ECOFRIENDLY MANAGEMENT OF MUSTARD APHID FOR QUALITY SEED PRODUCTION

MD. IMRAN HOSSAIN

INSTITUTE OF SEED TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY DHAKA-1207

JUNE 2018

ECOFRIENDLY MANAGEMENT OF MUSTARD APHID FOR QUALITY SEED PRODUCTION

BY

MD. IMRAN HOSSAIN
REGISTRATION NO. 12-04787

A Thesis submitted to the
Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)
IN
SEED TECHNOLOGY
SEMESTER: JANUARY-JUNE, 2018

Approved by:

Dr. Ayesha Akter Associate Professor & Supervisor Department of Entomology Sher-e-Bangla Agricultural University	**Dr. A.K.M Ruhul Amin** Professor & Co-Supervisor Department of Agronomy Sher-e-Bangla Agricultural University

Professor Dr. Mohammed Ali
Chairman
Examination Committee

INSTITUTE OF SEED TECHNOLOGY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh

Cell: 01711986293
Email : ayesha_sauento@yahoo.com
Web : www.sau.edu.bd

Ref: Date:

CERTIFICATE

This is to certify that the thesis entitled, **"ECOFRIENDLY MANAGEMENT OF MUSTARD APHID FOR QUALITY SEED PRODUCTION "** submitted to the Institute of Seed Tecgnology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SEED TECHNOLOGY,** embodies the result of a piece of *bona fide* research work carried out by **MD. IMRAN HOSSAIN**, Registration No.: 12-04787, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that any help or sources of information has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

Dr. Ayesha Akter
Associate Professor & Supervisor
Department of Entomology
Sher-e-Bangla Agricultural University

Dedicated
To

Almighty to bless me ever with the best of all the choices &
My loving parents and teachers who laid the foundation of my success.

ACKNOWLEDGEMENT

At first the author expresses his gratefulness to almighty Allah who has helped him to pursue his higher education in Agriculture and for giving the strength of successful completion of this research work.

With deepest emotion the author wishes to express his heartfelt gratitude, indebtedness, regards, sincere appreciation to his benevolent research Supervisor Dr. Ayesha Akter Associate Professor Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his intellectual guidance, intense supervision, affectionate feelings and continuous encouragement during the research work and for offering valuable suggestions for the improvement of the thesis.

He is highly grateful and obliged to his Co-Supervisor, Dr. A.K.M Ruhul Amin, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his continuous encouragement, innovative suggestion, and affectionate inspiration throughout the study.

Cordial thanks are extended to all respected teachers of the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and all the staffs.

Finally, the author expresses his heartfelt indebtedness to his beloved father Md. Ayub Ali; mother Zahura Begum, for their sacrifice, encouragement and blessing to carry out higher study which can never be forgotten.

June, 2018 The Author

ECOFRIENDLY MANAGEMENT OF MUSTAR APHID FOR QUALITY SEED PRODUCTION

ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the Rabi season 2017-2018 using BARI Sarisha-15 to evaluate the effectiveness of some promising bio-pesticides on aphid population abundance in field and laboratory condition. The treatments for the management were T_1: neem Oil, T_2: Bioneemplus 1EC, T_3: Neem seed kernel extract, T_4: Spinosad 45EC, T_5: Detergent, T_6: Field sanitation and T_7: untreated control. Among the treatments, Spinosad 45EC performed as the most effective insecticide in reducing the highest percent of aphid population on leaves (60.00%) whereas Detergent showed the least performance (39.54%). In inflorescence, Spinosad 45EC performed as the most effective bio-insecticide in reducing the highest percent of aphid population (68.06%) whereas detergent showed the least performance (53.57%). The maximum quality seed of BARI Sarisha-15 obtained from treatment Spinosad 45EC (1.62 mt ha^{-1}) due to lower aphid abundance. On the other hand, lower quality yield performance obtained from the T_7 treatment due to an untreated control (1.29 mt ha^{-1}). After harvesting of seed, height germination (95.33%) was found in T_4 (Spinosad 45EC), on the other hand lowest germination (77.67%) was found in T_7 (Control plot).

CONTENTS

LIST OF TABLE

LIST OF PLATES

LIST OF FIGURE

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Mustard locally known as *sharisha* is a popular and most common oil seed crop in Bangladesh and in other tropical and sub-tropical parts of the world. It is also known as rapeseed. It belongs to the family Cruciferae. Though mustard is produced mainly in the rabi season. It occupies an area of 91188 acre with an annual production of 66060 metric ton (BBS, 2016-2017). Mustard is a popular nutritious oil seed crop. The rapeseed is a rich source of oil and protein and it contain more than 40% oil (Weiss, 1983). Mustard oil is mainly used for cooking purposes and also as hair and body oil in rural areas. Oil cake is important animal feed. After threshing pods and plants are used as fodder. Leaves of the plant are popular vegetable in our country. Sticks of high yielding varieties are good fuel. Mustard aphis is the major constraint responsible for low yield as well as low quality seed, which is considered as key factor in reducing mustard production and sometime it is so severe that may cause yield loss up to 90% (Gupta *et al*., 2003). Mustard plant is attacked by a number of insect pests. Bakhetia and Sekhon (1989) found more than three dozens of insect pests, associated with various phenological stages of these crops. Among them *Lipaphis erysimi*, commonly known as mustard aphid is most destructive in Bangladesh (Alam *et al*., 1964). It belongs to the family Aphididae of the order Homoptera. The insect is distributed to many other countries of the world. The attack is severe in those regions where the numbers of cloudy days are more during the pest activity period.

Both nymphs and adults of mustard aphid, *Lipaphis erysimi* cause damage to mustard plants from vegetative to siliqua maturity stage (Verma and Singh, 1987). Siliqua is the most suitable part for development of this pest (Tripathi *et al*., 1986). They suck sap from twigs, siliqua, flower buds, flower and leaves of the plants. Maximum damage caused by aphid at pod formation stage. At heavy infestation large number of aphid congregate under side of leaves causing curling and yellowing. Poor pod formation and stunted growth is due to the high aphid on whole plant (Maiti *et al.,* 1988). As a result both the production and quality of mustard seed is poor with low market price. The environmental factors such as temperature, rainfall and relative humidity, usually influence the insect population greatly, depending on the prevailing environmental and the insect species. The aphid population increase in huge numbers. In recent years the use of synthetic

insecticides in crop protection programs around the world has resulted in disturbances of the environment, pest resurgences, pest resistance to pesticides and lethal effect to non-target organisms in the agro-ecosystems in addition to direct toxicity to users. Therefore, it has now become necessary to search for the alternative means of pest control, which can minimize the use of synthetic pesticides. Botanical pesticides are the important alternatives to minimize or replace the use of synthetic pesticides as they possess an array of properties including toxicity to the pest, repellency, antifeedance, insect growth regulatory activities against pests of agricultural importance (Prakash and Rao, 1997). More than three dozen of pests are known to be associated with various honological stages of rapeseed -mustard crops (Bakhetia and Sekhon, 1989). mong these pests, mustard aphid, Lipaphis erysimi (Kalt.) is considered one of the devastating insect pests for its successful production (Bakhetia and Sekhon,1989). In Nepal, yield loss up to 35 % as recorded in Brassica campestris var. Tori .Aphids also transmit plant viral diseases, i.e. turnip mosaic virus, which can be managed by effective control of aphid (Chowfla and Baruah, 1990).

Farmers used to apply different type of chemicals with repeated frequency in high dose and sometimes even banned chemicals. The use of chemicals for pest control leads to such problems as environmental pollution, development of resistance to insecticides, harmful effects on non-target organisms including pollinators, pest resurgence, upsetting the balance of nature and threat to the health of man. Twenty aphid species have gained resistance to insecticides (Minks and Harrewinj, 1998) particularly to organophosphate, carbamate and parathyroid insecticides (Drees, 1997). Realization of negative consequences of chemical pesticides and the growing consensuses in regard of health and environment, viable and sustainable alternatives other than chemical method of pest control is in search. In this search, microbial approaches with antagonistic entomopathogenic fungi and botanicals pesticides (NARC, 1992) have been included as the best alternatives.

Control of aphids is a difficult task because of their rapid growth, mode of reproduction, polymorphic nature and ability to adopt different kinds of environment. Farmers spray insecticides in their fields injudiciously without knowing their mode of action and chemical group which result in insecticide resistance in the pest, destruction of natural enemies and environment pollution. So it is necessary to find alternate economical and environmentally safe methods for pest control. Bio

pesticides are less expensive, less hazardous and safe for natural enemies. Approximately 2,400 plant species contain pesticidal properties, among which neem is on the top (Thacker, 2002). Neem based insecticides are non-phytotoxic, have good shelf life and also are used against many insects. Their active ingredient is azadirachtin, salaanin and meliontriol that comprises powerful insect growth regulator, feeding deterrent, ovipositional deterrence, repellency, reduced fitness, sterility, production of distorted adults and environment tenacity (Isman, 2006). When applied on crop they don't leave any residue. They work as systemic pesticide; immersed into the plant, transferred to all plant tissues and engulfed by the insect which feeding on them. Neem extracts can used to control aphids efficiently (Schmutterer, 1990) and may be suited for comprehension in integrated pest management with no harmful effects on predators (Tanzubil, 1996), parasitoids of mustard aphid and also on egg parasitoids (Abudulai and Shepard, 2003). Due to the importance of canola, economic losses induced by aphids and risk involved in synthetic insecticides, the present study was conducted to find out most effective neem product for the management of different morphs of mustard aphid. Different methods such as mechanical, biological and botanical were adopted singly as well as in combination to manage mustard aphid. The mustard aphid was regularly monitored during crop season to give treatments for management of mustard aphid on need basis. The application of treatments was done on the basis of ETL.The treatments comprising mechanical+botanical+biological control were found to be the best alternative to chemical control for management of mustard aphid.

