EFFECT OF SOME PROMISING CHEMICALS AND BOTANICALS ON THE MANAGEMENT OF APHID AND TOBACCO CUTWORM IN MUSTARD

SABEKUN NAHAR

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2022

EFFECT OF SOME PROMISING CHEMICALS AND BOTANICALS ON THE MANAGEMENT OF APHID AND TOBACCO CUTWORM IN MUSTARD

BY

SABEKUN NAHAR

REGISTRATION NO. 15-06819

Mobile No. +8801716294326

Email:sabekunalam9983@gmail.com

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

MASTER OF SCIENCE
IN
SEED TECHNOLOGY

SEMISTER: JANUARY- JUNE, 2022

Approved By:

Dr. S. M. Mizanur Rahman
Professor
Supervisor

Dr. Mohammed Ali
Professor
Co-Supervisor

Prof. Dr. Md. Ismail Hossain
Chairman, Examination Committee
&
Director, Institute of Seed Technology
Sher-e-Bangla Agricultural University

Dr. S. M. Mizanur Rahman
Professor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh
Mobile: +880171212707
Email: smmizanur@gmail.com

CERTIFICATE

*This is to certify that the thesis entitled, **"EFFECT OF SOME PROMISING CHEMICALS AND BOTANICALS ON THE MANAGEMENT OF APHID AND TOBACCO CUTWORM IN MUSTARD"** submitted to the Faculty of Agriculture, 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 bonafide research work carried out by **SABEKUN NAHAR**, Registration No. **15-06819** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2022
Place: Dhaka, Bangladesh

Dr. S. M. Mizanur Rahman
Professor
Supervisor

ACKNOWLEDGEMENTS

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

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

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

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

The author feels proud to express her deepest and endless gratitude to all of her class mates and friends to cooperate and help her during taking data from the field and preparation of the thesis. The author wishes to extend her special thanks to her lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses her heartfelt thanks to her beloved parents, elder sister and brother and all other family members for their prayers, encouragement, constant inspiration and moral support for her higher study. May Almighty bless and protect them all.

The Author

EFFECT OF SOME PROMISING CHEMICALS AND BOTANICALS ON THE MANAGEMENT OF APHID AND TOBACCO CUTWORM IN MUSTARD

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of some promising chemicals and botanicals on the management of aphid and tobacco cutworm in mustardin mustard during the period from October 2021 to February 2022 in the *Rabi* season. The experiment was laid out in Randomized Complete Block Design (RCBD) with five different treatment *viz:* T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: untreated control, for the management of aphid and tobacco cutworm of mustard with three replications for each treatment. Data on different parameters were recorded and significant variation was observed among different treatment. Experimental result showed that at early, mid and late stage of flowering and fruiting the highest number of aphid and cutworm was observed in T_5 treatment while the lowest number of aphid and cutworm was observed in T_4 treatment. In case of aphid at flowering fruiting stage the maximum number of healthy plant m^{-2} (28 and 24.67) and higher infestation reduction percentage (76.92 and 72.78 %) was observed in T_4 treatment. In the case of tobacco cutworm at the flowering and fruiting stages, the highest number of healthy plants per square meter (29.33 and 28.00) and the highest infestation reduction percentage (87.64and 76.92 %) was found in the T_4 treatment. In case of growth, yield contributing characters and yield of mustard, among different treatments the maximum plant height (106.35 cm), number branches plant^{-1} (16.02), siliqua plant^{-1} (105.10), siliqua length (4.14 cm), seeds siliqua^{-1} (26.87), 1000-seed weight (4.02 g) and higher seed yield (1.77 t ha^{-1}) was obtained from T_4 treatment which gave (84.38 %) more yield comparable to control treatment. Based on the investigation of the above results, it may be concluded that among seed treating chemical and few botanicals for controlling mustard aphid and tobacco cutworm, spraying Tracer 45 SC @0.4 ml/L of water at 10-day intervals was the most effective among the management practices for controlling mustard aphid and tobacco cutworm.

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

Abbreviations	Full word
Agr.	Agriculture
AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
Biol.	Biology
Biotechnol.	Biotechnology
Bot.	Botany
cv.	Cultivar
DW	Dry weight
Eds.	Editors
EC	Emulsifiable concentrate
Entomol.	Entomology
Environ.	Environments
FAO	Food and Agriculture Organization
FW	Fresh weight
Intl.	International
J.	Journal
LSD	Least Significant Difference
L	Liter
TSP	Triple super phosphate
Sci.	Science
SRDI	Soil Resource Development Institute
Technol.	Technology
SC	Soluble concentrate
Sl.	Serial

CHAPTER I

INTRODUCTION

Mustard (*Brassica spp*. L.) is a worldwide cultivated thermos- and photosensitive oilseed crop. Asia produces 41.50 % of mustard seed which occupies the first position in terms of percentage share of production followed by the USA (Sampa *et al*., 2020). Edible oils play vital roles in human nutrition by providing calories and aiding in the digestion of several fat-soluble vitamins, for example, Vitamin A (Miah and Mondal, 2017). The per capita recommended dietary allowance of oil is 6 g day^{-1} for a diet with 2700 Kcal (BNNC, 1984). Oilseeds were cultivated in less than 2.20 % of total arable land under the rice-based cultivation system in Bangladesh, where three fourth of total cultivable land was engaged in rice production in 2015-16 (BBS, 2019). Mustard is the major oilseeds in Bangladesh which exhibits an increase in production from 1994 to 2018 except few fluctuations in the case of total production and area under cultivation (FAOSTAT, 2018). Mustard occupied more than 69.94 % of the total cultivated area of oilseeds followed by sesame, groundnut, and soybean (BBS, 2019). With the increase in population, the demand for edible oil and oilseeds is on an increasing trend (Alam, 2020). Bangladesh has to import a noticeable amount of edible oil and oilseeds to meet up the existing accelerating demand. The value of imported oilseed and edible oil has increased dramatically from USD 544 million in 2002-03 to USD2371 million in 2018-19 which were 4.99 and 4.23 % of the total value of imports respectively (BB, 2020). The yield of mustard has increased from 0.75t ha^{-1} in 2001 to 1.15 t ha^{-1} in 2019 (MoA, 2008; BBS, 2019). Bangladesh was not in an advantageous position in the case of mustard production (Miah and Rashid, 2015) which was due to, lack of high-yielding varieties and poor management as practiced at farmer's fields.

Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (2011) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. *Brassica* (genus of mustard) has three species that produce edible oil, they are *B.*

napus, *B. campestris* and *B. juncea*. Of these, *B. napus* and *B. campestris* are of the greatest importance in the world's oil seed trade. In this subcontinent, *B. juncea* is also an important oil seed crop. Until recently, mustard varieties such as Tori-7, Sampad (both *B. campestris*), and Doulat (*B. juncea*) were mainly grown in this country. Recently several varieties of high-yielding potential characteristics have been developed by BARI.

One of the most significant factors limiting mustard's productivity and causing its low yield is the presence of insect pests. The mustard crop is highly vulnerable to attack of insect pests by more than 43 insect species. Out of which, mustard aphid *Lipaphis erysimi* (Katenbach); mustard sawfly, *Athalia proxima* (Kiug); Painted bug, *Bagrada hilaris* (Cruciferarum) (Burnmerister) pea leaf miner, *Chromatomyia hortico*la (Goureau) and Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) Leaf Webber (*crocidolomia binotalis*) (Zeller) are a serious pest causing yield loss of 13.2 to 81.3 per cent (Pawar *et al*., 2009).

Among the several insects infesting the mustard, mustard aphid, *Lipaphis erysimi* (Kalt.) is the most serious insect-pest of rapeseed-mustard. It may cause a yield loses ranging from 35.4 to 96% in favorable conditions and can reduce 5-6% oil content (Sahoo, 2012). Both nymphs and adults suck the sap from various parts of plant like leaves, inflorescence, tender stem and pods and cause economic damage. Due to heavy infestation, the symptoms of yellowing, curling and then drying of leaves appear, resulting in development of feeble pods and small seeds in the pods. It also secretes the honeydew which is responsible for development of sooty mould and reduces the photosynthetic rate (Kolte, 2009).

The tobacco cutworm, *Spodoptera litura,* is distributed throughout the temperate regions of Europe, Africa and Asia. In Himachal Pradesh, *Agrotis segetum and Agrotis ipsilon* are the two cutworm species associated with various crops (Verma and Verma, 2002). The infestation of these two species ranges from 3 to 18 percent in different vegetables/field crops (Anon, 2018). Among these two species, *Agrotis segetum* is one of the predominant cutworm species causing extensive damage in vegetables, ornamentals and field crops. The *Spodoptera litura* is prevalent in low and mid-hills, whereas *Agrotis segetum* is more abundant in higher elevations.

The application of fungicide, insecticide, or a mixture of both to seeds to disinfect and disinfect them from seed-borne or soil-borne pathogenic organisms and storage insects is referred to as seed treatment. It also refers to exposing seeds to solar light, immersing them in conditioned water, and so on. The major reasons for seed treatment are to prevent the spread of plant diseases, protect seed from seed rot and seedling blights, increase germination, protect against storage insects, and control soil insects (Amruta *et al*., 2015). Among different treatment of seed chemical treatment on seeds have been one of the most common techniques in use on current farming due to its low-cost technology, low-environmental impact, and, in general, a significant effect on yield (Zambolim, 2005). Silva (1998) stated that, when treating seeds, one can protect the plant during germination and young-seedling stages which are phases of greater susceptibility. This treatment aims to ensure seeds' full performance by achieving the desired planting density. Barros *et al.* (2005) verified greater percentage on bean seeds germination in treatments using the insecticide phipronil.

Crop protection is achieved primarily by exercising pest control measures both at the growing as well as storage stages of crop. A number of chemical insecticides have been found effective against pest in different parts of the country (Singh *et al.*, 2014). But chemical insecticides are not only toxic to natural enemies of aphid such as *Diaeretiella rapae*, *Chrysoperla zastrowi arabica*, coccinellids and syrphid flies (Nagar *et al*., 2012), but these are also responsible for environmental pollution, health hazards to human beings, toxic to pollinators, pest resurgence, development of resistance in insect-pests and residues in oil and cake (Egambaram, 2019). This has prompted the necessity for the development of non-insecticidal alternatives that could be feasible and effective for insect management while also being compatible with the environment**.**

Alternative methods of insect control utilizing botanical products are being used in many countries (Ahmed *et al*., 2022). It has been owing to the man's tendency to substitute pesticides for effective bio-environmental controls rather than restrict their use to emergent situations. Botanical pesticides or natural insecticides are organic and natural pesticides that are derived from plants and minerals that have naturally occurring defensive properties. Plant derived materials are more readily biodegradable, relatively specific in mode of action and easy to use. They are environmentally safe, less hazardous, less expensive and readily available. Different botanical formulations have been reported time to time showing pronounced insecticidal activity, repellence to pest, oviposition deterrence, adult emergence inhibition, ovicidal, larvicidal, pupaecidal activity and feeding deterrence based on their contact toxicity and fumigation effects and are safe to beneficial organisms like pollinators, predators etc. (Kedia *et al*., 2015).

Keeping in mind the above aspects in view, the present investigation entitled "Effect of seed treating chemical and few botanicals on the management of aphid and tobacco cutworm in mustard" was undertaken with following objectives

- To identify the incidence of mustard aphids and tobacco cutworm in different stages of crop growth.
- To evaluate the effect of a seed treating chemical and botanicals on aphid and tobacco cutworm infestation.
- To find out the most effective seed treating chemical and botanicals against mustard aphid and tobacco cutworm for quality seed production.

CHAPTER II

REVIEW OF LITERATURE

Mustard is attacked by a number of insects-pests causing an effect in many ways from the early stage of growth to maturity of the crop. Some of the insects, which cause-effect to the crops on regular basis are mustard sawfly, cutworm, painted bug, mustard aphid, leaf miner, and cabbage butterfly, among these insect-pests mustard aphids, *Lipaphis erysimi* (kalt.) is a key causing severe damage to the crop. Based on the information collected through the survey literatures and researches carried out on different aspects of insect-pests and their managements were in the past have been discussed.

2.1 Population dynamics of major insect pests of mustard

Pal and Debnath (2020) carried out an investigation during rabi, 2019-20 at Jaguli instructional farm of Bidhan Chandra Krishi Viswavidyalaya by using four varieties (ADV414, Bulet, TBM 204 and ADV 406) of rapeseed-mustard. Altogether two insects viz., mustard aphid (*Lipaphis erysimi*) and sawfly (*Athalia lugens proxima*) cause most of the damages at different crop growth stages. In the middle of January maximum intensity of sawfly was observed when the crop was flower bud formation stage. Maximum aphid population was noticed during 2nd week of February at silica formation stage of the crop irrespective of the varieties. The aphid population was very strongly correlated with the incidence of coccinellid population. The correlation study between sawfly population and weather parameters revealed that maximum and minimum temperature had significant negative correlation with the pest population.

Pradhan *et al.* (2020) conducted a field experiment in Institutional-Cum-Research (ICR) farm, Assam Agricultural University, Jorhat during Rabi 2018 and 2019 to investigate the insect pests and natural enemies of mustard. During the period of present investigation, a total number of four insect pests from four different families *viz,* mustard aphid, *Lipaphis erysimi* (Kalt.); mustard sawfly, *Athalialugens proxima* (Klug); Flea beetle, *Phyllotreta cruciferae* (Goeze); cabbage butterfly, *Pieris brassicae* (Linn.) were recorded at different stages of mustard crop.

Pal *et al*. (2018) carried out an experiment on the population dynamics of insect pests in mustard and eco-friendly management of *Lipaphis erysimi* (Kalten bach) in Uttrakh and reported that the peak population of mustard aphid on yellow sticky traps was recorded with 35.4±2.9 aphids/trap from 7th SW and it was active from 45th SW to 14th SW, where it was on peak with 712.4±16.4 aphids/plant under the field condition from untreated plots at 3rd SW. *Coccinella septempunctata* active from 50th SW to 13th SW of the season and peak population noticed from 5th SW with 14±0.4 grubs and adults/plant. Incidence of mustard sawfly was noticed at early stage of crop from 46th SW to 4th SW and population range was 0.3±0.2 to 7.3±0.6 larvae/plant. Painted bug active two times in a season from 45th – 52nd SW with peak population was 7.5±0.5 nymphs and adults/plant and 6th – 12th SW, where peak population was 8.9±0.5 nymphs and adults/plant.

