EFFECT OF INSECTICIDES APPLICATION TIMING ON INSECT PEST ATTACK, GROWTH, YIELD AND NUTRIENTS CONTENT OF MUSTARD

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DECEMBER, 2021

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A Thesis
Submitted to the Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

AGRICULTURAL CHEMISTRY

SEMESTER: JULY-DECEMBER, 2021

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF INSECTICIDE APPLICATION TIMING ON INSECT PEST ATTACK GROWTH, YIELD AND NUTRIENT CONTENT OF MUSTARD”** submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bonafide research work carried out by **MD. OMAR FARUK**, Registration No. 19-10310 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

December, 2021
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Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his 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 his gratitude and best regards to his respected Supervisor, ***Prof. Dr. Md. Abdur Razzaque****, Department of Agricultural Chemistry, 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 his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, ***Prof. Dr. Mohammed Sakhawat Hossain****, 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 his heartfelt thanks to the honorable Chairman, ***Prof. Dr. Sheikh Shawkat Zamil,*** *Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, along with all other teachers and staff members of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

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

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

The Author

EFFECT OF INSECTICIDE APPLICATION TIMING ON INSECT PEST ATTACK GROWTH, YIELD AND NUTRIENT CONTENT OF MUSTARD

ABSTRACT

The present experiment was carried out at Sher-e-Bangla Agricultural University research farm, Dhaka during the period from October 2020 to March 2021 to study the effect of insecticide application timing on insect pest attack growth, yield and nutrient content of mustard. Five treatments *viz*. T_0 (Control; without insecticide application (control), T_1 (Aktara; Thiamethoxam 25WG application in morning), T_2 (Aktara; Thiamethoxam 25WG application in afternoon), T_3 (Celcron; Profenofos 50EC application in morning) and T_4 (Celcron; Profenofos 50EC application in afternoon) were considered for the present study. Treatments were applied at 30 days after sowing. The experiment was laid out in Randomized Complete Block Design with three replications. The maximum effectiveness was found from the treatment Aktara (Thiamethoxam 25WG) application in afternoon whereas Celcron (Profenofos) 50EC application in morning showed least performance in controlling insect of mustard compared to control. At 24, 48, 72 and 96 hours of spray, Celcron (Profenofos) 50EC application in morning showed the lowest incidence of insect plot^{-1} (18.40, 25.33, 42.67 and 63.33, respectively). In case of mortality of insect, at 24, 48 and 72 hours of spray, the highest number of dead sawfly (21.67, 14.33 and 3.33 plot^{-1}, respectively) and dead aphid (48.33, 33.00 and 11.33 plot^{-1}, respectively) was recorded from Aktara (Thiamethoxam 25WG) application in afternoon but the number of dead bee (37.33, 24.33 and 7.00 plot^{-1}, respectively) was highest from the treatment Aktara (Thiamethoxam 25WG) application in morning whereas the lowest mortality was found from the treatment Celcron (Profenofos) 50EC application in morning for sawfly and aphid but the lower mortality of bee was found from Aktara (Thiamethoxam 25WG) application in afternoon and Celcron (Profenofos) 50EC application in afternoon. Similarly, the highest number of flowers plant^{-1} (126.00), number of pods plant^{-1} (112.70), number of seeds pod^{-1} (37.67), 1000 seed weight (4.10 g), seed yield ha^{-1} (1.87 t) and % oil content (40.33%) were recorded from Aktara (Thiamethoxam 25WG) application in afternoon. The maximum K content in seed (1.244%) was found from Aktara (Thiamethoxam 25WG) application in afternoon compared to control. It can be concluded that the treatment Aktara (Thiamethoxam 25WG) application in afternoon showed effective performance against insect of mustard followed by Celcron (Profenofos) 50EC application in afternoon. Again, it was also observed that application of insecticide in the afternoon was more effective than application of insecticide in the morning for both the insecticide of Aktara and Celcron 50EC.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Mustard *(Brassica* sp.) commonly known as 'Sarisha' in Bangla is the main cultivable edible *rabi* oilseed crop of Bangladesh. It is one of the most important oil seed crops of the world after soybean and groundnut (FAO, 2012). It is is being cultivated throughout the country during the winter season (November to March). It has a remarkable demand for edible oil in Bangladesh. Bangladesh occupies the 5^{th} place in respect of total oil seed production in the world and mustard occupies the first position in respect of area (61.2%) and production (52.6%) among the oil crops grown in Bangladesh (BBS, 2010).

Mustard oil plays an important role as a fat substitute in our daily diet. This oil is widely used in cooking and as medical ingredients. Mustard is not only a rich source of energy (about 9 kcal g^{-1}), but also rich in fat soluble vitamins like A, D, E and K (Alim *et al*., 2020). Mustard seeds contain 40-45% oil and 20-25% protein and mustard oilcake contains 40% protein that is used as nutritious animal feed and high quality manure for crop production (Alim *et al*., 2020). With increasing population, the demand of edible oil is increasing day by day.

The area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of *boro* rice. Among the oil seed crops grown in Bangladesh, mustard tops the list in respect of both production and acreage (BBS, 2015). The present area and production of mustard is 3.25 lac hectare and 3.59 lac metric ton respectively (BBS, 2018). The average yield of mustard in Bangladesh is very low (1.08 t ha^{-1}) (BBS, 2018) compared to other oilseeds growing countries of the world. Presently, on an average, 2.3 to 2.4 million tonnes of edible oils, both in oil and seeds form, are imported in the country (Alam, 2018). The internal production of edible oil can meet up only less than one-third of the annual requirement (Mondal and Wahhab, 2001). The major reasons for low yield of rapeseed-mustard in our country are due to lack of high yielding variety and proper management practices e.g. insect pest management, balanced nutrition, use of organic matter to maintain soil fertility level etc. There is a great scope of increasing yield of mustard by selecting high yielding varieties, improving nutrient and pest management practices (Bhuiyan *et al.*, 2008).

Among various constrains in the productivity of rapeseed-mustard, the biotic stresses caused by insects, fungi, bacteria, viruses and weeds together contributes to the yield loss of nearly 45% annually (Sharma *et al*., 2018). Among various biotic factors, insect pests play a major role for reducing the crop yield of rapeseed-mustard. Pests and diseases can reduce crop yield as well as its quality and subsequent returns. Insect pests and diseases can drastically reduce crop yield as well as its quality and subsequent returns. Among different insect pest of mustard, aphids, sawfly, leaf miner and diamond back moth, are the major pests on *Brassica*. Yield losses due to these pests extent from 20-70% (Reddy, 2009). Mustard aphid is the most serious one causes damage to the extent of 11.6-99% (Mishra and Agarwal, 1992). The nymphs and adults of the aphid suck cell sap from the inflorescence, terminal twig, siliqua (pod), leaves and branches. The pest causes 35.4 to 73.3 percent yield loss, 30.09 percent seed weight loss and 2.75 percent oil loss as reported by Bakhetia and Sekhon (1989), Singh and Premchand (1995) and Sharma and Kashyap (1998), respectively. Mustard sawfly which attacks the crop during seedling stage causes damage from 3.4 to 38 % (Singh *et al*., 2008). Combined infestation due to mustard aphid and sawfly varied from 34.62 to 59.33 % (Sahoo, 2016).

The principal role of honey bee in agriculture is pollination. These insects are of great economic importance because they not only produce honey and bee wax, but also act as primary pollinating agents of many agricultural and horticultural crops.

Honeybees are very important social insect known as the most economically valuable insect because of its honey production and pollinating activities (Lawal and Banjo 2010). Cross pollination of entomophile crops by honey bees are considered as one of the effective and the cheapest methods for triggering the crop yield both qualitatively and quantitatively (Singh *et al*. 2005 and Mohapatra *et al*. 2010).

An opportunity to fact the pest challenge by manipulating the manageable ecological parameters in the form of planting or harvesting time adjustment, varietal selection, correct time of pesticide application, etc. To control insect pests, most of the farmers prefer on the application of chemical insecticides in the field. A wide range of insecticides are being used to control insect pests. Systemic insecticides are very effective in controlling the sucking as well as chewing insect pests. The negative effects of pesticides on non-target organisms such as honeybees and other pollinators, increased cost of cultivation of per unit area, degradation of important ecosystem services such as control by natural enemies and creating significant hazards to human health (Corriols *et al*., 2009).

Time of insecticide application is important factor for successful management practice of insect pest in the crop field. Insecticide application in time reduces amount and frequencies of application in crop field which helps to reduce pest population successfully and is less hazardous for human and environment. Mortality of beneficial insect also reduces effectively through timely application of chemical insecticide.

Keeping all the above fact in view, the present investigation was undertaken to study the influence of insecticides application timing on insect attack and morphology, yield contributing characters, yield and nutrient content of mustard with the following objectives:

1. To investigate the effect of insecticides application timing on insect pest attack in mustard field.
2. To study the effect of insecticides application timing on growth, yield contributing characters, yield, oil and nutrients content of mustard.

CHAPTER II

REVIEW OF LITERATURE

The response of mustard to management of insect pest for its successful cultivation has been investigated by numerous investigators in various parts of the world. In Bangladesh, there have not enough studies on the effect of insecticide application timing on insect pest attack and growth, yield and nutrient content of mustard. However, the available research findings in this connection over the world have been reviewed in this chapter.

2.1 Insect pests of rapeseed-mustard

Bakhetia and Sekhon (1989) opined that, 38 insect pests are associated with rapeseed-mustard crop. The mustard aphid, *Lipaphis erysimi* (Kalt.) was considered as the key pest, whereas the sawfly, *Athalia lugens proxima* (Klug.), painted bug, *Bagrada hilaris* (Burm.), Bihar hairy caterpillar, *Diacrisia obliqua* (Walk.) and pea leaf miner, *Chromatomyia horticola* (Goureau.) were categorized as major pests. The cabbage butterfly, *Pieris brassica* (Linn.), flea beetle, *Phyllotreta cruciferae* (Goeze.), green peach aphid, *Myzus persicae* (Sulz.), diamond back moth, *Plutella xylostella* (Linn.) were considered to be minor pests. Other important pests like cabbage aphid, *Brevicoryne brassicae* (Linn.), larger cabbage moth, *Crocidolomia binotalis* (Zell.), cabbage top borer, *Hellula undalis* (Fab.), whitefly, *Bemisia tabaci* (Gen.), cabbage semi-looper, *Plusia orichalcea* (Fab.), turnip moth, *Agrotis segetum* (Dennis and Schiff) were recorded as new pests at that time.

Choudhury and Pal (2006) studied the pest and natural enemy complex of mustard during rabi seasons. Their studies revealed that 14 insect pests infest the mustard crop and among them mustard aphid, *L. erysimi (*Kalt.) was found most dominant and categorized as major pest. The studies revealed that 21 species of insect pests infest the mustard crop. The mustard aphid, *L. erysimi* was found as a key pest during the study period. Whereas, painted bug, *B. cruciferarum* was considered as a major pest, first at seedling stage and second at harvesting stage when the crop was at maturity. The sawfly, *A. lugens proxima* and pea leaf miner, *C. horticola* were categorized as serious pest. While flea beetle, *P. cruciferae* was recorded as a minor pest of the mustard crop (Singh *et al*., 2007). However, about 43 insect species have been found infesting mustard crop in Pakistan (Khan *et al*., 2013).

Bhati *et al*. (2015) reported from a study that 4 insects *viz*., mustard aphid (*L. erysimi*), mustard sawfly (*A. lugens proxima*), painted bug (*B. hilaris*) and cabbage butterfly (*P. brassicae*) were found attacking at different growth stages of rapeseed-mustard crop.

A study carried out by Singh *et al*. (2018) revealed that, a total of five insects *viz*. mustard sawfly, mustard aphid, painted bug, cabbage butterfly and coccinellids were associated with the mustard crop from germination to pre-harvest.

2.2 Incidence of aphid and mustard sawfly as major insect of mustard

2.2.1 Aphid (*Lipaphis erysimi*)

Gour and Pareek (2003) reported that the incidence of mustard aphid started in the 3rd week of November (6.34 aphids/10 cm twig), reached to its peak (102.24 aphids/10 cm twig) in the second week of January and disappeared from the third week of February.

As per the report of Takar *et al*. (2005), *L. erysimi* appeared on mustard in the first week of January (16.3 aphids/plant) and reached its peak (764.2 aphids/plant) in second week of February.

Ansari *et al*. (2007) observed the appearance of mustard aphid on 11thJanuary i.e.60 days after sowing (DAS) (2.56 aphids/10 cm twig) and disappeared after 2nd March i.e. 110 DAS of mustard with the peak (83.42 aphids/10 cm twig) on 10thFebruary when maximum, minimum and average temperature and mean relative humidity were23.37, 6.87 and 15.760 C and 54.75 percent, respectively.

