EVALUATION OF SOME POPULAR MUSTARD VARIETIES AGAINST APHID AND SAWFLY ATTACK UNDER FIELD CONDITION

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CERTIFICATE

*This is to certify that the thesis entitled, "**EVALUATION OF SOME POPULAR MUSTARD VARIETIES AGAINST APHID AND SAWFLY ATTACK UNDER FIELD CONDITION**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **TAHURA BEGUM**, Registration No. **14-06122** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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Place: Dhaka, Bangladesh

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EVALUATION OF SOME POPULAR MUSTARD VARIETIES AGAINST APHID AND SAWFLY ATTACK UNDER FIELD CONDITION

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to April 2021 in Rabi season, to evaluate some popular mustard varieties against aphid and sawfly attack under field condition. The experimental treatments were consisted of two factors, and followed by randomized complete block design with three replications. Factor A. mustard varieties (3) *viz;* V_1= BARI sharisha-1, V_2= BARI sharisha-9 and V_3= BARI sharisha-14 and Factor B: different biorational pesticides (3) *viz;* P_0= untreated (Control), P_1= Confidor 70 WG (imidacloprid) @ 0.2 g/L of water, and P_2= Tracer 45 SC (spinosad) @ 0.4 ml/L of water. The result of present studies related to the incidence of insect pests and its natural enemies revealed that the populations of mustard sawfly, mustard aphid and other insect-pests were ranged between 0.33 to 2.33 (larvae/plant), 0.33 to 55.33 (aphids/10 cm central twig/plant), 0.33 to 2.67 (insect-pests/plant), respectively. The population of *Coccnella* spp., syrphid fly, spider and other predators was ranged between 0.33 to 4.00 (larvae and adults/plant), 0.33 to 3.67 (larvae/plant), 1.00 to 2.67 (spiders/plant) and 0.33 to 2.33 (predators/plant), respectively. The major pest *i.e.* mustard aphid showed a significant positive correlation with coccinellids, spiders and others. However, a non-significant correlation of mustard sawfly appeared with coccinellids, Syrphid fly, spiders and others. The population of mustard sawfly and aphid reduced due to the application of biorationals pesticide and different mustard varieties treatments. The highest seed yield plot^{-1} (0.36 kg) was observed in V_3 (BARI sharisha-14) treatment. Among different biorational pesticide, application of Confidor 70 WG (imidacloprid) @ 0.2 g/L of water recorded the highest the seed yield plot^{-1} (0.51 kg). Among different treatment combination, V_3P_1 treatment combination performed best, recorded higher seed yield plot^{-1} (1.57 ton/ha) and was found superior overall other varieties and botanical to significantly minimum insect-pests incidence, high reduction percent and higher seed yield production of mustard comparable to other treatment combinations.

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LISTS OF ABBREVIATIONS

Abbreviation	Full form
%	Percent
^0C	Degree Celsius
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of Coefficient of Variance
DAT	Days after Transplanting
et al.	and others
FAO	Food and Agriculture Organization
G	gram
ha^{-1}	Per hectare
Kg	Kilogram
LSD	Least Significant Difference
Max	Maximum
Min	Minimum
MOP	Muriate of Potash
N	Nitrogen
NPK	Nitrogen, Phosphorus and Potassium
NS	Not significant
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TSP	Triple Super Phosphate
wt.	Weight

CHAPTER I

INTRODUCTION

Mustard (*Brassica* spp.) is a worldwide cultivated thermo and photosensitive oilseed crop. Asia produces 41.50 % of mustard seed which occupies the first position in terms of percentage share of production followed by the USA (FAOSTAT, 2018). Edible oils play vital roles in human nutrition by providing calories and aiding in the digestion of several fat-soluble vitamins, for example, Vitamin A (Miah and Mondal, 2017). The per capita recommended dietary allowance of oil is 6 g day^{-1} for a diet with 2700 Kcal (BNNC, 1984). Oilseeds were cultivated in less than 2.20 % of total arable land under the rice-based cultivation system in Bangladesh, where three fourth of total cultivable land was engaged in rice production in 2015-16 (BBS, 2019). Mustard is the major oilseeds in Bangladesh which exhibits an increase in production from 1994 to 2018 except few fluctuations in the case of total production and area under cultivation (FAOSTAT, 2018). Mustard occupied more than 69.94 % of the total cultivated area of oilseeds followed by sesame, groundnut, and soybean (BBS, 2019). With the increase in population, the demand for edible oil and oilseeds is on an increasing trend (Alam, 2020). Bangladesh has to import a noticeable amount of edible oil and oilseeds to meet up the existing accelerating demand. The value of imported oilseed and edible oil has increased dramatically from USD 544 million in 2002-03 to USD 2371 million in 2018-19 which were 4.99 and 4.23 % of the total value of imports respectively (BB, 2020). The yield of mustard has increased from 0.75 tha^{-1} in 2001 to 1.15 tha^{-1} in 2019 (BBS, 2019; MoA, 2008). Bangladesh was not in an advantageous position in the case of mustard production (Miah and Rashid, 2015) which was due to, lack of high-yielding varieties and poor management as practiced at farmer's fields.

Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (1987) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. *Brassica* (genus of mustard) has three species that produce edible oil, they are *B. napus, B.*

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

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

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

Out of many insect-pests, mustard sawfly, *Athalia lugens proxima* (Klug.) is considered a serious pest which causes extensive damage to different cruciferous plants in India (Yadav and Patel, 2017). Reduction in yield due to sawfly on an average is about 25 per cent but it may go up to 100 per cent. Sawfly activity was mostly found during seedling stage of the crop (Choudhury and Pal, 2006). The population of sawfly larvae is not found on the foliage during the day time under bright sunny condition. They are visible under shady condition at late hours of the day. Sawfly was observed attacking at about 15 days after germination of the mustard crop and its population reaches at its peak in the month of December after which it declined on rapeseed-mustard (Shweta *et al*., 2017) Thus, it is mandatory to monitor mustard crop regularly during the favorable period of mustard sawfly i.e. seedling stage of the crop.

Among the various control methods, varietal resistance has received priority in Integrated Pest Management Programme (Hobner, 1972). Plants that are resistant to insect pests have the unique advantages of providing inherent insect control to the crop. Plant resistance, in most cases biochemical nature and a number of factors are responsible for resistance i.e. non-preference, antibiosis and tolerance to insects (Kher and Rataul, 1991). In order to combat the disease infestation by the aphids, the Indian Agricultural Research Institute at Pusa has developed certain plant breeding programs. These programs aim to develop higher yielding disease resistant varieties of the crops. Such an aphid resistant variety of Rapeseed Mustard is Pusa Gaurav.Host plant resistance holds a great promise for exploitation in IPM programmes because the use of resistant varieties provides crop protection that is biologically, ecologically, economically and socially acceptable.

Crop protection is achieved primarily by exercising pest control measures both at the growing as well as storage stages of crop. A number of chemical insecticides have been found effective against pest in different parts of the country (Singh *et al.,* 2014). But chemical insecticides are not only toxic to natural enemies of aphid such as *Diaeretiella rapae*, *Chrysoperla zastrowi arabica*, coccinellids and syrphid flies (Nagar *et al*., 2012), but these are also responsible for environmental pollution, health hazards to human beings, toxic to pollinators, pest resurgence, development of resistance in insect-pests and residues in oil and cake (Egambaram, 2019). Recently, several biopesticides with novel mode of action have been introduced to overcome this situation. Some of the low-risked pesticides like spinosad, imidacloprid, neem-based products, microbials and natural products have been found promising in controlling lepidopteran pests. These may be derived from plants and microorganisms (phytochemicals, microbial products) or semiochemicals (Mazid *et al*., 2011).

Imidacloprid, a neonicotinoid, is extensively used in seed treatment pre-sowing and also as foliar spray in cotton and rice crops. Both these crops have been notified as being notorious because of their high percentage of insecticide usage as compared to other conventional crops (Chagnon *et al.* 2014; Barbee and Stout, 2009). Imidacloprid comes under the chemical family named chloronicotinyl nitroguanidine of the subclass neonicotinoids. The International Union of Pure and Applied Chemistry (IUPAC) name for imidacloprid is 1-(6-chloro-3-pyridimethyl)-N-nitroimidazolidin-2-ylideneamine. Imidacloprid is an effective insecticide in the control of sucking insects, some chewing insects like termites, soil insects, whiteflies, thrips, aphids, certain micro-Lepidoptera, beetles and fleas on pets. It creates interference within the neural pathway and hinders the transmission of stimuli resulting inparalysis and ultimately leading to death (Kidd and James, 1991).

Spinosad, indoxacarb and emamectin benzoate belong to a new chemical group of insecticides and are safe to the natural enemies i.e., predators (Nasreen *et al*., 2003) and parasitoids (Williams *et al*., 2003). Spinosad is an insecticide based on chemical compounds found in the bacterial species *Saccharopolyspora spinosa*. Spinosad is registered in many countries for use on a variety of crops, including cotton, corn, soybean, fruits and vegetables (West *et al*., 2000). It has a low order of toxicity to mammals, birds and fish, and also has a favourable environmental profile as it does not leach, bioaccumulate, volatilize or persist in the environment (Sparks *et al*., 1998).

Biorationals pesticides are preferred over chemical pesticides as they are target specific, leave no harmful residues, and are safe to beneficial organisms like pollinators, predators etc. In addition, Biorational pesticides are environment friendly, cost effective and form an important component of integrated pest management. So, it is already documented that varietal resistance and selected biorational pesticides may impact a synergistic effect against the colossal damage of those mentioned insect pests of mustard.

Hence, the present investigation was conducted to study the evaluation of some popular mustard varieties against two major insect pests--aphid and sawfly attack along with application of two promising insecticides under field condition by observing the following objectives-

- To find out the incidence of aphid and sawfly in mustard field;
- To evaluate the different varieties of mustard against aphid and sawfly;
- To evaluate the combined effect of variety and reduced-risk pesticides against the pest attack; and
- To assess the population of natural enemies of insect pest occurred on different varieties of mustard.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 Population dynamics of major insect pests of mustard

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

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

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

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

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

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

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

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

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

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

Bilashini and Singh (2011) observed numerical density of the predator was observed to increase in response to increase in density of aphid prey in the field and the correlation analysis showed highly significant positive correlationship between predator and aphid species.

Venkateswarlu *et al.* (2011) recorded the peak incidence of mustard aphids (169.9 aphids/plant), diamond back moth (7.9 larvae/plant), cabbage butterfly (27.7 caterpillars/plant) during 2^{nd} week of March, 1st week of March and 2 weeks of March, respectively.

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

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

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

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

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

2.2Taxonomic position, biology and nature of damage of mustard sawfly and aphid

2.2.1 Mustard sawfly

2.2.1.1 Taxonomic position

Common Name: Mustard sawfly

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Tenthredinidae

Genus: *Athalia*

Species: *Athalia lugensproxima*

2.2.1.2 Biology of sawfly

Dark green larvae have 8 pairs of abdominal prolegs. There are five black stripes on the back, and the body has a wrinkled appearance. A full-grown larva measures 16-18 mm in length. The adults are small orange yellow insects with black markings on the body and have smoky wings with black veins. The mustard sawfly breeds from October to March and undergoes pupal diapause during summer. The adults emerge from these cocoons early in October. They live for 2-8 days and lay 30-35 eggs singly, in slits made with saw like ovipositors along the underside of the leaf margins. Egg period is 4-8 days and the larvae feed exposed in groups of 3-6 on the leaves during morning and evening. They remain hidden during the day time and, when disturbed, fall to the ground and found death. There are 7 instars with a larval period of 16-35 days. Pupation is in water proof oval cocoons in soil and the pupal period is 11-31 clays. Lifecycle is completed in 31-34 days. It completes 2-3 generations from October to March.

2.2.1.3 Nature of damage

It has a great potential to defoliate the crop plant at seedling stage. Adults inflict damage by act of laying eggs with the help of their saw-like ovipositor. Larvae nibble margins of tender leaves and later bite holes in the leaves. Larvae generally feed during dawn and dusk.

2.2.2 Mustard aphid

2.2.2.1 Taxonomic position

Common Name: Mustard aphid

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Suborder: Sternorrhyncha
Family: Aphididae
Genus: *Lipaphis*
Species: *Lipaphis erysimi*

2.2.2.2 Biology of aphid

Mustard aphid is a small, globular, pear-shaped, delicate insect with a soft and fragile body. The pest breeds parthenogenetically and the females give birth to 26-133 nymphs. They grow very fast and are full-fed in 7-10 days. About 45 generations are completed in a year. Adult aphid is found in two forms *i.e*. winged (alate) and other wingless (delate). Wingless adult aphid varies in colour mostly green or pale green and 2 mm long in size. Winged form has transparent homogeneous wings and yellowish abdomen. Young ones (nymphs) are like wingless forms but smaller in size. Two tubular structures (cornicles or siphunculi) are present in the posterior region of the body. Cloudy and cold weather (20°C or below) is very favourable for the multiplication of this pest. The winged forms are produced in autumn and spring, and they spread from field to field and, from, locality to locality.