Thangjam *et al.* (2017) studied pest complex of king chili, *Capsicum chinensis* (Jacquin) in Assam, North- East India and reported 19 species of arthropod pests associated with king chilli at Jorhat, out of which *Aphis gossypii*, *Myzuspersicae*, *Bemisia tabaci*, *Bactrocera latifrons*, *Scirtothrips dorsalis*, *Polyphagotarsonemus latus* and *Spodoptera litura* as major pests.

Bhati *et al.* (2015) the present investigation was carried out during *Rabi*, 2013-14 at Student's Instructional Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (UP), India. Brassica oilseed crops are the major *Rabi* oilseed crops grown in India, which is collectively referred to as rapeseed-mustard. Altogether 4 insects' viz., mustard aphid (*Lipaphis erysimi*), mustard sawfly (*Athalia lugens proxima*), painted bug (*Bagrada hilaris*), and cabbage butterfly (*Pieris brassicae*) were found attacking at different growth stages of the rapeseed-mustard crop. In addition, to crop stage, the different Brassica species and weather conditions played a major role in the occurrence of insect-pests on Brassica species during the *Rabi* season of 2013-14.

Pal *et al*. (2015) recorded a population of aphid was noticed from last week of December and population was reach in second week of February.

Sahoo (2012) reported that mustard aphid, *Lipaphis erysimi* (Kalt.), is the most serious insect-pest of rapeseed- mustard and responsible for causing the yield losses ranging from 35.4 to 96 percent depending upon weather condition. The experiment was carried out to assess its incidence and its management during the winter seasons of 2009-10, 2010-11, and 2011-12 at the Pulses and Oilseeds Research Station, Berhampur, West Bengal (India). The natural appearances of the aphid on the yellow Sarson variety, Binoy (B-9) was observed from the 52nd standard week, with the peak population on 6th standard week and the aphid disappeared after 10th standard week.

Srivastava and Prajapati (2012) calculated the growing degree day (GDD) which was calculated from 1st to 25th January in both the seasons. It was observed that GDD accumulation from 1st to 15th January in both the seasons has capability to forewarn the peak aphid population. The correlation coefficients between maximum, minimum and mean temperature and aphid population were found to be marginally higher in case of late sown conditions. The rainfall affected aphid population but it was not significantly related with aphid population.

Singh *et al.* (2012) reported the incidence of mustard aphid *Lipaphis erysimi* was recorded from the 2nd to the 10th MW with varying population in different MW. The maximum population (146.5 aphids per 10 cm central twigs per plant) was in the 6th MW. Mustard aphid was recorded from flowering to pod bearing stage. The incidence of painted bug was observed at seedling stage and at maturity stage.

Rao *et al.* (2012) studied development of aphids on mustard crop using data collected from a field experiment conducted during *Rabi* seasons of 2001-2005 with cv. *Vanina* and 10 dates of sowing. Minimum temperature and maximum temperature showed significant negative correlation; whereas morning RH and rainfall showed positive correlation with aphid population. The afternoon relative humidity did not show any association with aphids. Aphid population build up, decline and thermal time were found to be non-linearly related.

Venkateswarlu *et al.* (2011) recorded the peak incidence of mustard aphids (169.9 aphids/plant), diamond back moth (7.9 larvae/plant), and cabbage butterfly (27.7

caterpillars/plant) during 2nd week of March, 1st week of March and 2 week of March, respectively.

Khan and Jha (2010) reported that the aphid population was highest during siliqua formation phase due to prevalent conducive weather conditions, followed by reproductive and vegetative phases over all varieties.

Sahito *et al.* (2010) studied the population of *B. picta* on different varieties of mustard. Painted bug appeared from 2nd week of November till the maturity of the crop, i-e.3 week of January. During this period only one peak in the population was recorded in 1st week of December, which was the early phase of the crop growth. After that the population started declining towards the maturity of the crop.

Huger *et al*. (2008) reported several insect species have been associated with the rapeseed-mustard crop. These insets- pests were grouped as a key pest, major pest, and minor pest based on economic importance.

Jat *et al.* (2006) observed the infestation of sawfly from the first week after sowing up to 4th week during *Rabi,* 2002-03. The sawfly population peaked (6 grubs 5 plants) during the 2nd week of November.

Atwal and Dhaliwal (2005) reported that the mustard sawfly is one of the Hymenopterous insects, which belong to the family Tenthredinidae. The grubs of this insect alone are destructive, which causes damage at the early stage of the crop. The grubs bite and make shot holes in leaves and skeletonize them completely in case of a severe attack.

2.2 Mustard aphid

The mustard aphid is an important insect causing severe damage to rapeseed- mustard. Both nymphs and adults of this insect suck the cell sap from leaves, flowers, pods and stems. The infested leaves manifested the symptoms of yellowing, curling and cupping. Consequently, the plants lost their vigor and failed to produce pods. The excessive secretion of honey dew by aphids was observed interfering the normal functioning of leaves due to mould formation (Kumar, 2018).

2.3 Assessment of yield loss due to mustard aphid

Sharma *et al.* (2019) conducted field study for determining losses caused by aphid in different mustard spp. sown under different timings. Their studies revealed that losses incurred vary between 9.27 and 17.49% and losses incurred regarding oil content varies from 3.37 to 6.34%.

Dotasara *et al.* (2018) did an experiment regarding losses occurred by pests in mustard plants. Their studies revealed that the aphid, *Lipaphis erysimi* cause losses which can be avoided up to 41.14 percent. The yield loss obtained in treated and untreated plots were 7.91 and 13.43 quintals/ha respectively.

Kumar (2017) carried out research for few years for the evaluation of yield loss percentage in *B. rapa*due to infestation of certain pests. The research was carried out by replicating thrice in RBD under two different protected and unprotected plots. On weekly intervals, data was recorded by them regarding population of aphid and yield loss was calculated as 8.3 to 24.15 %.

Kumar (2016) studied on alternatives for spraying insecticides to save mustard crop. He evaluated mustard, *Brassica carinata* as a trap crop borders surrounding *B. juncea* as an alternate strategy for pest management and compared with chemically protected (treated) plots. By this study he concluded that grain yield in the bordered plots was numerically not significant compared to obtained results in protected conditions.

Sahoo (2016) carried out an experiment to determine losses caused by insect pests in mustard (*B. rapa*var. yellow sarson) and other few varieties in two plots i.e., protected and unprotected. From the experiment he concluded that the losses in seed yield due to aphid and sawfly varies from 34.62 to 59.33% and also reported that protected plot has more yield than the unprotected.

Dhaliwal *et al.* (2015) did research on losses occurred due to various pests, globally and confined that in India there is a decline from 23.3 percent to 15.7 percent losses of crops. Their results revealed that actual production of rapeseed-mustard in India was 7.88 million tones and over 20% losses in yield.

Dinda *et al.* (2015) carried out research on mustard crop about effect of sowing date, growth, yield and aphid infestation and concluded that due to aphids the crop loses their vigor and their growth is hampered which ultimately affects the yield of the crop. He also concluded that yield losses may be 10-90% depending upon the aphid severity.

Alam *et al.* (2014) did an experiment by using certain genotypes of mustard on different sowing times to determine various physical characteristics. They concluded that date of sowing significantly influenced seed yield and oil content. They also mentioned that highest yield was obtained from the first planting i.e. 1535 kg/ha.

Razaq *et al.* (2011) did an experiment regarding pest status of *Lipaphis erysimi* on oil seed *Brassica* crops. Their experiment reveals that losses due to aphids depend on their severity. They stated that *L. erysimi* causes 10 to 90% losses of yield in India and in Pakistan losses ranging between 70 to 80% depends up on severity and different cultivars of *Brassica.*

Waskel (2010) did an experiment as a part of their thesis on mustard varietal screening and losses in yield occurred by aphid in both protected and unprotected conditions. His experiment showed results that mustard grown in protected varieties gave higher yields of 17.5q/ha against 6.80q/ha recorded in unprotected varieties. He concluded that mustard aphid caused a great reduction in yield causing average losses of 59.52%.

Kular and Kumar (2010) did study for six years regarding losses occurring in mustard due to various pests by conducting experiment in two different environments as unprotected and protected in RBD. Their studies revealed that damage and yield loss caused by cabbage caterpillar and aphid ranges between 6.5 to 26.4%.

Agarwal *et al* (2008) carried out research regarding calculation of gaps in yield on mustard. Their studies revealed that gaps in yields was nearly 860kg/ha and they concluded these gaps are due to rain-fed simulation.

Parmar *et al.,* (2007) did an experiment on avoidable losses regarding yield in mustard crop due to aphid, *Lipaphis erysimi* with a combination of fungal and synthetic insecticides. Their experiment finally revealed that percentage of avoidable losses in yield due to aphid in mustard seed was found approximately 11 to 68 %.

Gami *et al.,* (2004) conducted field study by using GM-2 as cultivar, with certain chemical treatments replicating thrice. Monocrotophos 0.04% used as protectant in protected treatments. Their results revealed that the chemical protectant used in the study found very effective in controlling sawfly, painted bug and aphid.

Patel *et al.* (2004) conducted field study to evaluate losses occurred due to aphid, *Lipaphis erysimi*. The study was done in two different (unprotected and protected) conditions under various environments. They concluded that under whatever conditions the crop was grown either protected or unprotected, yield will reduce due to delayed sowing including yield attributes. They also revealed that maximum yield was obtained under protected (1409kg/ha) than minimum in unprotected (279kg/ha) conditions.

Gupta *et al.* (2003) carried out research regarding yield loss calculations in *B. carinata* due to aphid, *Lipaphis erysimi*. Their results revealed that phosphamidon 0.04% spraying leads to declining of aphid infestation and finally recorded increased yields as comparing with control treatments.

Pink *et al.* (2003) studied on controlling wild species of aphid genetically. Their studies revealed that no sign of life of aphid, *Lipaphis erysimi* on most of the varieties used in the research while maximum number of aphids were observed on BSH-1.

2.4 Mustard Cutworm

Mustard cutworm includes tobacco cutworm (*Spodoptera litura*) and variegated cutworm (*Peridroma saucia*). The black cutworm moth is a uniform dark brown with a lighter irregular band near the wing tips and a distinct black dash. The wingspan is 1.5 to 2.12 inches long. Eggs are white at first, later turning brown. Larvae are a uniform gray to nearly black, lighter underneath, ranging from 0.19 inch to 2 inches as they pass through up to nine instars. The pupa is dark brown and about 0.75 inch long. Most feeding is at ground level at night, and plants are cut off at ground level. In the Willamette Valley, it is the most damaging cutworm species to vegetable crops. The last, largest in star does by far the most feeding, though middle instars can cut down seedlings. Variegated cutworm moths are about 1 inch long with a wingspan of 1.25 to 2 inches. They vary widely in color. Eggs are white to dull or off-white and ribbed. They generally are deposited in massed rows on crop foliage but frequently are on weeds. Larvae are brownish gray to grayish black, up to 1.75 inches long when fully grown. Pupae are mahogany brown and about 0.75 inch long. The variegated cutworm feeds readily on a wide variety of crops and climbs into the host plant to feed. Cutworms are most active and cause the most damage during spring and early summer (Chandel *et al*., 2021)

2.5 Assessment of yield loss due to cutworm

Joshi *et al.* (2020) reported that young cutworm larvae feed on the foliage or small roots of weeds or crops until they reach about 12 inch in length. They can start feeding on seedling stems at this stage, either cutting through them or burrowing into them. Common hosts include corn, peppers, tomatoes, beans, and members of the crucifer family, but they will attack any herbaceous plant.

According to Shinwari (2014), the most prevalent cutworm species found are black and variegated cutworms. The larvae are usually earthen-coloured with various stripes or spotted colour patterns. They curl into a C-shape when disturbed. The adults are dull-coloured brown to greyish moths. Cutworm larvae may cut off the stems of young potato plants and later feed on leaves. Tubers that are exposed or set very shallow in the soil may get damaged by cutworm attack.

Benssin (2011) reported that cutworms eat at night, causing severe damage to the stems and foliage of young plants. Plant stalks can be cut. The variegated cutworm climbs plants and feeds on the foliage and buds.

Kumar and Tiwary (2009) studied losses caused by cutworm, *A. ipsilon* on important varieties of potato at Muzafferpur Bihar. The maximum foliage damage (4.6 %) was recorded in variety 'Kufri Chandramukhi" and minimum foliage damage (0.5 %) in variety "Kufri Alakhar' and 'Kufri jawahar". Whereas, the maximum tuber infestation (12.60 and 12.90 %) was recorded both on number and weight basis in "Kufri

Chandramukhi' while as, minimum tuber infestation (2.25 %) on number and weight basis (2.50 %) was recorded in "Kufri Sutlej".

Bhat (2007) recorded maximum maize plant damage of 54.63 per cent due to *A. ipsilon* and a retrievable yield loss of 80.18 per cent with maximum infestation level of 6.05 larva/m^2.

Santos and Sheilds (1998) while working out the yield responses of corn to stimulated cutworm damage observed grain loss varying from 24 to 81 per cent depending upon the stages of corn development and damage level.

Thakur and Kashyap (1992) observed *A. ipsilon* Hufn. causing extensive damage to seedling maize (23.92 per cent) and in some pockets of Himachal Pradesh the farmers were forced to sow their maize crop again.

Bosque *et al.*, (1989) during their study on the damage caused by cutworm in maize in Mexico recorded average yield loss per plant as 46, 65, 73 and 74 per cent when plants were attacked at one, two, three and four leaf stages, respectively.

Ojha and Nath (1987) found cutworm infestation in the seedling stage of crop growth very much injurious because the injured plants do not recover. They further found that less infestation of cutworm in the field after development of prop roots may be due to structural build-up of the plant tissue.

Showers *et al.*, (1983) reported that the cutworm, *Spodoptera litura*is the most devastating among the cutworm complex that attacks young maize. It attacks during the coleoptile to one leaf stage of corn development and causes significant loss of plants (27 percent) and yield loss upto 2.9 t/ha.

