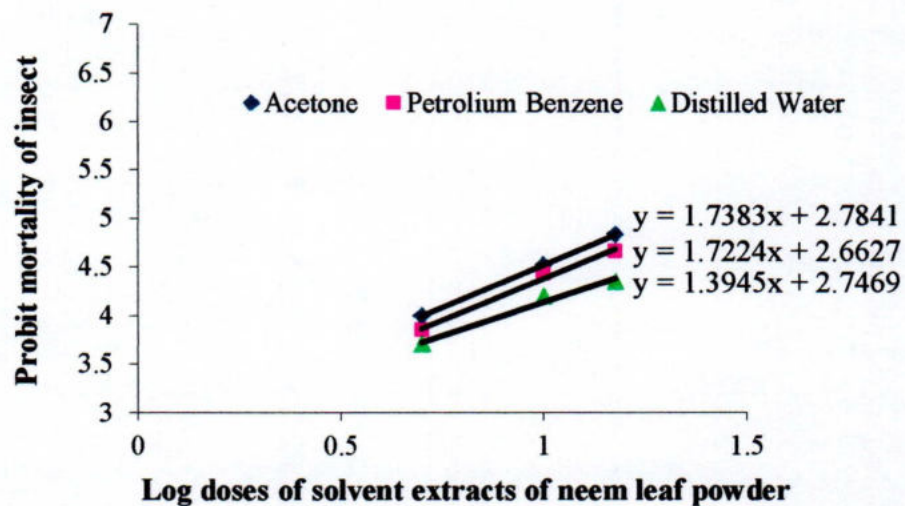


Figure 9. Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against *T. tabaci* at 3 HAT

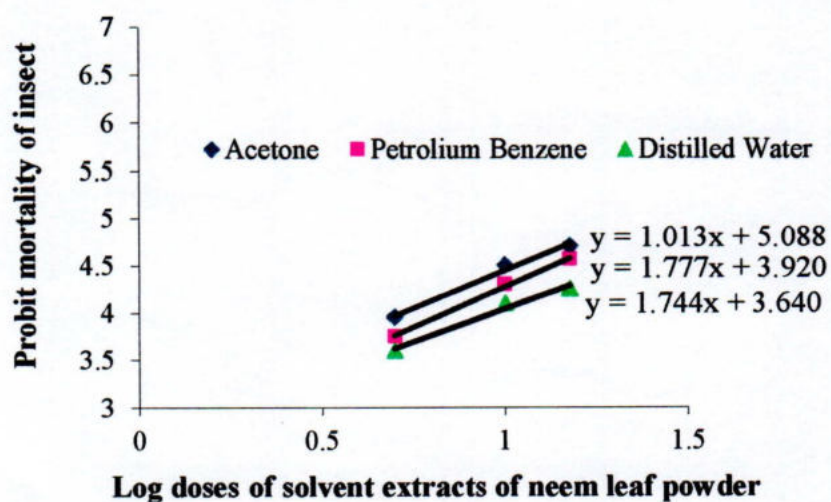


Figure 10. Relationship between probit mortality and log doses of different solvent extracts of neem leaf power against *T. tabaci* at 4 HAT

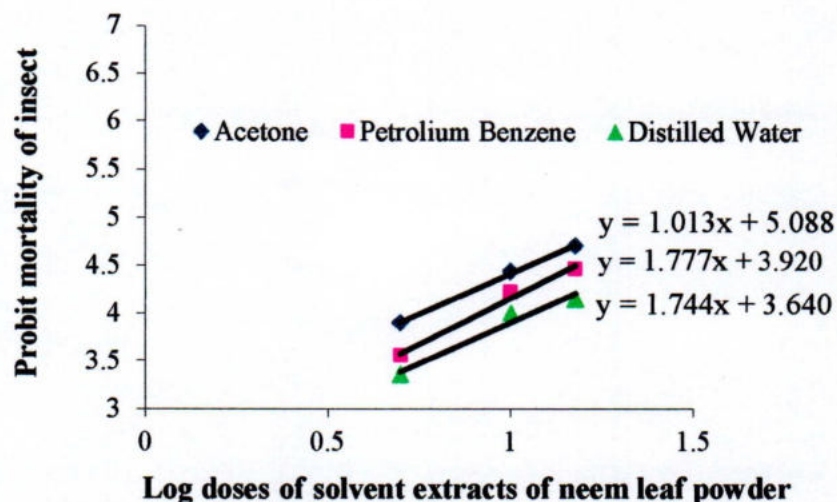


Figure 11. Relationship between probit mortality and log doses of different solvent extracts of neem leaf powder against *T. tabaci* at 5 HAT

4.5.6 Lethal effects of neem leaf powder extracts on onion thrips

Results of acute toxicity assay of three different solvent extracts of neem leaf powder are presented in Figure 13 and Table 5. Acetone extract was highly toxic to onion thrips nymphs, and 100% mortality occurred within 5 hours by exposure to residue. The LT_{50} (h) values of acetone extract (1.562) followed by petroleum benzene (1.985) and distilled water extract (2.610) were significantly lower than that of control (10.335) by residual film method (Table 5).

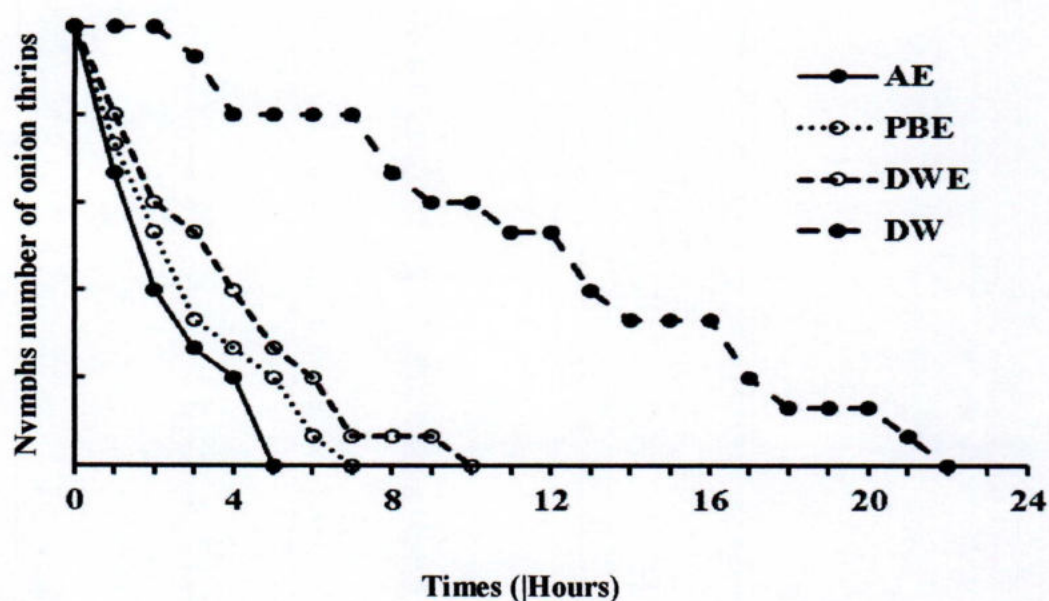


Figure 12. Proportion surviving of onion thrips nymph to various exposure times (hours) at 1.5 ml dose level. Here, the elaboration of the legend is: AE = Acetone extract; PBE = Petroleum benzene extract; DWE = Distilled water extract of neem leaf powder, and DW = Distilled water (Control).