The incidence of mustard aphid, *L. erysimi* started in the last week of December (16.90 and 12.23/10 cm terminal shoot) and reached on peak in 2ndweek of February with 284.15/10 cm and 364.45/10 cm terminal shoot on mustard (Jandial and Kumar, 2007).

Hugar *et al*. (2008) at Allahabad in Uttar Pradesh found that the infestation of the mustard aphid, *L. erysimi* commenced (2.60 aphids/plant) in the 1stweek of December and reached to peak in 3rdweek of January with 825 aphids/plant.

Hasan *et al*. (2009) observed that the aphid infestation was varied significantly at various parts of mustard plant and time of the day. The highest population was observed during the vegetative period followed by flowering and poding stage (88.22, 32.5 and 64.75 mean number of aphids/10 plants, respectively).

Singh *et al*. (2009) studied the influence of environmental factors on the population fluctuation of aphid, L. erysimi and reported that the infestation commenced from 3rdweek of December (0.2 aphid/10 cm twig) and reached at peak during 2ndweek of February (292.0 aphids/10 cm twig). During the peak period of aphid population, maximum temperature, minimum temperature and morning relative humidity were 24.7 to 24.8 °C, 10.6 to 14.5 °C and 83.6 to94.7 per cent, respectively.

Khedkar (2011) reported that aphid population commenced from 6thweek after sowing (WAS) i.e.1st week of January (1st SMW) with 0.31 aphid index. The activity of pest increased steadily and reached to the peak (3.88 aphid index) at 12thWAS coinciding with the 3rd week of February (7th SMW). The population gradually declined as the crop reached towards the maturity and disappeared from 15th WAS (10thSMW). Overall, the activity of pest was observed during 1stweek of January to 2nd week of March (starting from flowering stage to harvest of the crop) in the range of 0.31 to 3.88 aphid index with one peak.

Achintya and Debjani (2012) reported that infestation of *L. erysimi* was found to be influenced by various weather parameters maximum and minimum temperature, average wind speed and bright sunshine hours had significant positive correlation with number of *L. erysimi* individuals/sampling unit.

Kavad (2013) reported that activity of *L. erysimi* on mustard crop was begun in starting of December during 2011, while it was first appeared in last week of December during 2012. Its population was at low level up to December, but gradually increased in subsequent weeks. Peak population of the pest was registered in first week of February during first (104.58 aphids/twig) and second (82.04 aphids/twig) year of investigation. Thereafter, it was in decreasing trend up to harvest of the crop.

Malik and Sachan (2013) found that incidence of mustard aphid started in 51ststandard week i.e.3rdweek of December and reached to peak level in 5th standard week i.e.1st week of February and 8th standard week i.e. 4th week of February during both years, respectively. The studies revealed that positive correlation with maximum temperature that is non-significant in 2010-11 and significant during 2011-12, positive and non-significant correlation existed with minimum temperature and a negative and non-significant correlation was observed with mean relative humidity during both years.

2.2.2 Sawfly (*Athalia lugens proxima*)

Mustard sawfly infestation commenced after 3rdweek of sowing and increased the population in the last week of December. The pest reached to a peak level of 1.70, 1.90 and 2.30 larvae per plant on varieties GM-1, GM-2 and Varuna, respectively (Bhatt and Bapodra, 2004).

Patel (2005) studied effect of different weather parameters on incidence of mustard sawfly and reported that population was negatively correlated with bright sunshine hours, maximum temperature, minimum temperature, mean temperature, morning vapour pressure, evening vapour pressure, mean vapour pressure deficit and temperature range while it was positively correlated with evening and mean relative humidity.

Khedkar (2011) noticed that the pest appeared (0.33larva/quadrate (30 × 30 cm)) on the crop during 2^{nd} week after sowing (WAS) i.e. 2^{nd} week of December (49^{th} SMW) and reached to a first peak (0.90) during 4^{th} WAS (51^{st} SMW). There was slight reduction (0.83) in a subsequent weeks (5^{th} WAS –52^{nd} SMW) and again showed a second peak (1.83) during 6^{th} WAS coinciding with 1^{st} week of January (1^{st} SMW). The population declined at 9^{th} WAS (0.15) and disappeared from the crop i.e. 10^{th} WAS (5^{th} SMW). Thus, the activity of mustard sawfly was observed only during seedling stage i.e. from December to January on mustard crop with two peaks.

Singh *et al*. (2012) reported that sawfly (*A. lugens proxima*) appeared at early stage of crop growth from 0.17 to 0.55 grubs per plant during rabi 2005-06 and 0.62 to 1.78 grubs per plant during rabi 2006-07. During the two crop seasons, mustard sawfly was found attacking the crop at early stage of growth. This insect was observed from the 47^{th} to the 51^{st} standard week and from the 49^{th} to the 52^{nd} standard weeks during rabi 2005-06 and 2006-07, respectively.

2.3 Incidence of bee as beneficial insect of mustard in study area

The principal role of bee (honeybee) in Agriculture is pollination. Incidence of honeybees in crop field are of great economic importance because they not only produce honey and bee wax but also act as primary pollinating agents of many agricultural and horticultural crops. They are among the most important pollinating insects found within orchards and modern agricultural systems (Williams, 1994; Morse and Calderone, 2000). There are many species of honeybee, but four species are common these are *Apis florae*, *Apis dorsata*, *Apis cerana* and *Apis mellifera* are commons.

Of the 100 crops that provide 90% of the world‘s food, 71 are bee pollinated, and honey bees (*A. mellifera*) are the managed pollinator conscripted to provide the necessary pollination services for most of these crops (FAO, 2005).

2.4 Effect of insecticide as pest management practices

Kumar *et al*. (2007) studied the efficacy of nine insecticides against *L. erysimi* (Kalt.) on mustard (cv. Varuna) as foliar spray at Meerut, Uttar Pradesh during Rabi season of 2003-2004. Studies revealed that, after one and three days of spraying, oxydemeton methyl 25 EC @ 0.025% was proved most effective and reduced 88.0% and 96.7% aphid population, respectively. However, on seventh day, imidacloprid 17.8 SL @ 0.0178% was found most effective (99.6%) followed by oxydemeton methyl 0.025%, monocrotophos 0.036%, dimethoate 0.03%, chloropyriphos 0.05% , malathion 0.05%, endosulfan 0.07%, cypermethrin 0.01% and neemarin.

A field experiment was carried out to study the effect of different chemical pesticides on mustard aphid (L. erysimi) at Peshawar, Pakistan during 2008. The lowest mean population of 6.43aphids/cm^2 was recorded on fastkil followed by confidor (high), confidor (medium) and actara (high) i.e. 7.09, 7.48 and 7.56

aphids/cm², respectively. Highest number of aphids (14.42aphids/cm²) was recorded in control. The population density of aphids recorded on other treatments like confidor (low), actara (medium) and actara (low) were 8.23, 9.21 and 11.09 aphids/cm², respectively (Sohail *et al*., 2011).

Field experiment conducted in Junagadh during rabi seasons of 2010 and 2011 on mustard (cv. GM-2) crop to study bio-efficacy of bio-pesticides against *L. erysimi*. Single application of imidacloprid 17.8 SL (0.005%) and acetamiprid 20 SP (0.004%) were found most effective against L. erysimi. However, combined application of *L. lecanii* @1.0kg/ha and imidacloprid 17.8 SL (0.0025%), *B. bassiana* (1.25kg/ha) and imidacloprid 17.8 SL (0.0025%), *L. lecanii* 1.0kg/ha and acetamiprid 20 SP (0.002%) and *B. bassiana* 1.25kg/ha along with acetamiprid 20 SP (0.002%) were found moderate effective. Sole application of *L. lecanii* @ 2.0kg/ha and B. bassiana @ 2.5kg/ha were less effective (Ghadage *et al*., 2014).

Aziz *et al*. (2014) evaluated different neem products against mustard aphid on canola crop at Pakistan during 2010-11. The results revealed that, after 2 nd spraying imidacloprid and neem seed oil resulted in maximum (100%) reduction over precount including nymph, wingless and winged adults of mustard aphid (*L. erysimi*) followed by neem seed cake extract (86.13, 89.90 and 68.48%) and neem seed kernel extract (77.41, 55.11 and 34.26%).

Yu *et al*. (2014) reported that, field application rates of imidacloprid @ 15-60 g a.i. /ha in cotton cultivation in china has potential risks to beneficial arthropods.

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.

Xiao *et al*. (2016) evaluated the effects of sublethal concentrations (LC5 and 10% LC5) of imidacloprid on *C. septempunctata* in China. The adult longevity was shortened by 23.97 and 28.68 %, and the fecundity reduced by 52.81 and 56.09 % as compared to control population. In the F_1 generation the juvenile development was slower by 1.44 days and 0.66 days, and the oviposition period was shortened by 10 and 13 days, respectively. The fecundity of the F1 generation decreased by 17.88, 44.03 and 51.69 % when exposed to 1% LC5, 10% LC5, and LC5, respectively.

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 25WG (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.

Seven insecticides and two botanicals were evaluated against mustard aphid at Bikaner, Rajasthan. It revealed that imidacloprid 0.005% spray was the most effective followed by Thiamethoxam 25WG 0.005% and dimethoate 0.03%, while oxydemeton methyl 0.025%, fenvalerate 0.02%, profenophos 0.005% and lufenuron 0.0025% were moderately effective. The treatment of NSKE 5.0% was observed less effective followed by azadirachtin 0.5% (Kumar *et al*., 2017).

Patel *et al*. (2017) evaluated the efficacy of some insecticides against *L. erysimi* on mustard crop at Pantnagar and noted that, 10 days after spraying Thiamethoxam 25WG 25 WG was the most effective showing the minimum (0.00) numbers of L. erysimi followed by imidacloprid (0.00) and dimethoate (0.67).

A field experiment was conducted to evaluate the bioefficacy of certain insecticides against mustard aphid, *L. erysimi* (Kalt.) on mustard. Results revealed that, among different insecticidal treatments the overall percent reduction of aphids over control was maximum with imidacloprid (72.86%) followed by Thiamethoxam 25WG (69.42%) treated plot (Sen *et al*., 2017).

Singh *et al*. (2017) evaluated some insecticides and botanicals against mustard aphid on Indian mustard (cv. Laxmi) crop under field conditions during rabi 2013-14 and 2014-15 at Rajasthan. Results revealed that, maximum percent reduction of aphid population was in imidacloprid (0.005%) treated plot followed by Thiamethoxam 25WG (0.005%) and dimethoate (0.03%) and the chemical caused 95.54, 91.80 and 90.85 % reduction, respectively. Moderate insecticides, such as acephate (0.02%), profenophos (0.03%) and spinosad (0.01%) reduced the aphid population to the tune of 68.33, 67.25 and 64.58 %, respectively. Botanicals like neem oil 1ml/l, NSKE 5ml/l and karanj oil 5ml/l gave minimum reduction of aphid population i.e. 59.93, 58.41 and 53.65%, respectively.

2.5 Effect of insecticide against bee

Honey bees, like other insects, are reasonably sensitive to a range of chemical insecticides (Devillers *et al*., 2002; Stefanidou *et al*., 2003; Hardstone and Scott, 2010), and bees close to agricultural areas are particularly vulnerable to pesticide exposure through multiple routes (Krupke *et al*., 2012).

Yang *et al*. (2008) reported effects of sublethal doses of imidacloprid on the foraging behaviour of honey bees which manifested as a delay in their visit to the feeding site. The delay depended on the imidacloprid concentration.

Pesticides have been cited as one of the major drivers of pollinator loss. However, little is known about pesticide impacts on natural populations of native honey bee species. This study looked into the effect of pesticides with respect to oxidative stress in the laboratory and in field populations of two native Indian honey bee species (*Apis dorsata* and *A. cerana*) by examining a combination of biomarkers, e.g., superoxide dismutase, catalase and xanthine oxidase. A significant up-regulation of all three biomarkers was observed in both treated individuals in laboratory experiments and field populations sampled from a pesticide use gradient. This study reports, for the first time, an increase in expression of xanthine oxidase in an invertebrate system (honey bees) exposed to pesticides (Chakrabarti *et al*., 2015).

Schneider *et al*. (2012) found a significant reduction in foraging activity as well as longer foraging flights at doses of two neonicotinoid insecticides; 0.5 mg/bee or more for clothianidin and 1.5 mg/bee or more for imidacloprid during the first 3 h after treatment. In contrast, the presence of residues in the nectar and pollen of oilseed rape and maize due to seed treatment with Thiamethoxam 25WG was reported to represent a low risk to honey bees (Pilling *et al*., 2013).