Reshi, (1967) reported that in Kashmir valley, *A. ipsilon* is a destructive pest on maize, potato, vegetable crops, flowers and fruit seedlings. Thus, reducing the plant stand and biological yield an also five species of cutworms have been recorded in Kashmir valley that are *Agrotisipsilon, A. melafida, A. exclamationsis, Peridorma saucia* and *Noctus pronubo.*

2.6 Field-efficacy of botanical against major insect-pests of mustard

Sreeja and Kumar (2022)conducted an experiment at the Central Research Field (CRF), Department of Entomology, SHUATS, Prayagraj during Rabi 2021-2022. Seven treatments were evaluated against Lipaphis erysimi, i.e., Imidacloprid 17.8% SL (T1), Cypermethrin 10% EC (T2), Tracer 45% SC (T3), *Metarhizium anisopliae* (T4), Neem oil 5% (T5), NISCO MECH 333 (T6), NISCO Sixer Plus (T7) and untreated control (T8) were evaluated against mustard aphid (*Lipaphis erysimi*). Results revealed that, among the different treatments, the highest per cent population reduction of mustard aphid was recorded in Imidacloprid 17.8% SL (88.184%) followed by Tracer 45% SC (81.498%), Cypermethrin 10% EC (76.937%). It is followed by Neem oil 5% (72.976%) and NISCO MECH 333 (68.251%), NISCO Sixer Plus (58.914%) and *Metarhizium anisopliae* (53.123%) was the least effective among all treatments. While, the highest yield 18.15 q/ha was obtained from the treatment Imidacloprid 17.8% SL as well as B:C ratio 1: 5.20 was obtained high from this treatment. It was followed by Tracer 45% SC (1: 4.87), Cypermethrin 10% EC (1: 4.58), *Neem oil 5% (1:4.15), MECH 333 (1: 3.98), Sixer plus (1: 3.46), Metarhizium anisopliae* (1: 3.42), as compared to Control (1: 2.74).

Pravin *et al.,* (2021) carried out an experiment to study the efficacy of biopesticides against mustard aphid in mustard crop. The efficacy of bio pesticides *viz*., *Beauveria bassiana, Verticillium lecanii,* azadirachtin and a standard insecticide check, dimethoate was studied against mustard aphid, *Lipaphis erysimi* under field conditions at Oil seed farm Kalyanpur, Chandrashekhar Azad University of Agriculture and Technology (C.S.A.U.A.T.), Kanpur, India. All the bio pesticides and standard check insecticide dimethoate were found equally effective in reducing the aphid population over the untreated control. The reduction of aphid after the application of all biopesticides and dimethoate was observed significantly superior over control at all the interval of observation. However, all the bio pesticidal treatments singly and in their combination were at par with the standard check insecticide dimethoate in terms of mean aphid population after the application of three sprays.

Dey *et al.,* (2020) conducted an experiment at Balindi Research Complex Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal during Rabi season of 2018-2019 to evaluate the impact of spot application of Imidacloprid 17.8 SL @ 0.3 ml per litre of water to suppress the initial population of the mustard aphid (*Lipaphis erysim*i) to check build up of destructive form. The pesticide was applied as spot application in three different tillage with five different fertilizers regimes in five mustard cultivars (B- 54, ADV- 414, B- 9, Bullet, TBM- 204). Among the tillage, the best performance of imidacloprid was noted in zero tillage, recorded 4.95 aphid/twig followed by the reduced tillage and conventional tillage.

Harika *et al.,* (2019) reported that Tracer 45 SC proved to be the most effective treatments in reducing the larval population of *P. xylostella* in cauliflower. The highest marketable yield of cauliflower heads was recorded in Tracer 45 SC (228.80 q/ha) which was followed by indoxacarb 14.5 SC (219.10 q/ha) and emamectin benzoate 5% SG (193.90 q/ha).

Sahu *et al.,* (2018) reported, the highest reduction of aphid population was observed in the spray of neem oil (32.5%) followed by Monocrotophos (36.5%), *Beauveria bassiana* (37.5%), Dimethoate (40.0%), Extract of Lantana camera (42.5%). The mustard production was found highest yield, Dimethoate (93g), followed by Monocrotophos (86g), Lantana camera (53g) and neem oil (53g), *Beauveria bassiana* (52.5g) as compared to the control one (50.5g).

Ahmad *et al.,* (2017) determined the efficacy of four insecticides such as imidacloprid (Confidor 200 SL) @ 150 ml/acre, acetamiprid (Mospilan 20 SP) @ 80g/acre, carbosulfan (Advantage 20 EC) @ 300 ml/acre and thiamethoxam (Actara 25 WP) @ 24g/acre against *L. erysimi* (Kalt.) at Faisalabad, Pakistan during 2013- 2014. Results revealed that, after one day of spraying highest percent reduction of aphid infested plant was observed in advantage (80.50) treated plot followed by actara, mospilan and confidor and showed 70.94, 63.66 and 60.63% reduction of aphid infested plant, respectively.

In Manipur, Debbarma *et al.,* (2017) reported that Spinosad 2.5 SC @ 500 ml/ha was found most effective against *P. brassicae* registering lower extent of mean leaf damage by (24.30%). Also, treatment by mycojaal (*B. bassiana*) 10 SC @ 500 ml / ha showed 26.59 per cent reduction in mean leaf damage as compared to untreated control (69.18%).

Dotasara *et al.,* (2017) the efficacy to tested newer insecticides like neem oil, Imidacloprid and fipronil were found promosing against mustard aphids (*L. erysimi*).

Malik *et al.,* (2017) conducted a study on sub-lethal effects of methoxyfenozide on development and fecundity of cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) on cauliflower and observed that the copulation time, fecundity and fertility decrease with this insecticide. They further found maximum mortality on dose one (1680 ppm) after one week and minimum on dose five (720 ppm) after 24 hours with the maximum larval weight reduction on dose one (1680 ppm) and dose three (1200 ppm) after 24 hours.

Patel *et al.,* (2017) reported that a field study was conducted at Pantnagar (India) to determine the effectiveness of seven insecticides *viz*., quinalphos 25 EC, Thiamethoxan 25 WG, malathion 50 EC, fenvalerate 20 EC, chlorpyrifos 20EC, dimethoate 30 EC and imidacloprid 17.8 SL against mustard aphid, *Lipaphis erysimi* Kalt. The observations were recorded at 3,7 and 10 days after spraying of insecticides. The results revealed that thiamethoxam 25 WG was the most effective among the seven insecticides showing the minimum numbers of *L. erysimi* Kalt followed by imidacloprid and dimethoate. The maximum seed yield (12.36 q/ha) was obtained from the treatment of imidacloprid which remained on par with the treatments of thiamethoxam (10.0 q/ha) and quinalphos (9.31 q/ha). The lowest seed yield was obtained from untreated plots (6.04 q/ha). So neonicotinoid insecticides (thiamethoxam and imidacloprid) could be used in the mustard ecosystem to control mustard aphid, *Lipaphis erysimi* with high yield.

Sharma *et al.,* (2017) reported that Tracer 45 SC @0.01% was most effective in reducing the larval population of diamondback moth (94.33%) on cabbage which was at par with indoxacarb 14.5 SC @0.01% (91.00%) and flubendiamide 39.35 SC @0.01% (78.66%).

Kumar and Kumar (2016) the experiment was conducted on the bio-efficacy of Biopesticides and certain chemical insecticides against mustard aphid (*Lipaphis erysimi*

Kalt.) on mustard revealed that treatments of Dimethoate 30 EC followed by spraying of Malathion 50 EC and Neem oil (0.5%) were found more effective for control of *Lipaphis erysimi* Kalt., respectively. Whereas, the descending order of treatments was Neem oil > NSKE > Tobacco Leaf extract >*Bacillus thuringiensis*>*Beauveria bassiana*>*Metarhizium anisopliae*. The least effective treatment was *Verticillium lecanii*. The maximum infestation was recorded in control.

Ghule and Bagde (2016) reported that efficacy of different insecticide against pests (Aphid) infesting mustard revealed that out of eleven insecticides tested, The decreasing order of efficacy of different insecticidal treatments was 0.003 percent Thiamethoxan, 0.0505 percent lambda-cyhalothrin, 0.005 percent imidacloprid, 0.03 percent dimethoate, 0.5 percent nimbicidine, 0.05 percent fipronil, 0.05 percent quinalphos, and 0.05 percent car tap hydrochloride.

Khan *et al.,* (2015) the experiment was conducted during the *Rabi* season of 2011-12 to evaluated the chemical and botanical insecticides in the field against mustard aphid, *Lipaphis erysimi* (kalt) and their effect on its parasite natural enemies). Among the two sprays of chemical insecticides, imidacloprid was found most effective followed by bifenthrin, carbosulfan, and thiamethoxam. Neem seed kernel extracts were found least effective in comparison to chemical insecticides. The population of natural enemies ofmustard aphid *Diaretiella rapae* (mummified aphids) in all the treated plots ranged from 4.40 to 9.70 than untreated plots (15.31) per 10cm twig. The maximum mummified aphid population was recorded in plots treated with NSKE which was found significantly higher than the population in the plots treated with chemical insecticides, Minimum *Diaretiella rapae* population was recorded in plots treated with imidacloprid. Imidacloprid was more toxic than other chemical treatments.

Kafle (2015) reported that the effectiveness of botanicals to reduce the aphid population was significantly higher until 5 days of spray and decreases gradually after that.

Kumar *et al.,* (2015) evaluated efficacy of two neonicotinoids against mustard aphid, *L. erysimi* (Kalt.) on rapeseed crop (TS-36) in Assam during 2010-11 and 2011-12. Results revealed that, 10 days after spraying imidaclorprid showed maximum reduction i.e.

90.67, 93.01 and 95.32 % of *L. erysimi* population at 20, 40, and 60 g a.i. /ha, respectively.

Jeyasankar (2012) performed an experiment on antifeedant and insecticidal activity of some plant oils and observed highest deformities in gaultheria oil treated cutworm larvae and percentage of adult emergence deteriorated by gaultheria oil.

Ebssa and Koppenhofer (2011) determined the efficacy and persistence of entomo pathogenic nematodes for black cutworm management in turfgrass and found *Steinernema carpocapsae* performing best due to high control rates (83%), most consistent results, high speed kill and prevention of significant turf damage.

Arshad *et al.,* (2010) tested the bio-efficacies of four plant leaf extracts *viz,* the apple of Sodom, *calotropis procera* Aiton; Mexican poppy, *Argemone Mexicana* Linnaeus; Mexican marigold, *Tagetes minuta* Linnaeus, and Indian neem, *Azadirachta indica* and reported that the highest percent aphid reduction during first, second and third spray were 28.79, 40.52 and 59.32.

Anil and Sharma (2010) studies on bioefficacy of insecticides against *L. orbonalis* revealed that in terms of shoot and fruit infestation, spinosad was inferior to emamectin benzoate (@0.002%) in brinjal.

Atwal and Dhaliwal (2005) reported that *B. bassian*a (F_1, F_2, and F_3) exhibited moderate effect on the larvae of *P. rapae*, while the effect was high on the pupae. The larvae of *P. rapae* were more sensitive to spinosad than emamectin benzoate, while the pupal stage was less sensitive to both synthetic pesticides. Under field conditions, spinosad provided a therapeutic and residual level of control against *P. rapa*e. Moderate insect population reduction was obtained by *B. bassiana* (F_2), while the least insect population reduction occurred with *B. bassiana* (F_1).

Singh and Lal (2009) reported that Neem Seed Kernel Extract @ 5% and neem oil @ 2% were found more effective against mustard aphid than Eucalyptus Leaf Extracts @ 5% and Fennel Seed Extract @ 5%.

Bhagat *et al.,* (2008) studied efficacy of some biopesticides and insecticides in the management of *A. ipsilon* and concluded that seed treatment with chlorpyriphos and imidacloprid and insecticidal dust application of chlorpyriphos attributed to higher yield and less plant mortality.

Biswas (2000) reported that neem extract, reduced comparatively low aphid population than Malataf, but it is not toxic like chemical insecticides. It is safe for honeybee and other pollinators and also conserve natural enemies in the mustard fields.

Zaki *et al.,* (2006) while evaluating the efficacy of some insecticides in managing cutworm, *Agrotis ipsilon* Hufnagel infesting potato under rainfed conditions of Kashmir reported maximum plant stand in plots treated with carbofuran 3G and highest yield in seed treated plots with imidacloprid 200 SL. Further, they suggested the use of carbofuran 3G, imidacloprid 200 SL and chlorpyriphos 1.5 percent dust for effective management of cutworm infesting potato.

Agrawal *et al.,* (2004) reported methyl-o-demeton @ 0.025 per cent followed by dimethoate @ 0.03 per cent and phorate @ 1.5 kg a.i. per hectare + NSEKE 5 percent showed the most effective insecticide was which resulted in minimum aphid infestation observed at 15 days after spraying. The treatment of neem oil @ 1.0 percent concentration was least effective in controlling the aphid population.

Agrawal and Saroj (2003) reported that effect of fresh neem oil on mustard sawfly, *Athalia proxima* Klug was evaluated third instar larvae of *A. proxima*, were fed on treated mustard leaves and data on mortality, pupation, and adult emergence were reordered, maximum oil content of 50.75% was found from the neem seed kernel collected in the year 2000, followed by 46.46% in the year 1999 sample. Maximum larval mortality (47.5%) was recorded in 2% neem oil treatment followed by 1%, 0.5% 0.25% and 0.125% concentration. The pupal inhibitory effect on adult emergence was most significant at 2% neem oil which was recorded as 47.5% mortality.

Gupta *et al.,* (2001) evaluated the seven neem-based formulations against mustard aphid and found that reduction in pest population was highest with the spraying of neemazal and lowest with the spraying of Neemgold.

At Serio (Brazil), efficacy of chemicals against *A. ipsilon* was evaluated by Link *et al.*, (2000) with preventive spraying of insecticides on tobacco seedlings. They observed the commercial formulation (imidacloprid 500 g a.i./kg + cyfluthrin 10 g a.i./kg) most efficient in the control of the pest.

Sharma and Bhagat (2000) evaluated chlorpyriphos 20 EC, diazinon 20 EC, quinalphos (20 AF) and imidacloprid 70 WS as seed treatment and found imidacloprid effective in controlling *A. ipsilon* in maize.

Thakur and Vaidya (2000) evaluated the root extract (0.75%) of *Rumex nepalensis* against *A. ipsilon* infesting maize, along with some synthetic insecticides and found the efficacy of the extract less than chlorpyriphos but in close proximity to this insecticide.

2.7 Effect of botanicals on yield and yield contributing characteristics of mustard

Patel *et al.,* (2017) studied efficacy of some insecticides on mustard aphid in mustard (variety "Varuna") during 2015-16 and found that the maximum seed yield (12.36 q/ha) was obtained from imidacloprid followed by thiamethoxam (10.0 q/ha) and quinalphos (9.31 q/ha). The lowest seed yield was obtained from untreated plots (6.04 q/ha).

Sen *et al.,* (2017) studied the efficacy of imidacloprid @ 20 g a.i. /ha in *Brassica rapa*L. var. yellow sarson (cv. B-9) against mustard aphid. It revealed that, the highest seed yield (17.41 q/ ha) and the highest incremental cost-benefit ratio (1:14.62) was obtained with imidacloprid 17.8 SL followed by thiamethoxam 25 WG.