2.2.2.3 Nature of damage

Mustard aphid appears during the end of December and remains active up to the end of March. Both nymphs and adults suck the cell sap from different parts of the plant *i.e*. inflorescence, leaf, stem, twig and pods. The pest lives in the colony and has a high rate of multiplication. Aphids appear on vegetative buds and later spread on the whole plant and devitalize the whole plant. In case of heavy infestation, the plant becomes stunted and dries up resulting in no pod formation. Insect secretes honeydew, which is responsible for the growth of a black fungus called **'**sooty mould**'** which hinders the photosynthesis. Low temperature (8-18^{0}C) coupled with 60-80 percent relative humidity, cloudy and heavy weather conditions are most favourable for multiplication of the pest.

2.3 Natural enemies on different insect pest of mustard

Pradhan *et al.* (2020) conducted a field experiment in Instructional-Cum-Research (ICR) farm, Assam Agricultural University, Jorhat duringrabi 2018 & 2019 to investigate the insect pests and natural enemies of mustard. During the period of present investigation, a total number of four insect pests from four different families viz, mustard aphid, *Lipaphis erysimi* (Kalt.); mustard sawfly, *Athalia lugens proxima* (Klug); Flea beetle, *Phyllotreta Cruciferae* (Goeze); cabbage butterfly, *Pieris brassicae* (Linn.) were recorded at different stages of mustard crop. On the other hand, total three predators viz, coccinellid beetle (*Coccinella transversalis* (Fab.) and *Harmonia axyridis* (Fab.), green lacewing, *Chrysoperla carnea* (Stephens); syrphid fly, *Xanthogrammas cutellaris* (Fab.) and one aphid parasitoid, *Diaeretiella rapae* (M'lntosh) were recorded as major natural enemies on insect pests of mustard. However, out of both coccinellids *C. transversalis* was dominant and considered as major predator of aphids.

Arshad and Rizvi (2011) studied the development of *Cheilomenes sexmaculatus* under natural conditions. Newly hatched larvae were distributed on Indian mustard, common bean, coriander, *Verbena laciniata*and *Rosa chinensis* branches infested with *Lipaphis erysimi, Aphis craccivora, Hyadaphis coriandri, Rhophalosiphum nymphaeae* and *Macrosiphum rosae.* The incubation period of *C. sexmaculata* was minimum when fed with *M. rosae* and the highest when fed with *H. coriandri.* The maximum pupal period was obtained on beetles fed with *A. craccivora.* The male and female adult longevity was lowest when fed with *L. erysimi* and the highest when fed with *A. craccivora.* The overall generation length was the lowest in beetles fed with *L. erysimi*and the highest when fed with *A. craccivora.*

Singh and Lokeshwari (2010) studied the population build up of *C. septempunctata* in relation to two prey aphid species, *L. erysimi* and *B. brassicae* on three cruciferous crops *viz.,* cauliflower, *B. oleracea* var. botrytis, cabbage, *B. oleracea* and rapeseed, *Brassica juncea* cv. M-27 for two consecutive cropping seasons. On the other hand, C. *septempunctata* and *B. brassicae* had their peak population density during February on cauliflower whereas, predator population was negatively correlated. The relative abundance of the predator on three cruciferous crops suggested that C. *septempunctata* was most abundant on rapeseed infested with *L. erysimi*, whereas C. *septempunctata* preferred *B. brassicae* infesting cauliflower.

Hugar *et al.* (2008) observed the mustard aphid *Liphaphis erysimi* commenced from the first week of December and peaked, at the third week of January with 300 aphids/planThe aphidophagous predators, namely *Coccinella septempunctata, Coccinella transversalis* and *Menochilus sexmaculata (Cheilomenes sexmacultus*), occurred at high densities in the last week of January (20.00 coccinellid/plant) to the firs tweek of March. The aphid-predating syrphid populations were recorded and its population was maximum in the first week of February (1.80syrphids/plant). One egg parasitoid *Diaereuella rapae* was identified, and parasitism was maximum in the last week of February (16.9%).

Panwar and Singh (2007) studied the diurnal mobility periods of adult beetle (*Coccinella septempunctata*) based on time-specific increase in their number in the Indian mustard field and its correlation with the environmental parameters. *Coccinella septempunctata* adults encountered in depending on the prevailing environmental conditions. The mean capture was negatively correlated with the dew and this seems to be the true explanation for January when higher numbers of individuals were observed at 11.00 h than 09.30 h. during low temperature prevalence, the activity of the beetle was spread throughout the whole day (as in the case of January).

Singh and Paras (2007) studied the effects of sowing date (30 December; 6, 13, 20 and 27 January; 3, 10, 17 and 24 February and 3 March) of *B. juncea* cv. Varuna on the occurrence of coccinellid predators of *L. erysimi.* The coccinellids, *Coccinella septemputictata, C. transversalis, Menochielus sexmaculatus (Cheilominus sexmaculata*)' and *Brumus suturalis;* the syrphids *Episyrphus balteatus* and *Syrphus* sp. and the chrysopid *Chrysoperla camea.* The coccinellid population was highest in the last week of February and the lowest in the last week of December. When the coccinellid population was significantly high, the aphids were already in migration phase. At the peak of aphid population, the coccinellids were present but were not able to keep the aphid population below the economic injury level.

Indu and Chatterjee (2006) reported that the *Coccinella septempunctata* is an aphidophagous beetle and feeds upon aphids such as *Lipaphis erysimi, Brevicoryne brassicae, Acyrtho siphon piston, Schizaphis graminum, Hyadaphis coriandri, Aphis gossypii, Melanaphis sacchari* and *Rhopalosiphum maidis* which are enormous in number infesting various valuable crops grown in the field like mustard, cabbage and wheat. Then nymph and adult aphids and ladybird beetles at the minimum number of aphid nymphs were in April and November, when the predators were inabundance.

2.4 Performance of mustard varieties against different insect pests

Bhand *et al*. (2020) reported that maximum infestation of thrip, whitefly, aphid and jassid was observed for variety ‘P-23-R2’ and minimum was observed for variety ‘UCD-1202’. The peak infestation of thrip was observed on 15th January, 2018 in all five mustard varieties. The population of thrips was linear decreased from 22nd January, 2018 to 12th March, 2018.

Verma *et al.* (2013) experienced a great variation in the thrip population among different mustard cultivars.

Malik *et al*. (2012) argued that mustard varieties with resistance against sucking complex, particularly jassid is of great economic importance.

Arshad and Rizvi (2011) find out highly resistant varieties of rapeseed-mustard, sixty-five cultivars (brown sarson-1, Indian mustard- 42, goldi sarson-4, kiran rai-4, taramera-2 toria-5 and yellow sarson-7) were screened against mustard aphid during winter season and finding revealed that aphid commenced their attack while calculating mean aphid infestation index (MAD). Below 1.00 on Kranti, Maya, MYSL-203, PCR-7, Pusa Agrani, (Indian mustard), Pusa Swami (Kiran Rai) and NDYS-2, YST-151 (yellow sarson). These cultivars safely be placed under highly resistant category. Among late sown rapeseed mustard no cultivar found as highly resistant.

Sahito *et al.* (2010) studied on population dynamics of sucking insect pests of mustard crop was conducted. Six varieties of mustard crop *viz.* Yellow sarsoon, Brown sarsoon. Dark green leaves, Torya Early, Raya Anmol and Ria S-9 were cultivated. Results' indicated that sucking insect pests such as *Bemisia tabaci,* (Germ). *Lipaphis erysimi* (Kalt.) and *Bagrada picta* (F) Appeared from seedling till harvest of the crop. Two peaks in them population of *B. tabaci* and one peak in the population *of L. erysimi* and *B. picta* were recorded. The overall means showed that the maximum (6.71± 0.98) per leaf population of *B. tabaci* was recorded on Yellow sarson followed by Dark green leaves (6.30± 0.61); Brown sarsoon (6.19 ± 0.63), Raya Anmol (5.40 ± 0.55), Torya Early (5.38 ± 0.57) and Rai S-9(3.79 ± 0.50).

Kher and Rataul (2010) studied the settling behaviour of *L. erysimi* on 7 strains of *B. compestris,* 7 strains of *B. Juncea* (Indian mustard) and 5 strains of *B. napus* (rape), in free choice experiments with all plant species present at the cotyledon stage. *B. compestris* preferred, while *B. napus* was significantly less preferred than others. At the 2 leaf stage, sarson was again the least preferred and *B. compestris* BSH-1 was the most susceptible of the plants tested followed by *B. compestris* and YSPB-24, rape GSL-1512 was the most resistant followed by GLS-1501 and GSL-1.

Pawar *et al.* (2009) carried out field studies to investigate the relative resistance of twenty genotypes cultivars of mustard against leaf webber, *Crocidolomia binotalis* during rabi

2007-08. The results revealed that the genotype SKM-0301 was found the' least susceptible to the pest (0.99 larva/ five plants) and was followed by the genotypes SKM-0445, SKM-0513, SKM-0401, SKM-0533 and SKM-0518 with 1.02, 1.05, 1.32, 1.41 and 1.52 leaf webber larvae/five plants, respectively.

Joshi (2009) field studies were carried out to investigate the relative resistance of twenty genotypes/cultivars of mustard against leaf webber, *Crocidolomia binotalis.* The results revealed that the genotype SKM-0301 was found the least susceptible to the pest (0.99 larva/five plants) and was followed by the genotypes SKM-0445, SKM-0513, SKM- 0401, SKM-0533 and SKM-0518 with 1.02, 1.05,132, 1.41 and 1.52 leaf webber larvae/ five plants, respectively.

Roy and Konar (2005) showed that varietal screening of mustard against *Lipaphis erysimi* considering six varieties most susceptible to mustard aphid followed by Agani, Binoy, Seeta, Panchali and Jhumka respectively. It was recommended that Jhumka should be sown during early November and for cultivation of susceptible varieties (Agani and Panchali) applying management practices against the pest is required for total crop season that will increase the cost of cultivation as well as environment pollution.

Vekaria and Patel (2005) observed the incidence of aphid commenced 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AI) at 14 WAS coinciding with second week of February during 1993-94, however, during 1994-95 aphid incidence commenced late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AT) 13 WAS coinciding with first week of February. Out of six cultivars, GM-1 was found to be the least susceptible variety to aphid, whereas, PM-67 and Kranti proved to be more susceptible variety to aphid.

Vekaria and Patel (2000) recorded the relative resistance of forty promising *Brassica* and allied genotypes against mustard aphid, *Lipaphis erysimi* (Kalt.) was studied in field condition and the genotypes PC-5 *{B. carinata),* T-27 (*Eruca sativa),* local genotypes *(B. toumefortii)* and T-6342 were found resistant against mustard aphid. Mustard genotypes belonging to *B. compestris group* were found to be more susceptible to aphid than that of *B. juncea.*

2.5 Effect of mustard variety on yield and yield contributing characteristics

Mashfiqur *et al.* (2022) conducted a study to determine salt tolerant varieties for maximizing mustard yield, as well as farmers' income. Experimental result revealed that the yields range of the varieties was 1.13 to 2.09 t ha^{-1} and oil was 41.37 to 43.40%. Variety BARI Sarisha-18 (Canola) produced the maximum yield (2.09 t ha^{-1}) followed by BARI Sarisha-16 (1.98 t ha^{-1}) and BARI Sarisha-11 (1.84 t ha^{-1}). Because BARI Sarisha-18 (Canola) and BARI Sarisha-16 are suitable for coastal areas, combining this variety with a coastal area cropping pattern will increase cropping intensity, which will benefit farmers both economically and nutritionally.

Sarker *et al*. (2021) conducted an experiment at the experimental field of Agrotechnology Discipline, Khulna University, Khulna during Rabi season 2016-17 to investigate the growth and yield performance of mustard varieties. The experiment was arranged in a randomized complete block design consisting of eight mustard varieties (viz. BARI Sarisha-8, BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16, Rai and Tori-7) as treatment and replicated thrice. All the growth, yield attributes and yield were substantially influence among the mustard varieties except the phenological parameters. Results of the experiment showed that the highest plant height (131.33 cm), seed yield (1813.33 kg ha^{-1}) and stover yield (3876.67 kg ha^{-1}) were found in BARI Sarisha-16. BARI Sarisha-11 was found better in respect of maximum siliqua $plant^{-1}$, weight of seeds $plant^{-1}$, 1000-seed weight and harvest index. Besides this, BARI Sarisha-14 showed the maximum number of seeds $siliqua^{-1}$.

Thakur *et al.* (2021) indicated that harvest index significantly influenced by different varieties and maximum harvest index (36.95) was observed in T2 [genotype 45S35]. However, treatment T1 [BULLET] found to be statistically at par with T2 [45S35]. As discussed earlier, the different hybrids have different yield potential, which is the reason for yield variation among different varieties.

Tripathi *et al*. (2021) at Kanpur (Uttar Pradesh), conducted a field experiment to determine the effect of sowing dates on growth and yield of Indian mustard. The experimental result revealed that the yield attributes *viz*., number of seeds $siliqua^{-1}$, number of siliqua $plant^{-1}$, seed yield and siliqua length were significantly influenced due to varieties and variety Varuna recorded significantly higher yield attributes than Narendra Rai and Kranti. Test weight of mustard did not influence due to genotypes and variety Varuna observed statistically maximum test weight.