From behavioural alteration (Whitehorn *et al*., 2012) to neuro-physiological changes (Palmer *et al*., 2013) in adults as well as in broods (Henry *et al*., 2012), a number of recent studies have established deleterious responses of honey bees to pesticide toxicity.

Iwasa *et al*. (2004) determined the LD_{50} concentrations for several insecticides applied topically to adult honey bees in the laboratory. Of seven neonicotinoids tested, they found that imidacloprid was most toxic at 17.9 mg/bee. Clothianidan and Thiamethoxam 25WG were close behind at 21.8 and 29.9 mg/bee, respectively. These were followed by dinotefuran (75.0 mg/bee) and nitenpyram (138 mg/bee). Acetamiprid and thiacloprid, which have slightly different chemical structures, were much less toxic to bees.

Beginning in 1995, beekeepers in France noticed increased mortality of bees working in fields of maize, rape, and sunflowers, a phenomenon that spurred indepth research into the effect of imidacloprid on honey bees. Since then, a number of nations have placed restrictions on its use or have banned it altogether in certain crops (Suchail *et al*., 2003). Several types of imidacloprid toxicity have been described. Acute toxicity (LD_{50}) has been measured at concentrations from 3.7 to 40 μg/kg. Mortality of 50% can also be achieved by chronic exposure to imidacloprid at 0.1 to 10 μg/kg for 10 days. Sublethal toxicity has been observed beginning at 1 μg/kg in an adult bee. The ranges are due to variations in treatment and measurement protocols and natural variability in honey bee populations (Bonmatin *et al*., 2005).

Davis *et al*. (1988) found that the systemic insecticides carbofuran and dimethoate affected larval development at concentrations that were sublethal to adults. In their experiments, pre-measured concentrations of the insecticides were mixed with royal jelly and fed to larvae at various life stages. They found that although adults appeared to be unaffected by carbofuran at 1.25 μg/g royal jelly, dosages as low as 0.625 μg/g caused mature larval weights to be significantly lower than the controls. At 1.25 μg/g the number of potentially viable pupae was also lower than the controls.

Dai *et al*. (2010) examined the sublethal effects of two pyrethroidsbifenthrin and deltamethrin on the growth and development of *Apis mellifera ligustica*. The pyrethroids are synthetic forms of pyrethin, the insecticide derived from certain chrysanthemums. They are potent neurotoxins which typically cause paralysis in the target organisms. Pyrethroids are problematic because they are widely available in both commercial and consumer formulations, and because they are often considered safe and natural alternatives to the organophosphates.

Several studies indicated that the neonicotinoid insecticides are found in pollen at levels that affect learning and cognition in bees (Chauzat *et al*., 2006, Halm *et al*., 2006, Desneux *et al*., 2007). Since these sublethal levels are substantially below the regulatory adult LD_{50} for these chemicals, spraying at these levels is not prohibited by the EPA.

Yang *et al*. (2008) found that when bees were treated with an imidacloprid concentration higher than 1,200ug/liter, they showed abnormalities in revisiting the feeding site. Some of them went missing, and some were present again at the feeding site the next day. Returning bees also showed delay in their return trips. They show that sublethal dosages of imidacloprid were able to affect foraging behaviour of honeybees.

Danielle *et al*. (2009) found that applications of bifenthrin, Thiamethoxam 25WG and cartap hydrochloride were quite toxic to honeybees. Bifenthrin was the most deadly while lufenuron was only slightly toxic for adult honey bees.

Honeybees (*Apis mellifera* L.) are the most important pollinators in natural and agricultural settings affected by insecticides. Johnson *et al*. (2010) reported that both the unintentional and the intentional exposure of honeybees to pesticides have resulted in residues in hive products, especially beeswax. Although no single pesticide has been shown to cause colony collapse disorder, the additive and synergistic effects of multiple pesticide exposures may contribute to declining honey bee health.

Stanley *et al*. (2015) reported that pesticides at their field recommended doses on potted mustard plants showed monocrotophos as the highly toxic insecticide with 100% mortalityeven with 1 hour of exposure followed by Thiamethoxam 25WG, dichlorvos, profenofos and chlorpyriphos which are not to be recommended for use in pollinator attractive flowering plants. Acetamiprid did not cause any repellent effect on honeybees in the field trials and this endorses the usage of acetamiprid against sucking pest in flowering plant

Dolezal *et al*. (2016) reported that honeybees are exposed to a variety of environmental factors that impact their health, including nutritional stress, pathogens, and pesticides. In particular, there has been increasing evidence that sub-lethal exposure to pesticides can cause subtle, yet important effects on honey bee health and behaviour. They followed that bee-collected pollen containing sub-lethal levels of cyhalothrin, a pyrethroid insecticide, which, when fed to young honeybees, resulted in significant changes in lifespan, nutritional physiology and behavior.

Pashte and Patil (2017) reported that effect of different insecticides on the foraging activity of bees on sunflower (*Helianthus annuus*). The findings indicated that cypermethrin 10% EC and imidacloprid 17.8% SL sustained less bee visits up to two days. On third day, normal bee activity was restored in case of cypermethrin 10% EC and imidacloprid 17.8% SL treated plots. Fipronil 5% SC exhibited less bee visits only on the day of spraying. The reduction in the bee activity was observed for four days subsequent to application of indoxacarb 14.5% SC.

2.7 Effect of chemicals on yield of rapeseed and mustard

Bharti *et al*. (2009) conducted an experiment to control L. erysimi through insecticides and NSKE combination on mustard (variety Shivani) crop and found that, maximum yield (11.4 q/ha) was recorded in combination of NSKE 5% and imidacloprid 17.8 % SL treated plot followed by sole application of imidacloprid (9.6 q/ha) and NSKE (8.7 q/ha). Further, maximum cost benefit ratio (1.78) was obtained in (NSKE 5%+ imidacloprid) followed by imidacloprid (1.56) and NSKE (1.54).

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).

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 25WG (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. Higher infestation of insect showed lower dry matter production due to lower photosynthetic performance in plants. It also 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 25WG 25 WG.

Singh *et al*. (2017) studied bio-efficacy of some insecticides and botanicals on mustard (variety Laxmi) crop. It revealed that, imidacloprid gave higher growth and yield contributing parameters of mustered which resulted maximum seed yield (1866kg/ha) closely followed by Thiamethoxam 25WG (1813kg/ha) and dimethoate (1757kg/ha). The lowest seed yield (1239 kg/ha) was obtained from untreated control.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2020 to February 2021 to study the effect of insecticide application timing on insect pest attack and growth, yield and nutrient content of mustard. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

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

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix I.

3.3 Climate

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

3.4 Test crop: Rai (black)

Mustard cv. Rai (black) was considered as plant material for the present study. It is a high yielding variety developed by the Bangladesh Agricultural Research Institute (BARI). Rai (black), a short duration variety with light green colour leaf, smooth, two chambers are present in pod but as like as four chambers. Seed color black, 1000 seed weight 3.5-3.8 g, crop duration 75-80 days.

3.5 Experimental details

3.5.1 Treatments: Single factor experiment consisted of 5 treatments

1. T_0 = Without insecticide application (control)
2. T_1 = Aktara (Thiamethoxam 25WG) application in morning
3. T_2 = Aktara (Thiamethoxam 25WG) application in afternoon
4. T_3 = Celcron (Profenofos) 50EC application in morning
5. T_4 = Celcron (Profenofos) 50EC application in afternoon

3.5.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The area of the experimental plot was divided into three equal portions. Each portion was divided into 5 equal unit plots. The size of each unit plot 3 m × 2 m. Distances between plot to plot and replication to replication were 1 m and 1 m, respectively. The layout of the experiment field is presented in Appendix III.

3.6 Land preparation

The plot selected for the experiment was opened in the last week of October, 2020 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for seed sowing. The land preparation was completed on 7 November 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Manure and fertilizers application

The N, P, K, S, Zn and B nutrients were applied through urea, Triple super phosphate (TSP), Muriate of potash (MoP) Gypsum, $ZnSO_4$ and Boric acid, respectively. The doses of organic and inorganic fertilizers were applied according to Krishi Projukti Hat Boi, BARI, 2017.

Manures/fertilizers	Doses ha^{-1}
Cowdung	10 ton
Urea	225 kg
TSP	160 kg
MoP	80 kg
Gypsum	140 kg
$ZnSO_4$	4 kg
Boric acid	10 kg

Half of urea along with full amount of other fertilizers were applied during final land preparation as basal dose and thoroughly mixed with soil. The remaining Urea was top dressed in two equal installments at 25 and 40 days after sowing (DAS), respectively.

3.8 Seed sowing

Seeds were sown continuously @ 7 kg ha^{-1} on 7 November 2020 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. After sowing the seeds were covered with soil and slightly pressed by hand. Thinning operation was done to maintain uniform population density.

3.9 Intercultural Operation

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

3.9.1 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 22 November 2020. At the same time thinning was done. The final weeding and thinning were done after 25 days of sowing, on 2 December 2020. Care was taken to maintain uniform plant population per plot.

3.9.2 Pest management

Insecticides were applied according to the treatment. At 30 DAS (days after sowing), insecticides were sprayed in the crop field. All the treatments of the present study were applied with water and were sprayed by Knapsack Sprayer. The crop was kept under constant observations from sowing to harvesting.

3.10 General observations of experimental field

The plots under experiment were frequently observed to notice any change in plant growth and other characters were noted down immediately to make necessary measures.

3.11 Harvesting and post harvest operation

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 13 February 2021. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise.

3.12 Data Collection and Recording

Data on the incidence and mortality of insect were recorded. Before and after spraying of insecticides (spraying started at 30 DAS), number of insect incidence and mortality was observed and continued up to 96 hours of spray and data were recorded. Data on different growth, yield contributing parameters and yield of mustard were recorded at the time of harvest. The followings data were recorded during the experiment:

3.12.1 Incidence of insects

1. Incidence of insects plot^{-1} before insecticide spray
2. Incidence of insects plot^{-1} after spraying of insecticide recorded at 24, 48, 72 and 96 hours of spray
3. Mortality of insects plot^{-1} after spraying of insecticide recorded at 24, 48, 72 and 96 hours of spray

3.12.2 Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Dry weight plant^{-1} (g)

3.12.3 Yield contributing parameters

1. Total blooming period (days)
2. Number of flowers plant^{-1}
3. Number of pods plant^{-1}
4. Number of seeds pod^{-1}
5. 1000 seed weight (g)

3.12.4 Yield parameters and oil content

1. Seed yield ha^{-1} (t)
2. Oil content (%)

3.12.5 Nutrient content of seed

1. Nitrogen (N) content (%)
2. Phosphorus (P) content (%)
3. Potassium (K) content (%)

3.13 Procedure of recording data

3.13.1 Incidence of insect plot^{-1} before insecticide spray

For recording data on the incidence of insect plot^{-1} before insecticide spray, one hour visual observation was done on total number of insects and data were recorded at 30 DAS.

3.13.2 Incidence of insect plot^{-1} after spraying of insecticide

For recording data on the incidence of insect plot^{-1} after spraying of insecticide, incidence of total number of insects were counted by visual observation and data were recorded at 24, 48, 72 and 96 hours of spray.

3.13.3 Mortality of insect plot^{-1} after spraying of insecticide

For recording the data on mortality of insect plot^{-1} after spraying of insecticide, number of dead insects were counted and it were recorded at 24, 48, 72 and 96 hours of spray. Mainly three types of insects (mustard sawfly, aphid and bee) were identified which were presented in a considerable amount in the crop field.

3.13.4 Plant height (cm)

Plant height was measured using a meter scale from the ground level to the apex of the leaf or siliquae in randomly selected 10 plants from specific rows of each plot at the time of harvest and the mean plant height (cm) was recorded.

3.13.6 Number of leaves plant^{-1}

Ten plants were selected randomly from the inner rows of each plot. Leaves plant^{-1} was counted from each plant sample at harvest and then leaf number was recorded.

3.13.7 Number of branches plant^{-1}

The branches plant^{-1} was counted from ten randomly selected plants. By counting total number of branches of all sampled plants and average data were recorded.

3.13.8 Dry weight plant^{-1} (g)

Ten randomly selected sample plants in each plot were collected at the time of harvest. Then it were first air dried for one hour, then oven dried at 80±5°C till a constant weight was attained. Mean dry weight was expressed as per plant basis in gram (g).

3.13.9 Total blooming period (days)

Total blooming period was measured from first flower initiation to last flower and it was measured in days.