Table 5. Statistical comparison of the lethal effects of three different solvents extracts of neem leaf powder on onion nymphs (n=15)

Treatments (neem leaf powder extract)	LT ₅₀ (h)	95% CI (lower limit, upper limit)	Slope $\pm$ SE	χ^2 (df)
Acetone	1.562 a	(0.911, 2.069)	2.713 $\pm$ 0.7	2.240 (3)
Petroleum benzene	1.985 a	(1.337, 2.543)	2.686 $\pm$ 0.5	2.452 (5)
Distilled water	2.610 a	(1.932, 3.229)	2.722 $\pm$ 0.4	3.710 (8)
Distilled water (control)	10.335 b	(9.199, 11.525)	3.340 $\pm$ 0.3	9.694 (20)



Chapter V

Summary and Conclusion

SUMMARY AND CONCLUSION

The experiment was undertaken to study the incidence of onion thrips, *Thrips tabaci* in field conditions. Also tested mortality of onion thrips using neem leaf powder extracted with three different solvents viz. acetone, petroleum benzene and distilled water in the laboratory of the Department of Entomology, HSTU, Dinajpur during the period from December, 2016 to April, 2016. The seasonal population of onion thrips is significantly ($P < 0.05$) different at different days after transplanting. Among the dates, it shows that thrips population was started to build up from mid-March and increase gradually up to end of this month (27.03.2016). The highest number of thrips was observed at the end of March 2016. After then population number sharply declined and came to 3.925 due to heavily showering. The seasonal abundance of thrips due to plant height was significantly different ($P < 0.05$) at different days after transplanting. Among the plant height, it shows that thrips population was recorded the highest at the end of March where plant height was maximum (43.92 cm). Then the population declined suddenly and came to 3.93 per plant. The average number of nymphs per plant was 4.91 when plant height was 39.49 cm and then the average number of nymph was increasing up to 27-03-2016 when the plant height (42.78 cm). The plant height was positively correlated with increasing number of nymph. The seasonal population of thrips was also significantly ($p < 0.05$) different with leaves per plant at indicated days after transplanting. Among the dates, it shows that thrips population builds up from mid-March when average number of leaf per plant was 4.08 and increase gradually up to end of this month (27.03.2016) when average number of leaf per plant was 4.11. The maximum number of thrips (20.37) was observed at the end of March 2016 when average number of leaf per plant was 4.11. After then thrips population sharply declined and came to 3.93 at 30.03.2016. The number of thrips per plant was positively

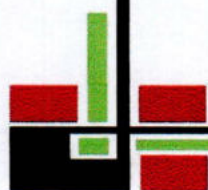
correlated with leaf per plant. Weather parameters i.e. temperature, humidity and rainfall have great influence on incidence of onion thrips population. In case of temperature, onion thrips population gradually increased with increasing average temperature at a certain level. On the other hand, thrips population decreased with increasing relative humidity and total rainfall.

In the present study, we evaluated three solvent extracts of neem plant to find out the most effective solvent and dose of neem leaf extract against onion thrips. Among the tested extract, acetone extract of neem leaf powder provided the highest (33.67 %) while distilled water caused the lowest mortality (12.33 %). The lowest LD₅₀ values of acetone extract of neem leaf powder at 1, 2, 3, 4 and 5 HAT indicated that acetone extract possessed highest toxic effects. The Chi-square values of different plant extracts at different hours after treatment are insignificant at 5% level of probability and did not show any heterogeneity of the mortality. Acetone extract was highly toxic to onion thrips nymphs, and 100 % mortality occurred within 5 hours by exposure to residue. The LT₅₀ (h) values of acetone extract (1.562) followed by petroleum benzene (1.985) and distilled water extract (2.610) were significantly lower than that of control (10.335) by residual film method.

It is revealed from the results that plant height, number of leaves and weather parameters have effect on incidence of onion thrips population. The results clearly indicated that acetone extract of neem leaf powder was performed successfully to check the *T. tabaci* infestation. So, acetone extract of neem leaf powder can be applied for the management of onion thrips to reduce the infestation.



References



REFERENCES

- Adesiyun, A. A., 1981. Seasonal abundance of shoot flies infesting sorghum and their natural enemies in Samaru, Zaria-Nigeria. *Ins. Sci. Appl.* 2(2): 49-53.
- Adesiyun, A. A., 1982. Effects of dates of planting on the damage by shoot flies to some cultivated varieties of sorghum. *Nigerian. J. Plant Pro.* 6: 3-9.
- Alimousavil, S. A., Hassandokht M. R., and Moharramipour S. 2007. Evaluation of Iranian onion germplasms for resistance to thrips. *Int. J. Agric. and Biol.* 9: 897-900.
- Anon, 1992. Thrips on onions and cole crops. IPM Practitioner. May-June. p.13.
- Anon, 2004. Conference Proceedings, June 2002, Yanco, The State of New South Wales (NSW). www.dpi.qld.gov.au/aphs/infopest.
- Antignus, Y., Lapidot, M., Hadar, D., Messika, Y. and Cohen, S. 1996. Ultraviolet-absorbing screens serve as optical barriers to protect crops from virus and insect pests. *J. of Econ. Ent.* 91(6): 1401-1405.
- Arrieche, N., Paz, R., Montagne, M. and Morales, Y. J. 2006. Estudios biológicos de *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) en cebolla, en el Estado Lara, Venezuela (In English: Biological studies of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) from onion fields, Lara State, Venezuela). *Bioagro* 18 (3) : 149-154.
- Asaduzzaman, M., Hasan, M. M., Hasan, M. M., Moniruzzaman, M., and Howlander, M. H. K. (2012). Effect of bulb size and plant spacing on seed production of onion (*Allium cepa* L.). *Bangladesh J. of Agric. Res.* 37(3), 405-414.