Information on the seasonal prevalence of insect pests, particularly mustard aphid in relation to weather factors is scanty (Bishoni *et al*., 1992). Good seed good crop. As mustard aphid is major constraints for quality seed production as a result it is reduced the yield of mustard. We can manage the mustard aphid by using different types of bio-pesticide and limited no of insecticides and by taking some mechanical control measure in eco-friendly manner.

The study was carried out to manage the mustard aphid with eco-friendly manner for quality seed production.

Considering above points the experiment was undertaken to fulfill the following objectives:

- To identify the incidence of mustard aphids in different stages of crop growth.
- To find out the most effective bio pesticide against mustard aphid for quality seed production.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Mustard aphid, *Lipaphis erysimi* (Kalt.) is one of the most important insect pests of cruciferous crops in Bangladesh. Good number of research works has been done on different aspects of mustard in different parts of the world. Although considerable literature dealing with loss occurred due to aphid infestation, effect of different insecticides on aphid infestation and reducing the loss occurred by aphid with treating different dose of insecticide and increasing the yield are available. Some of the works related to the present study have been presented below under the following sub-headings:

2.1 General review on mustard aphid

Literature dealing with taxonomy, distribution and host range of mustard aphid, *L. erysimi*, extent of damage and yield loss caused by mustard aphid have been presented below:

2.1.1. Taxonomy of mustard aphid

The taxonomic features of apterae and alate of *Lipaphis erysimi* (Kalt). It is a short bodied, yellowish and green or greenish colored species measuring 2-2.5 mm length when they are fully grown. The adults may be wingless (Apterae) or winged (Alate) with two pairs of hyaline wings. The fifth abdominal segment bears a pair of cornicles. The winged adults usually have black body markings and blackish head.

Taxonomic position of mustard aphid

Kingdom: Animalia

Class: Insecta

Sub-Class: Pterygota

Division: Exopterygota

Order: Homoptera

Family: Aphididae

Subfamily: Aphinidae

Genus: Lipaphis

Species: *Lipaphis erysimi* (Kalt.)

2.1.2. Distribution of mustard aphid

The mustard aphid, *L. erysimi* (Kalt.) is distributed worldwide (Martin 1983, Pradhan 1995). It is found in all tropical and subtropical countries (Scmutterer, 1978). According to Atwal *et al.*, 1976 it is recognized as a worldwide serious cruciferous pest).

2.1.3. Host range of mustard aphid

Jahan and Rahman (2011) conducted a study to know the diverse response on growth stages of mustard varieties to mustard aphids. Among ten mustard varieties, the maximum aphid population was recorded on Tori-7 at flowering stage but the population reached to the peak in BS-5 variety. Pod formation stage was more vulnerable for aphid infestation and increased population. Aphid infestation received higher at pod formation stage than flowering stage and consequently produced lower yield.

(Dixon 1982) stated that vegetable crops viz turnip, Chinese kale, mustard, flowering cabbage and Chinese cabbage possess 63.43, 10.04, 24.93, 23.32 and 114.31 aphids

plant^{-1}, respectively. In temperate climate, many aphid species are host alternating and have a

primary host, which is usually a woody plant and secondary hosts, which are generally herbaceous. *Lipaphis erysimi* is well known as a serious pest of mustard, cauliflower, turnip, kohlrabi, radish, Chinese cabbage, rai, tori, Brussels sprout, broccoli, kale and rutabaga and a minor pest of bean, beet spinach, pea celery, onion, stock, cucumber and potato (Scmutterer 1978).

2.1.4. Seasonal abundance of mustard aphid and its predators

Bhadra and Parna (2010) found that the mustard aphid, *Lipaphis erysimi* (Kalt) is a serious pest of mustard in tropical regions in the world. The population dynamics of this species is considerably influenced by immigrant alate, which migrate to the mustard crop from the off-season shelter. Aphids reproduce at a higher rate in the early vegetative stage of mustard plants when the developmental period is shortest and production of winged morphs is lowest. The population reaches an asymptote when the crop is 70 days old. The species regulates its developmental period, fecundity and intrinsic rate of increase in response to developmental changes of the mustard plant and maintains its dispersal throughout the duration of the mustard crop. In succeeding generations on a mustard plant new born nymphs took increasingly longer to develop into adults and over the same period these adults produced decreasingly fewer numbers of offspring. In the inflorescence and fruiting stages of mustard plants a higher proportion of the nymphs developed into alatae.

Aphids are an important group of plant insect pests. They have a high biological potential with some of aphid's species (Aphididae) having more than ten generations in one year (Iversen and Harding, 2007). Because of their direct (sucking) and indirect (transmission of viruses and honeydew secretion) damage on cultivated and wild-

growing plants, the producers of food plant, ornamental plants and feed for livestock and control them in different ways.

Vekaria and Patel (2005) conducted an experiment during Rabi 1993-94 and 1994-95 revealed that the incidence of aphid commenced from 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AT) at 14 weeks after sowing coinciding with second week of February during 1993-94, however, during 1994-95 aphid incidence commenced at late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AT) at 13 WAS coinciding with first week of February. The aphid population exceed above economic threshold level (ETL) between 11 and 14 WAS coinciding with the third week of January to second week of February. The predominant coccinellid predator *Coccinella septempunctata* was active between last week of January and last week of February with maximum population (5.52 and 3.07 beetles plant^{-1}) during third week of February in both the years.

Panget *et al.* (2010) conducted an experiment during the 1998-99 winter seasons to study the intensity and population fluctuation of *Lipaphis erysimi* on *Brassica juncea* in relation to the prevailing abiotic and biotic conditions. The aphid species infested the crop from the 2nd to the 14th standard week (SW) with its peak (302.10 aphids per plant) during 7th SW in 70 day old crops. The minimum temperature between 7.1 and 15.1°C, maximum temperature between 24.9 and 29°C were found to be congenial for the proper development of aphid population. The natural enemies like *Menochilus sexmaculatus* influenced the aphid population during their activity period from January to February.

Nayak *et al.* (2000) studied during the Rabi season of 1996-97 to determine the seasonal abundance of the *L. erysimi* pest. The highest aphid population was recorded on the second week of January, when it reached 42.95, 22.95, 22.30, 17.35, 16.32 and 11.72

on Indian mustard, cabbage, cauliflower, knolkhol, radish and turnip respectively. Thereafter, the aphid numbers declined. Overall, the mean aphid population during the season was highest (10.59) on radish and lowest (6.97) on turnip.

2.1.5. Extent of damage and yield loss caused by mustard aphid

Shelley (2009) found that two aphid species, *Brevicoryne brassicae* L., and *Lipahis eyrsimi* (Kalt.) were observed as the most devastating pests. Populations of B. *brassicae* were more than that of *L. eyrsimi*. All the varieties evaluated were found susceptible and weekly population of both the species of aphids did not differ significantly from their appearance till maturity of the crop. Appearance of aphids at all the locations was not uniform. However, the highest population was recorded during last week of February to second week of March.

Sam and Pang (1999) observed that the population dynamics of alates and apterous of turnip aphid, *Lipaphis erysimi* (Kalt.) on five host vegetable varieties in the field. The results showed that the average populations of apterous aphid on host vegetable varieties turnip, Chinese kale, mustard leaf, flowering cabbage and Chinese cabbage were 63. 425, 10. 041, 24. 928, 23. 323 and 114. 308 aphids/plant, respectively.

The mustard aphid *Lipaphis erysimi* (Kalt) causes serious losses of yield in Mustard crops and reduces its marketable value. Increase in population beyond 9.45 aphids per plant; reduce the seed yield by 59.3 per cent with an economic injury level of 2.04 aphids/plants with an index of 0.98 and infestation 37.4 per cent. The yield loss due to aphid infestation in mustard ranged from 87.16 to 98.16%. Greatest loss reported in yield only due to mustard aphid, (*Lipaphis eyrsimi* Kalt.) is 83% to rapeseed and mustard in India. Losses due to insect pests are estimated to be 70-80% in Pakistan. But in case of severe infestation inyears of sporadic attack there may be no grain formation at all (Khattak *et al.,* 2002). The colonies of mustard aphids feed on the new

shoots, inflorescence and underside of leaves. Loss in yield up to 91.3 % and oil contents up to 15 % (Verma and Singh, 1987).

The damage is caused by both nymphs and the adults, these are louse-like and pale greenish insects, is seen feeding in large numbers, often covering the entire surface of the flower buds, shoots, pods etc. (Ahmed and Jalil, 1993). In case of severe aphid infestation, leaves become curled, plant fails to develop pods, the young pods when developed fail to become mature and cannot produce healthy seeds. As a result, plants loss their vigor and growth becomes stunted (Morzia and Huq, 1991). Khan and Munir (1986) observed the effect of aphid infestation on seed yield and other characteristics of Raya. The number of pods per plant in the treated (506.25) and in un-treated (187.02) was found significantly different from each other.

2.2. Management of mustard aphid

The most frequently mentioned control methods are spraying the plants with insecticides (Parker *et al.*, 2006), the use of corresponding agro-technical measures and in a lower extent the use of biological control agents (Du *et al.*, 2004).