3.13.10 Number of flowers plant^{-1}

The number of flowers was counted from randomly taking 10 plants of each replication. The average value is calculated as the number of flowers plant^{-1}.

3.13.11 Number of pods plant^{-1}

The number of pods was counted from randomly taking 10 plants per replication of each treatment. The average value is calculated as the number of pods plant^{-1}.

3.13.12 Number of seeds pod^{-1}

The number of seeds was counted from randomly taking 10 pods per replication of each treatment. The average value is calculated as the number of seeds siliquae^{-1}.

3.13.13 Weight of 100 seeds (g)

From the seed stock of each plot, 100-seeeds were randomly collected and weighed by an electric balance. The 1000-seed weight was recorded in gram by multiplying 10.

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

At first the crop was harvested plot wise. The harvested plants plot^{-1} were carried to the threshing floor. The plants were sun dried and seeds were separated. Per plot yields of seed were recorded after drying the plants in the sun followed by threshing and cleaning at 10% moisture level. Seed yield from plot^{-1} area was converted to t ha^{-1}.

3.13.15 Oil extraction procedure

The invention provides a method for extracting mustard oil and mustard essential oil from mustard seeds. The method provided by the invention comprises the following steps of: coldly pressing mustard seeds at 40-45°C to produce a mustard seed dreg cake and mustard oil; adding water which is 4-10 times as much as the weight of the mustard seed dreg cake into the mustard seed dreg cake; agitating the mixture of the mustard seed dreg cake and the water and heating the mixture to about 40-70°C; distilling the mixture of the mustard seed dreg cake and the water by utilizing steam to produce an oil-water mixture and residues; separating mustard essential oil and water in the distilled oil-water mixture; drying the residues by a belt-type filter press and a heat pump and then pressing or extracting by an organic solvent to produce the mustard oil and final residues, wherein the final residues can be used as raw materials of animal feed.

3.13.16 Determination of nitrogen (%)

For the determination of N, an amount of 1 g oven dry seed sample was taken in a micro Kjeldahl flask. One gram catalyst mixture (K_2SO_4; $CuSO_4.5H_2O$ in the ratio of 100:10:1) and 10 ml conc. H_2SO_4 were added. The flasks were heated at 160°C and added 2 ml H_2O_2 than heating was continued at 360°C until digests become clear and colorless.

After cooling the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling with 10N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

The amount of nitrogen was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight (g)

3.13.16 Determination of phosphorus and potassium (%)

Exactly 1 g of oven dried seeds of mustard was taken in a 250 ml conical flask. 20 ml di-acid mixture was added (previously prepared by adding 60% HNO_3 and $HClO_4$ in 2:1 ration through wet oxidation method) to the seed sample.

Flask was stirred to moisten the entire mass of tissue and was placed on an electric hot plate. The content was heated at 180-200°C until white fume was evolved. 5 ml di-acid mixture was added to the flask if the contents become dry before the end of the digestion. The flask was removed from the hot plant and was allowed to cool. Than 20-30 ml distilled water was added and shaken and after that the solution was filtered with Whatman Filter Paper No.1 in 100 ml volumetric flask. The conical flask was washed several times to ensure that all the minerals are transferred to the volumetric flask. The volume was made upto the mark with distilled water.

The contents of phosphorus (P) was measured by Spectophotometer at 660 ηm and potassium (K) was measured by flame photometer.

3.14 Statistical Analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to study the effect of insecticide application timing on insect pest attack and growth, yield and nutrient content of mustard. Data on incidence and mortality of insects due to insecticide spray and their effect on growth and yield characters were recorded. The results of different parameter under the experiment have been presented, discussed, and possible interpretations are given under the following headings:

4.1 Incidence and mortality of insect plot^{-1} before and after insecticide spray

4.1.1 Incidence of total number of insect plot^{-1} before spray

Significant variation was recorded for the incidence of total number of insect plot^{-1} before spray of insecticide as regarded by different insecticide application time in mustard (Table 1 and Appendix IV). It was observed that the highest incidence of total number of insect plot^{-1} before spray of insecticide (148.50) was recorded from T_3 (Celcron; Profenofos 50EC application in morning) treatment which result significantly differed to other treatments followed by T_2 (Aktara; Thiamethoxam 25WG application in afternoon) and T_1 (Aktara; Thiamethoxam 25WG application in morning) whereas the T_2 and T_1 treatments showed non-significant variation between them. The lowest incidence of total number of insect plot^{-1} before spray of insecticide (133.33) was found from the control treatment T_0 (Without insecticide application) which showed non-significant variation with T_4 (Celcron; Profenofos 50EC application in afternoon) treatment.

4.1.2 Incidence of total number of insect plot^{-1} after spray

Significant variation was recorded for the incidence of number of insect plot^{-1} after spray of insecticide recorded at 24, 48, 72 and 96 hours of spray as influenced by different insecticide application time in mustard (Table 1 and Appendix IV).

At 24 hours of spray, the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) gave best performance and showed lowest incidence of total insects (18.40 plot^{-1}) which was significantly same to the treatment T_4 (20.25 plot^{-1}). Again, the highest incidence of total number of insect plot^{-1} (136.67) was recorded from T_0 (Without insecticide application) treatment which was followed by T_3 (Celcron; Profenofos 50EC application in morning) treatment (36.40) (Table 1).

At 48 hours of insecticide spray, the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) showed the lowest incidence of total number of insect plot^{-1} (25.33) which was not significantly differed with T_4 (Celcron; Profenofos 50EC application in afternoon) treatment whereas the treatment T_3 (Celcron; Profenofos 50EC application in morning) showed least performance (45.67) in controlling insect in mustard. On the other hand, control treatment T_0 (Without insecticide application) showed highest incidence of total number of insect plot^{-1} (141.00) that was followed by T_4 treatment (Table 1).

At 72 hours of insecticide spray, the lowest incidence of total number of insect plot^{-1} (42.67) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) which was significantly differed to all other the treatments. Again, the treatment T_3 (Celcron; Profenofos 50EC application in morning) showed minimum performance (72.33) in controlling insect of mustard whereas the highest incidence of total number of insect plot^{-1} (148.33) was recorded from T_0 (Without insecticide application) treatment (Table 1).

At 96 hours of insecticide spray, the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) showed the lowest incidence of total number of insect plot^{-1} (63.33) which was significantly differed with other treatments whereas the treatment T_3 showed least performance (103.33) in controlling insect in mustard. On the other hand, control treatment T_0 (Without insecticide application) showed highest incidence of total number of insect plot^{-1} (155.00) that was followed by T_3 treatment (Table 1).

The result of the present study on incidence of total number of insect plot^{-1} suggests that the highest effectiveness was given by T_2 (Aktara; Thiamethoxam 25WG application in afternoon) and next to T_4 (Celcron; Profenofos 50EC application in afternoon) for controlling insects in mustard whereas reverse result was found in control treatment. This result suggests that insecticide application in the afternoon was more effective than morning application. Lower incidence was observed in afternoon application of insecticide and it was minimum at 24 hours of spray and it was gradually increased with increasing of duration of spray which might be the cause of residual effect of insecticide. Higher residual effect of insecticides showed lower incidence of insect for a long time after spray. Ahmad *et al*. (2017) also found similar result in controlling insect and reported higher effectiveness of Aktara compared to mospilan and confidor application. Kumar *et al*. (2017) and Patel *et al*. (2017) also found similar result with the present study and found effectiveness of different insecticides against insect pest complex of mustard.

Table 1. Incidence of total number of insect pest per plot before insecticide application

Treatments	Incidence of total number of insect $plot^{-1}$ before insecticide spray	Incidence of total number of insect after spray			
		24 hours of spray	48 hours of spray	72 hours of spray	96 hours of spray
T_0	133.33 c	136.67 a	141.00 a	148.33 a	155.00 a
T_1	142.75 b	29.33 c	36.48 c	61.33 c	91.50 c
T_2	140.67 b	18.40 d	25.33 d	42.67 e	63.33 e
T_3	148.50 a	36.40 b	45.67 b	72.33 b	103.33 b
T_4	135.67 c	20.25 d	28.50 d	51.75 d	82.67 d
$LSD_{0.05}$	2.501	3.117	3.533	4.107	4.211
CV(%)	8.24	7.93	10.52	6.37	9.54

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.1.3 Number of dead insect per plot after insecticide application

Significant variation was recorded for the number of dead insect $plot^{-1}$ after spray of insecticide recorded at 24, 48 and 72 hours of spray as influenced by different insecticide application time in mustard (Table 2 and Appendix V) but at 96 hours of spray no dead insect was found (Table 2).

At 24 hours of insecticide spray, the highest number of dead mustard sawfly (21.67) was collected from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treated plot which was followed by T_4 (Celcron; Profenofos 50EC application in afternoon) treated plot (18.67 $plot^{-1}$) whereas T_3 (Celcron; Profenofos 50EC application in morning) treatment showed the lowest number of dead sawfly $plot^{-1}$ (15.00) which was not significantly differed to T_1 (Aktara; Thiamethoxam 25WG application in morning) treatment (15.33 $plot^{-1}$). In case of number of dead aphid $plot^{-1}$, T_2 treated plot showed highest frequency of dead aphid (48.33 $plot^{-1}$) at 24 hours of spray which was followed by T_4 (42.33 $plot^{-1}$)

whereas T_3 treatment showed least performance and showed lowest number of dead aphid plot^{-1} (32.67). Again at 24 hours of insecticide spray, the highest number of dead bee (37.33 plot^{-1}) was recorded from T_1 (Aktara; Thiamethoxam 25WG application in morning) treated plot followed by T_3 treatment (34.00 plot^{-1}) whereas the lowest (29.00 plot^{-1}) was found from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treated plot which was significantly same to T_4 treatment (30.00 plot^{-1}) (Table 2).

Similarly, at 48 hours of insecticide spray, the highest number of dead sawfly (14.33 plot^{-1}) was collected from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treated plot which was followed by T_4 (Celcron; Profenofos 50EC application in afternoon) (11.33 plot^{-1}) whereas T_3 (Celcron; Profenofos 50EC application in morning) treatment showed the lowest number of dead sawfly plot^{-1} (7.67) which was significantly differed to other treatments. In case of number of dead aphid plot^{-1}, T_2 treated plot showed highest frequency of dead aphid (33.00 plot^{-1}) at 48 hours of spray which was followed by T_4 (21.67 plot^{-1}) whereas T_3 treatment showed least performance and showed lowest number of dead aphid plot^{-1} (15.00). Again at 48 hours of insecticide spray, the highest number of dead bee (24.33 plot^{-1}) was recorded from T_1 treated plot followed by T_3 treatment (15.00 plot^{-1}) whereas the lowest (9.33 plot^{-1}) was found from T_4 treated plot which was significantly different to other treatments (Table 2).

At 72 hours of insecticide spray, collected dead insect was decreased compared to 24 and 48 hours of spray which might be due to cause of lower residual effect of insecticides. However, the highest number of dead sawfly (3.33 plot^{-1}) was recorded from T_2 treatment whereas T_3 treatment showed the lowest number of dead sawfly (1.33 plot^{-1}) which was not significantly differed to T_1 (Aktara; Thiamethoxam 25WG application in morning). In case of number of dead aphid plot^{-1}, T_2 treated plot showed highest frequency of dead aphid (11.33 plot^{-1}) at 72 hours of spray which was followed by T_4 (7.50 $plot^{-1}$) whereas T_3 treatment showed the lowest dead aphid $plot^{-1}$ (3.00). Again at 72 hours of insecticide spray, the highest number of dead bee (7.00 $plot^{-1}$) was recorded from T_1 treatment followed by T_3 treatment (4.67 $plot^{-1}$) whereas the lowest (2.00 $plot^{-1}$) was found from T_4 treatment which was significantly same to T_2 treatment (2.33 $plot^{-1}$) (Table 2).

At 96 hours of insecticide spray, no dead insect was found in the plots treated with insecticides which might be due to cause of no residual effect of insecticides at 96 hours of spray (Table 2) but incidence was lower than control treatment (Table 1).