Singh *et al.,* (2017) studied bio-efficacy of some insecticides and botanicals on mustard (variety Laxmi) crop. It revealed that, imidacloprid gave maximum seed yield (1866kg/ha) closely followed by thiamethoxam (1813kg/ha) and dimethoate (1757kg/ha). The lowest seed yield (1239 kg/ha) was obtained from untreated control.

Kumar *et al.,* (2015) evaluated the efficacy of two neonicotinoids on mustard aphid and its subsequent effect on yield. They noted that, imidacloprid @ 20 -60 g a.i./ha on rapeseed crop (TS-36) and recorded seed yield ranging from 10.31-11.19q/ha followed by thiacloprid @ 45 g a.i./ha. The yield increase ranged from 30.01-41.10% in imidacloprid followed by thiacloprid (23.20%). The lowest seed yield was noted in control (7.93 g a.i. /ha).

Shah *et al.,* (2008) reported that all the growth parameters namely, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, and seed yield were significantly increased over control with the application of insecticides. The overall growth in insecticides treated plants might be due to the control of mustard aphid, which led the plants a healthy growth over control.

Krishna Kumar *et al.,* (2001) reported that, among the different insecticides evaluated, imidacloprid (12 ml/kg seed) recorded highest yield followed by imidacloprid (9 ml/kg of seed) and thiamethoxam (0.2 g/l), lowest yield recorded in profenophos and monocrotophos treatments.

Sreelatha and Diwakar (1997) reported that seed treatment of imidacloprid with 7.5 g/kg seeds gave an increase in yield over control.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the effect of some promising chemicals and botanicals on the management of aphid and tobacco cutworm in mustard. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from October 2021 to February 2022 in *Rabi* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted the research field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding, about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by 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). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Planting materials

BARI sharisha-14 mustard variety was used as planting materials for this experiment.

3.4 Experimental treatment

The experiment was evaluated to determine the efficacy of seed treating chemical and few botanicalsto compare with each other in considering the less hazardous but effective control measures against major insect pests. The botanical based treatments and chemical insecticides as well as their doses were used in the study are given bellow: -

T_1: Confidor 70WG (imidacloprid) @3g/kg of seed
T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water at weekly interval
T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water at weekly interval
T_4: Tracer 45 EC (spinosad) @0.4 ml/L of water at weekly interval
T_5: Untreated control

3.5 Seed collection

Seeds of mustard varieties, were collected from Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

3.6 Field operation

The different field operations performed during the present investigation were given below in chronological order in list form.

Table 1. List of schedule of field operations done during experimentation

Sl. No.	Field operations	Date
1	Final land preparation	25 October 2021.
2	Layout of the experimental field	25 October 2021
3	Fertilizer application	25 October 2021
4	Seed treatment with chemical	26 October 2021
5	Sowing of seeds	26 October 2021
6	Germination of seeds	6 November 2021
7	Gap filling	6 November 2021
8	Application of botanical	Start in 25 November 2021
9	Thinning	25 November 2021
10	Weeding	25 November and 5 December
11	Irrigation	25 November and 5 December 2021
12	Harvesting	27 February 2022

3.7 Land preparation

Initially the field was prepared with the help of tractor drawn implement. After giving one deep ploughing the experimental field was cross harrowed and leveled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing seeds of the subsequent crops of the experimental study. Land preparation was done at 25 October 2021.

3.8 Experimental design

The experiment was laid out in randomized complete block design. There were 5 treatment Interaction and 15 unit plots with three replications. The unit plot size was 3.75 m^2 (2.5 m × 1.5 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.9 Fertilizer application

The following fertilizers with their corresponding rates were applied as followed:

Fertilizers	Quantity/requirement (kg ha^{-1})
Urea	250
TSP	170
MoP	85
Gypsum	150
Boric Acid	10
Cow dung	8000

Source: (BARI, 2019)

Urea, triple superphosphate (TSP), Muriate of potash (MoP), gypsum, zinc sulphate, boric acid and cow dung were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc, boron and others nutrient respectively. Total amount of TSP, MP, boric acid, cow-dung and one and half amount of urea were applied at final land preparation. Gypsum as the source of sulphur was also applied during final land preparation. The rest amount of urea was applied during flower initiation of mustard (BARI, 2019).

3.10 Seed treatment

Before planting, the seeds were treated with Confidor 70WG to prevent seeds from the attack of soil dwelling pests. Seeds were treated according to Jagadish and Gowda (1994) with few modifications. 300 g of mustard seeds were taken in a plastic container, and then 10 ml of water, 3-4 drops of gum (sticker) and 1g of Confidor 70WG (imidacloprid) were added to this and stirred thoroughly.

3.11 Sowing of seeds

Seeds were sown at the rate of 10 kg ha^{-1} in the furrow on date 23rd October 2021 and the furrows were covered with the soils soon after seeding. Seeds were being treated with Bavistin before sowing the seeds to control the seed-borne disease. The seeds were sown continuously in 30 cm apart rows at about 2-3 cm depth in the afternoon and covered with soil.

3.12 Intercultural operations

i) Weeding

Weeding was done at 15 and 40 DAT.

ii) Irrigation

Optimum irrigation was given to every plot for ensure soil moisture by using water cane. For establishing the young seedlings, irrigation was given for four days continuously. Then, irrigation was given in the following days. First irrigation was given at 15 DAT and the second irrigation at 40-45 DAT. A little irrigation was given at 55-60 DAT.

iii) Application of pesticides

In a knapsack sprayer with a pressure of 4-5 kg cm^{-2}, the precise amount of each botanicals were added, thoroughly mixed with water, and sprayed on the respective plot. By using a measuring cylinder in the sprayer, the necessary dosage of botanicals pesticides was taken. Botanicals were sprayed at various application interval. Bioneemplus 1EC botanical was sprayed at 10 days interval, Neem seed kernel extract was sprayed at 7 days interval and Tracer 45 SC was sprayed at 10 days interval after germination of the seeds.

iv) Observation of insect-pests and natural enemy of mustard

The incidence of insect pest was recorded on 10 randomly selected plants from each plot of each replication at a weekly interval from germination to harvesting stage of the crop by followed following mode of observations:

3.13 Harvesting

The mustard crop was harvest at maturity when the crop turned golden yellow. Harvesting was done on an individual plot basis excluding border rows from all sides. Threshing of the bundled crop was done Materials and Methods separately for each plot. After the threshing seed was cleaned and weight for a yield of each plot separately.

3.14 Monitoring of insect pest and data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at seedling stage to harvest. The results are presented as an average value of the five tagged plants. The data were recorded on different parameters. The following parameters were considered during data collection.

i. Number of insect pests and reduction percentage over control treatment

Pest insect populations (aphid and cutworm) were counted at intervals of 15 days. To gather data, five plants were chosen at random. The number of insects was counted at intervals of 15 days starting with the first occurrence and continuing up to 3 times in the morning. The reduction percentage was also calculated using control-treated plants, where the greatest number of major pest attacks occurred. The reduction percentage was calculated using the formula below.

$$\text{Reduction (\%)} = \frac{\text{No. of pest per treatment - No. of pest in control}}{\text{No. of pest in control}} \times 100$$

ii. Plant height (cm)

The height of the 5 selected plants was measured from the ground level to the tip of the plant at harvest respectively. Mean plant height of soybean plant were calculated and expressed in cm.

iii. No. of branches plant^{-1}

The primary branch plant^{-1} was counted from five randomly sampled plants. It was done by counting the total number of branches of all sampled plants then the average data were recorded. Data were recorded at harvest respectively.

iv) Number of infested siliqua plant^{-1}

Insect infested siliqua plant^{-1} was counted from the 5 randomly selected plant samples and then the averaged siliqua was calculated.

v) Number of non-infested siliqua plant^{-1}

Non infested siliqua plant^{-1} was counted from the 5 randomly selected plant samples and then the averaged siliqua was calculated.

vi) Seeds siliqua^{-1} (no.)

Seeds siliqua^{-1} was counted from splitting five siliqua which were collected randomly from sample plants and then mean value was calculated.

vii) 1000-seed weight (g)

1000-seed were counted randomly from the seeds of each sample plant, then weighed it in an electrical balance in gram (g).

viii. Seed yield plant^{-1} (g)

The weight of seeds plant^{-1} was calculated from the average of 5 selected plants randomly from each unit plot at harvest and was expressed in gram.

ix. Yield (kg ha^{-1})

The seeds harvested from each plot were sundried and threshed by pedal thresher. Seeds were properly sundried and their weights were recorded. Seed yield was then converted to kg ha^{-1}. Increase of yield was calculated by using the following formula-

$$\text{\% Increase of yield over control} = \frac{\text{Yield in treatments- Yield in control}}{\text{Yield in control}} \times 100$$

x. Benefit cost ratio analysis

The benefit cost ratio (BCR) was calculated on the basis of prevailing market prices of Mustard, cost of land, fertilizers, labours, equipment and cost of different seed treating chemicals and botanicals spraying. Benefit cost ratio was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return (Tk/ ha)}}{\text{Total Cost of production}}$$

3.15 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program named Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on the effect of some promising chemicals and botanicals on the management of aphid and tobacco cutworm in mustard. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Aphid population

4.1.1 At flowering stage

The number of aphids at the early, mid, and late flowering stages varied due to seed treating chemicals and use of few botanicals on aphid management showed significant variations (Table 1).

Table 1. Aphid population at early, mid and late flowering stages due to effect of treatments

Treatments	Number of aphid plant^{-1} at flowering stage		
	Early	Mid	Late
T_1	3.40 b	5.55 b	6.70 b
T_2	2.40 c	3.80 c	5.15 d
T_3	2.65 c	4.10 c	5.65 c
T_4	1.55 d	2.15 d	2.50 e
T_5	8.56 a	10.75 a	12.60 a
$LSD_{(0.05)}$	0.41	0.32	0.40
CV(%)	5.90	3.31	3.33

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

Data show that, during the early stages of flowering, the lowest number of aphid plant^{-1} (1.55) was observed in T_4 (Tracer 45 SC @0.4 ml/L of water) treatment followed by (2.40) T_2 (Bioneemplus 1EC @1.0 ml/L of water) and (2.65) T_2 (Bioneemplus 1EC @1.0

ml/L of water). While the highest number of aphid plant^{-1} (8.56) was observed in T_5 (Untreated control) treatment. At mid and late stage of flowering the lowest number of aphid plant^{-1} (2.15 and 2.50) was observed in T_4 treatment, while the highest number of aphid plant^{-1} (10.75 and 12.60) was observed in T_5 (Untreated control) treatment Khan *et al.,* (2015) reported that different chemical and botanical insecticides significantly reduced mustard aphid and among different insecticides application of two sprays of imidacloprid chemical insecticides, was found most effective followed by bifenthrin, carbosulfan, and thiamethoxam insecticides.

.4.1.2 At fruiting stage

Due to various seed treating chemicals and the use of a few botanicals on aphid management, the number of aphids at the early, mid, and late fruiting stages varied significantly (Table 2).

Table 2. Aphid population at early, mid and late fruiting stages due to effect of treatments

Treatments	Number of aphid plant^{-1} at fruiting stage		
	Early	Mid	Late
T_1	5.10 b	6.25 b	9.65 b
T_2	4.35 c	5.85 c	7.20 c
T_3	4.50 c	5.70 c	7.45 c
T_4	2.85 d	3.00 d	4.15 d
T_5	9.20 a	10.55 a	14.20 a
$LSD_{(0.05)}$	0.41	0.26	0.81
CV(%)	4.28	2.26	5.08

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

Experimental result shows that, at the early, mid, and late fruiting stages the lowest number of aphid plant^{-1} (2.85, 3.00 and 4.15) was observed in T_4 treatment. While T_5 treatment recorded the highest number of aphid plant^{-1} (9.20, 10.55 and 14.20, respectively) respectively at the early, mid, and late fruiting stages. From the findings it is observed that, the application of Tracer 45 SC@0.4 mL/L of water was more effective than the other management practices for controlling aphids during the entire fruiting stage of mustard. Khan and Jha (2010) reported that the aphid population was highest during siliqua formation phase due to prevalent conducive weather conditions, followed by reproductive and vegetative phases over all varieties

4.2 Aphid infested mustard plant

4.2.1 At flowering stage

The number of healthy plants, infested plants, and percent infestation of mustard plants differed significantly at the flowering stage for different mustard aphid management practices (Table 3). Experimental result showed that at flowering stage, the maximum number of healthy plant m^{-2} (29) was observed in T_4 treatment which was statistically similar with T_3 (28.33) and T_2 (28.67) treatment. While the lowest number of healthy plant m^{-2} (25.67) was observed in T_5 treatment.

Table 3. Effect of different treatments on aphid infested mustard plant at flowering stage

Treatments	At flowering stage			
	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant	Reduction %
T_1	28.00 b	2.00 b	6.67 b	53.78
T_2	28.67 ab	1.33 d	4.43 d	69.31
T_3	28.33 ab	1.67 c	5.57 c	61.40
T_4	29.00 a	1.00 e	3.33 e	76.92
T_5	25.67 c	4.33 a	14.43 a	
$LSD_{(0.05)}$	0.76	0.25	0.81	
CV(%)	1.46	6.44	6.31	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

The highest number of infested plant m^{-2} (4.33) was observed in T_5 treatment while the lowest number of infested plant m^{-2} (1.00) was observed in T_4 treatment. The highest percent infestation of infested plant (14.43 %) was observed in T_5 treatment while the lowest one (3.33 %) was observed in T_4 treatment. Mustard plant infestation percentage reduction over control at flowering stage was estimated for different management practices and the highest value (76.92 %) was found in T_4 treatment and the lowest value (53.78 %) from T_1 treatment. From the findings it was revealed that spraying of Tracer 45 SC@0.4 ml/L of water at 10 days interval was more effective among the management practices for reduction of plant infestation by aphid at the flowering stage. Kafle (2015) reported that the effectiveness of botanicals to reduce the aphid population was significantly higher comparable to control treatment.

4.2.2 At fruiting stage

For various mustard aphid management techniques, the number of healthy plants, plants with infestations, and the percentage infestation of infested plants varied significantly at the fruiting stage (Table 4). Experimental result showed that, the highest number of healthy plant m^{-2} (28) was found in T_4 treatment which was statistically similar with T_2 (26.67) treatment while the lowest number of healthy plant m^{-2} (22.33) was found in T_5 treatment.