Lal *et al.* (2020) from Bikaner conducted an experiment with four mustard varieties (RGN-73, RGN-229, RH-30 and Pusa bold) under late sown conditions and reported that variety Pusa bold gave significantly higher plant height and test weight than other varieties in comparison whereas, RGN-73 gave significantly higher siliquae per plant (170.1) seed yield (1231 kg ha^{-1}), stover yield (4597 kg ha^{-1}) and biological yield (5828 kg ha^{-1}) than other varieties in comparison.

Priyanka *et al.* (2020) from Hisar conducted an experiment to study the performance of different mustard varieties (Kranti, Giriraj, CS-54 and CS-58). The results revealed that maximum seed and stover yield were observed in variety CS-58 (21.84 and 78.41 q ha^{-1}) than other varieties in comparison.

Biswas *et al.* (2019) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques and founded that mustard varieties significantly affect seed yield. Among different varieties higher seed yield (2.24 t ha^{-1}) was observed in Improved Tori-7 variety which was followed by BARI Sarisha-16 (1.96 t ha^{-1}) and BARI Sarisha-13 (1.57 t ha^{-1}). The lowest seed yield (1.34 t ha^{-1}) was obtained from V_3 (BARI Sarisha-15) which was statistically similar with SAU SR-3 (1.53 t ha^{-1}).

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up.

Meena *et al.* (2017) noted that mustard cv. Laxmi and Pusa Agrani recorded significantly higher seed yield (1544 and 1575 kg ha^{-1}), stover yield (5117 and 5142 kg ha^{-1}) and found at par with mustard cv. Bio-902, seed yield (1646 kg ha^{-1}), stover yield (5224 kg ha^{-1}).

Sodani *et al.* (2017) observed that seed/siliqua were observed at after harvesting stage under both control and drought conditions. The highest no of seed/siliqua were observed in RH-0749 16.3 (control) and RGN-48 (13.75) under drought, while lowest in Geeta 12.7 (control) and NRCHB-101 10.33 (Drought). Under drought condition percent reduction was highest in RH-0749 38.72 % and lowest in RB-50 1.88%. They also reported that highest HI was observed in RH-0749 32.03% (control) and RGN-48 (28.47%) under drought, while lowest in GEETA 26.68% (control) and NHCHB-101 25.68% (Drought). Under drought condition per cent reduction was highest in NHCHB-101 18.54 % and lowest in RH-819 0.17%.

Helal *et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Dinda *et al.* (2015) from Mohanpur conducted a study on the performance of different mustard varieties (NRCHB 101, NPJ-112, JD-6 and SEJ-2) under late sown conditions and reported that NRCHB 101 achieved significantly higher seed yield (1.54 t ha^{-1}) than other mustard varieties viz. NPJ-112, JD-6 and SEJ-2 in comparison.

Nirmal *et al*. (2015) conducted an experiment in sandy loam soil of West Bengal on two varieties of rapeseed (NC-1, B-9) and four varieties of mustard (SEJ-2, NPJ-112, JD-6 and NRCHB 101) and reported that mustard variety JD-6 recorded significantly higher plant height (180.32 cm) and on par with NRCHB 101 (178.03 cm). NRCHB-101 achieved maximum number of siliqua per plant (146.10) and seed yield (1.54 t ha^{-1})

Pandey *et al.* (2015*)* at Faizabad (U.P.) reported that primary branches and secondary branches were significantly superior in *cv*. Narendra Rye-8501 over *cvs*. Rohini and NRC-HB 101 under plant geometry of 45 x 15 cm at all growth stages.

Patel *et al.* (2015) at Tikamgarh (M.P.) observed that mustard variety Pusa Bold led to record higher total dry biomass and its partitioning at all growth stages followed by *cvs*. Varuna and Pusa Agrani.

Sabia *et al.* (2015) in a field experiment in Kashmir valley reported that early planting on 1st October produced more number of siliquae (367.6 plant^{-1}), number of seed (21. 4 siliqua^{-1}) and 1000-seed weight (2.27 g) as compared to 15th October and 30th October sowings. They also reported significantly higher seed yield (17.7 q ha^{-1}), stover yield (56.7 q ha^{-1}) and biological yield (74.5 q ha^{-1}) as compared to 15th October (13.6, 39.9 and 53.7 q ha^{-1}, respectively) and 30th October (6.60, 20.9 and 27.5 q ha^{-1}, respectively) sowings.

Alam *et al.* (2014) conducted a field experiment to determine the changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Experimental result revealed that Varieties/genotypes of mustard used in the experiment exerted significant influence on yield and yield attributes and among different varieties maximum number of siliquae/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. This has contributed to higher yield. The lowest number of siliquae/plant (52.0 and 56.3) were found in BARI Sarisha-14.

Somondal *et al.* (2014) from Mohanpur conducted an experiment to study the performance of different mustard varieties (NRCHB 101, SEJ-2, Ashirwad, NPJ-112, JD-6, K-6 and B-9 as a control). The results revealed that significantly higher seed yield was observed in K-6 (1566 and 1633 kg ha^{-1}) in first and second year, respectively than other varieties in comparison.

Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Bio-902 remained at par with RGN-13 and significantly superior as compared to RGN-48 and PBR-357. Bio-902 cultivar produced 8.72 and 23.03 per cent higher yield, respectively, over RGN- 48 and PBR-357. However, RGN-13 and RGN-48 were remained at par with each other and significantly superior over PBR-357.

Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15. They also reported that BARI Sarisha-13 mustard variety performed well in terms of 1000 seed weight (4.0 g) over rest of varieties.

Sharma (2013) from Morena conducted an experiment to study the performance of different mustard varieties (Varuna, Kranti, Rohini, JM-1 and JM-2) and reported that Rohini resulted in significantly higher seed and stover yield (2465 and 5350 kg ha^{-1}) than other varieties in comparison.

Tyeb *et al.* (2013) reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars.

Jha *et al.* (2012) at IARI, New Delhi observed that mustard *cv*. Pusa Jagannath exhibited significantly higher total dry biomass production (647 g m^2) as compared to *cv*. Pusa Agrani (450 g m^2).

Kumari *et al*. (2012) observed that mustard hybrid DMH-1 recorded significantly greater plant height (212 cm) over *cv*. Kranti (203 cm) and hybrid NRCHB-506 (196 cm).

Adak *et al*. (2011) observed significantly higher seed yield in mustard genotype BIO169-96 (3.32 t ha^{-1}) over the genotype Pusa Jai kisan (3.12 t ha^{-1}).

Afroz *et al*. (2011) observed that *cv*. BARI Sarisha-6 exhibited significantly higher plant height (96.7 cm) as compared to *cv*. BARI Sarisha-9 (84.9 cm). They also reported significantly higher seed yield was found in *cv*. BARI Sarisha-9 (1.54 t ha^{-1}) as compared to *cv*. BARI Sarisha-6 (1.41 t ha^{-1}).

Lallu *et al.* (2010) at Kanpur (U.P) observed that among different mustard genotypes, plant height of genotype RGN-152 was significantly greater (184.7 cm) as compared to other genotypes in normal sowing and in late sown condition cv. RGN- 145 exhibited significantly greater (118.5 cm) plant height.

Rashid *et al.* (2010) conducted a field experiment to find out the effect of the different levels of fertilizers on the growth parameters of mustard varieties of BARI sharisa-9 (V_1), BARI sharisa-12 (V_2) and BARI sharisa-15 (V_3), and to find out the optimum and economically viable fertilizer dose and reported that variety BARI sharisa-15 is of the tall plant type and that others are of intermediate and short stature in plant height. The significant difference in plant height might be associated with the variety characteristics or genetic makeup of the plant.

Singh *et al*. (2010) conducted an experiment in sandy loam soils of Varanasi and reported that 'NRCHB-101' being at par to Ashirwad produced significantly higher seed yield and stover yield over Varuna, Kranti and Vardan in both the years (1,811 kg ha^{-1} and 1,827 kg ha^{-1}). On pooled basis, NRCHB-101 recorded seed yield of 1,819 kg ha^{-1}, which in turn recorded 3.72, 6.33, 7.23 and 7.92 per cent higher seed yield than Ashirwad, Varuna, Kranti and Vardan, respectively.

Sultana *et al.* (2009) studied that stover yield for different varieties of rapeseed under study differed significantly. Kollania produced higher stover yield (2159.0 kg ha^{-1}) which was statistically at par with SAU Sarisha-1 (2156.0 kg ha^{-1}) and higher than Improved Tori -7 (1681.0 kg ha^{-1}).

Sana *et al.* (2003) reported that, higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Singh *et al.* (2002) observed that biological yield was significantly higher in mustard *cv.* Laxmi (1370 kg ha^{-1}) over *cv.* BJH-1 (1190 kg ha^{-1}).

2.6 Effect of biorational pesticide on insect pest management of mustard

Sreeja and Kumar (2022) conducted an experiment at the Central Research Field (CRF), Department of Entomology, SHUATS, Prayagraj during Rabi 2021-2022. Seven treatments were evaluated against *Lipaphis erysimi*, i.e., Imidacloprid 17.8% SL (T_1), Cypermethrin 10% EC (T_2), Spinosad 45% SC (T_3), *Metarhizium anisopliae (*T_4), Neem oil 5% (T_5), NISCO MECH 333 (T_6), NISCO Sixer Plus (T_7) and untreated control (T_8) were evaluated against mustard aphid (*Lipaphis erysimi*). Results revealed that, among the different treatments, the highest per cent population reduction of mustard aphid was recorded in Imidacloprid 17.8% SL (88.184%) followed by Spinosad 45% SC (81.498%), Cypermethrin 10% EC (76.937%). It is followed by Neem oil 5% (72.976%) and NISCO MECH 333 (68.251%), NISCO Sixer Plus (58.914%) and *Metarhizium anisopliae*

(53.123%) was the least effective among all treatments. While, the highest yield 18.15 q/ha was obtained from the treatment Imidacloprid 17.8% SL as well as B:C ratio 1: 5.20 was obtained high from this treatment. It was followed by Spinosad 45% SC (1: 4.87), Cypermethrin 10% EC (1: 4.58), Neem oil 5% (1:4.15), MECH 333 (1: 3.98), Sixer plus (1: 3.46), Metarhizium anisopliae (1: 3.42), as compared to Control (1: 2.74).

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

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

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

Lal *et al*. (2018) reported that Imidacloprid 17.8% SL + NSKE 5% combination was found to be effective in suppressing the aphid population in a significant level.

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

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

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

Studies on the management of tomato fruit borer, *H. armigera* by chemical insecticides and neem products were carried out by Faqiri and Kumar (2016). The results revealed that the lowest fruit infestation (%) was recorded in profenophos 50% EC (4.35), followed by spinosad 45% SC (5.37), deltamethrin 2.8% EC (5.90), NSKE (5.90), chlorantraniliprole 18.5% SC (6.55) and neem oil (6.65). The highest yield was recorded in neem oil (15 q/ha), followed by NSKE (13.00 q/ha).

An investigation was undertaken by Bharati *et al.* (2015) on the persistence toxicity (PT) of some insecticides like spinosad 45 SC, against major insect pests of brinjal during kharif season. Spinosad @ 0.005% showed high levels of PT value against third instar larvae of *L. orbonalis* at third spray (800.24) and fourth spray (786.10), respectively.

Dhaka *et al*. (2015) conducted a field experiment to determine the comparative efficacy of insecticide, spinosad 45 SC @500 ml/ha, *Bt* @1.5 kg/ha and Neemarin 1500 ppm @3000 ml/ha, on chickpea crop (var. Surya) against *H. armigera* during rabi seasons. In comparison to untreated check plot (16.67% larval population), spinosad showed lowest pod infestation (1.83%).

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.

Sohail *et al.* (2011) carried out a field experiment 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/cm² 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.

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

Atwa *et al.* (2009) reported that *B. bassiana* (F1, F2, and F3) exhibited moderate effect on the larvae of *P. rapae*, while the effect was high on the pupae. The larvae of *P. rapae* were more sensitive to spinosad than emamectin benzoate, while the pupal stage was less sensitive to both synthetic pesticides. Under field conditions, spinosad provided a therapeutic and residual level of control against *P. rapae*. Moderate insect population reduction was obtained by *B. bassiana* (F2), while the least insect population reduction occurred with *B. bassiana* (F1).

Gill *et al.* (2008) determined the efficacy of new insecticides, namely spinosad 2.5 SC (spinosyn A 50% minimum and spinosyn D 50% maximum) at 600 ml/ha, emamectin benzoate 5 SG at 170 g/ha and KN-128 15 EC (indoxacarb) at 333 ml/ha for the control of

P. xylostella on cauliflower and cabbage in Ludhiana (Punjab). The three new insecticides significantly resulted in maximum reduction in *P. xylostella* larval population ranging from 84.54 to 93.58% on cauliflower and 89.24 to 91.49% on cabbage crop compared to 43.14-58.60% reduction in standard controls on cauliflower and 68.61-77.45% reduction on cabbage crop. The marketable yield was significantly higher in spinosad 2.5 SC treatment (193.03 q/ha of cauliflower and 320.26 q/ha of cabbage crop).

Sujay *et al.* (2008) reported that seed treatment with imidacloprid 70 WS at 5 g/kg seed + foliar spray of monocrotophos 36 SL at 500 g a.i./ha at 15 days after germination and cypermithrin 10 EC at 30 g a.i./ha at 60 days after germination was found effective in reducing jassids population in okra and the same treatment was found effective in reducing fruit borer infestations also.