Table 2. Number of dead insect per plot after insecticide application

Treatments	Number of dead insect at 24 hours of spray			Number of dead insect at 48 hours of spray			Number of dead insect at 72 hours of spray			Number of dead insect at 96 hours of spray		
	Sawfly	Aphid	Bee	Sawfly	Aphid	Bee	Sawfly	Aphid	Bee	Sawfly	Aphid	Bee
T_0	--	--	--	--	--	--	--	--	--	--	--	--
T_1	15.33 c	37.00 c	37.33 a	10.50 b	16.33 c	24.33 a	1.67 b	5.33 c	7.00 a	0.00	0.00	0.00
T_2	21.67 a	48.33 a	29.00 c	14.33 a	33.00 a	14.33 b	3.33 a	11.33 a	2.33 c	0.00	0.00	0.00
T_3	15.00 c	32.67 d	34.00 b	7.67 c	15.00 c	15.00 b	1.33 b	3.00 d	4.67 b	0.00	0.00	0.00
T_4	18.67 b	42.33 b	30.00 c	11.33 b	21.67 b	9.33 c	1.67 b	7.50 b	2.00 c	0.00	0.00	0.00
$LSD_{0.05}$	1.032	2.114	1.037	1.503	1.411	1.507	0.411	0.512	0.411	--	--	--
CV(%)	5.83	8.42	6.14	4.88	7.92	9.24	3.73	5.24	4.78	--	--	--

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

The result of the present study on dead insect number plot^{-1} suggests that the highest effectiveness was given by T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treatment and next to T_4 (Celcron; Profenofos 50EC application in afternoon) treatment. This result also suggests that morning application of insecticides was less effective than evening application. Under the present study, higher dead insect was observed from afternoon application of insecticide than morning application in case of sawfly and aphid but the lower death of bees were found from the afternoon application which result indicated that the application of insecticide in the afternoon was effective for harmful insect but less harmful for beneficial insect. Again, bee in the crop field do not exist generally at night the crop field (Winston, 1987 and Winfree *et al*., 2009). So, afternoon application of insecticides in the crop field saves bees compared to morning application.

4.2 Growth parameters

4.2.1 Plant height (cm)

Plant height of mustard was significantly influenced by the different insecticide application time as pest management practices (Figure 1 and Appendix VI). It was observed that the highest plant height (98.26 cm) was recorded from the treatment T_4 (Celcron; Profenofos 50EC application in afternoon) that was significantly same to T_3 (Celcron; Profenofos 50EC application in morning) (97.52 cm). Again, the lowest plant height (87.52 cm) was recorded from control treatment T_0 (Without insecticide application) which was significantly same to the treatment T_1 (Aktara; Thiamethoxam 25WG application in morning) (89.63 cm). The present finding indicated that insecticide application in the afternoon or in the morning and also insecticidal variation had significant influence on growth performance on mustard which resulted significant variation among different treatments on plant height of mustard.

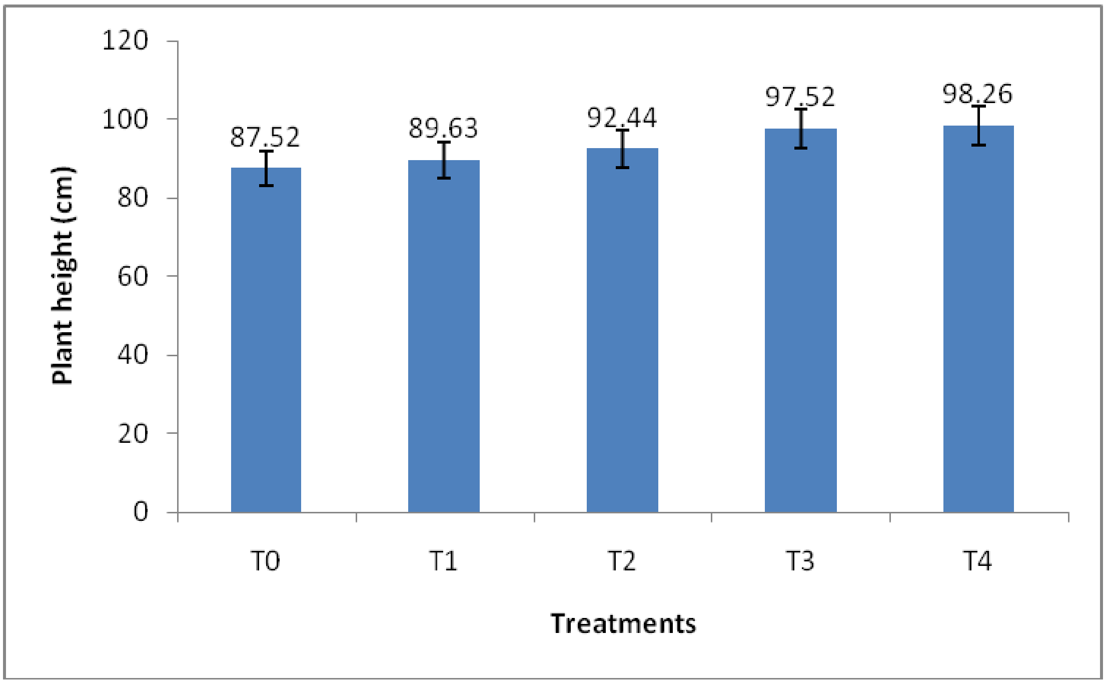


Figure 1. Plant height of mustard as influenced by insecticide application timing on insect pest of mustard

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.2.2 Number of leaves plant^{-1}

Significant variation was observed on number of leaves plant^{-1} of mustard as influenced by different time of insecticide application (Figure 2 and Appendix VI). Results exhibited that the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) gave the highest number of leaves plant^{-1} (41.48) which was not significantly different from T_4 (Celcron; Profenofos 50EC application in afternoon) (39.87). The lowest number of leaves plant^{-1} (31.63) was recorded from control treatment T_0 (Without insecticide application) that was significantly differed to other treatments. Treatment T_1 and T_3 showed non-significant difference between them on number of leaves plant^{-1}. This result indicated that morning application of insecticides was less effective on number of leaves plant^{-1} compared to afternoon application.

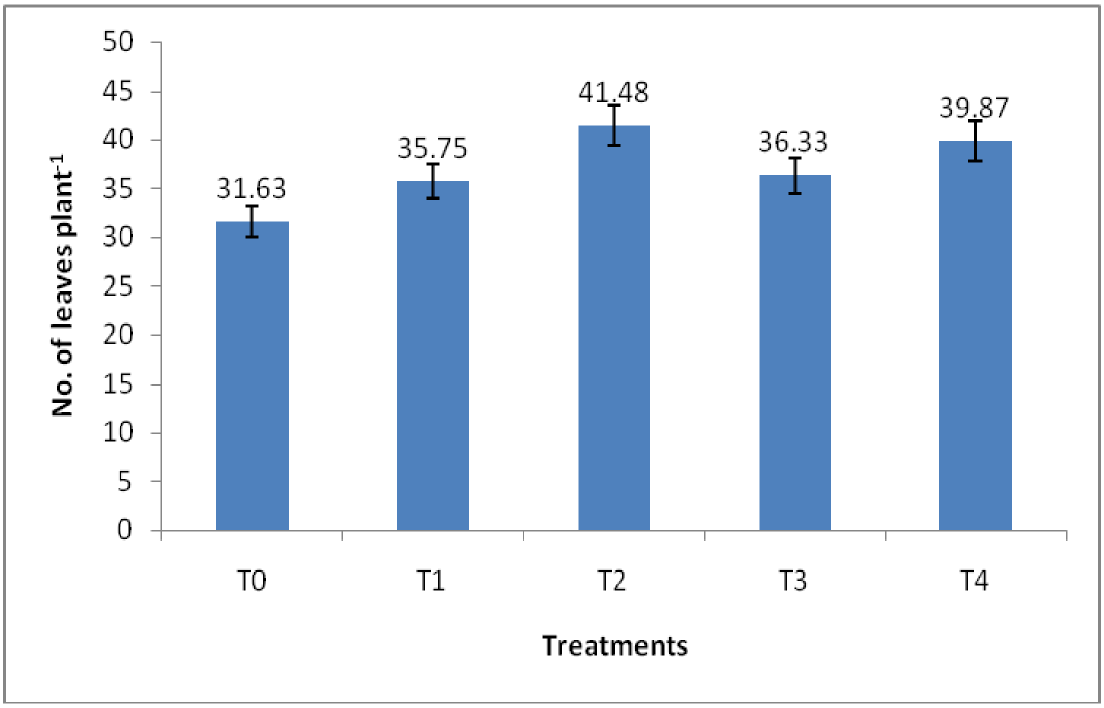


Figure 2. Number of leaves plant^{-1} of mustard as influenced by insecticide application timing on insect pest of mustard

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.2.3 Number of branches plant^{-1}

Number of branches plant^{-1} of mustard was influenced significantly due to different time of insecticide application as pest management practices (Table 3 and Appendix VI). Results showed that the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) gave the highest number of branches plant^{-1} (8.12) which was not significantly different from T_4 (Celcron; Profenofos 50EC application in afternoon) (7.94). Again, the lowest number of branches plant^{-1} (5.22) was recorded from control treatment T_0 (Without insecticide application) that was significantly differed to other treatments. Treatment T_1 and T_3 showed non-significant difference on number of branches plant^{-1} between them. The findings of the present study on number of branches plant^{-1} indicated that the day time of insecticide application (morning or afternoon) play significant role on branch number of mustard and the present findings indicated that afternoon application of insecticide was more effective to achieve higher number of branches plant^{-1} compared to morning application which might be the cause of lower incidence of insect in the afternoon application which facilitate higher nutrient use efficiency of mustard due to lower insect attack.

4.2.4 Dry weight plant^{-1}

Different time of insecticide application for controlling insect of mustard, significant variation was found on dry weight plant^{-1} (Table 3 and Appendix VI). Results revealed that the highest dry weight plant^{-1} (11.37 g) was given by the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) which was not significantly varied with T_4 (Celcron; Profenofos 50EC application in afternoon) treatment (10.97 g). Again, the control treatment T_0 (Without insecticide application) gave the lowest dry weight plant^{-1} (8.52 g) that was significantly differed to other treatments.

Table 3. Growth parameters of mustard cv. Rai (black) as influenced by insecticide application

Treatments	Growth parameters of mustard cv. Rai (black)	
	No. of branches plant^{-1}	Dry weight plant^{-1} (g)
T_0	5.22 c	8.52 d
T_1	6.48 b	9.27 c
T_2	8.12 a	11.37 a
T_3	6.75 b	10.04 b
T_4	7.94 a	10.97 a
$LSD_{0.05}$	0.344	0.632
CV(%)	6.22	4.86

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.3 Yield contributing parameters

4.3.1 Days to first flowering

Days to first flowering differed significantly due to different time of insecticide application (Table 4 and Appendix VII). Results showed that the lowest days to first flowering of mustard (25.00 days) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) significantly similar to the treatment T_1 (Aktara; Thiamethoxam 25WG application in morning) (25.33 days) whereas the highest days to first flowering (28.67 days) was recorded from control treatment T_0 (Without insecticide application) which was significantly different from other treatments. Similar result was also obtained by Sen *et al*. (2017) who reported that infested plants are restricted to produce dry matter which resulted lower yield of crops. Under the present study, Aktara and Celcron 50EC application in the afternoon showed lower infestation of insect in mustard which resulted higher dry matter production.

4.3.2 Number of flowers plant^{-1}

Statistically significant variation was recorded for number of flowers plant^{-1} of mustard influenced by different time of insecticide application (Table 4 and Appendix VII). It was observed that the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) gave the highest number of flowers plant^{-1} (126.00) which was statistically identical with the treatment T_4 (Celcron; Profenofos 50EC application in afternoon) (122.30). Again, the control treatment T_0 (Without insecticide application) gave the lowest number of flowers plant^{-1} (100.00).

Table 4. Yield contributing parameters; days to first flowering and number of flowers plant^{-1} of mustard cv. Rai (black) as influenced by insecticide application

Treatments	Yield contributing parameters of mustard cv. Rai (black)	
	Days to first flowering (days)	No. of flowers plant^{-1}
T_0	28.67 a	100.00 d
T_1	25.33 de	115.70 b
T_2	25.00 e	126.00 a
T_3	26.33 bc	112.70 bc
T_4	26.00 cd	122.30 a
$LSD_{0.05}$	0.956	4.752
CV(%)	3.44	6.37

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.3.3 Number of pods plant^{-1}

Number of pods plant^{-1} of mustard affected significantly due to different time of insecticide application (Figure 3 and Appendix VII). Results revealed that the highest number of pods plant^{-1} (112.70) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) which was statistically same to the treatment T_4 (Celcron; Profenofos 50EC application in afternoon) (110.30) whereas the control treatment T_0 (Without insecticide application) showed the lowest number of pods plant^{-1} (87.67). Afternoon application of insecticide showed lower death of bees and also higher controlling of aphid and sawfly; that's why lower insect plant infestation with this time of application, which might be resulted higher number of pods plant^{-1}.