Table 4. Effect of different treatments on aphid infested mustard plant at fruiting stage

Treatments	At fruiting stage			
	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant	Reduction %
T_1	24.67 b	5.00 b	16.67 b	34.27
T_2	26.67 ab	3.33 d	11.10 d	55.72
T_3	25.33 b	4.67 c	15.57 c	38.51
T_4	28.00 a	2.00 e	6.67 e	72.78
T_5	22.33 c	7.67 a	25.57 a	
$LSD_{(0.05)}$	2.11	0.24	1.03	
CV(%)	4.43	2.88	3.62	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

In case of infested mustard plant m^{-2} the highest number of infested plant m^{-2} (7.67) was found in T_5 treatment while the lowest number of infested mustard plant m^{-2} (2.00) was found in T_4 treatment. Among different treatments the highest percent infestation of infested plant (25.57 %) was observed in T_5 treatment while the lowest one (6.67 %) was observed in T_4 treatment. Mustard plant infestation percentage reduction over control at fruiting stage was estimated for various management practices, and with T_4 treatment having the highest value (72.78 %) and T_1 treatment having the lowest value (34.27 %). The result was quite similar with the findings of Dotasara *et al.,* (2017) who reported that the efficacy to tested newer insecticides like neem oil, Imidacloprid and fipronil were found promosing against mustard aphids (*L. erysimi*). Gupta *et al.,* (2001) evaluated the seven neem-based formulations against mustard aphid and found that reduction in pest population was highest with the spraying of Neemazal and lowest with the spraying of Neemgold.

4.3 Cutworm population

4.3.1 At flowering stage

The number of cutworms at the early, mid, and late flowering stages varied due to seed treating chemicals, and the use of few botanicals on cutworms management revealed significant variations (Table 5).

Table 5. Cutworm population at early, mid and late flowering stages due to effect of treatments

Treatments	Number of cutworm plant^{-1} at flowering stage		
	Early	Mid	Late
T_1	2.48 b	1.33 b	1.43 b
T_2	0.73 d	0.48 d	0.33 d
T_3	1.58 c	0.93 c	0.88 c
T_4	0.00 e	0.00 e	0.33 d
T_5	4.98 a	2.63 a	2.18 a
$LSD_{(0.05)}$	0.17	0.08	0.11
CV(%)	4.86	4.04	5.74

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

Experimental result revealed that, during the early stages of flowering, the lowest number of cutworm plant^{-1} (0.00) was observed in T_4 (Tracer 45 SC@0.4 ml/L of water) treatment followed by (0.73) T_2 (Bioneemplus 1EC @1.0 ml/L of water). While the highest number of cutworm plant^{-1} (4.98) was observed in T_5 (Untreated control) treatment. At mid and late stage of flowering the lowest number of aphid plant^{-1} (0.00 and 0.33) was observed in T_4 treatment, while the highest number of aphid plant^{-1} (2.63 and 2.18) was observed in T_5 (Untreated control) treatment. Zaki *et al.*, (2006) suggested that the use of carbofuran 3G, imidacloprid 200 SL and chlorpyriphos 1.5 percent dust was effective for management of cutworm infesting potato.

4.3.2 At fruiting stage

The number of cutworms at the early, mid, and late fruiting stages varied significantly due to various seed treating chemicals and the use of a few botanicals on cutworms management. (Table 6).

Table 6. Cutworm population at early, mid and late fruiting stages due to effect of treatments

Treatments	Number of cutworm plant^{-1} at fruiting stage		
	Early	Mid	Late
T_1	4.13 b	4.28 b	3.53 b
T_2	1.73 d	1.18 d	0.98 d
T_3	2.13 c	1.88 c	1.68 c
T_4	1.03 e	0.68 e	0.33 e
T_5	5.93 a	5.43 a	5.03 a
$LSD_{(0.05)}$	0.12	0.17	0.15
CV(%)	2.30	3.42	4.11

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

Experimental result shows that, at the early, mid, and late fruiting stages the lowest number of cutworm plant^{-1} (1.03, 0.68 and 0.33, respectively) respectively was observed in T_4 treatment. While T_5 treatment recorded the highest number of cutworm plant^{-1} (5.93, 5.43 and 5.03, respectively) respectively at the early, mid, and late fruiting stages. From the findings it was observed that, the application of Tracer 45 SC@0.4 mL/L of water at 10 days interval was more effective than the other management practices for controlling cutworms during the entire fruiting stage of mustard. The result was quite bit similar with the findings of Sharma *et al.*, (2017) who reported that Tracer 45 SC @0.01% was most effective in reducing the larval population of diamondback moth (94.33%) on cabbage

4.4 Cutworm infested mustard plant

4.4.1 At flowering stage

At the flowering stage, the number of healthy plants, infested plants, and percent infestation of mustard plants varied significantly depending on mustard cutworm management practices. (Table 7). Experimental result showed that at flowering stage, the maximum number of healthy plant m^{-2} (29.67) was observed in T_4 treatment which was statistically similar with T_1 (29.33) and T_2 (29.33) treatment. While the lowest number of healthy plant m^{-2} (27.33) was observed in T_5 treatment.

Table 7. Effect of different treatments on cutworm infested mustard plant at flowering stage

Treatments	At flowering stage			
	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant	Reduction %
T_1	29.33 ab	1.67 b	5.57 b	37.42
T_2	29.33 ab	0.67 d	2.23 d	74.94
T_3	28.67 b	1.33 c	4.43 c	50.22
T_4	29.67 a	0.33 e	1.10 e	87.64
T_5	27.33 c	2.67 a	8.90 a	
$LSD_{(0.05)}$	0.84	0.16	0.20	
CV(%)	1.55	6.53	2.46	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

Experimental result revealed that the T_5 treatment had the highest number of infested plant m^{-2} (2.67) and T_4 treatment had the lowest number of infested plant m^{-2} (0.33). The

T_5 treatment had the highest percentage of infested plants (8.90%), while the T_4 treatment had the lowest (1.10%). Mustard plant infestation percentage reduction over control at flowering stage was estimated for various management practices, and showed that the highest percentage of infestation reduction compared to control treatment was found in T_4 treatment (87.64%) while the lowest percentage of infestation reduction compared to control treatment was found in T_5 treatment (37.42%). From the findings it was revealed that spraying of Tracer 45 SC@0.4 ml/L of water at 10 days interval was more effective among the management practices for reduction of plant infestation by cutworm at the flowering stage. The result was quite similar with the findings of Ebssa and Koppenhofer (2011) who determined the efficacy and persistence of entomopathogenic nematodes for black cutworm management in turfgrass and found *Steinernema carpocapsae* performing best due to high control rates (83%), most consistent results, high speed kill and prevention of significant turf damage.

4.4.2 At fruiting stage

The number of healthy plants, plants with infestations, and the percentage infestation of infested plants varied significantly at the fruiting stage for various mustard cutworm management techniques. (Table 8). The experimental results revealed that the T_4 treatment had the highest number of healthy plant m^{-2} (29) and was statistically similar to the T_2 (28.67) and T_3 (28.33) treatment, while the T_5 treatment had the lowest number of healthy plant m^{-2} (25.57).In case of infested mustard plant m^{-2} the highest number of infested plant m^{-2} (4.33) was found in T_5 treatment while the lowest number of infested mustard plant m^{-2} (1.00) was found in T_4 treatment. Among different treatments the highest percent infestation of infested plant (14.43 %) was observed in T_5 treatment while the lowest one (3.33 %) was observed in T_4 treatment. Mustard plant infestation percentage reduction over control at fruiting stage was estimated for various management practices, and showed that the highest percentage of infestation reduction compared to control treatment was found in T_4 treatment (76.92%) while the lowest percentage of infestation reduction compared to control treatment was found in T_5 treatment (53.78%). Zaki *et al*. (2006) while evaluating the efficacy of some insecticides in managing cutworm, *Agrotis ipsilon* Hufnagel infesting potato under rainfed conditions of Kashmir reported that the use of carbofuran 3G, imidacloprid 200 SL and chlorpyriphos 1.5 percent was found to be effective for management of cutworm infesting potato.

Table 8. Effect of different treatments on cutworm infested mustard plant at fruiting stage

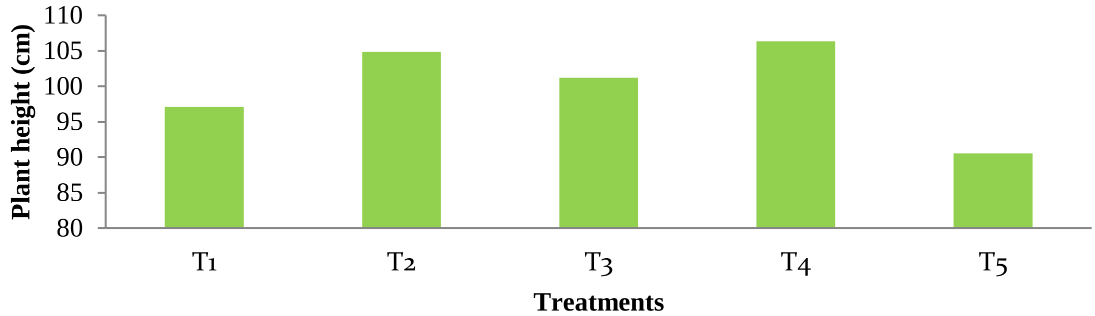
Treatments	At fruiting stage			
	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant	Reduction %
T_1	28.00 b	2.00 b	6.67 b	53.78
T_2	28.67 ab	1.33 d	4.43 d	69.30
T_3	28.33 ab	1.67 c	5.57 c	61.39
T_4	29.00 a	1.00 e	3.33 e	76.92
T_5	25.57 c	4.33 a	14.43 a	
$LSD_{(0.05)}$	0.82	0.25	0.86	
CV(%)	1.57	6.45	6.69	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4: Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control

4.5 Effect of treatments on yield contributing characters and yield of mustard

4.5.1 Plant height (cm)

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants (Fig. 1). At harvest plant height of mustard was significantly influenced by different management practices. Experimental result showed that among the treatments the maximum plant height (106.35 cm) was observed in T_4 treatment where minimum number of pest initiation was occurred which was statistically similar with T_2 (104.84 cm) treatment. On the other hand, the control treatment, recorded the lowest plant height (90.54 cm). Shah *et al.* (2008) reported that plant height, was significantly increased over control with the application of insecticides. The overall growth in insecticides treated plants might be due to the control of mustard aphid, and cutworm which led the plants a healthy growth over control.

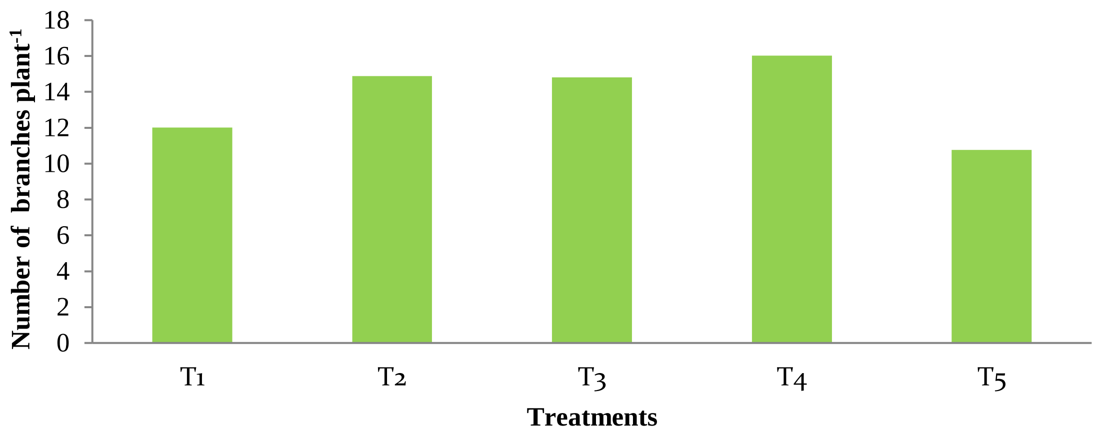


Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 1. Effect of different treatment on plant height of mustard

4.5.2 Number of branches plant^{-1}

Different management practices of aphid and cutworm significantly influenced the number of branches plant^{-1} of mustard at harvest (Fig. 2). The experimental results revealed that the T_4 treatment had the highest number branches plant^{-1} of mustard (16.02) where minimum number of aphid and cutworm were recorded. The control treatment, on the other hand, had the lowest number branches plant^{-1} of mustard (10.76).

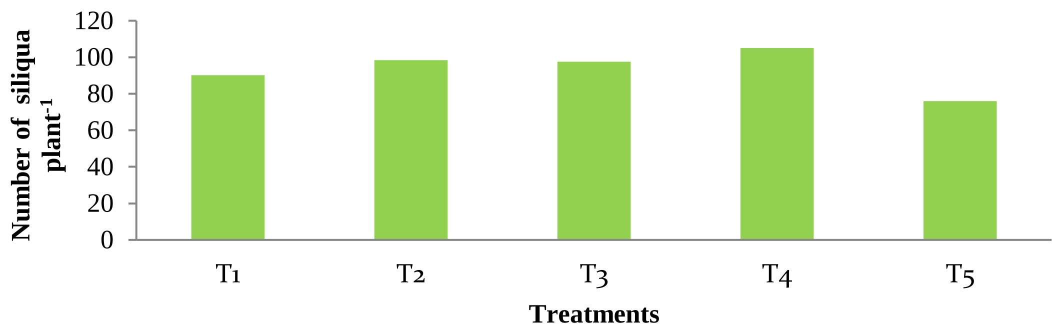


Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 2. Effect of different treatment on number of branches plant^{-1} of mustard

4.5.3 Number of siliqua plant^{-1}

Different mustard management practices for controlling aphids and cutworms resulted in statistically significant differences in the number of siliqua plant^{-1}. The highest number of siliqua plant^{-1} (105.10) was observed in T_4 treatment while the lowest number of siliqua plant^{-1} (76.00) was observed in T_5 treatment (Fig. 3).The results show that the maximum pest attack reduces plant growth, but different management practices used for controlling aphids and cutworms reduce pests while increasing plant height, number of branches, number of siliqua plant^{-1}, and so on. Khan and Jha (2010) reported that the aphid population was highest during siliqua formation phase due to prevalent conducive weather conditions, followed by reproductive and vegetative phases over all varieties. Sen *et al*. (2017) revealed that, the maximum yield nad yield contributing characters of mustard were obtained with imidacloprid 17.8 SL followed by thiamethoxam 25 WG. insecticide application.