2.2.1. Role of bio-rational for the management of mustard aphid

Biswas G. C. (2013) conduct and experiment and found effectiveness of different doses of neem extracts and a synthetic organic insecticide against mustard aphid was studied in the experimental farm of the Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during two consecutive years 2010-2011 and 2011-2012 for the control of mustard aphid. Eight treatments were evaluated against mustard aphid under field condition. The maximum aphid population was (180 per plant) observed at the pod formation stage of mustard crop. Among the treatments, Malataf (Malathion 57EC) @ 2 ml/L significantly reduced the highest aphid population (93.75%) over pretreatment which produced the highest seed yield

(1440 kg ha^{-1}) of mustard. The neem leaf extracts reduced 63.16-72.55% aphid population in mustard while neem seed extract reduced 73-81% aphid population over pretreated plants in both the years. Among the different doses of neem extracts, the highest aphid population reduction over pretreatment (81%) was recorded from 50g neem seed $litre^{-1}$ of water treated plots with high MBCR (3.88) followed by 75g neem seed $treated^{-1}$ plots having reduction of 80% and MBCR 3.78.

Ahmed (1984) listed about 221 plant species possessing insecticidal properties in this country. The neem tree, Azadirachtin indica, a source of several insecticidal alkaloids is a sub tropical tree native to the arid areas of Asia and Africa (Saha et al., 2006). Azadirachtin is the main pesticidal component of neem. Neem products are naturally available materials, cheaper, and also safe for beneficial organisms. It is distasteful and repells insects and may reduce the insect infestation (Sarode et al., 1995). It is necessary to determine the most effective dose of neem extract (both leaf and seed) for the control of mustard aphid. Information using different doses of neem extract for the control of mustard aphid in Bangladesh are scanty. Therefore, the present study was undertaken to find out the most effective dose of neem extract for eco-friendly management of mustard aphid.

Parma *et. al.* (2016) studied that mortality rate of Lipaphis erysimi and its larvae by using neem leaf extract and appropriate dose of concentrations for checking the insect population.For this cultivars were raised with three dates of sowing at an interval of 15 days each in subplots with three replications each and the clones of mustard aphids were maintained. Theeffect of neem leaf extract on different larvae stages of aphids was studied and for that neem leaf extract of different concentrations was prepared, rearing

of aphid's larvae was done and then the mortality rate of the aphid larvae (i.e. 1st, 3rd and 5th instars) in presence of neem leaf extract at different time intervals with different concentrations (5%, 10%, 15%, 20%) was studied.From the study it was observed that the aphid, L. erysimi was killed with the neem leaf extract at all concentrations but there was a significant difference among different concentrations, larval stage and period of treatment. Thus the study showed that by using eco-friendly insecticide, neem leaf extract, the spread of L. erysimi can be controlled which in turn will not hamper the yield of the mustard crop

Muhammad *et. al*. (2014) conducted an experiment to evaluate different neem extracts i.e., Neem leaf extract (10%), Neem seed oil (2.5%), Neem seed cake extract(10%), Neem seed kernel extract (10%) in comparison with imidacloprid (Confidor 70 WG) against different morphs of mustard aphid on *Brassaica napus* L. Among the all treatments imidacloprid and Neem seed oil resulted in maximum (100%) reduction over precount including nymph, wingless and winged adults of Lipaphis erysimi, followed Neem seed cake extract (86.13, 89.90 & 68.48%) and neem seed kernel extract (77.41, 55.11&34.26%). Imidacloprid and neem seed oil showed negative impact on the population increase index of parasitoids and predators of L. erysimi. All neem extracts had positive population increase index of mummified aphids. Neem leaf extract resulted in negative population increase index in case of predators. Neem seed kernel extract showed positive index in case of green lacewing and lady bird beetle larvae and Neem seed Cake extract showed positive population increase index in case of only lady bird beetle larvae. Maximum repellency effect was observed with both Neem leaf extract and Neem Cake Extract (97.92%) and minimum in case of Neem seed kernel extract (89.58%). Neem seed oil resulted in maximum mortality of aphids followed by Neem

Cake Extract. Reproduction (nymphs/aphid) was minimum with Neem seed oil followed by Neem Cake Extract. Highest net income was obtained by application of imidacloprid followed by Neem seed oil followed by Neem seed cake extract. Being effective against aphids and comparatively safer against natural enemie's neem products especially Neem cake extract may be used in ecofriendly management of mustard aphid on *B. napus.*

Sultana *et. al.* studied on the management on mustard aphid (Lipaphis erysimi) using Jet powder, Neem Kernel extract, Jet powder + Neem Kernel extract with two chemical insecticide Aktara® 25WG and Diazinon® 60EC and their integration was studied at Agricultaral Research Station, Comilla, during the winter season of 2008-2009. The highest aphid population was 84 per plant was observed in the 2 week of January in 2009. rd Among the treatments on an average Aktara reduced the highest aphid population (92%) with the highest BCR (4.20) followed by Diazinon® (89%) and Neem Kernel extract + Jet powder (65%). Diazinon® 60EC gave the second highest BCR (3.83) followed by Jet powder(3.62) and Neem kernel extract + Jet powder (3.07). The highest yield (1568 kg ha^{-1}) was also found in Aktara treated plot which was statistically similar to Diazinon® 1 treated plot (1485 kg ha^{-1}) and the lowest yield (840 kg ha^{-1}) was found in control plot.

Kalasaria (2016) revealed that schedule 4 consisting of flonicamid 0.02 per cent at seedling stage, flubendamide 0.014 per cent at pre-flowering stage, azadirachtin 0.15 per cent at 50% flowering stage and acephate + fenvalerate 0.028 per cent at 50% pod formation stage was significantly. The most effective treatment which recorded lowest aphid index (1.1) over stage of the crop and year, whereas the schedule S 3 (1.4 aphid

index) proved next better effective in comparison to control schedule S 6. The highest grain yield was found in schedule S 4 (1302 kg ha^{-1}) followed by S3 (1218 kg ha^{-1}) and schedule S 5 (1172 kg ha^{-1}) yield. Significantly the lowest grain yield was recorded in untreated control schedule S 6 (500 kg ha^{-1}). It showed highest gross realization in schedule S 4 (29674 Rs ha^{-1}) followed by schedule S 3 (26566 Rs ha^{-1}). The schedule S 2 generated highest ICBR ratio (1:6.7) followed by schedule S 3 (1:6.3) and schedule S 4 (1:6.3) whereas, schedule S 1 (1:3.1) gave significantly lower ICBR than other schedules. Thus, any one of the above effective and economical insecticidal spray schedule can be suggested for the control of mustard aphid.

2.2.2 **Integrated management of aphid**

A field experiment was conducted by Yadav (2004) in Punjab, India to investigate the integrated control of mustard pests. Integrated pest management was possible using the tolerant genotype PBR 91, sowing on 20 October, seed treatment with Apron 35 SD [metalaxyl] at 6 g/kg, and need based spraying with Ridomil MZ 72 WP [mancozeb + metalaxyl] at 0.25% + Indofil M-45 [mancozeb + thiophanate-methyl] at 0.2% (2 sprays at 20-day intervals).

An experiment was conducted by Singh *et al*. (2003a) during 1995/96 and 1996/97 to develop and validate an integrated pest management (IPM) module for mustard under Haryana, India, agroclimatic conditions. The treatments comprised IPM module (T1); chemical control (T2); and control (T3). Data were recorded for the incidence of pests, i.e. painted bug (*Bagrada hilaris*), saw fly (*Athalia lugens proxima* [*Athalia lugens*]), leaf miner (*Chromatomia horticola* [*Chromatomyia horticola*]), and aphid (*Lipaphis erysimi*). T1 reduced pest incidence compared to T2 and T3. There was no observed incidence of painted bug and saw fly. Leaf miner incidence was low during both cropping seasons. Crop yield was highest with T1 compared to T2 and T3. Tabulated data on the IPM module for mustard crop is also presented. Singh *et al*. (2003b) reported an integrated pest management (IPM) module, involving the timely sowing of the crop, seed treatment with carbendazim at 2 g kg^{-1} seed, soil application of the fungal biological control agent *Trichoderma* 50. *viride* at 1 kg $acre^{-1}$, mechanical removal of

aphid-infested twigs at the initial stage of attack and 3 inoculative releases of aphid predator (Chrysoperla carnea) larvae, was validated at farmers' fields in Bhora Khurd village, Guargon district, Haryana, India during 1997-98, for the management of pests and diseases of mustard. The IPM module reduced the pest attack on the crop and gave higher yield compared to untreated plots.

Four neem (*Azadirachta indica*) formulations, two synthetic insecticides (dimethoate and endosulfan) and *Bacillus thuringiensis* used alone and in combination with endosulfan were evaluated by Men *et al*. (2002) for safety to *Diaeretiella rapae*, a potential parasitoid of the mustard aphid, *Lipaphis erysimi*, on Indian mustard cv. Pusa Bold at Akola, Maharashtra, India, during 1999. It was found that *B. thuringiensis* (1 kg ha^{-1}) and Neemark (1%) were the safer treatments followed by neem leaf extract (5%), *B. thuringiensis* at 0.5 kg ha^{-1} + endosulfan (0.03%), endosulfan (0.05%), Achook (0.15%) and neem seed extract (5%). Dimethoate (0.03%) proved toxic to the hyperparasitoid.

The role of aphidophagous insects for field control of mustard aphid (*Lipaphis erysimi*), which infests Brassica juncea cv. M-27 is discussed by Devi *et al*. (2002) along with the efficacy of neem product and conventional chemical insecticides. The results of the field evaluation, Manipur, India indicated not only the reduction in aphid density but the population of the predatory insects were also not affected much by the insecticide treatment. This revealed that neem pesticide, endosulfan and phosalone could be used along with the biological control agents for the control of mustard aphid. Singh and Singh (2002) presented a comprehensive review of the integrated management of insect pests of rapeseed-mustard in India. The pests belonging to the insect families Aphididae, Pentatomidae, Tenethridinidae, Agromyzidae, Pieridae, Pyralidae, Arctiidae and Noctuidae are controlled by cultural, biological and chemical methods.