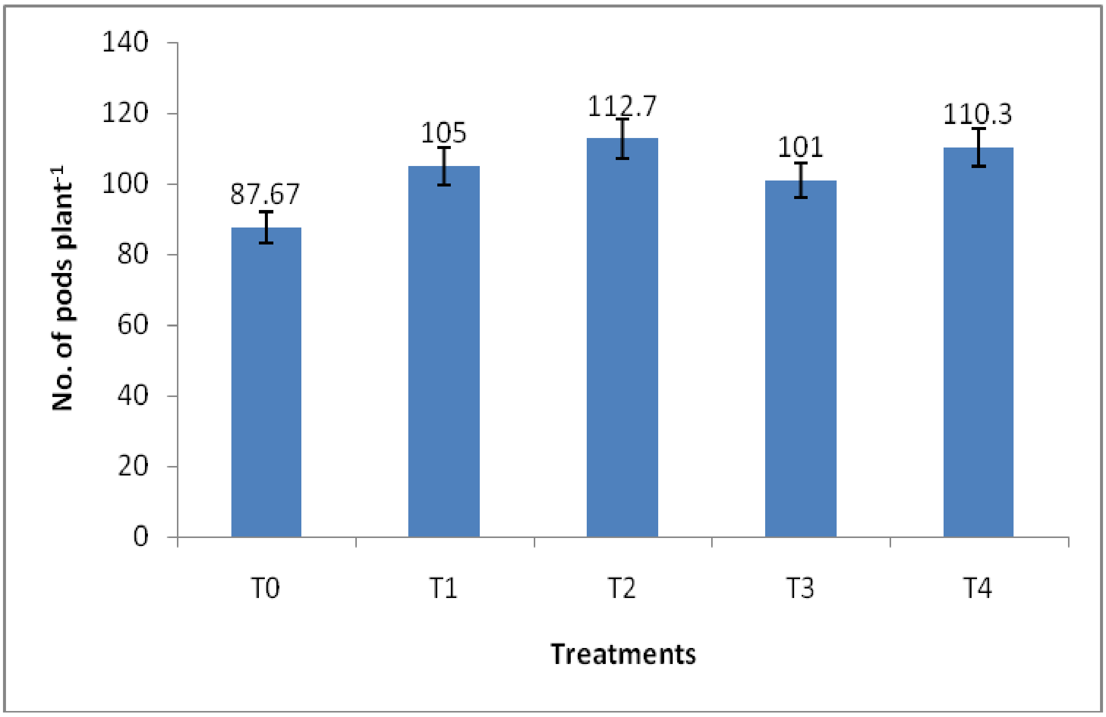


Figure 3. Number of pods plant^{-1} of mustard as influenced by insecticide application timing on insect pest of mustard

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.3.4 Number of seeds pod^{-1}

The effect of different time of insecticide application as pest management practices on number of seeds pod^{-1} of mustard was significant (Table 5 and Appendix VII). Results exhibited that the highest number of seeds pod^{-1} (37.67) was achieved from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) which was statistically similar to the treatment T_4 (Celcron; Profenofos 50EC application in afternoon). Again, the lowest number of seeds pod^{-1} (26.67) was recorded from control treatment T_0 (Without insecticide application) that was significantly differed to other treatments.

4.3.5 Weight of 1000 seeds

Significant variation was observed on 1000 seed weight of mustard as influenced by different time of insecticide application as pest management practices (Table 5 and Appendix VII). The highest 1000 seed weight (4.10 g) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) which was statistically similar with T_4 (Celcron; Profenofos 50EC application in afternoon) (4.05 g) whereas the lowest 1000 seed weight (3.78g) was recorded from the control treatment T_0 (Without insecticide application).

Table 5. Yield contributing parameters of mustard cv. Rai (black) as influenced by insecticide application

Treatments	Yield contributing parameters of mustard cv. Rai (black)	
	No. of seeds pod^{-1}	1000 seed weight (g)
T_0	26.67 e	3.78 e
T_1	35.33 bc	3.99 bc
T_2	37.67 a	4.10 a
T_3	33.67 cd	3.94 cd
T_4	36.00 ab	4.05 ab
$LSD_{0.05}$	1.832	0.097
CV(%)	4.86	4.09

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.4 Yield parameters and oil content

4.4.1 Seed yield ha^{-1}

Significant variation was found on seed yield ha^{-1} by the different time of insecticide application as pest management practices of mustard (Table 6 and Appendix VIII). Results showed that the highest seed yield (1.87 t ha^{-1}) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) that was significantly similar to the treatment (1.82 t ha^{-1}) whereas the lowest seed yield (1.49 t ha^{-1}) was recorded from control treatment T_0

(Without insecticide application) which was significantly different from other treatments. Among treated plots, T_3 (Celcron; Profenofos 50EC application in morning) gave the lowest seed yield (1.71 t ha^{-1}). Sen *et al.* (2017), Singh *et al.* (2017) and Patel *et al.* (2017) reported that successful controlling of insect pest in crop field (mustard) shows higher yield of mustard. Regarding the present study, Aktara and Celcron 50EC application in the afternoon gave lower infestation compared to morning application which might be resulted higher seed yield of mustard from Aktara and Celcron 50EC in the afternoon.

Table 6. Seed yield of mustard cv. Rai (black) as influenced by insecticide application

Treatments	Seed yield of mustard cv. Rai (black) (t ha^{-1})
T_0	1.49 d
T_1	1.79 b
T_2	1.87 a
T_3	1.71 c
T_4	1.82 ab
$LSD_{0.05}$	0.056
CV(%)	5.98

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.4.2 Percent oil content

Significant variation was found on percent oil content of mustard as influenced by different time of insecticide application as pest management practices of mustard (Figure 4 and Appendix VIII). Results showed that the highest percent oil content (40.33%) was recorded from the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) that was significantly similar to the treatment T_1 (Aktara; Thiamethoxam 25WG application in morning) (38.33%) and T_4 (Celcron; Profenofos 50EC application in afternoon) (39.67%) whereas the lowest percent oil content (31.67%) was recorded from control treatment T_0 (Without insecticide application) which was significantly different from other treatments.

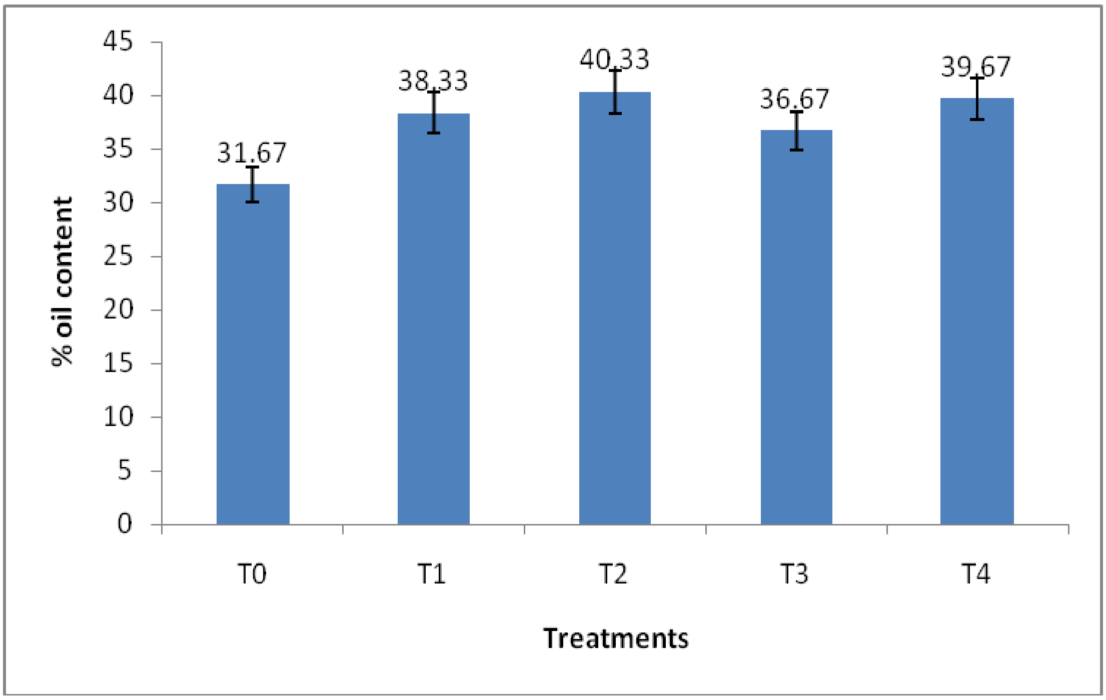


Figure 4. Percent oil content of mustard as influenced by insecticide application timing on insect pest of mustard

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.5 Nutrient content in seeds

4.5.1 Nitrogen (N) content

Non-significant variation was recorded for nitrogen content in seed among the treatments of different time of insecticide application (Table 7 and Appendix IX). However, the maximum nitrogen content (2.052%) was recorded from the treatment T_3 (Celcron; Profenofos 50EC application in morning) whereas control treatment T_0 (Without insecticide application) showed the minimum nitrogen content (2.028%).

4.5.2 Phosphorus (P) content

Significant variation was recorded for phosphorus content in seeds of mustard due to different time of insecticide application (Table 7 and Appendix IX). However, the highest phosphorus content (0.031%) was recorded from the treatment T_4 (Celcron; Profenofos 50EC application in afternoon) whereas the control treatment T_0 (Without insecticide application) showed the lowest phosphorus content in seed (0.019%).

Table 7. Nutrient content in seeds of mustard cv. Rai (black) as influenced by insecticide application

Treatments	Nutrient content in seeds of mustard cv. Rai (black)		
	N (%)	P (%)	K (%)
T_0	2.028	0.019	0.788 d
T_1	2.036	0.021	1.124 b
T_2	2.045	0.024	1.244 a
T_3	2.052	0.028	0.847 c
T_4	2.047	0.031	1.227 a
$LSD_{0.05}$	1.163	0.014	0.344
CV(%)	8.44	6.37	6.22

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Without insecticide application (control), T_1 = Aktara (Thiamethoxam 25WG) application in morning, T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, T_3 = Celcron (Profenofos) 50EC application in morning, T_4 = Celcron (Profenofos) 50EC application in afternoon

4.5.3 Potassium (K) content

Different treatments of time of insecticide application showed significant variation on potassium content in seeds of mustard (Table 7 and Appendix IX). It was observed that the T_2 (Aktara; Thiamethoxam 25WG application in afternoon) gave the highest potassium content (1.244%) which was significantly same to T_4 (Celcron; Profenofos 50EC application in afternoon) (1.227%) which was followed by T_1 (Aktara; Thiamethoxam 25WG application in morning) (1.124%) whereas the lowest potassium content (0.788%) was given by control treatment T_0 (Without insecticide application).

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2020 to March 2021 to study the effect of insecticide application timing on insect pest attack, growth, yield and nutrient content of mustard. The experiment consists of five treatments such as (i) T_0 = Without insecticide application (control), (ii) T_1 = Aktara (Thiamethoxam 25WG) application in morning, (iii) T_2 = Aktara (Thiamethoxam 25WG) application in afternoon, (iv) T_3 = Celcron (Profenofos) 50EC application in morning and (v) T_4 = Celcron (Profenofos) 50EC application in afternoon. Each of the treatments was applied at 30 days after sowing in the mustard field. The experiment was laid out in Randomized Complete Block Design with three replications. Data on the incidence of mustard sawfly, aphid and bee and their incidence and mortality due to application of insecticides and their effect on growth, yield contributing characters, yield and nutrient content in seeds were recorded.

Results indicated that the different time of insecticide application showed significant variation on incidence and mortality of insect. It was observed that insect incidence was decreased with insecticide application but insect population was gradually increased with increasing of duration after insecticide application. Again, mortality of insect gradually decreased with the increasing of duration after application of insecticide. Again, time of application of insecticide application showed significant variation on incidence and mortality of insect in mustard field.

The treatment of T_3 (Celcron; Profenofos 50EC application in morning) treated plot showed highest incidence of insect plot^{-1} (148.50) whereas the plot under control treatment T_0 (Without insecticide application) showed lowest incidence of insect plot^{-1} (133.33) before insecticide spray. But after the application of insecticides, the maximum effectiveness was found from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treatment whereas T_3 (Celcron; Profenofos 50EC application in morning) showed least performance in controlling insect of mustard compared to control. At 24, 48, 72 and 96 hours of spray, the lowest incidence of insect plot^{-1} (18.40, 25.33, 42.67 and 63.33, respectively) was recorded from T_3 (Celcron; Profenofos 50EC application in morning) treated plot.