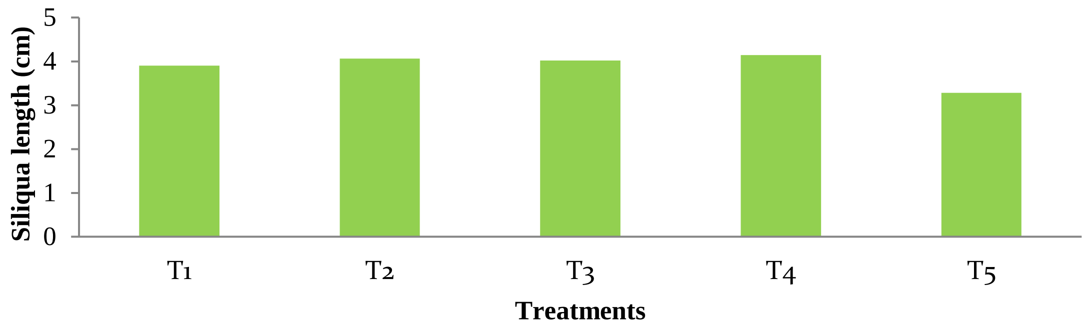


Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 3. Effect of different treatment on number of siliqua plant^{-1}of mustard

4.5.4 Siliqua length (cm)

Statistically significant variation was found in the length of the siliqua of mustard for controlling aphid and cutworm using various pest management practices. (Fig. 4). Experimental result showed that the highest siliqua length of mustard (4.14 cm) was observed in T_4 treatment which was statistically similar with T_2 (4.06 cm) treatment. While the lowest siliqua length of mustard (3.28 cm) was observed in T_4 treatment. Kumar *et al*. (2015) reported that application of imidacloprid @ 20-60 g a.i./ha on rapeseed crop (TS-36) significantly reduced insect-pest population of mustard crop and increased growth and yield contributing characteristic of mustard.

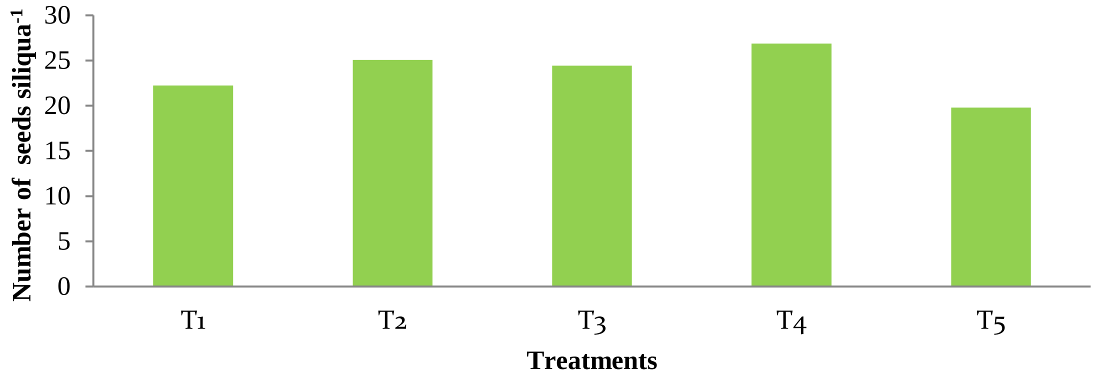


Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 4. Effect of different treatment on siliqua length of mustard

4.5.5 Number of seeds siliqua^{-1}

Due to the use of seed-treating chemicals and a few botanicals for the management of mustard aphid and tobacco cutworm, the number of seeds siliqua^{-1} significantly varied (Fig. 5). Experimental result showed that the highest number of seeds siliqua^{-1} (26.87) was observed in T_4 treatment while the lowest number of seeds siliqua^{-1} (19.80) was observed in T_5 treatment. The findings were quite similar to those of Singh *et al.*, (2017), who studied the bio-efficacy of some insecticides and botanicals on mustard (variety Laxmi) crop and discovered that, among different insecticides, imidacloprid gave the most number of seeds per siliqua of mustard due to reduction of different insect pest population of mustard, followed by thiamethoxam and dimethoate insecticide. The untreated control yielded the fewest seeds per siliqua of mustard.

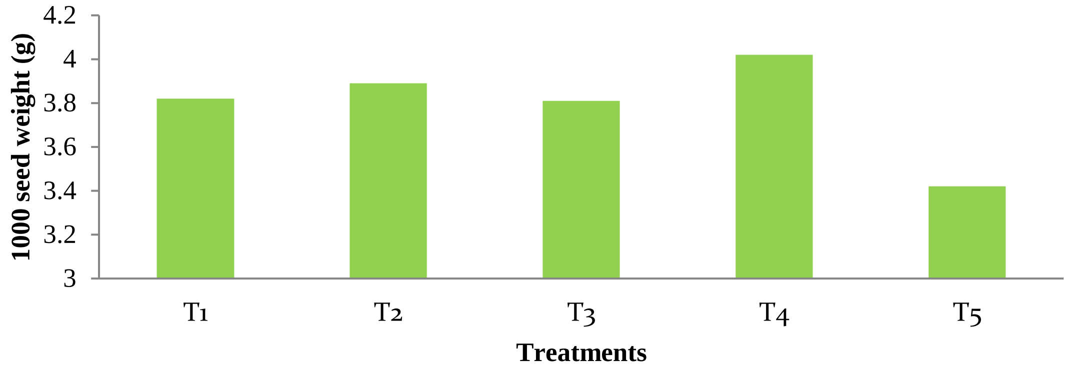


Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 5. Effect of different treatment on number of seeds siliqua^{-1} of mustard

4.5.6 1000-seed weight (g)

A significant variation was found due to the effects of different management against aphid and tobacco cutworm on mustard in relation to the weight of 1000 seeds (Fig. 6). Experimental result showed that the highest 1000-seed weight of mustard (4.02 g) was observed in T_4 treatment which was statistically similar (3.89 g) with T_2 treatment while the lowest 1000-seed weight of soybean (3.42 g) was observed in T_5 (Control treatment). Shah *et al.* (2008) reported that all the growth parameters namely, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, 1000 seed weight and seed yield were significantly increased over control with the application of insecticides. The overall growth in insecticides treated plants might be due to the control of mustard aphid, which led the plants a healthy growth over control.



Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Fig. 6. Effect of different treatment on 1000 seed weight of mustard

4.5.7 Seed yield (t ha^{-1})

Based on the seed yield obtained from various treatments, the effectiveness of various management practices against aphid and tobacco cutworm on mustard was also determined (Table 9). The results of the experiment revealed a significantly higher seed yield (1.77 t ha^{-1}) was obtained from T_4 treatment which gave (84.38 %) more yield comparable to control treatment (T_5), while the lowest seed yield (1.00 t ha^{-1}) was obtained from T_5 treatment. In comparison to control treatment the lowest increased yield over control was observed in T_1 (4.17%) treatment. From the above results investigate, it was found that the among all applied different treatments in this study, T_4 treatment showed the superior performance on control the pests as to ensure the optimum vegetative growth and highest number of siliqua plant^{-1} and 1000-seed weight as well as maximum yield. Dotasara *et al*. (2018) reported that the aphid, *Lipaphis erysimi* cause losses which can be avoided up to 41.14 percent through different management practices. The yield loss obtained in treated and untreated plots were 7.91 and 13.43 quintals/ha respectively. Benssin (2011) reported that cutworms eat at night, causing severe damage to the stems and foliage of young plants. Plant stalks can be cut. The variegated cutworm climbs plants and feeds on the foliage and buds. Debbarma *et al.* (2017) reported that Spinosad 2.5 SC @ 500 ml/ha was found most effective against *P. brassicae* registering lower extent of mean leaf damage by (24.30%). Patel *et al.* (2017) studied efficacy of some insecticides on mustard aphid in mustard (variety "*Varuna*") during 2015-16 and found that the maximum seed yield (12.36 q/ha) was obtained from insecticide treated plot while the lowest seed yield was obtained from untreated plots (6.04 q/ha).

Table 9. Effect of different treatments on yield of mustard

Treatments	Yield (t ha^{-1})	Increased yield over control
T_1	1.00 d	4.17
T_2	1.61 b	67.71
T_3	1.54 c	60.42
T_4	1.77 a	84.38
T_5	0.96 d	
$LSD_{(0.05)}$	0.05	
CV(%)	2.28	

Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

4.6 Benefit-cost ratio analysis

The T_4 (Tracer 45 SC@0.4 ml/L of water) treated plot had the highest benefit-cost ratio (2.04). The T_3 (Neem seed kernel extract @50 g/L of water) treated plot had the second highest benefit-cost ratio (1.99). While the lowest benefit cost ratio (1.79) was observed in control treatment. Similarly the net return was also the highest in T_4 treated plot i.e. Tk. 81277/ha. On the other hand, the lowest net return was found in T_5 (Untreated control) treatment which includes Tk. 38104 followed by T_1 (40347 Tk.) treatment (Table 10). The result was similar with the findings of Sen *et al*. (2017) who evaluated different insecticide for effective management of pest on mustard crop and reported that the chemical control of insect of mustard was found to be effective in reducing the insect infestation and recorded the highest BCR comparable to control treatment.

Table 10. Economic analysis of different botanicals for managing mustard insect pest

Treatments	Cost of pest management (TK)			Total cost of production	Yield (t/ha)	Gross return (Tk.)	Net return (Tk.)	Benefit cost ratio (BCR)
	Seed treatments and botanicals (Tk.)	Labour	Total					
T_1	255	900	1155	49653	1.0	90000	40347	1.81
T_2	16200	6300	22500	74733	1.61	144900	70167	1.94
T_3	12000	6300	18300	69798	1.54	138600	68802	1.99
T_4	19000	6300	25300	78023	1.77	159300	81277	2.04
T_5	0	0	0	48296	0.96	86400	38104	1.79

Here, T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4 : Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5 : Untreated control

Here, Overhead cost: Land value ha^{-1} was 200000 taka. Land cost at 12.5 % interest for 6 month was 12500 taka. Miscellaneous cost (common cost): It was 5% of total input cost, Price of mustard seed = TK 90.00/kg

Cost of insecticide

T_1: Confidor 70WG @3g/kg of seed = 17 taka/g.

T_2: Bioneemplus 1EC @1.0 ml/L of water = 400 taka/L

T_3: Neem seed kernel extract @50 g/L of water= 300 taka/L

T_4: Tracer 45 SC@0.4 ml/L of water= 475 taka/L

T_5: Control and

Cost of labour = tk 450.00/day.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the Effect of some promising chemicals and botanicals on the management of aphid and tobacco cutworm in mustard during the period from October 2021 to February 2022 in the *Rabi* season. The experiment was laid out in Randomized block design with five different treatment *viz:* T_1: Confidor 70WG (imidacloprid) @3g/kg of seed, T_2: Bioneemplus 1EC (azadirachtin) @1.0 ml/L of water, T_3: Neem seed kernel extract (azadirachtin) @50 g/L of water, T_4:Tracer 45 SC (spinosad) @0.4 ml/L of water and T_5: Untreated control, for the management of aphid and tobacco cutworm of mustard with three replications for each treatment. Data on different parameters were recorded and significant variation was observed among different treatment.

In case of aphid population, from the data it was found that during the early stages of flowering, the lowest number of aphid plant^{-1} (1.55) was observed in T_4 (Tracer 45 SC@0.4 ml/L of water) treatment while the highest number of aphid plant^{-1} (8.56) was observed in T_5 (Untreated control) treatment. At mid and late stage of flowering the lowest number of aphid plant^{-1} (2.15 and 2.50) was observed in T_4 treatment, while the highest number of aphid plant^{-1} (10.75 and 12.60) was observed in T_5 (Untreated control) treatment. At the early, mid, and late fruiting stages the lowest number of aphid plant^{-1} (2.85, 3.00 and 4.15) was observed in T_4 treatment. While T_5 treatment recorded the highest number of aphid plant^{-1} (9.20, 10.55 and 14.20) at the early, mid, and late fruiting stages.

In case of number of healthy plant, infested plants and percent infestation of mustard plant at flowering stage the maximum number of healthy plant m^{-2} (29) was observed in T_4 treatment. While the lowest number of healthy plant m^{-2} (25.67) was observed in T_5 treatment. The highest number of infested plant m^{-2} (4.33) was observed in T_5 treatment while the lowest number of infested plant m^{-2} (1.00) was observed in T_4 treatment. The highest percent infestation of infested plant (14.43 %) was observed in T_5 treatment while the lowest one (3.33 %) was observed in T_4 treatment. The highest value (76.92 %) of infestation percentage reduction over control at flowering stage was found in T_4 treatment while the lowest value (53.78 %) from T_1 treatment. At fruiting stage the highest number of healthy plant m^{-2} (28) was found in T_4 treatment while the lowest number of healthy plant m^{-2} (22.33) was found in T_5 treatment. The highest number of infested plant m^{-2} (7.67) was found in T_5 treatment while the lowest number of infested mustard plant m^{-2} (2.00) was found in T_4 treatment. Among different treatments the highest percent infestation of infested plant (25.57 %) was observed in T_5 treatment while the lowest one (6.67 %) was observed in T_4 treatment. Mustard plant infestation percentage reduction over control at fruiting stage was found maximum at T_4 treatment having the highest value (72.78 %) while the T_1 treatment having the lowest value (34.27 %) of it.

In case of cutworm population, during the early stages of flowering, the lowest number of cutworm plant^{-1} (0.00) was observed in T_4 (Tracer 45 SC@0.4 ml/L of water) treatment while the highest number of cutworm plant^{-1} (4.98) was observed in T_5 (Untreated control) treatment. At mid and late stage of flowering the lowest number of aphid plant^{-1} (0.08 and 0.11) was observed in T_4 treatment, while the highest number of aphid plant^{-1} (2.63 and 2.18) was observed in T_5 (Untreated control) treatment. At the early, mid, and late fruiting stages the lowest number of cutworm plant^{-1} (1.03, 0.68 and 0.33) was observed in T_4 treatment. While T_5 treatment recorded the highest number of cutworm plant^{-1} (5.93, 5.43 and 5.03) at the early, mid, and late fruiting stages.

At flowering stage, the maximum number of healthy plant m^{-2} (29.67) was observed in T_4 treatment while the lowest number of healthy plant m^{-2} (27.33) was observed in T_5 treatment. The T_5 treatment had the highest number of infested plant m^{-2} (2.67) and T_4 treatment had the lowest number of infested plant m^{-2} (0.33). The T_5 treatment had the highest percentage of infested plants (8.90%), while the T_4 treatment had the lowest percentage of infested plants (1.10%). Mustard plant infestation percentage reduction over control at fruiting stage was found maximum at T_4 treatment (87.64%) while the lowest percentage of infestation reduction compared to control treatment was found in T_5 treatment (37.42%).At fruiting stage the T_4 treatment had the highest number of healthy plant m^{-2} (29), while the T_5 treatment had the lowest number of healthy plant m^{-2} (25.57).The highest number of infested plant m^{-2} (4.33) was found in T_5 treatment while the lowest number of infested mustard plant m^{-2} (1.00) was found in T_4 treatment. The highest percent infestation of infested plant (14.43 %) was observed in T_5 treatment while the lowest one (3.33 %) was observed in T_4 treatment. Mustard plant infestation percentage reduction over control at fruiting stage was found maximum inT_4 treatment (76.92%) while the lowest percentage of infestation reduction compared to control treatment was found in T_5 treatment (53.78%).