Patil *et al.* (2008) studied the efficacy of thiamethoxam 500 FS at 2.0 and 3.0 g a.i./kg seeds, against sucking insects pests *viz.*, aphids, jassids and thrips. Results indicated that higher dosage thiamethoxam 500 FS at 3.0 g a.i./kg was found to be very effective in reducing the sucking pest population and recorded higher yield of seed cotton. Its efficacy it was as good as imidacloprid 70 WS and thiamethoxam 70 WS.

Preetha *et al.* (2007) evaluated the imidacloprid spray against bhendi aphid, *Aphis gossypii* and revealed that imidacloprid 17.8 SL at 25 g a.i./ha was effective in controlling the population of aphids upto 25 days.

Sinha and Sharma (2007) recommended the neo-nicotinoids choices such as *viz.*, imidacloprid seed treatment (3.0 or 5.4 g a.i./kg seed) or foliar spray of thiacloprid at 20 g a.i./ha or thiamethaxom 25 WG at 25 g a.i./ha for the management of *A. biguttula biguttula* population in okra.

Day *et al.* (2005) evaluated imidacloprid 70 WS as seed treatment chemical at the time of sowing and imidacloprid 17.8 SL was applied as foliar spray at 20 and 40 days after sowing. Carbosulfan 25 DS and monocrotophos 36 SL were applied as standard chemical checks. Results revealed that all the insecticides treated plots showed significantly superior control of whiteflies and leafhoppers. All the dosages of imidacloprd 70 WS *viz.*, 5, 7.5 and 10 g/kg seed provided excellent protection against, whiteflies and leafhopper upto 45 days after sowing and their efficiencies were significantly superior to carbosulfan at 50 g/kg of seed. The two foliar sprays of imidacloprid 17.8 SL, *viz.*, 100 and 125 ml/ha also provided excellent control of aphids, thrips, whiteflies and leafhoppers upto 15 days after spraying.

According to Kale *et al.* (2005) seed treatment with thiamethoxam at 5 g a.i./kg followed by alphamethrin 0.05% spray was the most effective treatment in reducing the whitefly populations in okra with higher yield and cost benefit ratio.

Lal and Sinha (2005) evaluated four (5, 9, 18, 36 g/kg) doses of imidacloprid as seed treatments against sucking pests of okra. Studies revealed that seeds treated with imidacloprid afforded an effective protection of okra crop against leafhoppers and their populations remained below economic threshold level throughout the experiment. But, the treatments having imidacloprid seed treatment at 5 g/kg seed along with two foliar sprays of betacyfluthrin or altering of lambdacyhalothrin and endosulfan were most effective treatments. While seed treatment at 36 g/kg was second effective treatment ($p<0.01$) against shoot and fruit borer and all the treatments recorded higher fruit yield.

Ganapathy and Karuppiah (2004) evaluated two seed treatment and seven spray formulations against whitefly, mungbean yellow mosaic virus (MYMV), urbn bean leaf crinkle virus (ULCV) disease incidence and its vector whitefly under field conditions. Results revealed that minimum (11.4 no./plants) whitefly population was recorded with thiamethoxam 0.2 g/l sprayed 15 days after sowing. The MYMV incidence 60 days after sowing was minimum (4.5%) in seed treatment with thiamethoxam at 5 g/kg and the ULCV disease incidence was minimum (5.8%) in thiamethoxam (0.2 g/l) sprayed plots, 15 days after sowing.

Patil *et al*. (2004) tested the efficacy of thiamethoxam 35 FS- a new seed dresser formulation for sucking pests of cotton. At the two dosages tested *viz*., 2.0 and 3.0 g a.i./kg of seeds, Cruiser 35 FS was found effective in reducing the population of aphids, leafhoppers and thrips and providing higher yield of seed cotton.

Prasanna *et al.* (2004) evaluated the thiamethoxam 70 WS against early sucking pests of cotton and found that thiamethoxam 10 g a.i./kg was highly effective against leafhopper upto 50 days. However, even at lower doses (2.85 and 4.28 g a.i./kg), it gave good control of sucking pests upto 40 days after treatment.

Rohilla *et al.* (2004) reported that both Imidacloprid and Thiomethoxam were found as effective against the aphid population.

Dikshit *et al.* (2002) observed that seed dressing of okra with imidacloprid 60 FS at 3, 5.4 and 10.8 g a.i./kg seed kept the crop free from leafhopper incidence upto a period of 45 days and thereafter build up in pest population was noticed in lower dosage treatment (3 g a.i./kg).

Krishna *et al*. (2001) evaluated the efficacy of imidacloprid (Gaucho 60 FS) and thiamethoxam 25 WG on okra leafhopper, *A. biguttula biguttula*. Results indicated that thiamethoxam was on par with imidacloprid seed treatment at 12 ml/kg of seed in reducing the leafhopper infestation.

Patil *et al.* (2001) reported that on acetamiprid 20 SP against early sucking pests and their predators in irrigated cotton, at RRS, Raichur. Results revealed that, acetamiprid 20 SP at dosage 26.25 g/kg of seed protected the cotton crop upto 39 days against early sucking pests. Whereas, two applications of acetamiprid 20 SP as foliar spray at 15 g a.i./ha on ETL basis protected the crop upto 60 days effectively.

Dandale *et al.* (2001) revealed the results with seed treatment of imidacloprid 70 WS and opined that imidacloprid at 5 g/kg seed was found effective in keeping the population of jassids below economic threshold level upto 60 days in cotton.

Mathirajan and Raghupathy (2001) reported that Thiamethoxam (applied 3 or 6 g a.i/kg of seeds) along with imidacloprid (5 g a.i./kg of seeds) were evaluated for their toxicity to cotton aphid, *A. gossypii*, and leafhopper, *A. biguttula biguttula*. Treatments of cotton seeds with thiamethoxam remained effective for 44 days against aphid and for 45 days against, leafhopper, when used at 6 g a.i./kg seed. Thiamethoxam at 100 g a.i./ha applied as foliar treatment persisted for 26 days against both the pests.

According to Vadodaria *et al.* (2001) seed dressing with insecticides *viz*., thiamethoxam (Cruiser) 70 WS at 4.3 and 2.8 g/kg seeds, imidacloprid (Gaucho) 60 FS at 12 ml and 9 ml/kg seeds and imidacloprid 70 WS at 7.5 g/kg seeds treatments kept the population of aphids and leafhopper in cotton below ETL level upto 50 and 60 days after sowing respectively than standard check Carbosulfan 25 DS at 50 g/kg seeds and untreated control.

Sunanda *et al*. (1998) evaluated the efficiency of imidacloprid 70 WS on chilli (15 g/kg chilli seeds) against thrips, aphids and mites and recorded the average count as 4.2, 10.1 and 3.2 per six leaves respectively at 30 days after sowing.

Sreelatha and Divakar (1997) found that seed treatment with imidacloprid at 7.5 g per kg of okra seed was effective against aphids up to 35 days after germination.

Boiteau *et al.* (1997) evaluated the efficacy of imidacloprid against potato aphids and reported that soil application of imidacloprid at 0.03 g a.i./ha effectively controlled the aphid, *Macrosiphum euphorbiae* (Thomas), *M. persicae* and *A. naslarlii* (Keltenbach) for 62-65 days.

Ayala *et al.* (1996) tested the efficiency and persistence of insecticides applied at sowing time and to foliage against colonies of *M. persicae* with differential resistance and *Aphis faba*e (Scop.) in natural and artificial infestation on sugarbeet and concluded that imidacloprid applied at sowing was most efficient insecticide for very resistant colonies of *M. persicae* with persistence of exceeding 60 days.

Desan *et al*. (1995) found that imidacloprid as seed treatment of sugar beet at 90 g per unit was effective against *M. persicae*.

2.7 Effect of biorational pesticide on natural enemies of insect pest of mustard

Bhatt *et al*. (2018) bio-efficacy of six insecticides *viz*. carbofuran 3% CG, thiamethoxam 25% WG, chlorantraniliprole 18.5% SC, quinalphos 25% EC, buprofezin 25% SC, cypermethrin 25% SC against aphids, whitefly and their predators in okra agro-ecosystem. Among all the treatments buprofezin 25% SC was highly effective against whitefly (77.45% and 74.22% reduction over control) after first and second spray, respectively. The plots treated with chlorantraniliprole 18.5% SC recorded the maximum population of spiders and *Coccinella* spp. Similarly, chlorantraniliprole 18.5% SC treated plot recorded the maximum yield followed by thiamethoxam 25% WG.

Wagh *et al*. (2017) effect of insecticides on natural enemies (lady bird beetle) revealed that the insecticides namely spinosad 45 SC and, abamectin 1.9 EC, chlorantraniliprole 18.5 SC and novaluron 10 EC were found safer to the predatory coccinellids. Whereas, flubendamide was moderately toxic to coccinellids. Cypermethrin 25 EC, indoxacarb 14.5 SC and emamectin benzoate 5 SG was found detrimental to the natural enemies.

Patil *et al.* (2007) reported that all the dosages (10, 15, 20 and 25 g a.i./ha) of clothianidin 50 WDG were safe to natural enemies (coccinellids and chrysopids) in cotton ecosystem.

Indumathi and Savithri (2006) studied the toxic effect of insecticides on predatory coccinellids beetles in the mango ecosystem. Study indicated that endosulfan was safe to coccinellids beetles than malathion and cypermethrin. Two spray of imidacloprid and single spray of carbaryl maintained similar population level, which indicated that imidacloprid was comparatively safer than carbaryl to coccinellids beetles.

Day *et al*. (2005) evaluated imidacloprid 70 WS as seed treatment chemical at the time of sowing and imidacloprid 17.8 SL was applied as foliar spray at 20 and 40 days after sowing. Significantly higher number of predatory coccinellid grubs was recorded in imidacloprid treated plots, irrespective of formulation and dosages.

Kadam *et al.* (2005) studied the impact of insecticide sequence on natural enemies in brinjal ecosystem and revealed that among different sequences, the treatment with imidacloprid followed by NSKE followed by imidacloprid sequence recorded significantly lower populations of coccinellids (9.0/ plot) as compared to spinosad followed by NSKE followed by spinosad (12.6 coccinellids/ plot) and untreated control (13.00/ plot).

Kannan *et al*. (2004) reported that seed treatment of transgenic cotton with imidacloprid 5 g/kg seed was not only safe but also attracted predators, *viz.*, coccinellids beetles, *Coccinellaseptumpunctata* (Linnaeus) and *C. sexmaculatus*; green lace wing, *C. carnea* and Lynx spider, *Oxyopes javanus* (Thorell); orb spider, *Argopeminuta* (Karsh);

wolf spider, *Lycosa pseudoannulata* (Boesenberg and Strand); long-javed spider, *Tetragnatha javana* (Thorell); *Neoscona theisi* (Walcknear) and *Peucetia viridana* (Stoliczka) in transgenic cotton.

Sunitha *et al*. (2004) studied the relative toxicity of different groups of chemicals *viz*., dichlorvos, nimbicidine, *B.t*. (Delfin), novaluron (IGR), spinosad and imidacloprid and combination of dichlorvos, spinosad and imidacloprid with novaluron and *B.t*. against predatory coccinellids beetles *C. sexmaculata* and *Micraspis univittata* (Hope) on okra. Results indicated that dichlorvos and imidacloprid alone were found to be toxic compared to their combination with eco-friendly chemicals. The treatments *B.t* and nimbicidine were found to be relatively safe to coccinellids.

Satpute *et al*. (2002) reported that seed treatment of cotton with imidacloprid and thiamethoxam was not only safe but also attracted the population of *C. sexmaculata* adults and *C. carnea* eggs. *C. sexmaculata* preferred plants raised from the imidacloprid treated seeds with higher dose, however, *C. carnea* preferred thiamethoxam for oviposition with lower dose.

Patil *et al.* (2001) evaluated bioefficacy of acetamiprid 20 SP against early sucking pests and their predators in irrigated cotton, at Regional Agricultural Research Station, Raichur. Results revealed that seed dressing has recorded higher population of predators.

Katole and Patil (2000) evaluated the biosafety of imidacloprid and thiamethoxam as seed treatment and foliar sprays to some predators. Results revealed that seed treatment was safer than foliar sprays. Imidacloprid at 10 g/kg seed treatment (higher dose) allowed activities of maximum lady bird beetle adults and thiamethoxam at 4 g/kg seed treatment allowed maximum oviposition of *Chrysoperla* at par with untreated control on cotton.

Patil and Lingappa (1999) studied the persistent toxicity of insecticides against *Cheilomenes sexmaculatus* (Fabricius), a predator of tobacco aphid, *Myzus nicotianae* Blackman. Among the tested insecticides acephate, imidacloprid and Carbosulfan exhibited considerable indirect toxic effect on the population of *Cheilomenes* *sexmaculatus*. However, oxydemeton methyl was relatively safe to *Cheilomenes sexmaculatus.*

2.8 Effect of biorational pesticide on yield and yield contributing characteristics of mustard

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

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

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

Kumar *et al*. (2015) evaluated the efficacy of two neonicotinoids on mustard aphid and its subsequent effect on yield. They noted that, imidacloprid @ 20 -60 g a.i./ha on rapeseed crop (TS-36) and recorded seed yield ranging from 10.31-11.19 q/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).