The use of botanical insecticides in the control of some pest families, and the role of pest resistance in some cultivars in integrated pest management are also mentioned.

Field experiments were conducted by Kular *et al*. (2001) in Punjab, India, from 1995/96 to 1999/2000 to study the effect of aphid management practices, such as cultural methods, use of resistant/tolerant genotypes, biological control agents (*Chrysoperla carnea* and *Verticillium lecanii*), and need [*Azadirachta indica*]-based applications of

insecticides, on the seed yield of rapeseed mustard. Early (18 October)-sown crops gave significantly higher yields (6.87 and 11.83 q ha^{-1}) than the late (17 November)-sown crops (4.48 and 4.91 q ha^{-1}) during 1995-96 and 1997-98, respectively; were on a par with normal (2 November)-sown crops during 1997-98; and superior to normal-sown crops (5.85 q ha^{-1}) during 1995-96. Significantly higher seed yield (7.75 q ha^{-1}) was obtained with *Brassica carinata* (cv. PC5), which showed tolerance to mustard aphid compared to *B. juncea* (cv. RL 1359) and *B. napus* (cv. GSL 2) during 1996-97. Significantly higher seed yields of 9.44, 8.44 and 6.89 q ha^{-1}were obtained when the aphid was controlled with insecticides at the economic threshold level (ETL) compared to untreated crops (2.49, 2.00 and 1.22 q ha^{-1}) under early, normal, and late sowing conditions, respectively, during 1995-96. However, the yield was on a par with fixed spray schedule (8.78 q ha^{-1}) under early sowing conditions but significantly higher than fixed spray schedule under normal sowing and late sowing conditions. Thus, insecticidal sprays given at ETL were more effective than fixed spray schedule of insecticides.

The above cited review represents that aphid pest management in mustard suggested that the use of botanical pesticide and chemical pesticide in integrated way was more effective.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207 / during the period from November 2017 to February 2018 to explore the efficiency of bio insecticides on the reduction of infestation level of mustard aphids for quality seed production. The details of different experimental materials and methodologies followed during the course of the investigation are described under the following sub-headings:

3.1. Location and duration of the experimental site

The research work was conducted in the central farm and Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207 (Plate 1) during the Rabi season of 2017-18 (from November 2017 to February 2018).

3.2. Soil of the experimental site

The soil of the experimental field belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace Soils (Appendix ii). It was medium high land, fertile, well drained, fairly leveled and slightly acidic with pH varying from 5.8 to 6.5, CEC 25-28 (Haider *et al.*, 1991).

3.3. Climate

The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. Temperature during the cropping period ranged from 13.32 to 24.12º C (Appendix i).

Plate 1. The experimental field of mustard laid out in the farm of SAU, Dhaka

3.4. Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator, afterwards the land was ploughed and cross-ploughed followed by laddering to obtain a good tilth. The corners of the field were spaded, weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. The target land was leveled and the experimental field was divided into 28 equal plots with a plot size of 2.0 m X 3.0 m and plot to plot distance 0.5 m; block to block distance 1.0 m.

3.5. Application of fertilizers

Recommended doses of N, P, Zn and B (30 kg N from urea, 30 kg P from TSP and 2 kg Zn from ZnO respectively) were applied. The whole amount of TSP and ZnO, half of

the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 20-22 days of germination.

3.6. Design of the experiment and layout

The experiment was laid out in a Randomized Complete Block Design with four replications. The total numbers of plots were 28 for 7 treatments, each measuring 2 m × 3 m (6 m^2). The adjacent block and neighboring plots were separated by 1.0 m and 0.5 m, respectively.

3.7. Treatments

Five bio insecticides, field sanitation and control were evaluated in this study against mustard aphid. The group wise insecticides with their specific dose applied as treatment are given below:

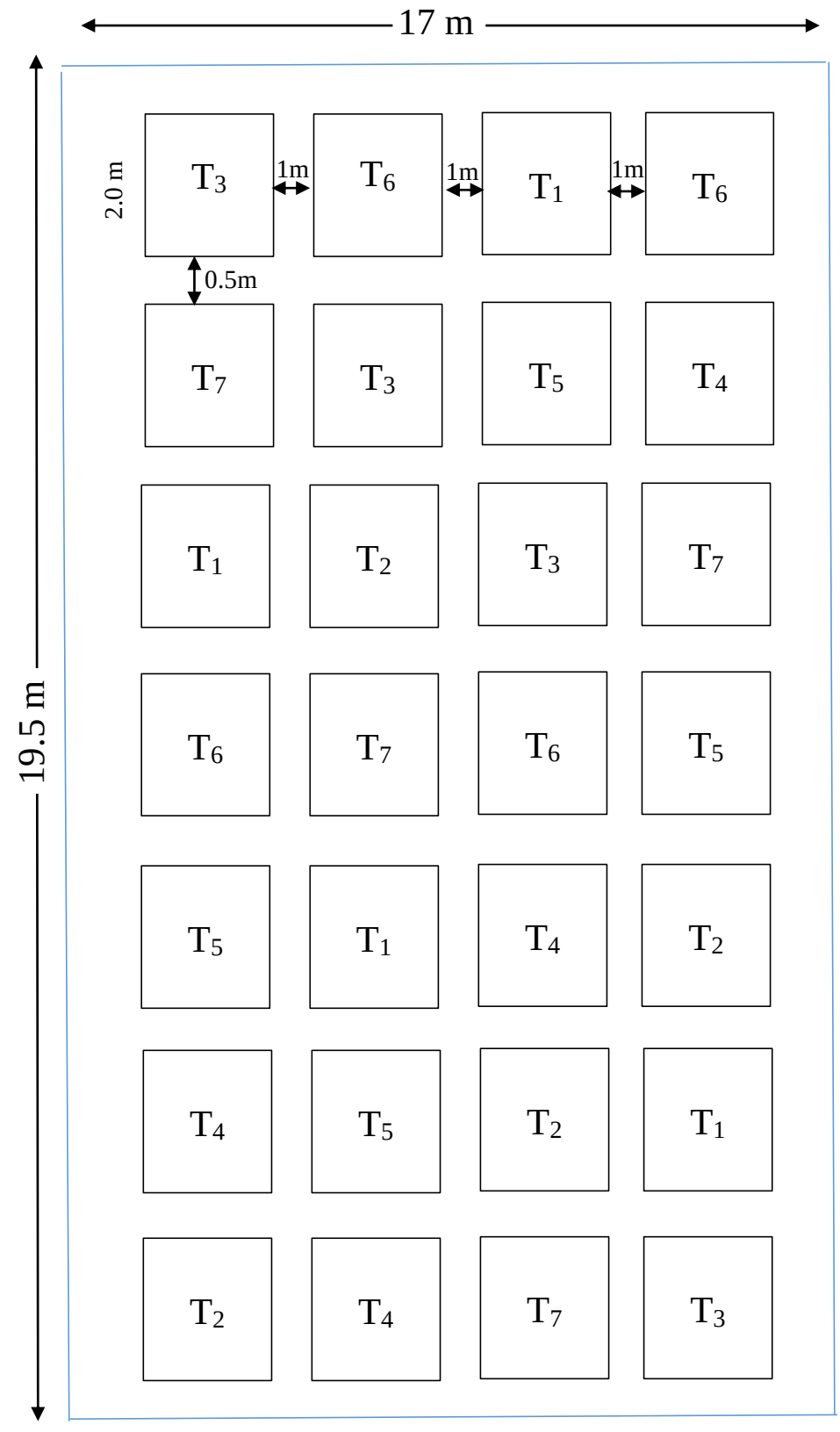
Treatments	Insecticides	Dose	Application interval
T_1	Spraying Neem Oil	3.0 ml/L of water	7 days interval.
T_2	Bioneemplus 1EC	1.0 ml/L of water	10 days interval
T_3	Neem seed kernel extract	50 g/L of water	7 days interval
T_4	Spinosad 45EC	0.4 ml/L of water	10 days interval.
T_5	Detergent	10 g/L of water	7 days interval
T_6	Field sanitation	Regular cleaning of the plot	
T_7	Control		

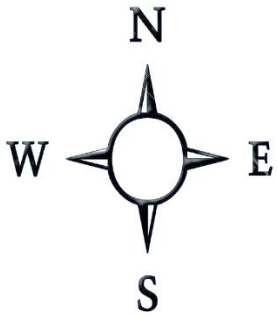
3.8. Detail procedure of the study

The detail procedure considering the materials used and methodology followed in the study are given below:

3.8.1. Materials

The mustard variety BARI-15 was cultivated in the designed field to investigate the present study according to the objectives mentioned earlier.





Plot size: 3.0 m × 2.0 m

Plot spacing: 50 cm

Between replication: 1.0 m

Treatments:

T_1: Neem Oil @ 3.0 ml/L of water with at 7 days interval,

T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,

T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,

T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,

T_5 : Detergent @ 10 g/L of water at 7 days interval,

T_6 : Field sanitation @ regular cleaning of the plot

T_7 : Control]

Figure 1. Layout of the experimental plot

3.8.2. Seed sowing

Seeds of the BARI-15 variety of mustard collected from BARI were sown in the selected field on 1th October 2017 in lines following the recommended row to row distance of 75 cm. After germination the seedlings (Plate 2) were sprinkled with water.

Plate 2. Seedlings of mustard in the experimental plot

3.8.3. Intercultural operation

The weeds found in the mustard field were cleaned and removed manually. The thinning of the mustard seedlings was also done as required during the growing season and care was taken to maintain uniform plant population per plot. Three times flood irrigation were given in the field at vegetative stage.