- Ashamo, M. O., 2004. Effects of some plant powders on yam moth, *Dasydes rugosella* Stainton (Lepidoptera: Tineidae). *Biol. Sci. Res. Comm.* 16: 41-46.
- Bagheri, S., Mosaddegh, M. and Kamali, K. 2002. Study on biology of *Thrips tabaci* in north of Khuzestan. Proc. of 15th Plant Protection Congress, Iran, p. 78.
- Bailey, S. F. 1940. The distribution of injurious thrips in the United States. *J. Econ. Entomol.* 33: 133 –136.
- Bakr, M. A., Afzal, M. A., Hamid, A., Haque, M. M. and Aktar, M. S. 2004. Blackgram in Bangladesh. Lentil, Blackgram and Mungbean Development Pilot Project, Publication No. 25, Pulses Research Centre, BARI, Gazipur, p 60.
- BARI, (Bangladesh Agriculture Research Institute) 2006. Krishi Projukti Hatboi (in Bangla). 4th ed., Bangladesh Agric. Res. Inst., Gazipur, Bangladesh. pp. 209-211.
- Barman, S. K., 1993. Azadirachtin affects growth and survival of immature tawny mole cricket. *Florida Entomol.* 76(3): 526-530.
- BBS, 2013. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.
- Belder, E., Elderson, J. and Vereijken, P. F. G. 2000. Effects of under own clover on host-plant selection by *Thrips tabaci* adults in leek. *Exp. Entomol. Appl.* 94: 173-182.

- Bergant K, Trdan S, Znidari D, Riponsek D, Kajfez-Bogataj L. 2005. Impact of climate change on developmental dynamics of *Thrips tabaci* (Thysanoptera: Thripidae): *Environ. Entomol.* 34:755-766.
- Blum, M. S., 1991. Chemical ecology of the Thysanoptera, pp. 95 –108. In B. L. Parker, M. Skinner and T. Lewis [eds.], Towards Understanding Thysanoptera. Proceedings of the International Conference on Thrips. USDA Technical Report NE-147, Radnor, PA.
- Brewster, J. L., 1994. Onions and other Vegetable Alliums. Horticulture Research International, Wellesbourne, CAB International. p. 236.
- Burkett-Cadena, M., Kokalis-Burelle, N., Lawrence, K.S., van Santen, E. and Kloepper, J.W. 2008. Suppressiveness of root-knot nematodes mediated by rhizobacteria. *Biol. Control.* 47: 55-59.
- Butani, P. G. and Mittal, V. P. 1993. The comparative efficacy of botanical insecticides (neem seed kernel suspension) and other insecticides against pod borer. *Rev. Agri. Entomol.* 81: 793.
- Butler, G. D. and Rao, S. B. P. 1990. Cotton seed oil to combat whitefly. *Indian Tex. J.* 1990: 20-25.
- Butterworth, J. H. and Morgan, E. D. 1968. Isolation of substance that suppress feeding in locusts. *Chem. Commun.* pp. 23-24.
- Cantisano, A. 1999. Onion thrips cause trouble in many regions. Growing for Market. December, 8-9.

- Childers, C.C. 1997. Feeding and oviposition injuries to plants. In: Thrips as Crop Pests. T. Lewis (ed.). CAB International, New York. pp. 505-537.
- Cooper, J., Dobson, H., & Maritime, C. 2007. Pesticides and humanity: the benefits of using pesticides. *Natural Res. Ins.*, University of Greenwich, UK.
- Dai, Y., Shao, M., Hannaway, D., Wang, L., Liang, J., Hu, L. and Lu, H. 2009. Effect of *Thrips tabaci* on anatomical features, photo synthetic characteristics and chlorophyll fluorescence of *Hypericum sampsonii* leaves. *Crop Protect.* 28: 327– 332.
- Derksen, A. I. 2009. Host susceptibility and population dynamics of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) on select ornamental hosts in southern Florida (Doctoral dissertation, University of Florida).
- Diaz-Montano, J., Fuchs, M., Nault, B. A. and Shelton, A. M. 2010. Evaluation of onion cultivars for resistance to onion thrips (Thysanoptera: Thripidae) on onion plants. *World App. Sci.*, 10(3): 117-120.
- Duranti, A. and Cuocolo, L. 1989. Chemical weed control and mulching in onion (*Allium cepa* L.) and garlic (*Allium sativum* L.). *Adv. Hort. Sci.* 37: 338-42.
- Edelson, J. V. Cartwright, B. and Royer, T. A. 1989. Economics of controlling onion thrips (Thysanoptera: Thripidae) on onions with insecticides in South Texas. *J. Econ. Entomol.* 82(2): 561-564.
- Edelson, J. V. Cartwright, B. and Royer, T. A. 1986. Distribution and Impact of *Thrips tabaci* (Thysanoptera: Thripidae) on onion. *J. Econ. Entomol.* 79(2): 502-505.

- Ellis, B. W. and Fern, M. B. 1992. The organic gardeners Handbook of Natural insect and disease control. Rodale press Emmaus, PA, 534.
- FAO, 2004. Human Energy Requirements, Report of a Joint FAO/WHO/UNU Expert Consultation, FAO Food and Nutrition Technical Report Series No 1, Rome.
- Foster, S. P. Gorman, K. and Denholm, I. 2010. English field samples of *Thrips tabaci* show strong and ubiquitous resistance to deltamethrin. *Pest Manage. Sci.* 66: 861-864.
- Fournier, F. Guy, B. and Robin, S. 1995. Effect of *Thrips tabaci* (Thysanoptera: Thripidae) on yellow onion yields and economic thresholds for its management. *J. Entomol. Soc. America.* 88: 1401-1407.
- Gachu, S. M. Muthomi, J. W. Narla, R. D. Nderitu, J. H. Olubayo F. M. and Wagacha J. M. 2012. Management of thrips (*Thrips tabaci*) in bulb onion by use of vegetable intercrops. *Int. J. Agric. Sci.* 2(5): 393-402.
- Gareth, G. Laurence, T. Timothy, C. Brian, T. and Brian, S. 2002. Onions - A global benefit to health. *Phytother. Res.* 16: 603-615.
- Gent, D. H., Schwartz, H. R. and Khosla, R. 2004. Distribution and incidence of IYSV in Colorado and its relation to onion plant population and yield. *Plant Disease.* 88: 446-452.
- Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. A Wiley Int. Sci. Publ. John Wiley and Sons. New York, Brisbane, Singapore. pp. 139-240.