Aziz *et al.* (2014) evaluated different neem products to manage mustard aphid and its effect on crop yield and cost benefit ratio. They revealed that, highest yield was obtained in imidacloprid (1557kg/ha) treated plot followed by neem seed oil (1472 kg/ha) and neem seed kernel extract (1429 kg/ha). Further, maximum cost benefit ratio was observed in imidacloprid treated plot (28.00) followed by neem leaf extract (11.38) and neem seed cake extract (10.11).

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

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

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

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the evaluation of some popular mustard varieties against aphid and mustard sawfly attack under field condition. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from November 2020 to April 2021 in Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

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

3.2.2 Agro-Ecological Zone

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

3.2.3 Soil

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

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Planting materials

Different mustard varieties were used as planting materials for this experiment.

3.4 Experimental treatment

There were two factors in the experiment namely different mustard varieties and different biorational pesticides as mentioned below:

Factor A: Mustard varieties (3) *viz;*

V_1 = BARI sharisha-1,
V_2 = BARI sharisha-9 and
V_3 = BARI sharisha-14

BARI Sharisha-1

Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, developed BARI Sharisha-1. In the year 1976, the variety was released. Plant height ranges between 60-70cm, primary branches 2-3, pods/plant 50-60, two chambered pod, and 10-12 seed/pod. Because the petiole of the flower is long, the blooming flower is located at the top of the bud. The siliqua is slightly thick, the seed is round and pale in color, and 1000 seeds weigh between 2.6-2.7 g. It is planted during the Rabi season, from mid October to mid November, with a yield of 1.0-1.2 t/ha, an oil content of 38-41%, and a moderate waterlog tolerance. This variety is currently under attack from various diseases and insects. Therefore, it is demoralizing to grow this variety.

BARI Sharisha-9

Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, developed BARI Sharisha-9. In the year 2000, the variety was released. Plant height ranges between 80-95 cm, having 4-6 primary branches per plant, leaf light green and smooth, blooming flower in upright position on axils, stem coated by pedicel of leaf, flower is yellow, number of siliqua /plant 80-100, seed color pink, seed/siliqua 15-20 and 1000 seed weight ranges between 2.5-3.0 g. Because of its short lifespan, it is easily cultivated. It is planted during the Rabi season, from mid October to mid November, with a yield of 1.25-1.45 t/ha and an oil content of 43-44%.

BARI Sharisha-14

Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, developed BARI Sharisha-14. Tori and Sonali Sarisha varieties were crossed to create this character, which was released in 2006. Short duration variety. Plant height ranges between 75-85 cm, leaf light green, smooth, siliqua/plant 80-102, pod has two chambers but appears to have four chambers. Seed/siliqua 22-26, seed color pink, 1000 seed weight ranges between 3.5-3.8 g, crop duration 75-80 days. Because of its short duration, it is easily cultivated. It is planted during the Rabi season, from mid October to mid November, with a yield of 1.45-1.60 t/ha and an oil content of 44-45%.

Factor B: Different biorational pesticides (3) *viz;*

P_0 = Untreated (Control)

P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water; manufacturer: Bayer Crop Science Limited

P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water; manufacturer: Auto Crop Care Limited.

3.5 Seed collection

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

3.6 Field operation

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

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

Sl. No.	Field operations	Date
1	Final land preparation	10 November 2020.
4	Layout of the experimental field	10 November 2020
3	Fertilizer application	10 November 2020
5	Sowing of seeds	13 November 2020
10	Germination of seeds	19 November 2020
11	Gap filling	6 December 2020
12	Application of pesticides	Start in 10 December 2020 and carried in once in a week
13	Thinning	10 December 2020
14	Weeding	10 December and 5 January
15	Irrigation	20 January and 19 February 2021
16	Harvesting	7, 9 and 11 April 2021

3.7 Land preparation

Initially the field was prepared with the help of tractor drawn implement. After giving one deep ploughing the experimental field was cross harrowed and leveled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing seeds of the subsequent crops of the experimental study. Land preparation was done at 10 November 2020.

3.8 Experimental design

The experiment was laid out in randomized complete block design. There were 3 treatment Interactions and 27 unit plots with three replications. The unit plot size was 3.75 m^2 (2.5 m

× 1.5 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was shown in Appendix- IV.

3.9 Fertilizer application

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

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

Source: (BARI, 2019)

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

3.10 Intercultural operations

i) Weeding

Weeding were done at 15 and 40 DAT.

ii) Irrigation

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

iii) Application of pesticides

The required quantity of volume of spray solution was diluted by mixing water and all treatments were sprayed with the help of Knapsack Sprayer.

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

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

Table 2. Mode of observation of insect-pests and predators

Sl. No.	Insect-pests/ Predator	Mode of observation
A.	Insect- pests	
1.	Mustard aphid	Number of nymph and adult of aphid/upper 10 cm central twig/plant
2.	Mustard sawfly	Number of larvae/plant
3.	Other pests	Number of insect/plant
B.	Predators	
1.	Lady bird beetle	Number of grub and adults/plant
2.	Syrphid Fly	Number of both larvae and adult of syrphidfly/plant
3.	Spiders	Number of Spiders/plant

3.11 Harvesting

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

3.12 Data collection

The data were recorded on the following parameters;

i. Incidence of insect pest complex (e.g. aphid, sawfly, others) at different DAS

ii. The occurrence of major predators (e.g. ladybird beetle, syrphid fly, spider) at different DAS
iii. Number of infested siliqua plant^{-1} (selected plants)
iv. Number of healthy siliqua plant^{-1} (selected plants)
v. Seeds siliqua^{-1} (10 randomly selected siliqua/plot after harvest)
vi. 1000-seed weight (g)/plot
vii. Seed yield/plot

3.13 Procedure of recording data

i. Incidence of insect pest complex at different DAS

Insect pests found in all treated plots including control plots were recorded in order to evaluate their incidence and severity.For this purpose, 10 plants were randomly selected from each plot and each treatment. Observations were recorded at 7 days interval starting from 1st day of germination up to harvesting. Data were collected on the number of aphids, sawflies and other minor insect pests through visual counting.

ii. The occurrence of major predators at different DAS

Number of natural enemies present per ten randomly selected plants of mustard were counted at 7 days intervals starting from1st days of germination up to harvesting. This operation was done by visual observation at early in the morning. Number of natural enemies like lady bird beetle (both grub and adult), hover fly larvae and adult, spider, etc. were counted separately for each treatment through visual observation in the field.

iii. Number of infested siliqua plant^{-1}

Insect infested siliqua plant^{-1} was counted from the 10 randomly selected plant samples and then the averaged siliqua was calculated.

iv. **Number of healthy siliqua plant^{-1}**

Healthy (non-infested) siliqua plant^{-1} was counted from the 10 randomly selected plant samples and then the averaged siliqua was calculated.

v. Seeds siliqua^{-1} (10 randomly selected siliqua/plot after harvest)

After harvesting, seeds siliqua^{-1} was counted separately from splitting ten siliquae which were collected randomly from each plot and then mean value was calculated.

vi. 1000-seed weight (g)

Thousand-seed were counted randomly from the seeds of each plot, then weighed it in an electrical balance in gram (g). It was conducted after harvesting and threshing.

vii. Seed yield plot^{-1} (kg)

The weight of total seeds plot^{-1} was calculated at harvested and was expressed in kilogram (kg) in dry weight basis.

3.14 Data analysis technique

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

CHAPTER IV

RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on the evaluation of some popular mustard varieties against aphid and sawfly attack under field condition. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Incidence of major insect-pests during crop seasons

Based on regular monitoring of the field of mustard for major insect-pests of mustard and its natural enemies started from germination to harvest during 2020-2021 showed that only two insect-pests' *viz*. mustard sawfly (*Athalia lugens proxima*) and mustard aphid (*Lipaphis erysimi*) caused damage to mustard in this area. The natural enemies' population was also recorded (Table 3). The incidence of these insect pests and natural enemies were fluctuating under varying weather conditions. Thus, recorded data were statistically analyzed and depicted here as under Table 3.

4.1.1 Mustard sawfly

The incidence of mustard sawfly recorded at weekly intervals during crop season revealed that the insect appeared at an early stage (49th standard week (SW) of 2020 to 2nd standard week of 2021) of crop growth. During Rabi 2020-21, the initial population of this insect (0.33 larvae/plant) was recorded in the 49th standard week (2nd week of December 2020). This was increased to the level of 2.33 larvae/plant in 1st standard week (1st week of January 2021). Thereafter, the population of mustard sawfly declined and it was not observed at the 3rd standard week (Table 3). Jat *et al*. (2006) observed the infestation of sawfly from the first week after sowing up to 4th week during Rabi, 2002-03. The sawfly population peaked (6 larvae 5 plants) during the 2nd week of November.

4.1.2 Mustard aphid

The appearance of mustard aphid was stated from 51st standard week (Fourth week of December 2020) to 14th standard week (First week of April 2021) with 0.33%, this population ranging from 0.33 to 55.33 aphids/10 cm central twig/plant in different standard weeks. The peak period of occurrence of this insect was observed in the 10^{th} standard week (Second week of March 2021). The maximum population of aphid was recorded as 55.33 aphids/10 cm central twig/plant recorded at a minimum temperature of 13.92°C, the maximum temperature of 26.57°C, the relative humidity of 72.92%, and sunshine for 7.18 hours. The minimum population 0.33 aphids /10 cm central twig/plant was recorded at 2^{nd} standard week with a minimum temperature of 13.94°C, a maximum temperature of 16.35°C and sunshine for 1.97 hours (Table 3). Pal *et al*. (2015) recorded a population of aphid was noticed from last week of December and population was reach in second week of February.

4.1.3: Other insect-pest

The occurrence of other insect-pests (grasshopper, green bug, cabbage butterfly, moths, etc.) was started from 2^{nd} SW (Second week of January 2021) to 10th SW (Second week of March 2021) with a varying population ranging from 0.33 to 2.67 insects per plant in different standard weeks. The peak period of occurrence of these insects was observed in 6^{nd} and 8^{nd} SW. During Rabi 2020-21, the maximum population of these insects was recorded as 2.67 insects/plants. The minimum population 0.33 insects/plant was recorded at 2^{nd} SW with a minimum temperature of 13.94°C, the maximum temperature of 16.35°C and sunshine for 1.97 hours. (Table 3 and Appendix III).

4.2. The occurrence of major predators

4.2.1 Ladybird beetle (*Coccinella* spp.)

The Incidence of ladybird beetle *Coccinella* spp. as a predator of mustard, aphid was recorded on the crop with various species. *Coccinella* spp**.** was observed active in predating on mustard aphid from 1^{st} standard week (First week of January 2021) to 10^{th} standard week (First week of March 2021) during Rabi 2020-21. The*Coccinella* spp. population ranged from 0.33 to 4.0 (adult and larvae/plant) during the whole observation period. The population of the predator was initially low (0.33 adult and larvae/plant) on the 3^{rd} and 10^{th} standard week. The population of the predator increased gradually and reached a peak, (4 adult and grub/plant) on the 10^{th} standard week (Table 3).

4.2.2 Syrphid fly

The incidence of the syrphid fly as a predator of mustard aphid was recorded on the crop with various species. The syrphid fly was observed active in predating on mustard aphid from 1st standard week (First week of January 2021) to 8th standard week (Third week of February 2021) during Rabi 2020-21. The syrphid fly population ranged from 0.33 to 3.67 (adult/plant) during the whole observation period. The population of the predator was initially low (0.33 adult/plant) in a different standard week. The population of predator increased gradually and reached at peak (3.67 adult/plant) in 6th standard week (Second week of February 2021) with a minimum temperature 14.21 °C, the maximum temperature of 22.5°C and sunshine for 8.18 hours ((Table 3 and Appendix III).

4.2.3 Spider

The incidence of a spider as a predator of mustard insects-pests was recorded in mustard crops with various species. The spider was observed active in predating on mustard insect-pests from the 49th standard week (First week of November 2020) to the 11th standard week (Third week of March 2021) during Rabi 2020-21. The Spider population ranged from 0.33 to 2.67 (spider/plant) during the whole observation period. The population of the predator was low (1.0 spider/plant) at 49th, 2th, 5th, 7th, and 10th standard week. The maximum population of predator (2.67 spider/plant) on 8th SW (Table 3).

4.2.4 Other predator

The incidence of unidentified predators was recorded periodically during crop season, revealed these predators appeared at 1st standard week to 10th SW of crop growth period during Rabi 2020-21. The initial and minimum 0.33 predator/plant population of these predator has recorded in 1st SW as well as 10th SW also. This population increased up to the maximum level with 2.33 predator/plant in 8th SW (4th week of February 2021). Thereafter, the population of predators declined and it was not observed from 11th onward (Table 3)

Table 3. Occurrence of mustard insect-pests and predator population during Rabi season, 2020-2021

	Insect-Pests			Predator			
Standard Week	**Sawfly (larvae/ plant)**	**Mustard Aphid (nymph and adult/ 10 cm central twig/plant)**	**Other**	***Coccinella* spp. (adult and grub/plant)**	**Syrphid fly (adult/plant)**	**Spider**	**Other**
47	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
49	0.33	0	0	0	0	1	0
50	0.33	0	0	0	0	0.33	0
51	1	0.33	0	0	0	0	0
52	1.33	1	0	0	0	0	0
1	2.33	0.67	0	0	0.33	2	0.33
2	1.66	2	0.33	0	0.33	1	1
3	0	2.66	0	0.33	0	1.33	0.67
4	0	4.66	0.67	0	1.67	2	1
5	0	3.33	1	0.67	3	1	0
6	0	2.66	2.67	1	3.67	0.67	0.67
7	0	43.00	3	1.67	2.33	1	1.33
8	0	54	1.67	2.33	1.33	2.67	2.33
9	0	55	1.33	3.33	0	1.67	1
10	0	55.33	0.67	4	0	1	0.33
11	0	51.33	0	2.67	0	2	0
12	0	9.33	0	1.33	0	0	0
13	0	5.33	0	0.67	0	0	0
14	0	2.67	0	0.33	0	0	0

Date of sowing: 19 November 2020.