3.8.4. Application of the treatments

The selected treatments comprising different bio insecticides with their assigned doses were started to apply in the respective plots when the aphids were first appeared in the mustard field. The first appearance or incidence of aphids was determined by visit and daily direct visual observation of mustard plants. Therefore, considering the first appearance of the aphids in the field, treatment applications were started at 40 days

after sowing (DAS) of the mustard seeds. The treatments were applied at different interval and continued up to the silique were formed.

3.9. Data collection and calculation

Data collection was started at 40 days after sowing when aphids were visible the first time. Randomly 5 plants were selected and number of aphid were counted on level of leaves infestation, level of inflorescence infestation, level of stem infestation and level of pod infestation by direct visual count method throughout the growing period of mustard in the field before spraying of insecticides.

3.9.1 Plant height

Plant height was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded at 40, 55 and 70 days after sowing to observe the growth rate.

3.9.2 Leaves plant^{-1}

Number of leaves was counted from the sample plants and means value was calculated. Number of leaves was recorded 40, 55 and 70 days after sowing to observe the growth rate.

Leaf plant^{-1} = (Total number of leafs from five sample plants)/5

3.9.3 Number of branches plant^{-1}

Total number of branches was counted from all sample plants and mean was calculated by the following formula:

Branches plant^{-1} = (Total number of branches from five sample plants)/5

3.9.4 Number of silique plant^{-1}

Numbers of total silique of selected plants from each plot were counted and the mean numbers were expressed as per plant basis. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.9.5 Length of silique

Length of silique was taken from randomly selected ten silique and the mean length was expressed on silique^{-1} basis.

3.9.6 Number of seeds silique^{-1}

The number of seeds silique^{-1} was recorded from randomly selected 10 silique at the time of harvest. Data were recorded as the average and express in seeds silique^{-1}.

3.9.7 1000 seeds weight

One thousand cleaned, dried seeds of mustard were counted from each harvest sample and weighed by using a digital electronic balance and weight was expressed in gram (g).

3.9.8 Seed yield plant^{-1}

The seeds collected from five plants and sun dried properly, weighted and data were recorded seed yield of gm plant^{-1} then averaged.

3.9.9 Seed yield ha^{-1}

The seeds collected from (1 m × 1 m) 1 meter square area of each plot and sun dried properly, weighted and data were converted seed yield of ton ha^{-1}.

3.9.10 Seed germination %

The harvested seeds under different treatment were germinated in Petri dishes (12 cm diameter) containing two layers of filter paper with 15 mL of distilled water. Each Petri dish contained 15 seeds representing an experimental unit. The seeds were considered to have germinated after radicle emergence. Germination percentage was calculated by following formula

$$\text{Germination (\%)} = \frac{\text{Number of seeds that germinated}}{\text{Number of seeds on the petridish}} \times 100$$

3.9.11 Shoot length (cm)

Seedlings were collected after 7 days of sowing form experimental plot and measure the shoot of 10 seedling with scale and data were recorded as the average in cm.

3.9.12 Root length (cm)

Seedlings were collected after 7 days of sowing form experimental and measure the root of 10 seedling with scale after that data were recorded as the average in cm.

3.9.13 Seedling length (cm)

Seedlings were collected after 7 days of sowing form experimental and measured 10 seedling with scale after that data were recorded as the average in cm.

3.9.14 Aphid population on leaves

The number of aphid population on five randomly selected plants from each plot was counted at 1, 4and 7 days after spraying. The infested 5 leaves of selected plant were cut and put into the polythene bags separately, and then brought to the laboratory. The aphids were removed from the infested leaves with the help of a soft camel hail brush and placed on a piece of white paper. The numbers of aphids for each leaves were counted visually as well as with the help of a magnifying glass and then recorded the number of each treatment. The percent reduction of aphid population from insecticide treated plot over the untreated control was calculated using the following formula (Khosla, 1997):

$$\% \text{ aphid population over control} = \frac{\text{Mean of untreated plot- Mean of treated plot} \times 100}{\text{Mean of treated plot}}$$

Plate 3: Aphid on inflorescence in mustard plant.

Plate 4: Aphid on stem in mustard plant.

3.9.15 Aphid population on inflorescence

The population of aphids in the field on the five randomly selected plants from each plot were counted before spraying of insecticides and then 1, 4 and 7 days after first and second spraying of insecticides. The top 5 cm epical twigs of these selected plants were cut and brought to the laboratory in polythene bags separately. The aphids were removed from the plants with the help of a soft brush and placed on a piece of white paper. Their number was counted with the help of magnifying glass and hand tally counter. Infested twigs and inflorescence were checked carefully, so that not a single aphid could escape at the time of counting. The numbers of aphids per plant were converted in percent reduction of aphid population by using the following formula.

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot- Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.16 Aphid population on stem

The number of aphid population on five randomly selected plants from each plot was counted at 1, 4and 7 days after spraying. The infested stem of selected plant were cut into 3 cm and put into the polythene bags separately, and then brought to the laboratory. The aphids were removed from the infested stem with the help of a soft camel hail brush and placed on a piece of white paper. The numbers of aphids for each stem were counted visually as well as with the help of a magnifying glass and then recorded the number of each treatment. The percent reduction of aphid population from insecticide treated plot over the untreated control was calculated using the following formula (Khosla, 1997)

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot- Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.17 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using MSTAT-C package and the mean difference were adjusted by LSD technique. (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISSCUSSION

The results on different parameters of the study have been interpreted and discussed under the following sub-headings:

4.1. Plant height (cm)

Plant height is an important character of a plant, which is closely related proper growth and development of a plant and finally produced higher yield. Plant height of mustard varied significantly at 40, 55 and 70 days after sowing (DAS) due to different treatment (Figure-2 and Appendix III). At 70 DAS, the longest (92.33 cm) plant was produced from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment and the shortest (80 cm) was found from T_7 (control) treatment. The increase in height may be due to the influence of Spinosad 45EC. The present result also agrees well with M. Moniruzzaman (2009), who obtained the highest plant height (46.7 cm) with bio pesticides.

4.2 Number of leaves plant^{-1}

Number of leaves per plant is an important parameter of crop plant because of its physiological role in photosynthetic activities. Number of leaves is directly related to the mustard yield.

Number of leaves per plant of mustard varied significantly at 40, 55 and 70 days after sowing (DAS) due to different treatment (Table 2 and Appendix IV). At 90 DAS, the highest number of leaves (25.83) per plant was obtained from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment and the lowest (17.80) from (control) T_7 treatment.

The result obtained from the present supported by Verma *et al*. (2015) in respect of number of leaves per plant.

Table 1: Effect of treatments on Plant height per plant at different days after sowing of mustard.

Treatments	Plant height at(cm)		
	40 DAS	**55 DAS**	**70 DAS**
T_1	29.33 ab	56.33 bcd	85.67 ab
T_2	29.00 ab	61.00 ab	86.67 ab
T_3	28.70 ab	58.00 bc	85.33 ab
T_4	32.90 a	65.09 a	92.33 a
T_5	28.00 bc	50.33 de	84.67 b
T_6	24.00 c	54.00 cd	81.33 b
T_7	27.00 bc	45.33 e	80.00 b
LSD (0.05)	**4.68**	**6.49**	**7.47**
CV (%)	**5.77**	**4.08**	**3.07**

Table 2: Effect of treatments on number of leaves per plant at different days after sowing of mustard.

Treatments	No. of leaves per plant at		
	40 DAS	**55 DAS**	**70 DAS**
T_1	8.33 c	21.83 ab	23.50 ab
T_2	9.40 b	21.53 b	23.03 b
T_3	8.43 bc	19.77 bc	21.77 bc
T_4	10.47 a	23.83 a	25.83 a
T_5	8.03 c	18.57 cd	20.00 cd
T_6	8.20 c	19.80 bc	21.80 bc
T_7	6.57 d	16.83 d	17.80 d
LSD (0.05)	**1.05**	**2.06**	**2.34**
CV (%)	**4.33**	**3.56**	**3.74**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

DBS =Day before spraying
DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,
T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,
T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,
T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,
T_5 : Detergent @ 10 g/L of water at 7 days interval,
T_6 : Field sanitation @ regular cleaning of the plot
T_7 : Control]

4.3. Number of branch plant^{-1}

Number of branches plant^{-1} in mustard showed significant difference where the number of branches (9.20) was found in T_4 (Spinosad 45EC @ 0.4 ml/L) followed by T_2 (8.13) and T_1 (8.07). Minimum number of branch plant^{-1} was recorded 6.00 in T_7 (Control) (Table 3). Maninder and Brar (1995) found highest 12.28 branches mustard. Alam, M. Z., Ahmed, A. and Siddique A. (1964) reported that no. of branches increased with increasing rate of bio pesticide.

4.4. Number of silique plant^{-1}

Silique number plant^{-1} was observed maximum in T_4 (Spinosad 45EC @ 0.4 ml/L of water) i.e. 82.33 closely followed by T_2 (77.33) and minimum number of silique plant^{-1} was found 54.33 in T_7 (Control) (Table 3). The number of silique from this experiment was supported by Bakhetia, D.R.C. (1993) in respect of bio pesticide application.

4.5. Length of silique

Height length of silique was found 8.53 in T_4 (Spinosad 45EC @ 0.4 ml/L) which is closely followed by T_2 (7.73) and lowest number of silique per plant was found 5.60 in T_7 (Control) (Table 3). The length of silique from this experiment was supported by Bakhetia, D.R.C. (1993) in respect of bio pesticide application.

4.6. Total number of seed silique^{-1}

Maximum number of seed silique^{-1} was found 22.67 in T_4 (Spinosad 45EC @ 0.4 ml/L) which is closely followed by T_2 (19.67) and minimum number of seed silique^{-1} was found 14.43 in T_7 (Control) (Table 3). The number of seed silique^{-1} from this experiment was supported by Bakhetia, D.R.C. (1993) in respect of bio pesticide application.