In case of growth, yield contributing characters and yield of mustard, among different treatments the maximum plant height (106.35 cm) was observed in T_4 treatment while the control treatment, recorded the lowest plant height (90.54 cm). The highest number branches plant^{-1} (16.02), siliqua plant^{-1} (105.10), siliqua length (4.14 cm), seeds siliqua^{-1} (26.87), 1000-seed weight (4.02 g) and higher seed yield (1.77 t ha^{-1}) was obtained from T_4 treatment which gave (84.38 %) more yield comparable to control treatment. The corresponding lowest value was found in control treatment.

Conclusion

The results above suggest that among the management practices for controlling mustard aphid and tobacco cutworm, spraying Tracer 45 SC @0.4 ml/L of water at 10-day intervals was the most effective for controlling these insect and increased seeds siliqua^{-1} (26.87), 1000-seed weight (4.02 g) and seed yield (1.77 t ha^{-1})comparable to control treatment.

Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

i. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
ii. Others seed treating chemical and botanicals may be included in further study for aphid and tobacco cutworm in mustard.

REFERENCES

Agarwal, P.K., Hebbar, K.B., Venugopal, M., Rani, S., Bala, A., Biswal, A. and Wani, S.P. (2008). Quantification of yield gaps in rainfed rice, wheat, cotton and mustard in India. Global theme on Agroecosystems Report no 43, Patancheru-502 324, Andhra Pradesh, India: ICRISAT. pp.35-36.

Agrawal, N. and Saroj, S.R. (2003). Bio efficacy of fresh neem oil against larvae of mustard sawfly. *Athalia lugens proxima* Klug. Infesting mustard. *J. Ento. Res.* **27**(4): 347-351.

Agrawal, N., Verma, R.K. and Rajak, S.K. (2004). Comparative efficacy of some neem-based and chemical insecticides against *Lipaphis erysimi* (Kalt.) on mustard. *Farm Sci. J.* **14**(1): 22-24.

Ahmad, S., Aftab, A., Sabri, M.A., Ghazal, A., Ullah, Z., Ahmad, M.I., Bilal, H., Mohsin, M. and Naz, S.I. (2017). Efficacy of four different insecticides with different mode of action against canola aphid (*Lipaphis erysimi*) under field condition. *J. Ento. Zoo. Stud.* **5**(3): 626-629.

Ahmed, N., Alam, M., Saeed, M., Ullah, H., Iqbal, T., Awadh Al-Mutairi, K. and Salman, M. (2022). Botanical insecticides are a non-toxic alternative to conventional pesticides in the control of insects and pests. *Intech Open*. pp. 1-2.

Alam, A.K.M.F. (2020). Rising trend in consumption of oils and fats in Bangladesh. https://thefinancialexpress.com.bd. Accessed 27thJune, 2020.

Alam, M., Begum, F. and Roy, P. (2014). Yield and yield attributes of rapeseed-mustard (*Brassica*) genotypes grown under late sown condition. *Bangladesh J. Agric. Res.* **39**(2): 311-336.

Amruta, N., Sarika, G., Maruthi, J. and Basavaraju, G. (2015). Effect of botanicals and insecticides seed treatment and containers on seed longevity of black gram under natural ageing conditions. *J. App. Nat. Sci.* **7**: 328-334.

Anil, K. and Sharma, P.C. (2010). Bioefficacy of insecticides against *Leucinodes orbonalis* on brinjal. *J. Environ. Bio*. **31**(4): 399-402.

Anonymous (1988a). The Year Book of Production. FAO, Rome, Italy.

Anonymous (1988b). Land resources appraisal of Bangladesh for agricultural development. Report No.2. Agro-ecological regions of Bangladesh, UNDP and FAO. pp. 472–496.

Anonymous (2004). Effect of seedling throwing on the grain yield of wart landrice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

Anonymous (2018). Statistical Digest (2018-2019). Directorate of Economics and Statistics, Planning and Development, Government of Jammu and Kashmir, Srinagar, pp.105-108.

Arshad, A., Parvez, Q.A. and Farmanur, R.K. (2010) Bio-efficacy of some plant leaf extract against mustard aphid, *Brassica juncea*. *J. Plant Prot. Res.* **50**(2): 5-6.

Atwal, A. S. and Dhaliwal, G. S. (2005). Agriculture Pests of South Asia and Their Management, *Kalayani publishers*, New Delhi. pp: 505.

BARI (Bangladesh Agricultural research Institute) (2001). Annual Report of 2000-2001. Oilseed Research Centre. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur, Bangladesh. p.30.

BARI (2019). Handbook on Agricultural Technology, Bangladesh Agril. Res. Inst. Joydebpur, Gazipur, Bangladesh. p.102.

Barros, R.G., Barrigossi, J.A.F. and Costa, J.L.S. (2005). Efeito do armazenamento na compatibilidade de fungicidas e inseticidas, associados ou não a um polímero no tratamento de sementes de feijão. *Bragantia Campinas*. **64**(3): 459-465.

BB (Bangladesh Bank). (2020). Category-wise import payments. https://www.bb.org.bd/econdata. Accessed 6th June, 2020.

BBS (2019). Annual Statistical yearbook. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p.1-8.

Benssin, R. (2011). Cabbage insects. Cooperative Extension Service. University of Kentucky-College of Agriculture. pp. 1-13.

Bhagat, R.M., Khajuria, M.K., Shankar, U., Monobrullah, M.D. and Koul, V.K. (2008). Efficacy of biopesticides and insecticides in controlling maize cutworm in Jammu. *J. Bio. Cont.* **22**: 99-106.

Bhat, M.A. (2007). A report on insect pests associated with Cole crops in Kashmir. *App. Bio. Res.* **10**: 66-67.

Bhati, R., Sharma, R.C. and Singh, R. (2015). Studies on the occurrence of insect-pests of different *Brassica* spp. *Int. J. Cur. Sci.* **14**: 125-132.

Biswas, G.C. and Das, C.P. (2008). Population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) in relation to weather parameters. *Bangladesh. J. Ento.* **10**: 15-22.

BNNC (Bangladesh National Nutrition Council) (1984). Nutrition policy and programme for Bangladesh, Bangladesh National Nutrition Council, 19/1 Rasulbagh, Mohakhali, Dhaka. pp.70-79.

Bosque, R.D., Rodriguez, B. and Del, R.D. (1989). Damage by the black cutworm *Agrotis ipsilon* (Hufnagel) in the maize crop in Northern Tamaulipas. *Agricultura Tecnida En Mexico* **12**: 65-75.

Chandel, R.S., Verma, S.K., Rana, A., Sanjta, S., Badiyala, A., Vashisth, S., Kumar, R. and Baloda, A.S. (2021). The ecology and management of cutworms in India. *Oriental Insects.* **56**(2): 245-270.

Debbarma, A., Singh, K.I., Gupta, M.K. and Sobitadevi, P. (2017). Biorational management of major lepidopterous pests and their influence on yield of cabbage crop under Manipur valley. *J. Ent. Zoology Stud.* **5**(5): 1546-1551.

Dey, S., Tufleuddin, B., Mahafuzar, R., Suvendu, B. and Krishna K. (2020). Effect of spot application of imidacloprid 17.8 SL on mustard aphid (*Lipaphis erysimi*) under conservation agricultural practices, West Bengal, India. *Int. J. Curr. Microbiol. App. Sci*. **9**(07): 3620-3627.

Dhaliwal, G.S., Jindal, V. and Mohindru, B. (2015). Crop losses due to insect pests: global and Indian scenario. *Indian J. Ento.* **77**(2): 165-168.

Dinda, N., Ray, M. and Sarkar, P. (2015). Effect of sowing date *vis-a-vis* variety of rapeseed and mustard on growth, yield and aphid infestation in Gangetic plains of West Bengal. *The Ecoscan.* **9**: 21-24.

Dotasara, S.K., Agrawal, N., Singh, N., Swami, D. (2017). Efficacy of some newer insecticides against mustard aphid *Lipaphis erysimi* Kalt. in cauliflower. *J. Ento. Zoo. Stud.* **5**(2): 654-656.

Dotasara, S.K., Kumawat, K.C., Swami, D., Jat, G.C., Choudhary, H.S. and Jat, S.L. (2018). Assessment of crop loss due to insect pests in Indian mustard in semi-arid region of Rajasthan. *J. Ento. Zoo. Stud.* **6**(3): 770-772.

Ebssa, L. and Koppenhofer, A.M. (2011). Efficacy and persistence of entomopathogenic nematodes for black cutworm control in turfgrass. *Bio. Sci. Tech.* **21**: 779-796.

Edris, K.M., Islam, A.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, BAU and Govt. Peoples' Republic of Bangladesh. pp.118.

Egambaram, S. (2019). Pesticide resistance and its management in insect pests. *Agro. New*. **18**: 82-83.

FAOSTAT (2018). Food and Agricultural Commodities Production, FAOSTAT, Food and Agricultural Organization of the United Nations. Accessed 6th June, 2020. pp.1-2.

Gami, J.M., Bapodra, J.G. and Rathod, R.R. (2004). Estimation of avoidable yield loss due to pest complex in mustard. *Agric. Sci. Dig.* **24** (4): 309-310.

Ghule, D.D. and Bagde, A.S. (2016). Efficacy of different insecticides against mustard aphid *L. erysimi* infesting mustard crop. *J. Global Bio. Sci.* **5** (5): 4109-4113.

Gomez, M.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons. New York, Brisbane, Toronto. pp. 207-215.

Gupta, M.P., Verma, M.L., Chourasia, S.K. and Rai, H.S. (2003). Assessment of avoidable yield losses in Karan Rai (*Brassica carinata* Braun) varieties due to mustard aphid *(Lipaphis erysimi* Kalt.). *Ann. Plant Prot. Sci.* **11**(1): 225-228.

Gupta, R.; Agrawal, N.; Pandey, S.D. and Srivastava, J.P. (2001). Management of mustard aphid, *Lipaphis erysimi* (Kalt.) using botanical pesticides. *Flora. Fauna J.* **7**(2): 58-63.

Harika, G., Dhurua, S., Madugula, S. and Sreesandhya, N. (2019). Evaluation of certain insecticides against diamondback moth (DBM) *Plutella xylostella* on cauliflower. *Int. J. Bio-res. Stress Manage.* **10**(1): 70-76.

Huger, P.G., Anandhi, P., Verma, S. and Sarvanan, L. (2008). Seasonal incidence of important insect-pests of mustard and their natural enemies in relation to weather in Allahabad region. *J. Ento. Res.* **32**(2): 109-112.

Jagadish, K.S. and G. Gowda. (1994). Efficacy of certain insecticides as seed treatment in the management of cowpea stem fly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae). *Seed Res.* **22**(2): 156-159.

Jat, D.S., Jat, M.C. and Sharma, M.M. (2006). Seasonal incidence of insect-pests of mustard in relation to abiotic factor. *Ann. Plant Prot. Sci.* **14**(2): 475-476.

Jeyasankar, A. (2012). Antifeedant, insecticidal and growth inhibitory activities of selected plant oils on black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae). *Asian Pacific J. Trop. Dis.* **2**: 347-351.

Joshi, M., Varadharasu, P., Solanki, C. and Birari, V. (2020). Potato Cutworm, *Agrotis ipsilon*: An Overview and their Management. *Agric. Food*. **2**(5): 188.

Kafle, K. (2015). Management of Mustard aphid *(Lipaphis erysimi*). *Int. J. App. Sci. Biotech*. **3**(3):537-540**.**

Kedia, A., Prakash, B., Mishra, P.K., Singh, K. and Dubey, N.K. (2015). Botanicals as eco friendly biorational alternatives of synthetic pesticides against *Callosobruchus* spp. (*Coleoptera: Bruchidae*)-a review. *J Food Sci. Technol.* **52**(3):1239-1257.

Khan, S., Prasad, G., Bhadauria, V.N.S., Shrivastva, V.K. and Bhadauria, N.K.S. (2015). Effect of chemical and botanical insecticides on mustard aphid *Lipaphis erysimi* (Kalt.) and its parasite. *J. Bhartiya Krishi Anus. Patrika*. **30**(3): 131-133.

Khan, S.A, and Jha,S. (2010). Effect of dates of sowing, moisture regimes, varieties and weather factors on incidences of aphid, *Lipaphis erysimi* (Kalt.) in rape and mustard. *The J. Plant Prot. Sci.* **2**(2): 9-18.

Kolte, S.J. (2009). Management of major diseases and pests of mustard in India (online). Available at http://gcirc.org/fileadmin/documents/Bulletins/B25/B25_04Mustard_in.pdf.

Krishna K.N.K., Krishna M.P.N. and Eswara, R.S.G. (2001). Imidacloprid and thiamethoxam for control of okra leafhopper, *Amrasca biguttula biguttula* (Ishida). *Pest Manage. Hort. Eco.* **7**(2): 117-123.

Kular, J.S and Kumar, S. (2010). Quantification of avoidable yield losses in oilseed *Brassica* caused by insect pests. *J. Plant Prot.* **51**(1): 254-258.

Kumar, M. and Trivary, S.K. (2009). Variability of varietal resistance of potato against cutworm, *Agrotis ipsilon.* Hufnagel. *Proc. Zoo. Soc. India.* **8**(1)111-114.

Kumar, M.P., Rahman, A. and Saikia, J. (2015). Efficacy of two neonicotinoids against mustard aphid, *Lipaphis erysimi* (Kalt.) and their toxicity to honey bee, *Apis cerana* F. *Pest. Res. J.* **27**(2): 187-190.

Kumar, S. (2016). Potential of Ethiopian mustard, *Brassica carinata* as a trap crop for large white butterfly, *Pieris brassicae* infesting Indian mustard, *Brassica juncea*. *J. Pest Sci.* **24**(2): 256.

Kumar, S. (2017). Assessment of avoidable yield losses in crop Brassicas by insect pests. *J. Ento. Zoo. Stud.* **5**(3): 1814-1818.

Kumar, S. (2018). Aphid-Plant Interactions: Implications for Pest Management. *Intech Open*. pp. 1-12.

Kumar, S. and Kumar, A. (2016). Bio-efficacy of biopesticides and certain chemical insecticides against mustard aphid (*Lipaphis erysimi* Kalt.) on mustard crop under field condition. *Int. J. Plant Prot.* **9**(1): 129-132.