4.3. The correlation coefficient between the occurrence of insect pests with biotic (Predators) factors

The incidence of insect-pests recorded in crop seasons, Rabi 2020-21 was correlated with biotic (Predators) factors to determine the correlation coefficients with natural enemies (Table 4).

4.3.1 Mustard sawfly with biotic factor

The correlation co-efficients between the incidence of mustard sawfly and biotic factors revealed both positive and negative correlations. However, none of the correlation coefficients were found significant in whole crop seasons with biotic parameters.

4.3.2 Mustard aphid with biotic (Predators) factor

Positive correlation coefficients between the occurrence of mustard aphid and biotic parameters were found. These correlation coefficients values were found significant with *coccinella* spp., spider, and other. Bilashini and Singh (2011) observed numerical density of the predator was observed to increase in response to increase in density of aphid prey in the field and the correlation analysis showed highly significant positive correlationship between predator and aphid species.

4.3.3 Other insects with biotic (Predators) factor

The correlation coefficients between the incidence of other insects and biotic parameters showed a positive relationship. A significant positive relationship was observed with the syrphid fly and others (Predator).

Table 4. Corelation coefficients of the insect-pests population with biotic (Predators) factors during Rabi season, 2020-2021

S. No.	Insects	Biotic factor (Predators)			
		***Coccinella* spp.**	**Syrphid Fly**	**Spider**	**Others**
1.	**Mustard sawfly**	-0.398	-0.211	0.054	-0.073
2.	**Mustard aphid**	0.921*	-0.076	0.405*	0.385*
4.	**Others**	0.408	0.801*	0.321	0.659*

*Significant at 5% level of significance

4.4 Effectiveness of treatments against mustard sawfly

One day before spraying of the treatment (pre-treatment) the population of mustard sawfly was observed ranging from 1.33 to 2.33 larvae/ plant, which was significant during Rabi 2020-21 (Table 5).

The application of treatments reduced the population of mustard sawfly, whereas the population of mustard sawfly increased in control, indicating that all treatments were effective in controlling mustard sawfly. However, cultivation of BARI sharisha-14 in conjunction with Confidor 70WG (imidacloprid) @ 0.2 g/L of water application (V_3P_1) resulted in lower mustard sawfly infestation and was found to be superior overall to other varieties and botanicals up to 15 days after spraying.

Table 5. Effectiveness of biorationals pesticide against mustard sawfly during *Rabi* season2020-2021

Treatment combinations	The population of mustard sawfly (Av. No. larvae/ plant)				
	Pretreatment*	Post-treatment**			
	1 DBS	1 DAS	3 DAS	7 DAS	15 DAS
V_1P_0	2.33 a	2.00 a	1.87 a	1.67 a	1.33 a
V_1P_1	1.67 c	1.33 c	1.00 d	1.00 c	0.67 c
V_1P_2	1.67 c	1.33 c	1.00 d	1.00 c	0.67 c
V_2P_0	2.33 a	1.67 b	1.33 c	1.00 c	1.00 b
V_2P_1	1.67 c	1.33 c	1.00 d	1.00 c	0.67 c
V_2P_2	2.00 b	1.67 b	1.33 c	1.33 b	1.00 b
V_3P_0	2.00 b	1.67 b	1.67 b	1.33 b	1.00 b
V_3P_1	1.33 d	0.67 d	0.67 e	0.67 d	0.33 d
V_3P_2	1.67 c	1.33 c	1.00 d	1.00 c	0.67 c
LSD $_{(0.05)}$	0.25	0.17	0.66	0.11	0.06
CV (%)	7.87	6.87	3.16	5.95	4.61

* Pre-treatment: 1 Day before spray (DBS), ** Post-treatment: Day after spray (DAS). In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Control, P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

It was discovered that the treatment combination differed significantly from each other based on the number of population of mustard sawfly and its reduction percent data recorded after 1 day after spraying (DAS). The V_3P_1 combination treatment had the lowest population (1.33 larvae/plant) and the highest reduction (54.27%) among treatment combinations (Tables 5 and 6). While the V_1P_0 treatment combination had the highest population (2 larvae/plant) with the lowest reduction (23.04%).

The effectiveness of the treatments was further compared at 3 days after spray and it was found that all the treatments were superior over control in controlling mustard sawfly. The lowest population (0.67 larvae/plant) with the highest reduction (73.17%) was recorded in V_3P_1 combination treatment. While the highest population (1.87 larvae/plant) with the lowest reduction (31.51 %) was found in V_1P_0 treatment combination (Table 6).

The effectiveness of the treatments was further compared at 7 and 15 days after spray and it was found that all the treatments were superior over control in controlling mustard sawfly. The lowest population (0.67 and 0.33 larvae/plant) with the highest reduction (79.28 and 90.25 %) at 7 and 15 days after spray were recorded in V_3P_1 combination treatment, respectively. While the highest population (1.67 and 1.33 larvae/plant) with the lowest reduction (40.00 and 61.22%) was found in V_1P_0 treatment combination.

Based on reduction percent (Table 6) among treatment combination V_3P_1 combination treatment preformed best and reduced maximum infestation of sawfly comparable to other treatment combination at different days after spraying.

Table 6. Effectiveness of treatments based on reduction (%) in the population of mustard sawfly (larvae/plant) during Rabi season2020-2021

Treatment combinations	Reduction %			
	1 DAS	3 DAS	7 DAS	15 DAS
V_1P_0	23.04 d	31.51 e	40.00 e	61.22 e
V_1P_1	37.08 b	48.18 b	63.42 b	79.28 b
V_1P_2	37.58 b	47.27 b	62.42 b	77.58 b
V_2P_0	30.31 c	40.60 d	45.45 d	70.31 d
V_2P_1	35.38 b	44.52 c	54.87 c	72.57 cd
V_2P_2	36.58 b	45.73 bc	61.59 b	73.17 c
V_3P_0	36.58 b	45.73 bc	61.59 b	73.17 c
V_3P_1	54.27 a	73.17 a	79.28 a	90.25 a
V_3P_2	31.92 c	43.38 c	53.00 c	71.68 cd
LSD $_{(0.05)}$	2.70	2.70	3.17	2.46
CV (%)	4.36	3.35	3.16	1.92

* Pre-treatment: 1 Day before spray (DBS), ** Post-treatment: Day after spray (DAS). In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Control, P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

4.5 Effectiveness of treatments against mustard aphid

One day before spraying of the treatment (Pre-treatment) the population of mustard aphid was observed ranging from 54.67 to 55.33 aphids/10 cm central twig/plant, which was non-significant during Rabi 2020-21 (Table 7).

The population of mustard aphid reduced due to the application of biorationals pesticide and different mustard varieties treatments whereas, the population of mustard aphid was increased in control, which indicated that all the treatments were found effective in controlling mustard aphid. However, cultivation of BARI sharisha-14 along with Confidor 70WG (imidacloprid) @ 0.2 g/L of water application (V_3P_1) recorded lower infestation of aphid and was found superior overall other varieties and botanical up to 15 days after spraying.

Table 7. Effectiveness of biorationals pesticides against mustard aphid during Rabi season 2020-2021

Treatment combinations	The population of mustard aphid (Av. No./10 cm central twig /plant)				
	Pre treatment*	Post-treatment**			
	1 DBS	1 DAS	3 DAS	7 DAS	15 DAS
V_1P_0	55.00	42.33 a	37.67 a	33.00 a	21.33 a
V_1P_1	54.67	35.33 cd	30.33 cd	24.67 c	15.00 b
V_1P_2	54.67	34.67 d	29.67 cd	21.00 d	14.67 b
V_2P_0	55.00	38.33 b	32.67 b	30.00 b	16.33 b
V_2P_1	54.67	34.40 d	28.33 d	20.00 d	11.33 c
V_2P_2	55.00	34.33 d	29.00 d	20.67 d	12.33 c
V_3P_0	55.33	37.67 bc	31.33 bc	26.00 c	15.67 b
V_3P_1	54.67	25.00 e	14.67 e	11.33 e	5.33 d
V_3P_2	54.67	34.67 d	29.67 cd	21.00 d	14.67 b
LSD $_{(0.05)}$	-	2.70	2.13	2.28	1.73
CV (%)	-	4.44	4.22	5.73	7.11

* Pre-treatment: 1 Day before spray (DBS), ** Post-treatment: Day after spray (DAS). In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Control, P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

Based on the number of population mustard aphid and its reduction percent data recorded after 1 day after spraying (DAS), it was found that the treatment combination differed significantly from each other. The significantly lowest population (25.00 aphids/10cm central twig/plant) with the highest reduction (73.17 %) among treatment combination was recorded in V_3P_1 combination treatment followed by V_3P_2, V_2P_2, V_2P_1 and V_1P_2 combination treatment (Table 7 and 8). While the highest population (55.33 aphids/10cm central twig/plant) with the lowest reduction (23.04 %) was found in V_3P_0 and V_1P_0 treatment combination.

The effectiveness of the treatments was further compared at 3 days after spray and it was found that all the treatments were superior over control in controlling mustard aphid. The lowest population (14.67 aphids/10cm central twig/plant) with the highest reduction (73.17 %) was recorded in V_3P_1 combination treatment. While the highest population (37.67 aphids/10cm central twig/plant) with the lowest reduction (31.51 %) was found in V_1P_0 treatment combination.

The effectiveness of the treatments was further compared at 7 and 15 days after spray and it was found that all the treatments were superior over control in controlling mustard aphid. The lowest population (11.33 and 5.33 aphids/10cm central twig/plant) with the highest reduction (79.28 and 90.25 %) at 7 and days after spray, respectively were recorded in V_3P_1 combination treatment. While the highest population (33.00 and 21.33 aphids/10cm central twig/plant) with the lowest reduction (40.00 and 61.22%) was found in V_1P_0 treatment combination.

Based on reduction percent (Table 8) among treatment combination V_3P_1 combination treatment preformed best and reduced maximum infestation of aphid comparable to other treatment combination at different days after spraying. Verma *et al.* (2013) experienced a great variation in the thrip population among different mustard cultivars. Lal *et al*. (2018) reprted that Imidacloprid 17.8% SL + NSKE 5% combination was found to be effective in suppressing the aphid population in a significant level.

Table 8. Effectiveness of treatments based onreduction (%) in the population of mustard aphid during *Rabi season* 2020-2021

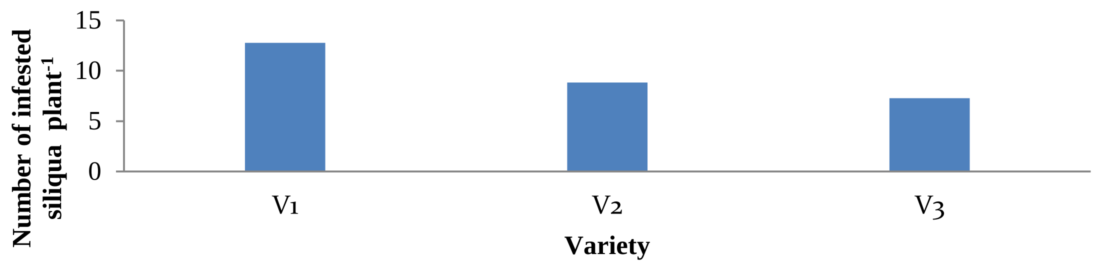
Treatment combinations	Reduction %			
	1 DAS	3 DAS	7 DAS	15 DAS
V_1P_0	23.04 d	31.51 e	40.00 e	61.22 e
V_1P_1	35.38 b	44.52 c	54.87 c	72.57 cd
V_1P_2	36.58 b	45.73 bc	61.59 b	73.17 c
V_2P_0	30.31 c	40.60 d	45.45 d	70.31 d
V_2P_1	37.08 b	48.18 b	63.42 b	79.28 b
V_2P_2	37.58 b	47.27 b	62.42 b	77.58 b
V_3P_0	31.92 c	43.38 c	53.00 c	71.68 cd
V_3P_1	54.27 a	73.17 a	79.28 a	90.25 a
V_3P_2	36.58 b	45.73 bc	61.59 b	73.17 c
LSD $_{(0.05)}$	2.70	2.71	2.17	2.46
CV (%)	4.36	3.35	3.16	2.92

* Pre-treatment: 1 Day before spray (DBS), ** Post-treatment: Day after spray (DAS). In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Control, P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

4.6 Effect of different treatment and their combination on yield contributing characteristic and yield of mustard

4.6.1 Number of infested siliqua plant^{-1}

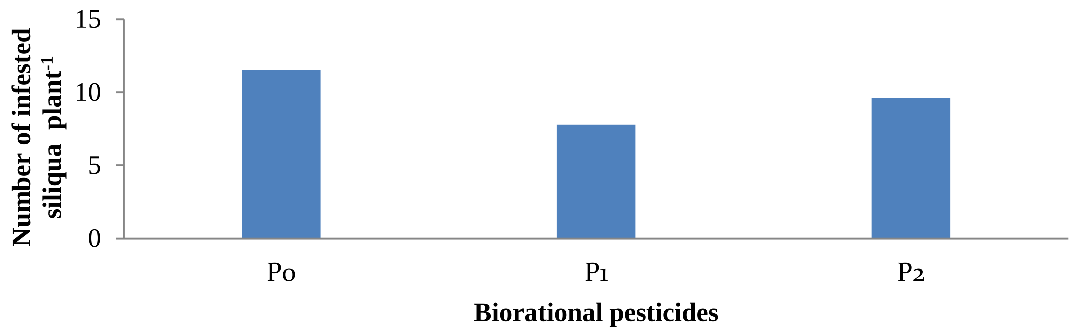
The number of infested siliqua plant^{-1} was significantly influenced by different mustard varieties. The highest number of infested siliqua plant^{-1} (12.78) was observed in the V_1 treatment, while the lowest number of infested siliqua plant^{-1} (7.29) was observed in the V_3 treatment (Fig. 1)



Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14.