Table 3: Effect of treatments on number of branch Plant^{-1}, number of silique Plant^{-1}, length of silique and total number of seed silique^{-1} of mustard.

Treatment	Number of branches plant^{-1}	Number of silique Plant^{-1}	Length of silique	Total number of seed silique^{-1}.
T_1	8.07 b	73.67 bc	7.40 b	18.40 b
T_2	8.13 b	77.33 ab	7.73 ab	19.67 ab
T_3	7.50 bc	71.10 bc	7.13 bc	18.67 b
T_4	9.20 a	82.33 a	8.53 a	22.67 a
T_5	7.20 c	70.67 bc	7.20 bc	18.00 bc
T_6	7.00 c	67.67 c	6.53 c	17.20 bc
T_7	6.00 d	54.33 d	5.60 d	14.43 c
LSD (0.05)	**0.72**	**8.21**	**0.84**	**3.63**
CV %	**3.33**	**4.05**	**4.15**	**6.89**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,
T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,
T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,
T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,
T_5 : Detergent @ 10 g/L of water at 7 days interval,
T_6 : Field sanitation @ regular cleaning of the plot
T_7 : Control]

4.7. 1000 seeds weight

There is no significant difference found in 1000 seed weight though higher 1000 seeds weight 3.52 found in T_6 (Field sanitation) and lower 1000 seeds weight 3.30 found in T_2 (Bioneemplus 1EC @ 1.0 ml/L) (Table 4).

4.8 Seed yield plot^{-1}

Yield is the ultimate economic product of the crop, which is determined mainly by seed weight, number of seeds, silique plant^{-1}. It was observed different levels of bio pesticide application significantly effect on the seed yield per plant of mustard (Table 4). Highest seed yield per plot was revealed 264.33 Kg in T_4 (Spinosad 45EC @ 0.4 ml/L) and lowest seed yield per plot was found 289.67 Kg in T_7 (Control) (Table 4). Saha *et. al.* (2006) reported that plant height, no. of branches per plant and seed yield increased due to application of different bio pesticide.

Table 4: Effect of treatment on 1000 seeds weight, seed yield plot^{-1}, seed yield ton ha^{-1} and germination of mustard.

Treatment	1000 seeds weight(gm)	Seed yield Plot^{-1} (kg)	Seed yield ton ha^{-1}	Germination %
T_1	3.50	324.33 c	1.44 c	85.67 bc
T_2	3.30	344.33 b	1.53 b	89.67 b
T_3	3.43	312.33 c	1.39 c	84.00 c
T_4	3.40	364.33 a	1.62 a	95.33 a
T_5	3.40	311.67 c	1.40 c	83.00 c
T_6	3.52	313.33 c	1.41 c	83.00 c
T_7	3.37	289.67 d	1.29 d	77.67 d
LSD (0.05)	**0.08**	**15.67**	**0.06**	**5.06**
CV %	**3.15**	**1.70**	**1.66**	**2.07**

Table 5: Effect of treatment on Shoot length, Root length, Seedling length of mustard.

Treatment	Shoot length (cm)	Root length(cm)	Seedling length (cm)
T_1	6.03 b	6.87 ab	14.50 b
T_2	6.17 b	7.10 a	14.77 ab
T_3	5.90 b	6.43 bc	14.33 bc
T_4	6.77 a	7.33 a	15.50 a
T_5	5.80 bc	6.03 cd	13.53 cd
T_6	6.07 b	5.80 d	12.67 d
T_7	5.33 c	5.25 e	11.43 e
LSD (0.05)	**0.49**	**0.53**	**0.96**
CV %	**2.91**	**2.93**	**2.43**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,

T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,

T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,

T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,

T_5 : Detergent @ 10 g/L of water at 7 days interval,

T_6 : Field sanitation @ regular cleaning of the plot

T_7 : Control]

4.9 Seed yield ton hectare $^{-1}$

Seed yield ton hectare $^{-1}$ was showed statistically significant variation due to different treatment application (Table 4). The maximum seed yield ton per hectare (1.62) was found in T_4 (Spinosad 45EC @ 0.4 ml/L). On the other hand, the minimum seed yield ton hectare $^{-1}$ (1.29) was found in T_7 (control) treatment. Saha *et. al.* (2006) found that high interval of bio pesticide application significantly reduced seed yield. Application of bio pesticide in low interval produced significantly higher seed yield.

4.10 Germination %

Different treatment application significantly influenced the germination of harvested mustard (Table 4). The highest (95.33%) germination was found from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment. The lowest (77.67%) germination from was observed in T_7 (control) treatment. Rohilla *et. al.* (2004) also experienced the similar result due to application of bio-pesticide.

4.11 Shoot length (cm)

A significant variation was found in shoot length of mustard due to application of bio insectiside (Table 5). The highest (6.77 cm) shoot length of mustard was found from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment. The lowest (5.33 cm) shoot length of mustard was observed in T_7 (control) treatment. Mathur, Y. K. and Upadhyay, K. D. (2000) who reported that application of spinosad significantly increased the shoot and root length of mustard.

4.12 Root length (cm)

Different levels of treatment significantly influenced the root length of mustard (Table 5). The highest (7.33 cm) root length of mustard was found from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment. The lowest (5.25 cm) root length of mustard was found from T_7 (control) treatment. Mathur, Y. K. and Upadhyay, K. D. (2000) who reported that application of spinosad significantly increased the shoot and root length of mustard.

4.13 Seedling length (cm)

A significant variation was found in seedling length (cm) of mustard due to application of different treatments (Table 5). The maximum (15.50 cm) seedling length of mustard was found from T_4 (Spinosad 45EC @ 0.4 ml/L) treatment. The minimum (11.43 cm) root length of mustard was found from T_7 (control) treatment. Mathur, Y. K. and Upadhyay, K. D. (2000) who reported that application of spinosad significantly increased the shoot and root length of mustard.

4.14 Effect of bio-rational on the incidence of aphid population on leaves

The number of aphid population was observed before spraying insecticide. The highest population was recorded in T_7 (113.3 aphid leaves^{-1}) followed by T_1 (98.33 aphid leaves^{-1}) and the lowest aphid population was recorded in T_4 (71.67 aphid leaves^{-1}) preceding T_5 (78.33 aphid leaves^{-1}). Statistically significant variations were observed among the results of .The highest aphid population (178.33 aphid leaves^{-1}) was recorded in untreated control plot T_7, which was statistically different to that of T_3 (48.33 aphid leaves^{-1}) i.e., spraying of Neem seed kernel extract @ 50 g/L of water at 7 days interval and T_1 (43.33 aphid leaves^{-1}) treated plot (Table 6). On the other hand, the lowest aphid population (33.33 aphid leaves^{-1}) was recorded in T_2 i.e., spraying of Bio neemplus 1EC @ 1.0 ml/L of water at 10 days interval followed by T_4 (43.33 aphid leaves^{-1}) i.e., spraying of Spinosad 45EC @ 0.4 ml/L of water at 10 days interval. followed by T_5 (38.33) comprising of Spraying of Detergent @ 10 g/L of water at 7 days interval. In case 4 days after spraying (DAS), the highest aphid population (225.00 aphid leaves^{-1}) was also recorded in control plot T_4 which was statistically different from all other treatments. It was followed by T_5 (60.00 aphid leaves^{-1}) and T_3 & T_2 (48.33 aphid leaves^{-1}). On the other hand, the lowest aphid population (38.33 aphid leaves^{-1}) was also recorded in T_4 followed by T_6 (45.67 aphid leaves^{-1}) and T_1 (46.67 aphid leaves^{-1}) treated plots. In case of 7 days after spraying (DAS), the Highest aphid population of aphid leaves^{-1}) was recorded control plot followed by T_7 (380.00 aphid leaves^{-1}) and T5 (68.33 aphid leaves^{-1}) which is statistically different. On the other hand, the lowest aphid population (50.00 aphid leaves^{-1}) was recorded in T_4 followed by T_1 (52.00 aphid leaves^{-1}) and T6 (56.00 aphid leaves^{-1})

Table 6. Effect of treatments on number of aphids on leaves plant^{-1} before and after spray

Treatments	Number of aphids				Aphid reduction over control (%)
	DBS	1 DAS	4 DAS	7 DAS	
T1	71.67 c	33.33 c	38.33 c	50.00 b	32.76
T2	93.33 bc	42.33 bc	48.33 bc	68.33 b	42.69
T3	97.67 ab	42.33 bc	45.67 bc	56.00 b	27.54
T4	98.33 ab	43.33 bc	46.67 bc	52.00 b	47.11
T5	88.33 bc	38.33 bc	60.00 b	68.33 b	27.08
T6	80.00 bc	48.33 b	48.33 bc	58.33 b	26.78
T7	113.3 a	178.3 a	225.0 a	380.0 a	----
LSD(0.05)	**22.45**	**13.39**	**20.25**	**21.53**	**----**
CV (%)	**14.27**	**11.47**	**14.73**	**10.6**	**----**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD test at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,
T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,
T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,
T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,
T_5 : Detergent @ 10 g/L of water at 7 days interval,
T_6 : Field sanitation @ regular cleaning of the plot
T_7 : Control]