- Grainage, M., Ahmed, S. Mitchel and Hylin, J. H. 1985. Plant species reportedly possessing pest control properties. An EWC/UH database. Resource Systems Institute, East-West Center, Honolulu, Hawaii. P 240.
- Grainge, M. and Ahmed, S. 1988. Handbook of plants with pest control properties. John Wiley and Sons, New York, p.470.
- Grimaldi, D. A. Shmakov, N. Fraser, 2004. Mesozoic Thrips and Early Evolution of the Order Thysanoptera (Insecta). *J. Paleontol.* 64:123-127.
- Gunasekaran, K. and Chelliah, Y. 1985. Juvenile hormone activity of *Tribulus terrestris* L. on *Spodoptera litura* F. and *Heliothis armigera* (Hb). Pages 146-149. In: A. Regupathy and S. Jayaraj, eds. Behavioural and physiological Approaches in the Management of Crop Pests. Tamil Nadu Agric. Univ., Coimbatore.
- Gupta, M. P. and Pathak, R. K. 2009. Bioefficacy of neem products and insecticides against the incidence of whitefly, yellow mosaic virus and pod borer in Black gram. *Nat. pro. Radian.* 8(2): 133-136.
- Haq, M. A. 2011. farmers practices for combating insect pests of jute in three intensive jute growing areas in Bangladesh and their on-station validation to develop an ipm package utilizing bio-control agent and neem products.
- Havey, M. J. Galmarini, C. R. Gokce, A. F. and Henson, C. 2004. QTL affecting soluble carbohydrate concentrations in stored onion bulbs and their association with flavor and health-enhancing attributes. *Genome.* 47: 463-468.

- Heming, B. S. 1993. Structure, function, ontogeny, and evolution of feeding in thrips (Thysanoptera). In C. W. Shaefer and R. A. B. Leschen [eds.], *Functional Morphology of Insect Feeding* Lanham, Maryland.
- Hoffmann, Michael, P., Curtis, H., Petzoldt, Anne, C. and Frodsham, 1996. *Integrated Pest Management for Onions*. Cornell University. Cornell, NY.
- Hossain, M. 2001. Samonnito Kitpatango Bebosthapon. In Bengali, Bangla Academy, Dhaka. p155.
- Ibrahim, N. D. Adesiyun, A. A. 2008. Effects of staggered planting dates on the control of *Thrips tabaci* Lindeman and yield of onion in Nigeria. *African J. Agric. Res.* 4: 033-039.
- Javadzadeh, A. Ghorbanihaghjo, A. Bonyadi, S. Rashidi, M. R. Mesgari, M. Rashtchizadeh, N. and Argani, H. 2009. Preventive effect of onion juice on selenite-induced experimental cataract. *Indian J. Ophthal.* 57(3):185-189.
- Jayaraj, S. 1988. Nonchemical management methods of some key mungbean pests. In: Shanmugasundaram, S. (ed.) *Mungbean: Proceedings of the Second International symposium on Mungbean*. 16-20 November 1987. Bangkok, Thailand AVRDC, Shanhua, Tainan, Taiwan (ROC). p.367.
- Jensen, L. Simko, B., Shock, C. and Saunders, L. 2002. Alternative methods for controlling onion thrips (*Thrips tabaci*) in spanish onion. Malheur Experiment Station Oregon State University, Oregon.
- Jeyakumar, P. and Gupta, G. P. 1999. Effect of neem seed kernel extract (NSKE) on *Helicoverpa armigera*. *Pestic. Res. J.* 11: 32-36.

- Jones, F. G. and Jones, M. G. 1974. Pests of Field Crops, Publ. Edward Arnold, London. p. 448.
- Karar, H. Abbas, G. Hameed, A. Ahmad, G. and Ali, A. 2014. Losses in Onion (*Allium cepa*) Due to Onion Thrips (*Thrips tabaci*) (Thysanoptera: Thripidae) and Effect of Weather Factors on Population Dynamics of Thrips. World Applied Sciences Journal 32(11): 2250-2258.
- Kavitha, C., Thangamani, C., & Vadivel, E. 2008. Genetic Transformation for Secondary Metabolites Production. *Inno. Horti*. 277.
- Kendall, D. M. and Capinera, J. L. 1987. Susceptibility of onion growth stages to onion thrips (Thysanoptera: Thripidae) damage and mechanical defoliation. *Environ. Entomol.* 16: 859-863.
- Kidiavai, E. L. 2009. International Centre for Insect Physiology and Ecology (IPE), Nairobi, Kenya.
- Kirk, W. D. J. 1995. Feeding behavior and nutritional requirements. In B. L. Parker, M. Skinner and T. Lewis [eds.], Thrips Biology and Management. Plenum Press, New York, NY. pp. 21 –29
- Kisha, J. S. A. 1977. Cultural and insecticidal control of *Thrips tabaci* on onions in the Sudan. *Ann. Appl. Biol.* 86: 219 -228.
- Kranz, S., Schmutterer, H. and Koch, W. 1977. Diseases, Pests and Weeds in Tropical Crops, John Wiley and Sons, New York and Toronto. p. 666.

- Kucharczyk, H., Legutowska, H. 2002. *Thrips tabaci* as a pest of leek cultivated in different conditions. Thrips and Tospovirus, Proceedings of the 7th International Symposium on Thysanoptera, Reggio Calabria, Australian National Insect Collection Canberra, 211-213.
- Larentzaki, E. A., Shelton, M., Plate, J. 2007. Effect of kaolin particle film on *Thrips tabaci* (Thysanoptera: Thripidae), oviposition, feeding and development on onions: A lab and field case study. *Crop Prot.* 27: 727-734.
- Leuschner, K. 1972. Effect of an unknown plant substance on shield bug. *Nourwissenschaften.* 59: 217-218.
- Lewis, T. 1973. Thrips, their Biology, Ecology and Economic Importance, Academic Press, London. p. 349.
- Lewis, T. 1997. Pest thrips in perspective. p. 1-14. "Thrips as Crop Pests. CAB International, Wallingford, U.K.
- Lewis, T. 1973. Thrips, their Biology, Ecology and Economic Importance, Academic Press, London. p. 349.
- Liu, T. X. 2005. Seasonal population dynamics, life stage composition of *Thrips tabaci* (Thysanoptera: Thripidae), and predaceous natural enemies on onions in south Texas. *Southwestern Entomol.* 29(2): 127-136.
- Lockwood, S. 1956. Onion Thrips, *Thrips tabaci*. California Department of Agriculture, Bureau of Entomology. Loose- Leaf Manual of Insect Control: 739-749.

- Luckman, W. H. and Metcalf R. L. 1978. The pest management concept. An Introduction to Insect Pest Management. John Wiley and Sons, NY. pp. 3-35.
- Ludger, J. S. Jean, R.V. 2005. Integrated management of onion thrips (*Thrips tabaci*) in onion (*Allium cepa*). *Proc. Fla State Hort. Soc.* 118: 125-126.
- Mandal, T., Ghosh, S. K., & Chakraborty, K. 2016. Seasonal incidence of thrips (*Thrips tabaci*) infesting som plant leaves (*Machilus bombycina* king) and their management using biopesticides. *Int. J. Sci. Env. And Tech.* 5(4):2245-2256.
- Martin, N. A., Workman, P. J. and Butler, R. C. 2003. Insecticide resistance in onion thrips (*Thrips tabaci*) (Thysanoptera: Thripidae). *New Zealand J. Crop. Hort. Sci.* 31: 99-106.
- Mound, L. A. 2005. Thysanoptera: diversity and interactions. *Annl. Rev. Entomol.* 50: 247–269.
- Mound, L. A. 2013. Homologies and host-plant specificity: Recurrent problems in the study of thrips. *Fla. Entomol.* 96: 318–322.
- Mound, L.A., and Palmer, J.M. 1981. Phylogenetic relationships between some genera of Thripidae (Thysanoptera). *Entomol. Soc.* 15: 153-17.
- Muendo, K. M., and Tschirley, D. 2004. Imp production and marketing system: Current competitiveness, forces of change, and challenges for the future. Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya.
- Muhammad, F., Mohammad, N. and Zahid, H. 2003. Efficacy of Synthetic Insecticide and Botanical Infusions Against Onion Thrips in Balochistan, Pakistan-I. *Asian J. Plant Sci.* 2: 779-781.