In case of mortality of insect, at 24, 48 and 72 hours of spray, the highest number of dead sawfly (21.67, 14.33 and 3.33 plot^{-1}, respectively) and dead aphid (48.33, 33.00 and 11.33 plot^{-1}, respectively) was recorded from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) but the number of dead bee (37.33, 24.33 and 7.00 plot^{-1}, respectively) was highest from the treatment T_1 (Aktara; Thiamethoxam 25WG application in morning) whereas the lowest mortality was found from T_3 (Celcron; Profenofos 50EC application in morning) for sawfly and aphid but the lower mortality of bee was found from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) and T_4 (Celcron; Profenofos 50EC application in afternoon) treatments. Results also showed no dead insect at 96 hours of insecticide spray.

In case growth parameters, treatment T_4 (Celcron; Profenofos 50EC application in afternoon) showed highest plant height (98.26 cm) while the highest number of leaves plant^{-1} (41.48), number of branches plant^{-1} (8.12) and dry weight plant^{-1} (11.37 g) was recorded from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treatment whereas control treatment T_0 (Without insecticide application) showed the lowest plant height (87.52 cm), number of leaves plant^{-1} (31.63), number of branches plant^{-1} (5.22) and dry weight plant^{-1} (8.52 g).

Regarding yield contributing parameters, yield and oil content of mustard, the minimum days to first flowering (25.00 days) was recorded from T_2 (Aktara; Thiamethoxam 25WG application in afternoon) treatment whereas the maximum days to first flowering (28.67 days) was recorded from control treatment

T_0 (Without insecticide application). Again, the highest number of flowers plant^{-1} (126.00), number of pods plant^{-1} (112.70), number of seeds pod^{-1} (37.67), 1000 seed weight (4.10 g), seed yield ha^{-1} (1.87 t) and % oil content (40.33%) were recorded from T_2 treatment followed by T_4 treatment whereas the lowest number of flowers plant^{-1} (100.00), number of pods plant^{-1} (87.67), number of seeds pod^{-1} (26.67), 1000 seed weight (3.78 g), seed yield ha^{-1} (1.49 t) and % oil content (31.67%) were given by the control treatment T_0 (Without insecticide application). The nitrogen (N) and phosphorus (P) content of seeds was not significantly influenced by different time of insecticide application but potassium (K) content affected significantly. The maximum K content in seed (1.244%) was found from T_2 treatment whereas control treatment T_0 (Without insecticide application) showed the minimum K content (0.788%) in mustard seeds.

From the above findings, it can be concluded that the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) showed best efficiency in controlling insect of mustard followed by T_4 (Celcron; Profenofos 50EC application in afternoon) where treatment T_1 (Aktara; Thiamethoxam 25WG application in morning) and T_3 (Celcron; Profenofos 50EC application in morning) gave lower efficiency in controlling insect of mustard and as a result higher seed yield and % oil content of mustard was achieved the treatment T_2 (Aktara; Thiamethoxam 25WG application in afternoon) followed by T_4 (Celcron; Profenofos 50EC application in afternoon). It can also be concluded that application of insecticide in the afternoon was more effective than application of insecticide in the morning for both the insecticide of Aktara and Celcron 50EC.

REFERENCES

Achintya, P. and Debjani, D. (2012). Influence of weather parameters on population dynamics of Lipaphis erysimi (Kaltenbach) and its parasitoid Diaereiiella rapae (McIntosh)in mustard. *J. Ent. Res*., **36**(4): 305-308.

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. Entomol. Zool. Stud*. **5**(3): 626-629.

Alam, A.K.M.F. (2018). Edible oil Import Grows. The Financial Express, August. **19**: 2018.

Alim, M.A., Mahfuza, M., Hossain, M.B., Rahman, M.A., Mostofa, M.S. and Rakibul (2020). Effects of integrated nutrient management on the yield and yield attributes of mustard varieties. *Bangladesh J. Agric. Life Sci*. **1**(1): 19-27.

Ansari, M. S.;Hussain, B. and Qazi, N. A. (2007). Influence of abiotic environment on the population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) on *Brassica* Germplasm. *J. Bio. Sci*. **7**(6): 993-996.

Aziz, M.A., Shahzad, A.R., Naeem, M. and Shabbir, G. (2014). Evaluation of different neem products in comparison with imidacloprid against different morphs of mustard aphid (Lipaphis erysimi Kalt.) on canola crop, *Asian J. Agric. Biol*. **2**(3): 191-201.

Bakhetia, D.R.C. and Sekhon, B.S. (1989). Insect pests and their management in rapeseed and mustard. *J. Oilseed Res*. **6**: 269-299.

BBS (Bangladesh Bureau of Statistics) (2015). The Year Book of Agricultural Statistics of Bangladesh, 2014. Statistics and Informatics Division (SID) Ministry of Planning Government of the People’s Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2018).The Year Book of Agricultural Statistics of Bangladesh, 2017.Statistics and Informatics Division (SID) Ministry of Planning Government of the People's Republic of Bangladesh, Dhaka. pp.123-124.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

Bharti, N., Singh, U.K. and Kumar, V. (2009). Control of mustard aphid (*Lipaphis erysimi* Kalt.) through insecticides and NSKE combination. *J. Appl. Biol*. **19**(1-2): 16-19.

Bhati, R., Sharma, R.C. and Singh, R. (2015). Studies on occurrence of insect-pests of different Brassica species, International Journal of Current Science, 14(E): 125-132.

Bhatt, G. N., Wani, A. R. and Ansari, I. A. (2004). Screening of mustard, Brassica campestris L. varieties against mustard aphid, *Lipaphis erysimi* Kalt. (Homoptera: Aphididae). *Shashpa*. **11**(1): 79-81.

Bhuiyan, M.S., Mondol, M.R.I., Rahaman, M.A., Alam, M.S. and Faisal, A.H.M.A. (2008). Yield and Yield Attributes of Rapeseed as Influenced by Date of Planting. *Int. J. Sust. Crop Prod*. **3**(3): 25-29.

Bonmatin, J.M., Marchand, P.A., Charvet, R., Moineau, I., Bengsch, E.R. and Colin, M.E. (2005). Quantification of imidacloprid uptake in maize crops. *J. Agri. Chem*. **53**: 5336-5341.

Chakrabarti, P., Rana, S., Sarkar, S., Smith, B. and Basu, P. (2015). Pesticide-induced oxidative stress in laboratory and field populations of native honey bees along intensive agricultural landscapes in two Eastern Indian states. *Apidologie*. **46**:107-129.

Chauzat, M.P., Faucon, J.P., Martel, A.C., Lachaize, J., Cougoule, N. and Aubert, M. (2006). A survey on pesticide residues in pollen loads collected by honey-bees (Apis mellifera) in France. *J. Econ. Entomol*. **99**: 253-262.

Choudhury, S. and Pal, D. (2006). Pest complex and their succession in mustard under terai ecological conditions of West Bengal. *Indian J. Entomol*. **68**(4): 387-395.

Corriols, M., Marin, J., Berroteram, J., Lozano, L.M. and Lundberg, I. (2009). Incidence of acute pesticide poisonings in Nicaragua: a public health concern. *Occup. Environm. Medic*. **66**: 205-210.

Dai, P.L., Wang, Q., Sun, J.H., Liu, F., Wang, X., Wu, Y.Y. and Zhou, T. (2010). Effects of sublethal concentrations of bifenthrin and deltamethrin on fecundity, growth, and development of the honeybee *Apis mellifera ligustica*. *Environ. Toxic*. Chem. **29**(3): 644-649.

Danielle, T., Miguel, F., Soria, C. K., Vladson, C., Roni, P. F., Paulo, E. D. and Valter, V. A. (2009). Selectivity of insecticides for adult workers of *Apis mellifera* (Hymenoptera: Apidae). *Revista Colombiana de Entomología*. **35**(2):173-176.

Davis, A.R., Solomon, K.R. and Shuel, R.W. (1988). Laboratory studies of honeybee larval growth and development as affected by systemic insecticides at adult sub-lethal levels. *J. Api. Res*. **27**: 146-161.

Desneux, N., Decourtye, A. and Delpuech, J. M. (2007). The sublethal effects of pesticides on beneficial Arthropods. *Ann. Rev. Entomol*. **52**: 81-106.

Devillers, J., Pham-Delegue, M.H., Decourtye, A., Budzinski, H., Cluzeau, S. and Maurin, G. (2002). Structure-toxicity modeling of pesticides to honey bees. *Environ. Res*. **13**: 7–8 & 641– 648.

Dolezal, A.G., Tripp, J.C., Miller, W.A., Bonning, B.C. and Toth, A.L. (2016). Pollen Contaminated With Field-Relevant Levels of Cyhalothrin Affects Honey Bee Survival, Nutritional Physiology and Pollen Consumption Behavior. *J. Econ. Entomol*. **109**(1) 41–48.

FAO (Food and Agriculture Organization of the United Nations). (2005). Protecting the pollinators. FAO spotlight. (http://www.fao.org/ag/ magazine/0512sp1.html) (accessed 6 July 2015).

FAO (Food and Agriculture Organization). **(**2012**)**. FAO Production Year Book. Food and Agriculture Organization of the United Nations, Rome 00100, Italy. **56**: 118.

Ghadage, S.M., Bharodia, R.K., Yewale, P.H. and Zagade, S.N. (2014). Bioefficacy of biopesticides against Liphaphis erysimi (Kaltenbach) on mustard, Bioinfolet. **11**(2C): 620-623.

Gour, I. S. and Pareek, B. L. (2003). Field evaluation of insecticides against mustard aphid, L. erysimi(Kalt.) under semi-arid region of Rajasthan. *Indian J. Plant Prot*. **31**(2): 25-27.

Halm, M.P., Rortais, A., Arnold, G., Tasei, J. N. and Rault, S. (2006). New risk assessment approach for systemic insecticides: The case of honey bees and imidacloprid (Gaucho.) *Environ. Sci. Techn*. **40**: 2448-2454.

Hardstone, M.C. and Scott, J.G. (2010). Is *Apis mellifera* more sensitive to insecticides than other insects? *Pest Manag. Sci*. **66**(11): 1171–1180.

Hasan, M. R.; Ahmad, M.;Rahman, M. H. and Haque, M. A. (2009). Aphid incidence and its correlation with different environmental factors. *J. Bangladesh Agril. Univ*. **7**(1): 15–18.

Henry, N., Beguin, M., Requier, F., Rollin, O., Odoux, J.F., Aupinel, P., Aptel, J., Tchamitchian, S. and Decourtye, A. (2012). A common pesticide decreases foraging success and survival in honey bees. Science. **336**(6079): 348–350.

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

Iwasa, T., Motoyama, N., Ambrose, J. T. and Roe, R.M. (2004). Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, *Apis mellifera*. *Crop Protection*. **23**: 371-378.

Jandial, V. K. and Kumar, A. (2007). Seasonal incidence and population fluctuation of mustard aphid, Lipaphis erysimi (Kalt). In relation to ecological parameters. *Indian J. Ent*. 69(2): 62-67.

Johnson, R. M., Ellis, M. D., Mullin, C. A. and Frazier, M. (2010). Pesticides and honey bee toxicity –USA. *Apidologie*. pp. 312–331.

Kavad, N.K. (2013). Biology and activity of Diaeretiella rapae(McIntosh) anendo parasitoid of aphids infesting cruciferous crops. M. Sc. (Agri.) thesis submitted to Anand Agricultural University, Anand.

Khan, M.H, Nazir, A., Rashdi, S.M.M.S., Ismail, M., Rauf, I., Tofique, M.M. (2013). Studies on the compactibity of neem oil with predator, Chyrsoperla carnea for the management of aphids (Homoptera: Aphididae) in canola (*Brassica napus* L.). *J. Cereals and Oilseeds*. **4**(6): 85-88.

Khedkar, A. A. (2011). Population dynamics and impact of nitrogenous fertilizer on major insect pests and management of aphid, L. erysimiin mustard. M. Sc. (Agri.) thesis submitted to Anand Agricultural University, AAU, Anand.

Krupke, C.H., Hunt, G.J., Eitzer, B.D., Andino, G. and Given, K. (2012). Multiple routes of pesticide exposure for honey bees living near agricultural fields. *PLoS One*. **7**(1): e29268.

Kumar. A., Jandial, V.K. and Parihar, S.B.S. (2007). Efficacy of different insecticides against mustard aphid, Lipaphis erysimi (Kalt.) on mustard under field conditions. *Int. J. Agric. Sci*. **3**(2): 90-91.

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. *Pesticide Res. J*. **27**(2): 187-190.

Lawal, O. A. and Banjo, A. D. (2010). Appraising the beekeeping knowledge and perception of pest's problem in beekeeping business at different ecological zones in South-Western Nigeria. *World J. Zool*. **5**: 137-142.