Fig. 1. Effect of variety on number of infested siliqua plant^{-1} of mustard

The application of various biorational pesticides had a significant impact on the number of infested siliqua plant^{-1} (Fig. 2). The experimental results showed that the P_0 (Control) treatment had the highest number of infested siliqua plant^{-1} (11.51), while the P_1 treatment had the lowest number (9.62).

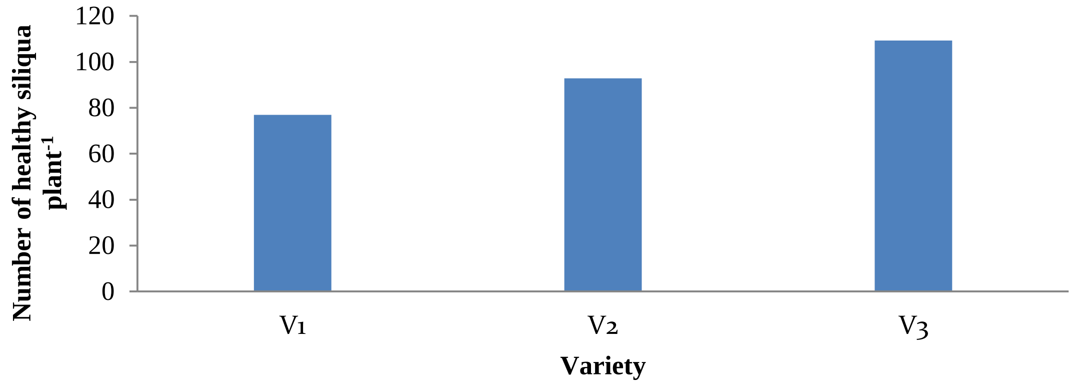


Here, P_0 = Untreated (Control), P_1= Confidor 70WG (imidacloprid) @ 0. 2g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

Fig. 2. Effect of biorational pesticides on number of infested siliqua plant^{-1} of mustard

4.6.2 Number of healthy siliqua plant^{-1}

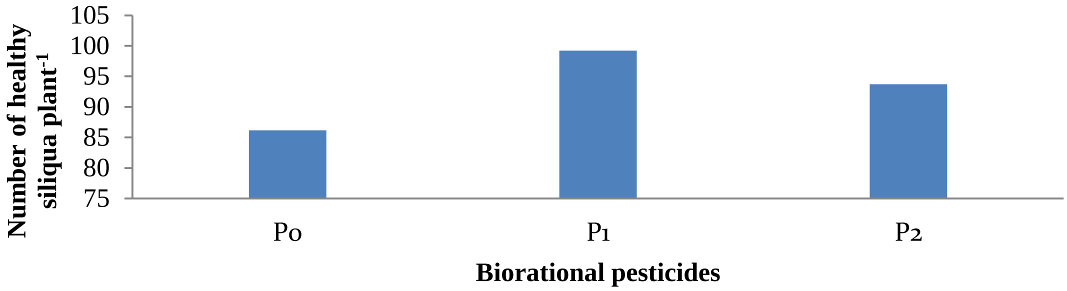
Different varieties of mustard significantly influenced on number of healthy siliqua plant^{-1} (Fig. 3). Experimental result showed that the highest number of healthy siliqua plant^{-1} (109.38) was observed in V_3 (BARI sharisha-14) treatment, while the lowest number of healthy siliqua plant^{-1} (76.89) was observed in V_1 (BARI sharisha-1) treatment. Different varieties have different genetic make-ups, and their defensive properties reduce insect infestation, resulting in more infested siliqua plant^{-1}. Verma *et al.* (2013) experienced a great variation in the thrip population among different mustard cultivars. Malik *et al.* (2012) argued that mustard varieties with resistance against sucking complex, particularly jassid is of great economic importance.



Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14.

Fig. 3. Effect of variety on number of healthy siliqua plant^{-1} of mustard

The number of healthy siliqua plant^{-1} was significantly influenced due to application of different biorational pesticide (Fig. 4). Experimental result showed that the highest number of healthy siliqua plant^{-1} (99.22) was observed in P_1 (Confidor 70 WG (imidacloprid) @ 0.2 g/L of water) treatment, while the lowest number of healthy siliqua plant^{-1} (86.16) was observed in P_0 (Control) treatment. Shah *et al.* (2008) reported that all the growth parameters namely, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, and seed yield were significantly increased over control with the application of insecticides. The overall growth in insecticides treated plants might be due to the control of mustard aphid, which led the plants a healthy growth over control.



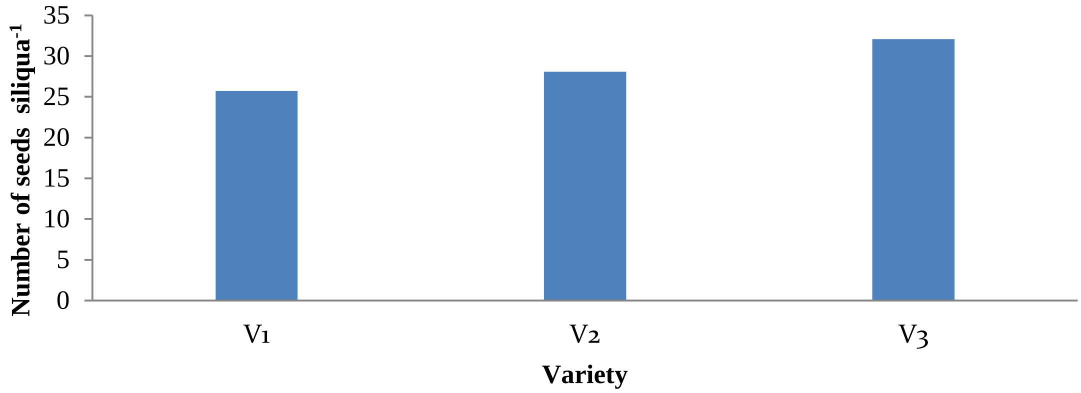
Here, P_0 = Untreated (Control), P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

Fig. 4. Effect of biorational pesticides on number of healthy siliqua plant^{-1} of mustard

Combined effect of variety and biorational pesticide had shown significant effect on number of healthy siliqua plant^{-1} (Table 9). The V_3P_1 treatment combination recorded the highest number of healthy siliqua plant^{-1} (116.33) which was statistically similar with V_3P_2 (111.33) treatment combination. While the lowest number of healthy siliqua plant^{-1} (70.67) V_1P_0 treatment combination.

4.6.3 Number of seeds siliqua^{-1}

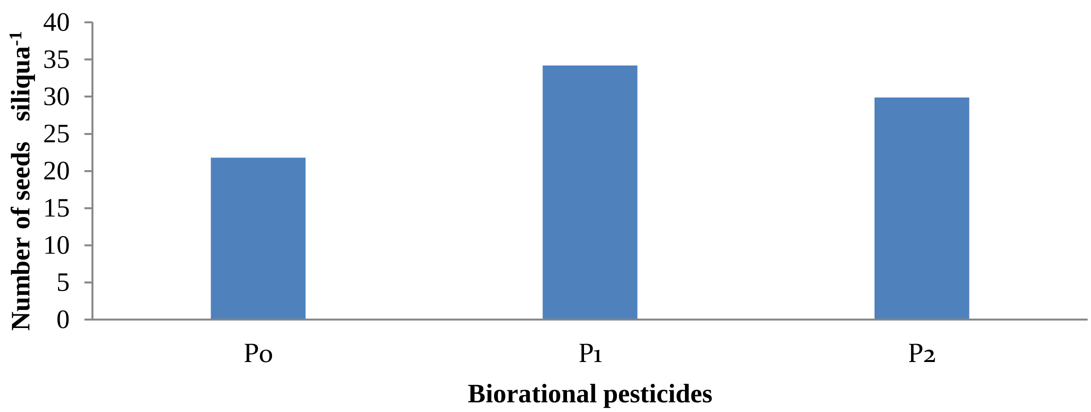
Different varieties had a significant impact on the number of seeds siliqua^{-1}of mustard (Fig. 5). The V_3 treatment had the highest number of seeds siliqua^{-1}of mustard (32.08). However, the V_1 treatment had the lowest number of seeds siliqua^{-1}of mustard (25.73). This may be due to genetic characteristic of the variety. Similar results are in conformity to the findings of, Tripathi *et al*. (2021) who reported that the yield attributes *viz*., number of seeds siliqua^{-1}, number of siliqua plant^{-1}, seed yield and siliqua length were significantly influenced due to varieties.



Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14.

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

The number of seeds siliqua^{-1} was significantly influenced due to application of different biorational pesticide (Fig. 6). Experimental result showed that the highest number of seed siliqua^{-1} (34.21) was observed in P_1 treatment, while the lowest number of seeds siliqua^{1} (21.79) was observed in P_0 treatment. The result was similar with the findings of Patel *et al.* (2017).



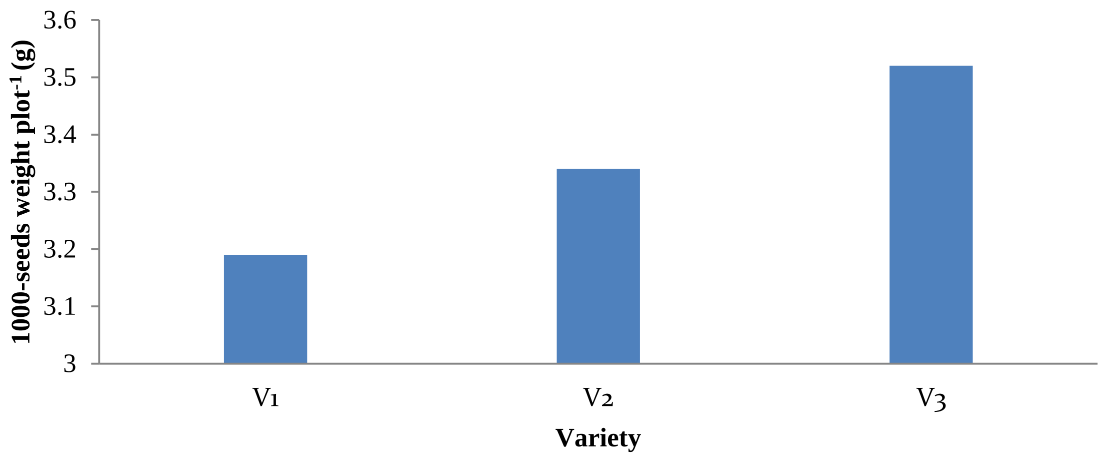
Here, P_0 = Untreated (Control), P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0. 4ml/L of water.

Fig. 6. Effect of biorational pesticides on number of seeds siliqua^{-1}of mustard

The combination of variety and biorational pesticide had a significant effect on the number of seeds siliqua^{-1} (Table 9). The V_3P_0 treatment combination had the highest number of seed siliqua^{-1}(40.34) while the V_3P_1 treatment combination had the lowest number of seeds siliqua^{-1} (18.91).