- Nagarare, V.S. and More G.D. 1998. Economics using bioagents against *Helicoverpa armigera* in pigeonpea. *Indian J. Entomol.* 60(2): 203-206.
- Narayanasamy, P. 2013. *Biological management of diseases of crops*. Springer.
- Nas, M. N. 2004. In vitro studies on some natural beverages as botanical pesticides against *Erwinia amylovora* and *Curobacterium flaceumfaciensis* subsp. *poinsettiae*. *Turk. J. Agric.* 28: 57-61.
- Nault, B.A and Shelton, A.M. 2010. Impact of insecticide efficacy on developing action thresholds for pest management: a case study of onion thrips (Thysanoptera: Thripidae) on onion. *J. Econ. Entomol.* 103: 1315-1326.
- Nazrussalam, Ansari, M. S., Haidar, A. and Tufail, A. 2008. Efficacy of multi neem and NSKE with insecticides for management of *Amrasca biguttula biguttula* and *Earias vittella* on okra. *Ann. Plant Protect. Sci.* 16(1): 17-20.
- Neil, H., Kevin, B., Nigel, D. C. 2004. A Color hand book of biological control in plant protection. The Royal Horticultural Society. London, UK, 112.
- Northfield, T. D., Paini, D. R., Funderburk, J.E., and Reitz, S.R. 2008. Annual cycles of *Frankliniella* spp. (Thysanoptera: Thripidae) thrips abundance in north Florida uncultivated reproductive hosts: Predicting possible sources of pest outbreaks. *Ann. Entomol. Soc. America.* 101: 769-778.
- Parella, M. P. and Lewis, T. 1997. IPM in Field Crops. In Thrips as crop pests. Edited by T. Lewis. CAB International. Institute of Arable Crops Research Rothamsted, Harpenden, Herts, UK, 595-614.

- Parella, M. P. and Murphy, B. 1996. Western flower thrips: Identification biology and research on the development of control strategies. BILB/SROP, USA. 19: 115-118.
- Puri, S. N. Butler, G. D. and Henneberry, T. J. 1991. Plant derived oils and soap solutions as control agents for the whitefly on cotton. *J. Appl. Zool. Res.* 2: 1-5.
- Quarles, W. 1990. Reflective mulch and thrips-vectored virus. IPM Practitioner. November-December. p. 7.
- Rabinowitch, H. D. Currah, L. 2002. Allium crop science: Recent advances. CAB International Wallington, UK, p. 551.
- Radwan, H. S. A., Ammar, I. M. A., Eisa, A. A., Assal, O. M. and Omar, H. I. H. 1985. Development, retardation and inhibition of adult emergence in cotton whitefly *Beinisia tabaci* Genn. Following immature stage treatments with two molt inhibitors. *Bull. Entomol. Soc. Egypt.* 13: 175- 181.
- Raheja, A. K. 1973. Onion Thrips and their control in northern Nigeria. *Samaru Agric. Newsletter.* 15(2): 82-86.
- Rateaver, B. and Rateaver, G. 1993. Organic Method Primer Update. The Rateavers, San Diego, C. A. 596 31. Bentz, J. A. and Larew, H. G. (1992). Oviposition preference and Nymphal pereforma of *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) on *Dendranthema grandiflora* under different fertilizer regimes. *J. Econ. Entomol.* 85: 514-517.
- Reitz, S. R., Gao, Y. L. and Lei, Z. R. 2011. Thrips: pests of concern to China and the United States. *Agric. Sci. China.* 10(6): 867-892.

- Reitz, S. R., Kund, G. S., Carson, W. G., Phillips, P. A. and Trumble, J. T. 1999. Economics of reducing insecticide use on celery through low-input pest management strategies. *Agric. Ecosyst. Env.* 73:185-197.
- Reuda, A., and Shelton, A. M. 2003. Development of a bioassay system for monitoring susceptibility in *Thrips tabaci*. *Pest Manage.* 59(5): 553-558.
- Rice, A. R., Johnson, J. L., Thill, D. C. and Morra, M. J. 2007. Vegetable crop emergence and weed control following amendment with different *Brassicaceae* seed meals. *Ren. Agric. and Food Sys.* 22(3): 204-212.
- Russell, D.F. (1986). MSTAT-C package programme. Dept. Crop Soil Sci. Michigan State Univ. USA. p. 59-60. Sanderson, J. (1999). *Thrips tabaci*. Grower Talks. July. p. 128.
- Sarode, S. V., Deotale, R. O., Jumdi, Y. S. and Thakare, H. S. 1994. Fields evaluation of *Heliothis nuclear polyhedrosis virus* (HNPV) for the management of *Helicoverpa armigera* (Hub.) on pigeonpea. *Indian J. Entomol.* 56(2): 176-179.
- Saxena, R. C., Georg, G., Orphae, L. and Paulin, D. 2004. A study on the use of indigenous technological knowledge (ITK) for rice pest management in Assam. *Ins. Env.* 8(1): 94-99.
- Saxena, R. C., Waldbauer, G. P., Liquido, N. J. and Puma, B. C. 1981. Effects of neem seed oil on the rice leaf folder *Cnaphalocrosis medinalis*. Proc. 1st Int. Neem Conf. Rottach-Egern., Germany. 16-18 June, 1980. pp 189-204.
- Saxena, S. C. 1992. *Biology of Insects*. Published by Raju Primlanifor Oxford and IBH Publishing Co. Pvt. Ltd., 66 Janapath, New Delhi 1100 .p366.