Malik, R. and Sachan, S. K. (2013). Population buildup of mustard, Lipaphis erysimi (Kalt.) on indian mustard in relation to some abiotic factors. *Prog. Agric*. **13**(1): 153-157.

Mishra, H.P. and Agarwal, M.P. (1992). Evaluation of some synthetic insecticides and neem oil against mustard aphid (Lipaphis erysimi Kalt.), *Indian J. Entomol*. **55**: 58-61.

Mohapatra, L. N., Sontakke, B. K. and Ranasingh, N. (2010). Enhancement of crop production through bee pollination. Orissa review. pp: 44-47.

Mondal, M.R.I. and Wahhab, M.A. (2001). Production technology of oil crops. Oilseed Research Center. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur, pp. 6-15.

Morse, R.A. and Calderone, N.W. (2000).The value of honeybees as pollinators of U.S. crops. *J. Bee Culture*. **3**: 128.

Pashte, V.V. and Patil, C. S. (2017). Impact of different insecticides on the activity of bees on sunflower. *Res. Crops*. **18** (1): 153-156.

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

Patel, H. M. (2005). Studies on population dynamics of major insect pests of mustard in relation to dates of sowing, life tables on different hosts and management of Athalia lugens proxima (Klug). Ph. D. thesissubmitted to AAU, Anand (Gujarat).

Pilling, E., Campbell, P., Coulson, M., Ruddle, N. and Tornier, I. (2013). A four-year field program investigating long-term effects of repeated exposure of honey bee colonies to flowering crops treated with Thiamethoxam 25WG. PLoS ONE. 8(10): e77193. DOI: 10.1371/journal.pone.0077193.

Reddy, S.R. (2009). Rapeseed and mustard, Agronomy of field crops, 387-403.

Sahoo, S.K. (2016). Estimation of yield losses in Brassica due to insect pests. *Indian J. Entomol*. **78**(4): 317-321.

Schneider, C.W., Tautz, J., Grünewald, B. and Fuchs, S. (2012). RFID tracking of sublethal effects of two neonicotinoid insecticides on the foraging behavior of Apis mellifera. *PLoS ONE*. **7**(1): e30023.

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 Weed*. **13**(2): 235-237.

Sharma, P., Sharma, H.O. and Rai, P.K. (2018). Strategies and technologies for enhancing rapeseed-mustard production and farmer income. *Indian Farming*. **68**(1): 44-48.

Sharma, P. K. and Kashyap, N. P. (1998). Estimation of losses in three different oil seed Brassica crops due to aphid complex in Himachal Pradesh (India). *J. Ento. Res*. **22**: 22-25.

Singh, R.K., Verma, R.A. and Rajak, D.C. (2008). Bio-efficacy of insecticides against mustard sawfly on mustard. *Ann. plant protection Sci*. **16**(1): 203-267.

Singh, A.P., Singh, P.P. and Singh, Y.P. (2007). Pest complex of Indian mustard [(*Brassica juncea* (L.) Czern and Cosson] in eastern Rajasthan. *J. Expt. Zool*. **10**(2): 415-416.

Singh, G., Singh, A.K., Giri, S.K., Yadav, S.K. and Ramveer. (2018). Studies on occurrence of major insect-pests of Indian mustard *Brassica juncea* L., *J. Entomol. Zool. Stud*. **6**(2): 1209-1211.

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, India. *J. Expt. Zool*. **20**(1): 249-253.

Singh, C., Lal, 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. *Indian J. Ent*., **74**(2): 183-185.

Singh, P. K. and Premchand. (1995). Yield loss due to the mustard aphid Lipaphis erysimi (Kalt) in Eastern Bihar Plateau. *J. Appl. Zoological Res*. **6**: 97-100.

Singh, R. K., Rajak, S. K. and Verma, R. A. (2009). Influence of abiotic factors on population of Lipaphis erysimi Kalt. *J. Ent. Res*. **33**(2): 129-131.

Singh, R., Chaudhary, B. K., Bhowmick and Singh, R. P. (2005). Honeybee flora of Bihar, Uttar Pradesh and Madhy Pradesh. International Beekeeping Congress. 53 pp.

Sohail, K., Jan, S., Shah, S.F., Ali, H., Israr, M., Farooq, M., Jan, S., Arif, M. and Ahmad, B. (2011). Effect of different chemical pesticides on mustard aphid (*Lipaphis erysimi*) and their adverse effects on ladybird beetle. *Sarhad J. Agric*. **27**(4).

Stanley, J., Sah, K., Jain, S. K., Bhatt, J. C. and Sushil, S. N. (2015). Evaluation of pesticide toxicity at their field recommended doses to honeybees, Apis ceranaand Apis melliferathrough laboratory, semi-field and field studies. *Chemosphere*. **119**: 668-674.

Stefanidou, M., Athanaselis, S. and Koutselinis, A. (2003). The toxicology of honey bee poisoning. *Vet. Hum. Toxicol*. **45**(5): 261–265.

Suchail, S., Debrauwer, L. and Belzunces, L. P. (2003). Metabolism of imidacloprid in Apis mellifera. *Pest Manag. Sci*. **60**: 291-296.

Takar, B.L., Jat, K.L., Kanwat, P.M. and Sharma, J.K. (2005). Efficacy of some insecticides against *Lipaphis erysimi* (Kalt.) on mustard. *Agri. Sci. Digest*. **25**(3): 14-18.

Whitehorn, P.R., O'Connor, S., Wackers, F.L. and Goulson, D. (2012). Neonicotinoid pesticide reduces bumble bee colony growth and queen production. *Science*. **336**(6079): 351–352.

Williams, I.H. (1994). The dependence of crop production within the European Union on pollination by honeybees. *Agril Zool. Rev*. **6**: 229-257.

Winfree, R., Aguilar, R., Vázquez, D.P., LeBuhn, G. and Aizen, M.A. (2009). A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology*. **90**(8): 2068–2076.

Winston, M.L. (1987). The Biology of the Honey Bee. Harvard University Press. Cambridge, MA.

Xiao, D., Zhao, J., Guo, X., Chen, H., Qu, M., Zhai, W., Desneux, N., Biondi, A., Zhang, F. and Wang, S. (2016). Sublethal effects of imidacloprid on the predatory seven-spot ladybird beetle *Coccinella septempunctata*. *J. Ecotoxicol*. **25**(10): 1782– 1793.

Yang, E.C., Chuang, Y.C., Chen, Y.L. and Chang, L.H. (2008). Abnormal foraging behavior induced by sublethal dosage of imidacloprid in the honey bee (Hymenoptera: Apidae). *J. Econ. Entom*. **101**: 1743–1748.

Yu, C., Lin, R., Fu, M., Zhou, Y., Zong, F., Jiang, H., Piao, X., Zhang, J., Liu, Y. and Brock, T.C. (2014). Impact of imidacloprid on life-cycle development of Coccinella septempunctata in laboratory microcosms. *Ecotoxicol. Environ. Safety*. **110**: 168-173.

APPENDICES

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

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

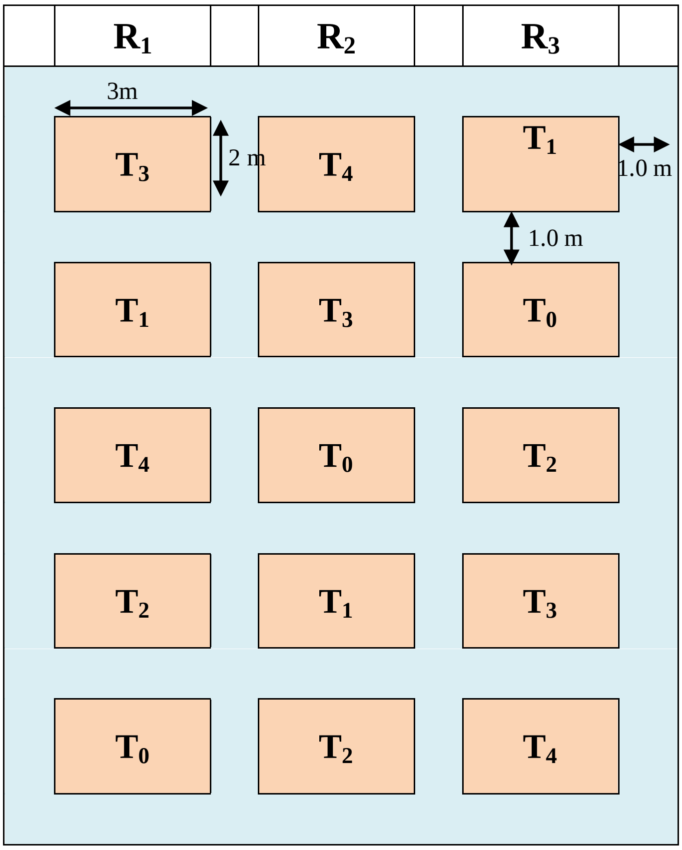
Source: Soil Resource Development Institute (SRDI)

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2020 to February 2021.

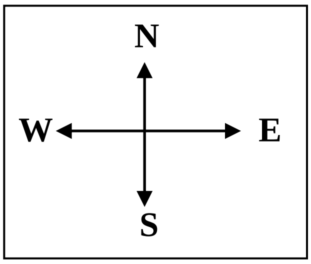
Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	November	28.60	8.52	18.56	56.75	14.40
2020	December	25.50	6.70	16.10	54.80	0.0
2021	January	23.80	11.70	17.75	46.20	0.0
2021	February	22.75	14.26	18.51	37.90	0.0

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

Appendix III. Layout of the experiment field



Legend



Treatments:

1. T_0 = Without insecticide application (control),
2. T_1 = Aktara (Thiamethoxam 25WG) application in morning,
3. T_2 = Aktara (Thiamethoxam 25WG) application in afternoon,
4. T_3 = Celcron (Profenofos) 50EC application in morning,
5. T_4 = Celcron (Profenofos) 50EC application in afternoon

Figure 5. Layout of the experimental plot

Appendix IV. Mean square of incidence of total number of insect pest per plot

Sources of variation	Degrees of freedom	Mean square of incidence of total number of insect plot^{-1} before insecticide spray	Mean square of incidence of total number of insect after spray			
			24 hours of spray	48 hours of spray	72 hours of spray	96 hours of spray
Replication	2	4.071	2.533	3.104	0.536	0.366
Factor A	4	312.88*	128.36*	86.503*	32.18*	13.07**
Error	8	6.107	3.012	2.882	1.031	0.411

* = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of number of dead insect per plot after insecticide application

Sources of variation	df	Mean square of number of dead insect at 24 hours of spray			Mean square of number of dead insect at 48 hours of spray			Mean square of number of dead insect at 72 hours of spray		
		Sawfly	Aphid	Bee	Sawfly	Aphid	Bee	Sawfly	Aphid	Bee
Replication	2	1.146	2.037	0.604	1.058	1.344	0.512	0.311	0.401	0.052
Factor A	4	74.37*	107.25*	46.09*	63.92*	83.63*	33.92*	6.41**	11.14*	2.01*
Error	8	2.104	3.102	1.861	1.536	2.004	0.614	0.103	0.315	0.018

* = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of growth parameters of mustard cv. Rai (black) as influenced by insecticide application

Sources of variation	Degrees of freedom	Mean square of growth parameters			
		Plant height	No. of leaves plant^{-1}	No. of branches plant^{-1}	Dry weight plant^{-1}
Replication	2	3.045	1.371	0.652	0.137
Factor A	4	155.24*	103.28*	31.93*	11.24**
Error	8	5.052	4.389	0.304	0.244

* = Significant at 5% level ** = Significant at 1% level

Appendix VII. Yield contributing parameters of mustard cv. Rai (black) as influenced by insecticide application

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Days to first flowering	No. of flowers plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight
Replication	2	3.000	1.190	1.333	8.333	0.002
Factor A	4	5.651**	260.54*	231.32*	40.97*	0.037**
Error	8	0.289	7.135	5.056	1.061	0.003

* = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of seed yield and oil content of mustard as influenced by insecticide application

Sources of variation	Degrees of freedom	Mean square of seed yield and oil content of mustard	
		Seed yield ha^{-1}	% oil content
Replication	2	0.001	1.714
Factor A	4	0.051**	30.08*
Error	8	0.001	1.770

* = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of nutrient content in seeds of mustard as influenced by insecticide application

Sources of variation	Degrees of freedom	Mean square of nutrient content in seeds of mustard cv. Rai (black)		
		N (%)	P (%)	K (%)
Replication	2	0.001	0.001	0.003
Factor A	4	0.012^{NS}	0.009^{NS}	0.244**
Error	8	0.001	0.001	0.001

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