4.15. Effect of treatments on the abundance of aphid inflorescence plant^{-1}

Significant variations were observed among different bio-insecticidal treatments in terms of inflorescence infestation due to aphid infestation on mustard (Table 7). Statistically significant variation was observed among the results of different treatment application in terms of total infestation at different days after spraying during the management of mustard. In case of 1 days after spraying (DAS), the highest number of infestation (266.7 aphid inflorescence^{-1}) was recorded in T_7 composed which was statistically different from all other treatment followed by T_5 (48.33 aphid inflorescence^{-1}) spraying of Detergent @ 10 g/L of water at 7 days interval and T6 (43.33 aphid inflorescence^{-1}) treated plot (Table 7). On the other hand, the lowest number of infestation (38.33 aphid inflorescence^{-1}) was recorded in T_4 comprised of spraying of Spinosad 45EC @ 0.4 ml/L of water at 10 days interval followed by T_2 (40.33 aphid inflorescence^{-1}) comprised of spraying of Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval. In case 4 days after spraying (DAS), the highest infestation (340.00 aphid inflorescence^{-1}) was recorded in T_7 which was statistically different from all other treatment. This was followed by T_1 (58.33 aphid inflorescence^{-1}) and T_5 (55.00 aphid inflorescence^{-1}) treated plot. On the other hand, the lowest number of infestation T_4 (43.33 aphid inflorescence^{-1}) was recorded in treated control plot followed by T_2 (44.33 aphid/inflorescence). In case of 7 days after spraying (DAS), more or less similar trends were observed among different treatment application in terms of number aphid inflorescence^{-1} (Table 7). The highest number of infestation (400.0) was recorded in T_7 which was statistically different from all other treatment followed by T1 (70.00) and T_5 (65.00). On the other hand, the lowest aphid population (58.33) was recorded T_4 in control plot followed by T_2 (58.33) and T_3 (60.00).

Table 7. Effect of treatments on number of aphids on inflorescence plant^{-1} before and after spray

Treatments	Number of aphids				Aphid reduction over control(%)
	DBS	1 DAS	4 DAS	7 DAS	
T_1	105.0 b	43.33 b	58.33 b	70.00 b	41.91
T_2	118.0 b	40.33 b	44.33 b	58.33 b	50.56
T_3	103.3 b	43.33 b	45.00 b	60.00 b	41.80
T_4	120.0 b	43.33 b	48.33 b	58.33 b	51.39
T_5	111.7 b	48.33 b	55.00 b	65.00 b	37.5
T_6	93.33 b	38.33 b	43.33 b	58.33 b	33.33
T_7	206.7 a	266.7 a	340.0 a	400.0 a	---
LSD(0.05)	**46.56**	**22.38**	**25.35**	**12.5**	**---**
CV (%)	**20.74**	**15.27**	**14.17**	**5.79**	**---**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD test at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,
T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,
T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,
T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,
T_5 : Detergent @ 10 g/L of water at 7 days interval,
T_6 : Field sanitation @ regular cleaning of the plot
T_7 : Control]

Table 8. Effect of treatments on number of aphids on stem plant^{-1} before and after spray

Treatments	Number of aphids				Aphid reduction over control(%)
	DBS	1 DAS	4 DAS	7 DAS	
T_1	98.33 bc	40.00 b	52.00 b	68.67 ab	33.79
T_2	100.7 b	42.67 b	51.67 b	66.67 a	33.79
T_3	103.3 c	43.33 b	58.33 b	65 bc	31.38
T_4	93.33 a	36.67 b	45.33 b	65 a	39.35
T_5	118.3 c	50.00 b	70.00 b	71.67 cd	30.42
T_6	111.7 c	41.67 b	65.00 b	76.67 d	30.16
T_7	121.7 d	216.70 a	325.0 a	405 e	----
LSD(0.05)	**18.17**	**22.99**	**19.63**	**11.39**	**----**
CV (%)	**9.27**	**17.7**	**10.38**	**5.01**	**----**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1: Neem oil @ 3.0 ml/L of water with at 7 days interval,
T_2 : Bioneemplus 1EC @ 1.0 ml/L of water at 10 days interval,
T_3 : Neem seed kernel extract @ 50 g/L of water at 7 days interval,
T_4 : Spinosad 45EC @ 0.4 ml/L of water at 10 days interval,
T_5 : Detergent @ 10 g/L of water at 7 days interval,
T_6 : Field sanitation @ regular cleaning of the plot
T_7 : Control]

4.16. Effect of treatments on the number of aphid population per stem plant^{-1}

Statistically significant variation was observed among the results of different management practices in terms of total infestation at different days after spraying (DAS) during the management of mustard. In case of 1 days after spraying (DAS), the highest number of infestation (216.7 aphid stem^{-1}) was recorded in T_7 which was statistically different from all other treatment followed by T_5 (50.00 aphid stem^{-1}) spraying of Detergent @ 10 g/L of water at 7 days interval and T_3 (43.33 aphid stem^{-1}) treated plot (Table 2). On the other hand, the lowest number of infestation (36.67 aphid stem^{-1}) was recorded in T_4 comprised of spraying of Spinosad 45EC @ 0.4 ml/L of water at 10 days interval which is similar with T_1 (40.00 aphid stem^{-1}) comprised of spraying of Neem oil @ 3.0 ml/L of water with at 7 days interval, which similar with T_6 (41.67 aphid stem^{-1}) comprised of sanitation. In case 4 days after spraying (DAS), the highest infestation (325.0 aphid stem^{-1}) was recorded in T_7 which was statistically different from all other treatment. This was followed by T_5 (70.00 aphid/stem) and T_6 (65.00 aphid stem^{-1}) treated plot. On the other hand, the lowest number of infestation T_4 (45.67 aphid stem^{-1}) was recorded in treated control plot followed by T_2 (51.67 aphid stem^{-1}) treated plot followed by T_1 (52.00 aphid stem^{-1}) treated plot (Table 8). In case of 7 days after spraying (DAS), more or less similar trends were observed among different management practice in terms of number aphid/inflorescence (Table 8). Considering the highest number of infestation (405.0) was recorded in T_7 followed by T_6 (76.67) and T_5 (71.67). On the other hand, the lowest aphid population (65.00) was recorded T_4 in control plot followed by

T_3 (65.00) and followed by T_2 (66.67)

CHAPTER V
SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

In terms of the abundance of aphid population into leaves, among different management practices, T_4 comprising Spinosad 45EC @ 0.4 ml/L of water performed as the most effective bio insecticide in reducing the highest percent of aphid population (60.00%) over control. Whereas, Neem seed kernel extract @ 50 g/L of water at 7 days interval showed the least performance in reducing the aphid population (39.54%). As a result, the order of trend of efficiency of five bio-rational along with untreated control in terms of reducing the aphid population was T_4 (Spinosad 45EC)> T_1 (Neem oil)> T_2 (Bioneemplus 1EC)> T_3 (Neem seed kernel extract)> T_5 (Detergent)> T_6 (Field sanitation)> T_7 (Control).

In respect of inflorescence infestation, Spinosad 45EC @ l ml/L water performed as the most effective insecticide in reducing the highest percent of aphid population (68.08%) over control. Whereas, field sanitation showed the least performance in reducing the inflorescence infestation (53.57%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing aphid population was T_4 (Spinosad 45EC)> T_2 (Bioneemplus 1EC)> T_1 (Neem oil)> T_3 (Neem seed kernel extract)> T_5 (Detergent) > T_6 (Field sanitation)> T_7 (Control).

In terms of stem infestation, Spinosad 45EC @ 0.4 ml/L of water at 10 days interval also performed as the most effective bio-rational in reducing the highest percent of stem infestation (62.67%) over control. Whereas, Detergent showed the least performance in reducing the stem infestation (57.73%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the

number of aphid on stem was T_4 (Spinosad 45EC)> T_1 (Neem oil)> T_2 (Bioneemplus 1EC)> T_3 (Neem seed kernel extract)> T_5 (Detergent)> T_6 (Field sanitation)> T_7 (Control).

CONCLUSION

Based on the above findings of the study, the following conclusions have been drawn:

- In case of percent leaves aphid population reduction over control, the highest percent of aphid population reduction (47.11%) was observed in T_4. while the lowest percent of aphid population reduction over control was observed in T_6(26.78%).
- The percent of inflorescence infestation reduction over control indicate that the highest percent of inflorescence infestation reduction (51.39%) was recorded in T_4. while, the lowest percent of reduction over control (33.33%) was recorded in T_6.
- The percent reduction of stem infestation over control indicate that the highest percent of infestation reduction (39.35%) was recorded in T_4. while, the lowest percent of stem aphid reduction over control (30.16%) was recorded in T_7.
- The maximum yield found in the treatment T_4 (1.62 mt ha^{-1}) because of low aphid infestation followed by T_2 (1.53 mt ha^{-1}) and T_3 (1.44 mt ha^{-1}). While low yield performance found in the T_7 treatment was untreated control (1.29 mt ha^{-1}).

RECOMMENDATIONS

Considering the findings of the study following recommendations may be drawn: Spinosad 45EC and Bioneemplus may be recommended as effective bio-rational for the management of mustard aphid as compared with Neem oil, Neem seed kernel extract and Ditergent;

- Spinosad 45EC may be recommended as best bio-rational for controlling mustard aphid.
- Further intensive studies based on different doses of Spinosad 45EC, Bioneemplus, Neem oil, Neem seed kernel extract and Ditergent should be done.
- More bio-rational should be included in further research for controlling mustard aphid in different agro-ecological zones of Bangladesh.

REFERENCES

REFERENCES

Abudulai, M. and Shepard, B.M. (2003). Effect of neem (*Azadirachta indica A. Juss*.) on Trissolcus basalis (Wollaston) (Hymenoptera: Scelionidae), a parasitoid of Nezaraviridula (Hemiptera: Pentatomidae). *J. Entomol. Sci*. **38**: 386-397.