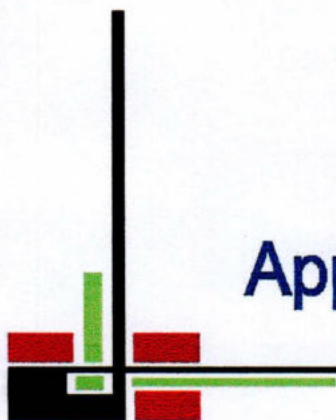
- Sedaratian, A. A., Fathipour, Y., Talebi, A. A., and Farahani, S. 2010. Population density and spatial distribution pattern of *Thrips tabaci* (Thysanoptera: Thripidae) on different soybean varieties. *J. Agric. Sci. and Tech.* 12, 275-288.
- Shelton, A. M. and North, R. C. 1987. Injury and Control of Onion Thrips (Thysanoptera: Thripidae) on Edible Podded Peas. *J. Econ. Entomol.* 80(6): 1325-1350.
- Shelton, A. M., Stamer, J. R., Wilsey, W. T., Stoyla, B. O. and Andaloro, J. T. 1982. Onion thrips (Thysanoptera: Thripidae) damage and contamination in Sauerkraut. *J. Econ. Entomol.* 75: 492-495.
- Shiberu, T. 2013. In vitro Evaluation of Aqua Extracts of Some Botanicals against Maize Stem Borer, *Busseola fusca* F. (Lepidoptera: Noctuidae). *J. Plant Pathol. Microb.* 4: 179.
- Shock, C. C., Feibert, E. B. G., Barlow, K. J., Rock, A. L., Saunders, L. D., Jemmett, E. and Reitz, S. 2012. Insecticide rotations for thrips control in onions, 2012, pp. 63– 69. In C. C. Shock [ed.], Oregon State University, Malheur Experiment Station, Annu. Rep. 2012. Dept. Crop and Soil Sci. Ext/CrS 144, Ontario, OR.
- Shock, C. C., Feibert, E. B., Saunders, L. D., Mohan, S. K. and Sampangi, R. S. 2009. Management of onion cultural practices to control the expression of iris yellow spot vims. Malheur Experiment Station *Ann. Rep.* 2008. 25: 41–60.
- Singh, R. R. and Srivastava, B. G. 1985. Alcohol extract of neem (*Azadiracta indica* A. Juss.) seed oil as oviposition deterrent for *Dacus cucurbitae* Coq. *Indian J. Entomol.*, 45(4): 497-498.

- Steets, R. 1976. Zur wicklung eines gereinigten extraktes aus Iruchten von *A-zdiractu irzclicu auf hepfinotursu decenrlneulu* Say (Colleoptera: Chysumelidae). *J. Angew Er.* (82): 167-176.
- Tang, G. W., Gong, X. W. and Meng, G. L. 2002. Studies on species of *Thrips* in fields of vegetable in Wuhan region. *J. Huazhong Agric. Univ.* 21(1): 5-9.
- Trdan, S., Vali, N., Zezlina, I., Bergant, K. and Znidar, D. 2005. Light blue sticky boards for mass trapping of onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), in onion crops. *J. Plant Disease Prot.* 12: 173-180.
- Trdan, S., Znicdarcic, D., Valic, N., Rozman, L. and Vidrih, M. 2006. Intercropping against onion thrips, *Thrips tabaci* Lindeman (Thysanoptera : Thripidae) in onion production: on the suitability of orchard grass, lacy phacelia, and buckwheat as alternatives for white clover. *J. Plant Disease Prot.* 113: 24-30.
- Uckland, K., Reeve, J. R., Alston, D., Nischwitz, C. and Drost, D. 2013. Effects of nitrogen fertility and crop rotation on onion growth and yield, thrips densities, Iris yellow spot vims and soil properties. *Agric. Ecosyst. Env.* 177: 63–74.
- Visalakshmi, V, Ranga Rao G. V. and Arjuna, R. P. 2005. Integrated pest management strategy against *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae). *Indian J. Plant Protec.* 33: 17–22.
- Waiganjo, M. M., Gitonga, L. M., and Mueke, J. M. 2008. Effects of weather on thrips population dynamics and its implications on the thrips pest management. *African J. Hort. Sci.* 1.

- Waiganjo, M. M., Gitonga, L. M., and Mueke, J. M. 2011. Effects of weather on thrips population dynamics and its implications on the thrips pest management. *African J. of Hort. Sci.*, 5(4):19-28.
- Waiganjo, M. M., Mueke, J. M. and Gitonga, L. M. 2008. Susceptible onion growth stages for selective and economic protection from onion thrips infestation. *Acta Hort.* 767: 193-200.
- Waterhouse, D. F. 1987. *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) onion thrips. In: Biological Control: Pacific Prospe Norris, eds. Inkata Press, Melbourne, Australia, p138.
- Zawirska, I. 1980. Studies on the tobacco thrips (*Thrips tabaci* Lind.) and it role in the transmission of tomato spotted wilt virus (TSWV) on tobacco. *Sesji Nauk. Inst. Ochr. Roślin.* 19:267-278.