Link, D., Weber, L.F. and Leal, R.S. (2000). Control of black cutworm, the tobacco stem corer and the green peach aphid with insecticides sprayed on tobacco seedlings produced by float system. *Revista-de-Agricultura-Piracicaba.* **75**: 175-186.

Malik, A.Q., Sahito, H.A., Kousar, T., Mal, B., Abbasi, N.A., Soomro, A.A., Jaffery, S.M., Mastoi, S.M., Jatoi, F.A. and Mangrio, W.M. (2017). Sub-lethal effects of methoxyfenozide on development and fecundity of cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) on cauliflower. *J. Adv. Bot. Zoo.* **5**: 301-306.

Miah, M.A.M. and Mondal, M.R.I. (2017). Oilseeds sector of Bangladesh: challenges and opportunities. *SAARC J. Agri.* **15**(1): 161-172.

Miah, M.M. and Rashid, M.A. (2015). Profitability and comparative advantage of oilseed production in Bangladesh. *Bangladesh Develop. Stud*. **38**(3): 35-54.

MoA (2008). Agricultural Handbook of Bangladesh, 2007. Ministry of Agriculture, Government of Bangladesh, Dhaka.

Nagar, A., Singh, S.P., Singh, Y.P., Singh, R., Meena, H. and Nagar, R. (2012). Bioefficacy of vegetable and organics oils, cakes and plant extracts against mustard aphid. *Lipaphis erysimi* (Kalt.). *Indian J. Ento.* **74**(2): 114-119.

Ojha, K.N. and Nath, P. (1987). Studies on the relative preference of different cultivars to *Agrotis ipsilon* in Varanasi. *Indian J. App. Ento.* **1**: 17-20.

Pal , S., Singh, D.K. and Ram, S.U. (2018). Population dynamics of insect pests in mustard and eco-friendly management of *Lipaphis erysimi* (Kaltenbach) in Uttrakhand. *Int. J. Curr. Microbiol. App. Sci.* **7**(7): 324-331.

Pal, S. and Debnath, P. (2020). Seasonal incidence of major insect pests and predators of mustard in lower gangetic plains of West Bengal, *J. Ento. Zoo. Stud.* 8(6): 1424-1430.

Parmar, G.M., Kapadia, M.N., Jadav, N.B. and Zizala, V.J. (2007). Avoidable losses in mustard due to *Lipaphis erysimi* (Kalt.). *Asian J. Bio. Sci.* **2**(2): 73-75.

Patel, S., Yadav, S.K. and Singh, C.P. (2017). Bio-efficacy of insecticides against *Lipaphis erysimi* (Kalt.) in mustard ecosystem. *J. Ento. Zoo. Stud.* **5**(2): 1247-1250.

Patel, S.R., Awasthi, A. and Tomar, R.K.S (2004). Assessment of yield losses in mustard occur (*B. juncea* L.) due to *Lipaphis erysimi* (Kalt.) under different thermal of environment in eastern central India. *Applied Eco. Environ. Res.* **2**: 1-5.

Pawar, V.R., Bapodra, J.G., Joshi, M.D. and Gaikwad, S.E. (2009). Screening of mustard genotypes for resistance to leaf Webber, *Crodolomia binotalis* (Zeller). *Int. J. Plant Prot*. **2**(2): 209-210.

Pink, D.A., Ellis, P.R., McClement, S.J., Lynn, J., Tatchell, G.M. (2003). Genetic Control of Resistance to the Aphid *Brevicoryne brassicae* in the Wild Species *Brassica Fruticulosa*. *Plant Breeding*. **122**(1): 24–29.

Pradhan, P.P., Borkakati, R.N. and Saikia, D.K. (2020). Insect pests of mustard and their natural enemies in Assam. *Int. J. Curr. Microbiol. App. Sci.* **9**(7): 2785-2790.

Pravin, G.S., Divekar, P., Singh, D., Pal, D. and Nadaf, A. (2021). Bio-pesticide management strategy for mustard aphid *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae). *The Pharma Inn. J*. **10**(7): 397-400.

Rao, B.B., Ramaraj, A.P. and Chattopadhyay, H. (2012). Predictive model for mustard aphid infestation for eastern plains of Rajasthan. *J. Agro*. **14**(1): 60-62.

Razaq, M., Aslam, M., Amer, M. and Shad, S.A. (2011). Insect pest status of aphids on oilseed *Brassica* crops and need for chemical control. *Crop Environ.* **2**(2): 60-63.

Reshi, N.D. (1967). Studies on insect pests of Kashmir part. vegetables, major pests with their life history and control measures. *Kashmir Sci.* **4**: 66-69.

Sahito, H.A., Longer, A.G. and Mai, B. (2010). Studies on population dynamics of sucking insect pests of mustard crop (*Brassica campestris). Pak. J. Agri.* **26**(1) 66-74.

Sahoo, S. (2016). Estimation of yield losses in *Brassica* due to insect pests. *Indian J. Ento.* **78**: 317.

Sahoo, S.K. (2012). Incidence of mustard aphid (*Liphaphis erysimi* Kalten bach) in West Bengal. *J. Plant Prot. Sci.* **4**(1): 20-26.

Sahu, V., Singh, R.P., Yadav, R.R., Kumar, A., and Bareliya P.K. (2018). Evaluate the efficacy of insecticides, botanicals, entomopathogenic fungal and biocontrol agent against infestation of aphid, *Lipaphis erysimi* on mustard. *Int. J. Pure App. Bio. SPI.* **6**(3): 538-543.

Sampa, A.Y., Sarker, F., Rahman, M.R. and Begum, R. (2020). Profitability and resource use efficiency of mustard cultivation. *SAARC J. Agric*. **18**(2): 195-206.

Santos, L. and Sheilds, E.J. (1998). Yield response of corn to stimulated black cutworm (Lepidoptera: Noctuidae) damage. *J. Economic Ento.* **91**: 748-758.

Sen, K., Samanta, A., Hansda, A., Dhar, P.P. and Samanta, A. (2017). Bioefficacy and economics of some insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) infesting mustard. *J. Crop and Weed*. **13**(2): 235-237.

Shah, M. M. R., Maula, A. K. M., Siddquie, M. N. A. Mamun, M. A. A. and Islam, M. S. (2008). Effect of insecticides on the growth parameters, yield and oil content of mustard. *Int. J. Sustain. Crop Prod*. **3**(6):11-15.

Sharma, D., Yadav, S.P. and Yadav, S. (2019). Assessment of avoidable yield losses due to *Lipaphis erysimi* Kalt in various Brassica spp. *Indian J. Cur. Microb. App. Sci.* **8**(6): 2020-2025.

Sharma, P., Kumawat, K.C., Khinchi, S.K., Kumar, V. and Prasad, B. (2017). Bioefficacy of different insecticides against diamondback moth. *Int. J. Chem. Stud*. **5**(3): 891-893.

Sharma, P.K. and Bhagat, R.M. (2000). Comparative efficacy of various insecticides used as seed and soil treatments against cutworm, *Agrotis ipsilon* (Rott.) infesting maize. *J. Ento. Res.* **24**: 163-165.

Shinwari, N. (2014). Potato cutworm: *Agrotis ipsilon*; *Peridroma saucia.* Plant. Know. Bank. pp. 1- 2.

Showers, W.B., Kaster, L.V., Sappington, T.W., Mulder, P.G., Whitford, F. and Von. K.L. (1983). Corn seedling growth stage and black cutworm (Lepidoptera: Noctuidae) damage. *Environ. Ento.* **12**: 241-244.

Silva, M.T.B. (1998). Inseticidas na proteção de sementes e plantas. *Seed News. Pelotas.* **2**(5): 26-27.

Singh, C, Lai, M.N. and Singh, P.S. (2012). Occurrence of insect pests on rapeseed, *Brassica rapa* (var. YST-151) and its association with weather variables in eastern Uttar Pradesh. *Ind. J. Ent*. **74**(2): 183-185.

Singh, C. and Lal, M.N. (2009) Bio-efficacy of plant extracts against mustard aphid, *Lipaphis erysimi* (Kalt.) in *Brassica* oilseed crops. *Crop Res.* **37**: 203-206.

Singh, D.K., Pal, S., Dwivedi, R.K. and Singh, A.K. (2014). Bio-intensive pest management of mustard aphid, *Lipaphis erysimi*. *Ann. Plant Prot. Sci.* **22**(2): 327-331.

Singh, H. Deshwal, H.L. Haldhar, S.M. and Singh, V. (2017). Bio-efficacy of some insecticides and botanicals against mustard aphid, *Lipaphis erysimi* Kalt. (Hemiptera: Aphididae) on Indian mustard. *J. Exp. Zoo. India.* **20**(1): 249-253.

Sreeja, S. and Kumar, A. (2022). Field efficacy of selected chemicals and biopesticides against mustard aphid [*Lipaphis erysimi* (Kaltenbach)] on mustard [*Brassica juncea* (L.)] at Prayagraj (U.P.). *The Pharma Inn. J.* **11**(5): 1706-1710.

Sreelatha, M. and Divakar, B.J. (1997). Impact of imidacloprid seed treatment on insect pest incidence in okra. *Indian J. Pl. Protect.* **25**: 52-55.

Srivastava, A. and Prajapati, R. (2012). Population build up of mustard aphid, *Lipaphis erysimi (Kalt.)* on Brassica in relation to weather factors. *J. Insect Sci. Ludhiana*. **12**(2): 141-142.

Thakur, S.P. and Kashyap, N.P. (1992). Unusual occurrence of black cutworm, *Agrotis ipsilon* (Rottenburg) in Himachal Pradesh. *Himachal J. Agric. Res.* **18**: 64-66.

Thakur, S.S. and Vaidya, D.N. (2000). Management of cutworm, *Agrotis ipsilon* in maize. *Insect Environ.* **6**: 91-92.

Thangjam, R., Borah, R. K. and Saikia, D. K. 2017. Pest complex of king chilli, *Capsicum chinensis* (Jacquin) in Assam, North- East India. *The Bioscan,* **12**: 2069-2073.

Uddin, M.J., Ahmed, S., Harun–or–Rashid, M., Hasan, M.A. and Asaduzzaman, M. (2011). Effect of spacing on the yield and yield attributes of transplanted Aman rice cultivars in medium lowland ecosystem of Bangladesh. *J. Agric. Res.* **49**(4): 465-476.

Venkateswarlu, V., Sharma, R.K. Chander, S. and Singh, S.D. (2011). Population dynamics of major insect pests and their natural enemies in cabbage. *Ann. Plant Prot. Sci.* **19**: 272-277.

Verma, K.S. and Verma, A.K. (2002). Biological studies of *Agrotis ipsilon* (Hufnagel) in Himachal Pradesh. *Himachal J. Agric. Res*. **28**: 43-47.

Waskel, V. (2010). Screening of mustard varieties *Brassica juncea* (Czern and Coss) against mustard aphid *Lipaphis erysimi* (Kalt.). M.Sc (Ag.) thesis submitted to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P). pp.173.

Zaki, F.A., Bhat, Z.H. and Wani, A.R. (2006). Evaluation of some insecticides and biopesticides against cutworm, *Agrotis ipsilon* Hufnagel damaging potato under rainfed conditions of Kashmir valley. *Oriental Sci.* **11**(2): 81-85.

Zambolim, L. (2005). Sementes: qualidade fitossanitária. *Viçosa: UFV*. pp.502.

APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

Appendix III. Monthly meteorological information during the period from October 2021to February, 2022

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on aphid population at early, mid and late flowering stages

Source	Df	Incidence of aphid		
		Early	Mid	Late
Replication	2	0.1280	0.0605	0.0845
Treatment	4	23.3429	32.5298	41.8448
Error	8	0.0480	0.0305	0.0470

** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on aphid population at early, mid and late fruiting stages

Source	Df	Incidence of aphid		
		Early	Mid	Late
Replication	2	0.0845	0.0500	0.2880
Treatment	4	17.0588	22.1348	41.6423
Error	8	0.0495	0.0200	0.1880

** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on aphid infested mustard plant at flowering stage

Source	Df	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant
Replication	2	0.51200	0.01922	0.3538
Treatment	4	5.22369	5.22369	58.0256
Error	8	0.16700	0.01772	0.1888

** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on aphid infested mustard plant at fruiting stage

Source	Df	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant
Replication	2	1.2667	0.0320	0.800
Treatment	4	13.7554	13.4557	149.528
Error	8	1.2667	0.0170	0.300

** : Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on cutworm population at early, mid and late flowering stages

Source	Df	Incidence ofcutworm		
		Early	Mid	Late
Replication	2	0.0140	0.00338	0.00600
Treatment	4	11.1671	3.01029	1.86375
Error	8	0.0090	0.00188	0.00350

** : Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on cutworm population at early, mid and late fruiting stages

Source	Df	Incidence of cutworm		
		Early	Mid	Late
Replication	2	0.0080	0.0125	0.0140
Treatment	4	12.0840	12.7590	11.2298
Error	8	0.0047	0.0085	0.0090

** : Significant at 0.01 level of probability

Appendix X. Analysis of variance of the data on cutworm infested mustard plant at flowering stage

Source	Df	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant
Replication	2	0.20000	0.01058	0.0320
Treatment	4	2.60604	2.51004	27.9061
Error	8	0.20000	0.00758	0.0120

** : Significant at 0.01 level of probability

Appendix XI. Analysis of variance of the data on cutworm infested mustard plant at fruiting stage

Source	Df	Healthy plant (No.)	Infested plant (No)	% infestation of infested plant
Replication	2	0.26600	0.01998	0.3120
Treatment	4	5.56929	5.22369	58.0256
Error	8	0.19100	0.01773	0.2120

** : Significant at 0.01 level of probability

Appendix XII. Analysis of variance of the data on plant height, number of branches plant^{1} and number of siliqua plant^{-1} of mustard

Source	Df	Plant height (cm)	No. branches plant^{-1}	No. siliqua plant^{-1}
Replication	2	1.400	0.2000	3.200
Treatment	4	122.353	14.6225	369.320
Error	8	2.150	0.2000	7.700

** : Significant at 0.01 level of probability

Appendix XIII. Analysis of variance of the data on siliqua length, Number of seeds siliqua^{-1}, 1000 seed weight and yield of mustard

Source	Df	Siliqua length (cm)	No. seeds siliqua^{-1}	1000 seed weight	Yield (t ha^{-1})
Replication	2	0.00168	1.0783	0.01400	0.00098
Treatment	4	0.36000	22.3886	0.15081	0.41349
Error	8	0.00368	0.8408	0.00650	0.00098

** : Significant at 0.01 level of probability