Ahmed, M.U., Ahmed, A. and Mannan, M.A. (1977). Studies on the comparative effectiveness of organophosphorus insecticides for control if mustard aphid in Bangladesh. *Bangladesh J. Agric. Res.***11** (2): 16 – 1

Alam, M.Z., Ahmed, A. and Siddique, A. (1964). Control of winter aphids in East Pakistan. A Review of Research Division of Entomology, 1947-64. Agricultural Information Service. 3 R. K. Mission Road, Dhaka – 3, pp. 256-259.

Atwal, A.S., Chaudhary, J.P. and Ramjan, M. (1976). Pests of oilseed crops. Agricultural pests of India and South East Asia. Kalyani publishers, New Delhi, pp. 296-298.

Bakhetia, D.R.C. and Sekhon, B.S. (1989).Insect-pests and their management in rapeseed-mustard. *Journal of Oilseeds Research* **6**: 269-299.

Bakhetia, D.R.C. (1983). Losses in rapeseed mustard due to *Lipaphis erysimi* (*Kalt.)* in India - A literature study. Proceedings of the 11th International Rapeseed Congress Paris, pp. 1142-1147.

BBS. (2017). Monthly Statistical Bulletin-Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. June, p.68

Begum, S. (1988). Screening of different Varieties of mustard (*B.napus*) for resistance to aphids under PYT. Annual Research Report 1990-91d. Entomol. Div. BARI, joydebpur, Gazipur, p.123.

Bhadra, R.H. and Parna, S.G. (2010). Efficacy of insecticides against aphids and natural enemies in cotton field and in laboratory. *Pest Mgt. Sci*. **3**(16): 307-310.

Bishoni, O.P., Singh, H. and Singh, R. (1992). Incidience and multipolication of mustard aphid *Lipaphis erysimi (kalt)* in relation to metrological variables. *Indian. J. of Agric. Sci*. **62** (10):710-712.

Biswas, G.C. (2008). Efficacy of some plant materials against the mustard aphid, Lipaphiserysimi (Kalt.) *Journal. Asiat. Soc. Bangladesh Sci.* **34** (1):79-82.

Biswas, G.C. (2013). Comparative Effectiveness of Neem Extracts and Synthetic Organic Insecticide against Mustard Aphid. *Bangladesh J. Agril. Res*. **38** (2): 181-187.

Brar, K.S. and Sandhu, G.S. (1978). Comparative resistance of different *Brassica* species /varieties to the mustard aphid *Lipaphis erysimi (kalt.).*Under natural and artificial condition. *Indian Agril.* Res **12**(3):198-200.

Chowfla, S. and Baruah, S.K. (2006). Effects of insect growth regulators on the non-target soil arthropod Folsomia candida (Collembola). *J. Ecotoxicol. Environ. Saf.* **63**: 216-225.

Dixon, A.F.G. and Wellings, P.W. (1982). Seasonality and reproduction in Aphids. *European J. Entomology*. **90**: 383-402.

Dress, B.M. (1997). Aphid management (Retrieved on July 30, 2009 from website: http://entowww.tamu.edu/Edu/Extension/Bulletions/uc/uc-031.html)

Gupta, M.P.M., Verma, S.K., Chourasia, N. and Rai, H.S. (2003). Assesment of avoidable yield losses in karan rai (*Brassica carinata* Braun) varieties due to mustard aphid (*Lipaphiserysimi Kalt.). Ann. Pl. Protec. Sci.*, **11**(1): 11-15

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

Iversen, T., Harding, S. (2007). Life table parameters affecting the population development of the woolly beech aphid, *Phyllaphisfagi. Entomol. Exp. Appl*.**123**: 109-117.

Jahan, S.M.H. and Rahman, M.A. (2011). Diverse Response of Growth Stages of *Brassica* Varieties to *Lipaphiserysimi* Kaltenbach (Homoptera: Aphididae). *International Journal of Zoological Res*.**7**(3): 286-292.

Kafle, K. (2015). Management of Mustard aphid (*Lipaphis erysimi*). *International Journal of Applied Science and Biotechnology*. **3**(3): 537-540.

Kalasariya, R.L. (2016). Management of Aphid, *Lipaphis erysimi* in mustard with different spray schedule. *Indian Journal of Plant Protection.* **44** (1): 16-23

Kranz, J.H., and Schmutterer, H. (1987). Diseases, Pests and Weeds in Tropical Crops. John Wiley and Sons, Chichester New York-Brisbane-Torrento. pp. 237-221.

Maiti, S., Hedge, M.R. and Chattopadhyay, S.B. (1988). Hand book of annual oil seed crops. Oxford and IBH Publishing Co. Pvt. Ltd. New Dehli, India. pp. 87-93.

Martin, J.H. (1983). The identification of common aphid pests of tropical agriculture. *J. Insect Sci*. **2**(2): 139-145.

Mathur, Y. K. and Upadhyay, K. D. (2000). Evaluation and economics of some modern bio-insecticides against mustard aphid, *Lipaphis erysimi* (*Kalt.).* Pesticides **60**: 328-332.

Minks, A.K. and Harrewijn, P. (1998). Aphids: Their biology, natural enemies and control. lsevier Publishers, Amsterdam, The Netherlands. p.312.

Mondal, M.R.I. and Wahab, M. A. (2001). Production Technology of Oil Crops. Oil seed Res. Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. p. 4.

Morzia, B. and Huq, S.B. (1991). Evaluation of different genotypes of Indian mustard (*Brssica juncea*) for their reaction to mustard aphid *L. erysimi*. *Indian J. Agril.Sci*. **61**(3): 210-213.

Muhammad, A.A., Ali, R.S., Muhammad, N., Ghulam, S. (2014). Evaluation of Different Neem Products in Comparison with Imidacloprid against Different Morrphs of Mustard Aphid (*Lipaphis erysimi Kalt*.) on Canola Crop. *Asian J. Agri. Biol*, **2**(3):191-201.

Nayak, P. K., Baral, D. and Sethi, P. (2000). Study of insecticidal persistence on mustard aphid *Lipaphis erysimi (*Kalt). *J. Inter academicia* **1**(4): 311-312.

Nisbet, C.T., Stephen, A., Jennifer, M., Jeremy, J. and Hatch, I. (1994). Effect of AZA- treated diet on aphids. *J. Insect. Physiol.* **52**(1): 70-79.

NORP (1989/90) Annual report. National Oilseed Research Program, Nawalpur, Sarlahi, Nepal. p.123.

Panget, N.D., Singh, L., Singh, Y.P., and Tripathi, E.P., (2010). Effect of certain plant extracts against *Lipaphis erysimi (Kalt*.) under laboratory condition. *Ind. J. Entomol.* **49**(2): 238-242.

Prema, V.C., Mishra, M.S. and Srivastava, A.N. (2016). Residual Effect of Neem Leaf Extract on The Mortality of *Lipaphis erysimi* and its Larvae. *Journal of Environmental Science, Toxicology and Food Technology.* **10** (10): 115-119.

Rohilla, H.R., Bhatnagar, P. and Yadav, P.R. (2004). Chemical control of mustard aphid with newer and conventional insecticides. *Indian J. Ent.* **66** (1): 30-32.

Saha, B.N., Islam, W. and Khan, A.R. (2006). Effect of *Azadirachtin* on the growth and development of the pulse beetle, *Callosobruchus chinensis* L. *Journal. Asiat. Soc. Bangladesh Sci.* **32** (1): 69-65.

Sam, Z. H. and Pang, K. Y. (1999). Present status and countermeasures of incecticide resistance in agricultural pests in *China. Pestic. Sci*. ***23*:**168-170.

Schmutterer, H. (1990). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Annu. Rev. Entomol.* **35**: 271-297

Shelley, G., Kalpana, H. and Pandey, I.P. (2009). Persistence of toxicity of some insecticides in dust and wettable forms against mustard aphid, *Lipaphis erysimi (Kalt). International J. Agric. Sci*. **1**(2):44-45.

Singh, A. and Sircar, P. (2011). Evaluation of insecticides for aphicidal activity. *Entomol. Indian Agri. Res. Inst*. **4**: 342-364.

Sultana, N.A., Khan, M.A.H., Islam, M.N. and Mirza, H. (2009). Integrated Management of Aphid *(Lipaphis erysimiKalt.)* in Mustard. *World Journal of Zoology* **4** (2): 105-108.

Tanzubil, P.B. (1996). Potential for neem in armyworm control in Africa. Oxford and IBH publishing Co. Pvt. L.td. New Delhi, India. pp. 27-38.

Thacker, J.R.M. (2002). An Introduction to Arthropod Pest Control. *J. Appl. Entomol. Zool.* **3**(1): 241-245.

Tripathi, N.L.M., Sachan, G.C., Verma, S.K. and Pathak, P.K. (1996). Developmental behaviour of *Lipaphis erysimi* (Kaltenback) on different part/stages of *Brassica campestris* Var. toria. *Indian J. Entomol*. **48**(3): 295-300.

Vekaria, B. K. and Patel, P. (2005). Numerical response of ladybird beetles (Coleoptera: Coccinellidae) to aphid prey (Hom: Aphididae) in a field bean in northeast India. *J. Appld. Entomol*. **123**: 401–405.

Verma, S. N. and Singh, O. P. (1987). Estimation of avoidable losses to mustard by the aphid, *Lipaphis erysimi* in Madhya Pradesh. *Indian J. Plant Prot*. **15**(1): 87- 89.

Weiss, E.A. (1983). Rapeseed in Oil Seed crops. Longman group, New York. pp. 161-215.

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2017 to March 2018

Month	*Air temperature (^{0}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2011	25.82	16.04	78	00
December, 2011	22.4	13.5	74	00
January, 2012	24.5	12.4	68	00
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	11

* Monthly average,

*** Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212**

Appendix II. Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
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