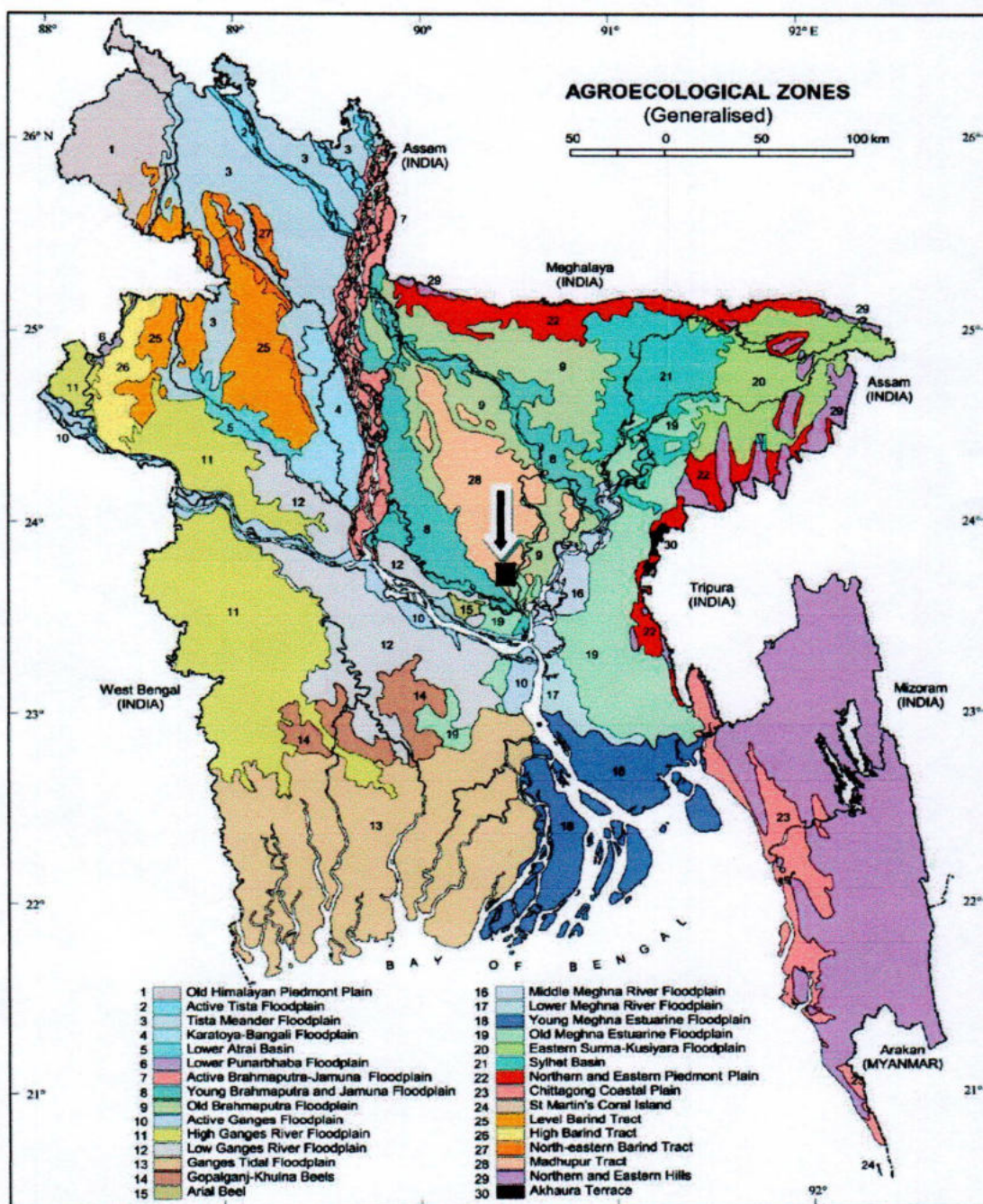


Appendices



APPENDICES

Appendix I: Experimental location in the map of Agro-Ecological Zones of Bangladesh



Appendix II. Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Nashipur, Dinajpur-5200.

A. Morphological characteristics of the experimental field 2014.

Morphological features	Characteristics
Location	Central Farm, HSTU, Dinajpur
AEZ	Old Himalayan Piedmont Plain (AEZ-1)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	50.8
% Silt	32.4
% clay	16.8
pH	6.13
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III: Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site.

Month (2016)	Temperature		Relative humidity (%)	Rainfall (mm) (Total)	Sunshine (hr) (Total)
	Maximum	Minimum			
January	23.43	10.29	81.61	11.00	3.83
February	28.19	13.98	73.69	0.00	5.73
March	31.91	18.81	66.52	8.30	6.42
April	34.54	22.98	69.5	26.00	5.64

Source: Bangladesh Meteorological Department (Weather Observatory Station),
Rajbati, Dinajpur-5200

Appendix table IV: ANOVA table of the toxic effect of different solvent extracts of neem leaf powder against the nymph of *Thrips tabaci* at 1 HAT.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	3.417	1.139	3.7273	0.0249
4	Factor B	2	4.056	2.028	6.6364	0.0051
6	AB	6	2.167	0.361	1.1818	0.3489
-7	Error	24	7.333	0.306		
	Total	35	16.972			

Coefficient of Variation: 44.74%

Appendix table V: ANOVA table of the toxic effect of different solvent extracts against the nymph of *Thrips tabaci* at 2 HAT.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	13.194	4.398	22.6190	0.0000
4	Factor B	2	11.722	5.861	30.1429	0.0000
6	AB	6	5.389	0.898	4.6190	0.0030
-7	Error	24	4.667	0.194		
	Total	35	34.972			

Coefficient of Variation: 42.90%

Appendix table VI: ANOVA table of the toxic effect of different solvent extracts against the nymph of *Thrips tabaci* at 3 HAT.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	22.528	7.509	30.0370	0.0000
4	Factor B	2	17.556	8.778	35.1111	0.0000
6	AB	6	6.889	1.148	4.5926	0.0031
-7	Error	24	6.000	0.250		
	Total	35	52.972			

Coefficient of Variation: 33.96%

Appendix table VII: ANOVA table of the toxic effect of different solvent extracts against the nymph of *Thrips tabaci* at 4 HAT.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	26.083	8.694	26.0833	0.0000
4	Factor B	2	19.500	9.750	29.2500	0.0000
6	AB	6	7.167	1.194	3.5833	0.0112
-7	Error	24	8.000	0.333		
	Total	35	60.750			

Coefficient of Variation: 30.12%

Appendix table VIII: ANOVA table of the toxic effect of different solvent extracts against the nymph of *Thrips tabaci* at 5 HAT.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	33.417	11.139	44.5556	0.0000
4	Factor B	2	23.722	11.861	47.4444	0.0000
6	AB	6	10.500	1.750	7.0000	0.0002
-7	Error	24	6.000	0.250		
	Total	35	73.639			

Coefficient of Variation: 21.69%

Appendix table IX: ANOVA table of the effect of day on onion thrips number per plant.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Factor A	9	68.550	7.617	6.8442	0.0000
2	Factor B	6	2590.070	4.678	7.9015	0.0000
-3	Error	54	60.094	1.113		
	Total	69	2718.714			

Coefficient of Variation: 8.78%

Appendix table X: ANOVA table of the effect of plant height on onion thrips number per plant.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	9	372.957	41.440	1.1549	0.3778
2	Factor A	2	116.484	58.242	1.6232	0.2248
-3	Error	18	645.843	35.880		
	Total	29	1135.284			

Coefficient of Variation: 14.56%

Appendix table XI: ANOVA table of the effect of leaf per plant on onion thrips number.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	9	0.970	0.108	1.9064	0.0000
2	Factor A	2	0.002	0.001	1.0000	0.3874
-3	Error	18	0.017	0.001		
	Total	29	0.989			

Coefficient of Variation: 0.76%

Appendix table XII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in acetone solvent at 1 HAT

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	5	33.33	33	4.56	4.34	4.59	7.98	4.34
1	1	15	1	6.67	7	3.52	3.99	3.60	6.08	3.99
0.5	0.69	15	1	6.67	7	3.52	3.29	3.63	2.7	3.31

$Y = 1.700527 + 2.29339 x$; χ^2 is 1.501916 with 1 degrees of freedom; No sig.

heterogeneity; LD-50 is 2.745924; 95% confidence limits are 0.7849435 to 9.605913.

Appendix table XIII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in acetone solvent at 2 HAT

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	9	60	60	5.25	4.85	5.28	9.41	4.95
1	1	15	2	13.33	13	3.87	4.51	3.98	8.72	4.56
0.5	.69	15	3	20	20	4.16	3.93	4.2	6.08	3.91

$Y = 2.57242 + 1.934824x$; χ^2 is 4.486739 with 1 degrees of freedom;

Variance has been adjusted for heterogeneity; LD-50 is 1.589656; 95% confidence limits are 0.4217896 to 5.991153.

Appendix table XIV: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in acetone solvent at 3 HAT

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	11	73.34	71	5.55	5.24	5.56	9.41	5.29
1	1	15	4	26.67	21	4.19	4.68	4.27	9.02	4.68
.5	0.69	15	3	20	14	3.92	3.74	3.95	5.04	3.65

$Y = 1.248446 + 3.435924 x$; χ^2 is 3.064829 with 1 degrees of freedom; No sig.

heterogeneity; LD-50 is 1.235554; 95% confidence limits are 0.9144281 to 1.669453.

Appendix table XV: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in acetone solvent at 4 HAT

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	12	80	75	5.67	5.25	5.67	9.41	5.31
1	1	15	5	33.33	17	4.05	4.72	4.14	9.24	4.73
.5	0.69	15	5	33.33	17	4.05	3.81	4.08	5.55	3.72

$Y = 1.390836 + 3.332221 x$; χ^2 is 5.047272 with 1 degrees of freedom; variance has been adjusted for heterogeneity; LD-50 is 1.210907; 95% confidence limits are 0.6126043 to 2.393544.

Appendix table XVI: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in acetone solvent at 5 HAT

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	14	93.33	92	6.41	5.66	6.18	8.37	5.69
1	1	15	6	40	25	4.33	5.05	4.38	9.56	5.06
0.5	0.69	15	6	40	25	4.33	4.00	4.38	6.59	3.99

$Y = 1.524016 + 3.538081 x$; χ^2 is 7.452304 with 1 degrees of freedom; variance has been adjusted for heterogeneity; LD-50 is 0.9603927; 95% confidence limits are 0.475268 to 1.940704.

Appendix table XVII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in petroleum benzene solvent at 1 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight ht	Final probit
1.5	1.18	15	4	26.67	27	4.39	4.16	4.44	7.07	4.26
1	1	15	1	6.67	7	3.52	3.88	3.56	5.55	3.92
.5	.69	15	1	6.67	7	3.52	3.39	3.57	3.12	3.34

$Y = 1.990609 + 1.930166 X$; χ^2 is 1.080124 with 1 degrees of freedom; No. sig.

heterogeneity; LD-50 is 3.623566; 95% confidence limits are 0.5492557 to 23.9055.

Appendix table XVIII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in petroleum benzene solvent at 2 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.19	15	7	46.67	47	4.92	4.77	4.92	9.24	4.79
1	1	15	3	20	20	4.16	4.42	4.18	8.37	4.48
.5	.69	15	2	13.33	13	3.87	3.78	3.89	5.04	3.75

$Y = 2.234071 + 2.174436 X$; Chi-squared is 0.6934738 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 1.870774; 95% confidence limits are 0.8598866 to 4.070066.

Appendix table XIX: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in petroleum benzene solvent at 3 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	10	66.67	67	5.44	5.28	5.46	9.41	5.30
1	1	15	5	33.33	33	4.56	4.83	4.57	9.41	4.88
0.5	0.69	15	3	20	20	4.16	4.06	4.16	6.59	4.03

$Y = 2.157563 + 2.673774 x$; chi-squared is .9613061 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 1.156326; 95% confidence limits are 0.8054431 to 1.660068.

Appendix table XX: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in petroleum benzene solvent at 4 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	11	73.34	73	5.61	5.44	5.59	9.02	5.43
1	1	15	6	40	40	4.75	5.0	4.75	9.555	4.99
0.5	0.69	15	4	26.67	27	4.39	4.29	4.39	7.545	4.27

$Y = 2.582669 + 2.41633 X$; chi-squared is .9445891 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 1.000954; 95% confidence limits are 0.6920573 to 1.447726.

Appendix table XXI: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in petroleum benzene solvent at 5 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	12	80	79	5.81	5.65	5.79	8.37	5.62
1	1	15	7	46.67	43	4.82	5.08	4.85	9.56	5.05
0.5	0.69	15	4	26.67	21	4.19	4.1	4.21	6.59	4.08

$Y = 1.812421 + 3.241713 X$; chi-squared is 0.8287821 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 0.9622784; 95% confidence limits are 0.726349 to 1.274841.

Appendix table XXII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in distilled water solvent at 1 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	3	20	20	4.16	4.14	4.17	7.07	4.15
1	1	15	2	13.33	13	3.87	3.91	3.88	6.08	3.91
0.5	0.69	15	1	6.67	7	3.52	3.51	3.52	4.04	3.50

$Y = 2.546074 + 1.365361 X$; Chi-squared is 1.053584E-02 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 6.270085; 95% confidence limits are 0.183674 to 214.0421.

Appendix table XXIII: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in distilled water solvent at 2 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	6	40	40	4.75	4.64	4.74	9.01	4.65
1	1	15	3	20	20	4.16	4.33	4.17	7.98	4.33
0.5	0.69	15	2	13.33	13	3.87	3.81	3.87	5.55	3.79

$Y = 2.523735 + 1.807751 X$; Chi-squared is .3222578 with 1 degrees of freedom;

No. sig. heterogeneity; LD-50 is 2.343173; 95% confidence limits are 0.721335 to 7.611527.

Appendix table XXIV: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in distilled water solvent at 3 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	7	46.67	47	4.92	4.97	4.92	9.51	4.96
1	1	15	6	40	40	4.75	4.68	4.74	9.02	4.68
0.5	0.69	15	3	20	20	4.16	4.19	4.17	7.07	4.20

$Y = 3.096908 + 1.578652 X$; Chi-squared is $5.806375e-02$ with 1 degrees of freedom; No. sig. Heterogeneity; LD-50 is 1.605156; 95% confidence limits are 0.671869 to 3.834865.

Appendix table XXV: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in distilled water solvent at 4 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	9	60	57	5.18	5.33	5.16	9.24	5.35
1	1	15	9	60	57	5.18	4.95	5.17	9.51	4.99
0.5	0.69	15	4	26.67	21	4.19	4.28	4.18	7.54	4.29

$Y = 2.796193 + 2.138662 X$; Chi-squared is 0.7966438 with 1 degrees of freedom; No. sig. heterogeneity; LD-50 is 1.072658; 95% confidence limits are 0.6989588 to 1.646154.

Appendix table XXVI: Doses mortality data of nymph of *Thrips tabaci* treated with neem leaf extract in distilled water solvent at 5 HAT.

Dose	Log dose	Number	Kill	% kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
1.5	1.18	15	11	73.34	69	5.5	5.57	5.47	8.72	5.55
1	1	15	10	66.66	62	5.31	5.19	5.29	9.51	5.18
0.5	0.69	15	6	40	31	4.5	4.54	4.49	8.72	4.54

$Y = 3.044616 + 2.130942 X$; Chi-squared is 0.1972032 with 1 degrees of freedom; No. sig. heterogeneity; LD-50 is .8272084; 95% confidence limits are 0.5448975 to 1.255784.