4.6.4 1000-seeds weight plot^{-1} (g)

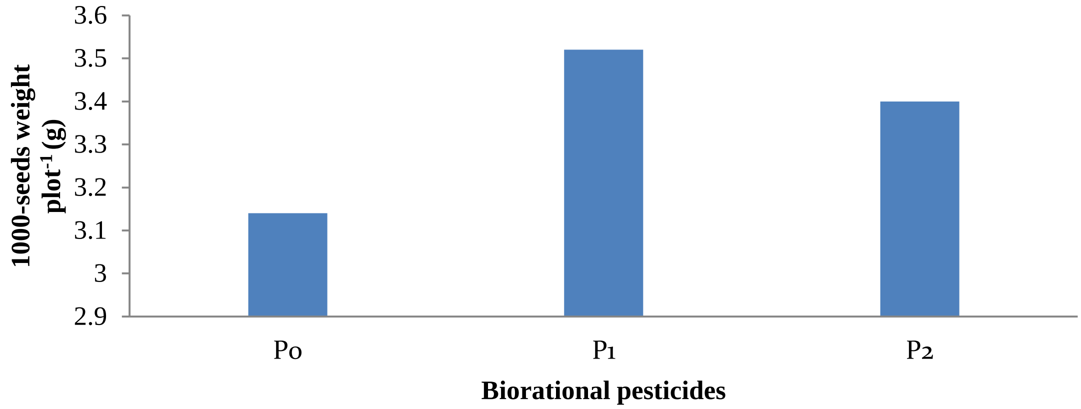
The 1000 seeds weight plot^{-1} was significantly influenced by various mustard varieties (Fig. 7). According to the experimental findings, the V_3 treatment had the highest 1000 seeds weight plot^{-1} of mustard (3.52 g). While the lowest 1000 seeds weight plot^{-1} of mustard (3.19 g) was found in the V_1 treatment. The genetic makeup of the varieties might be the possible reasons for these variations. Mashfiqur *et al.* (2022) discovered a similar effect, reporting that variety had a substantial impact on 1000-seeds weight of mustard. Because the performance of varieties varies inversely with their genetic potential and adaptability to the environment, there is potential for enhancing mustard output through the cultivation of climate and insect-pest resilient varieties.



Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14.

Fig. 7. Effect of variety on 1000-seeds weight plot^{-1} of mustard

The 1000 seeds weight plot^{-1} of mustard was significantly influenced due to application of different birational pesticide (Fig. 8). Experimental result showed that the highest 1000 seeds weight plot^{-1} of mustard (3.52 g) was observed in P_1 treatment, while the lowest 1000 seeds weight plot^{-1} of mustard (3.14 g) was observed in P_0 treatment.



Here, P_0 = Untreated (Control), P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

Fig. 8. Effect of biorational pesticides on 1000-seeds weight plot^{-1} of mustard

The weight of 1000 mustard seeds was significantly influenced by the combination of variety and biorational pesticide application (Table 9). The highest 1000 seeds weight plot^{-1} of mustard (3.81 g) was observed in the V_3P_1 combination treatment. While the lowest 1000 seed weight plot^{-1} of mustard (3.03 g) was observed in V_1P_0 combination treatment which was statistically similar with V_2P_0 (3.14 g) combination treatment.

Table 9. Combined effect of variety and biorational pesticide on yield contributing characteristics of mustard

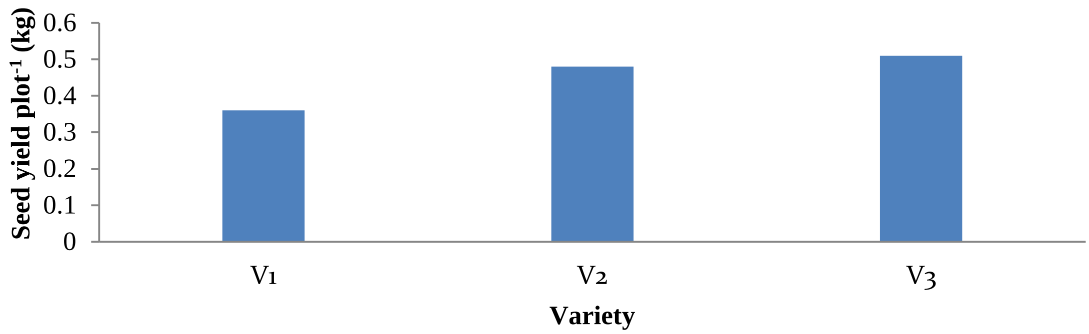
Treatment combinations	Number of infested siliqua plant^{-1}	Number of healthy siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000-seed weight plot^{-1} (g)
V_1P_0	15.33 a	70.67 e	18.91 f	3.03 e
V_1P_1	10.33 c	81.67 d	31.02 b	3.29 c
V_1P_2	12.67 b	78.33 d	27.26 c	3.25 cd
V_2P_0	10.67 c	87.33 c	22.17 e	3.14 de
V_2P_1	7.33 e	99.67 b	31.26 b	3.45 b
V_2P_2	8.53 d	91.47 c	30.80 b	3.44 b
V_3P_0	8.53 d	100.47 b	24.29 d	3.25 cd
V_3P_1	5.67 f	116.33 a	40.34 a	3.81 a
V_3P_2	7.67 de	111.33 a	31.60 b	3.51 b
$LSD_{(0.05)}$	0.98	5.41	2.08	0.14
CV (%)	5.93	3.36	4.20	2.49

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Control, P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

The combination of variety and biorational pesticide had a significant effect on the number of infested siliqua plant^{-1} (Table 9). The V_1P_0 treatment combination had the most infested siliqua plant^{-1} (15.33) while the V_3P_1 treatment combination had the fewest infested siliqua plant^{-1} (5.67).

4.6.5 Seed yield plot^{-1}(kg)

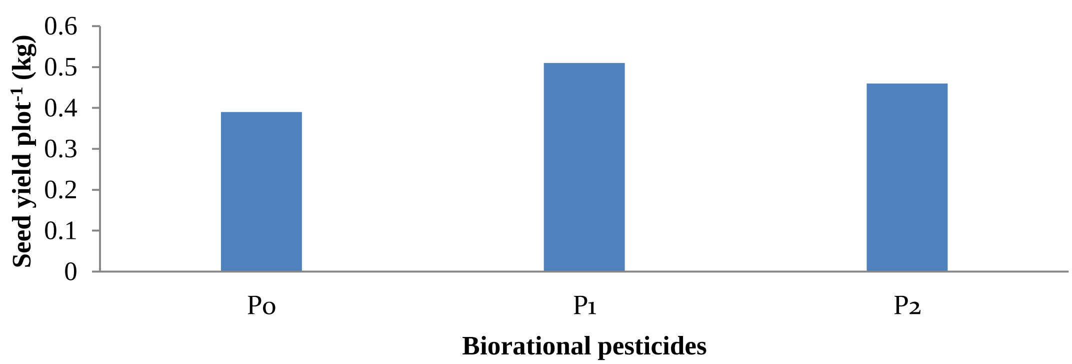
Different varieties significantly influenced seed yield plot^{-1} of mustard (Fig. 9). Experimental result showed that the highest seed yield plot^{-1} (0.51 kg) was observed in V_3 treatment, where as the lowest seed yield plot^{-1} (0.36 kg) was observed in V_1 treatment. Different mustard varieties had different genetic makeup which affects the growth and yield among varieties. The result obtained from the present study was similar with the findings of Junjariya (2014) who reported that seed yield of Indian mustard was influenced significantly with different cultivars.



Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14.

Fig. 9. Effect of variety on seed yield plot^{-1}of mustard

Different biorational pesticide application significantly influenced seed yield plot^{-1} of mustard (Fig. 10). Experimental result showed that the highest seed yield plot^{-1} (0.51 kg) was observed in P_1 treatment while the lowest seed yield plot^{-1} (0.39 kg) was observed in P_o treatment. The result was similar with the findings of Singh *et al.* (2017) who studied bio-efficacy of some insecticides and botanicals on mustard (variety Laxmi) crop and reported that, imidacloprid gave maximum seed yield (1866kg/ha) closely followed by thiamethoxam (1813kg/ha) and dimethoate (1757kg/ha). The lowest seed yield (1239 kg/ha) was obtained from untreated control.



Here, P_0 = Untreated (Control), P_1= Confidor 70 WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45 SC (Spinosad) @ 0.4 ml/L of water.

Fig. 10. Effect of biorational pesticides on seed yield plot^{-1}of mustard

The effectiveness of each treatment combination was also determined using seed yield plot^{-1} results from various treatment combinations (Table 10). Significantly higher seed yield plot^{-1} (0.59 kg) was obtained from V_3P_1 treatment combination which gave (37.21 %) more yield comparable to control treatment (V_3P_0), while the lowest seed yield plot^{-1} (0.33) was obtained from V_1P_0 treatment combination.

In case of seed yield per hactere the effectiveness of each treatment combination varierd significantly (Table 10). Significantly higher seed yield (1.58 t ha^{-1}) was obtained from V_3P_1 treatment combination which gave (38.60%) more yield comparable to control treatment (V_3P_0), while the lowest seed yield plot^{-1} (0.87 t ha^{-1}) was obtained from V_1P_0 treatment combination.

Table 10. Combined effect of variety and biorational pesticide on seed yield and increase in yield percentage over control treatment of mustard

Treatment combinations	Seed yield plot^{-1} (kg)	Increase in yield over control (%)	Seed yield t ha^{-1}	Increase in yield over control (%)
V_1P_0	0.33 g	0	0.87 e	0.00
V_1P_1	0.40 e	21.21	1.07 d	22.99
V_1P_2	0.36 f	9.09	0.95 e	9.20
V_2P_0	0.41 de	0	1.10 d	0.00
V_2P_1	0.54 b	31.71	1.44 b	30.91
V_2P_2	0.49 c	19.51	1.30 c	18.18
V_3P_0	0.43 d	0	1.14 d	0.00
V_3P_1	0.59 a	37.21	1.58 a	38.60
V_3P_2	0.52 b	25.58	1.43 b	25.44
$LSD_{(0.05)}$	0.02	-	0.11	-
CV (%)	2.58	-	5.51	-

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sharisha-1, V_2 = BARI sharisha-9, V_3 = BARI sharisha-14, P_0 = Untreated (Control), P_1= Confidor 70WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45SC (Spinosad) @ 0.4 ml/L of water.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from October 2020 to April 2021in Rabi season, to evaluation of some popular mustard varieties against aphid and sawfly attack under field condition. The experiment consisted of two factors, and followed Randomized block design with three replications. Factor A. Mustard varieties (3) *viz;* V_1 = BARI sharisha-1, V_2 = BARI sharisha-9 and V_3 = BARI sharisha-14 and Factor B: Different biorational pesticides (3) *viz;* P_0 = Untreated (Control), P_1= Confidor 70 WG (imidacloprid) @ 0.2 g/L of water and P_2= Tracer 45 SC (Spinosad) @ 0.4 ml/L of water. For the purpose of evaluating the experimental out comes, data on various parameters were evaluated. To record the incidence of major insect-pests of mustard, the weekly observations were done from the starting of germination to the harvest of the crop. Two major insect- pests' were recorded *viz.*, mustard sawfly (*Athalia lugens Proxima*), mustard aphid (*Lipaphis erysimi*) in this area. The incidence of these insect-pests was fluctuating under varying weather conditions. The beginning of the incidence of mustard sawfly (0.33larvae/plant), was recorded in the 51^{st} standard week (4^{th} week of December 2020). This increased gradually up to the level of 2.33 larvae/plant in 1^{th} SW (1^{st} week of January 2021).

The occurrence of mustard aphid was stated from 51^{th} SW (December 2020) to 14^{th} standard week (April 2021) with a varying population ranging from 0.33 to 55.33 aphids/10 cm on central twig/ plant in different standard weeks. The maximum population of this insect was recorded as 55.33 aphids/10 cm central twig/plant during 10^{th} SW (second week of March 2021). The occurrence of other insect-pests (grasshopper, green bug, cabbage butterfly, etc.) was started from 2^{nd} standard week to 10^{th} standard week with a varying population ranging from 0.33 to 3.00 insects per plant in different standard weeks. The peak period of occurrence of these insects was observed in the 7^{th} standard week. The maximum population of these insects was recorded as a 3.00 insect/plant. The minimum population 0.33 insect/plant was recorded at 3^{rd} standard week.

Among predators of mustard aphid, the incidence of ladybird beetle *Coccinella* spp. was recorded on the crop with various species. *Coccinella* spp. was observed active in predating on mustard aphid from3rd standard week (Third week of January 2021) to 14th standard week (First week of April 2021) during Rabi 2020-21. The*Coccinella* spp. population ranged from 0.33 to 4.0 (grub/plant) during the whole observation period. The syrphid fly was observed active in predating on mustard aphid from 1st standard week to 8th standard week. The syrphid fly population ranged from 0.33 to 3.67 (larvae/plant) during the whole observation period. The spider population was observed active in predating on mustard insect-pests from the 50th standard week to 11th standard week. The spider population ranged from 0.33 to 2.00 (spider/plant) during the whole observation period.

The correlation-coefficients determined between the incidence of mustard sawfly and biotic factors revealed both positive and negative correlations. However, none of the correlation coefficients were found significant in whole crop seasons. Positive correlation coefficients between the incidence of mustard aphid and biotic parameters were found. These correlation coefficients values were found non-significant negative with the syrphid fly. However, a positive significant correlation was observed with spider, *coccinella* spp and others. The correlation coefficients between the incidence of mustard aphid and abiotic factors during Rabi 2020-21 showed both positive as well as negative relationships at a non-significant level. The correlation coefficients between the incidence of other insects and biotic parameters showed a positive relationship. An only a significant positive relationship was observed with the syrphid fly and others.

One day before spraying of the treatment (pre-treatment) the population of mustard sawfly and aphid was observed ranging from 1.33 to 2.33 larvae/plant and 54.67 to 55.33 aphids/10 cm central twig/plant, which was significant for sawfly but non significant to aphid during Rabi 2020-21.The population of mustard sawfly and aphid reduced due to the application of biorational pesticides and different mustard varieties treatments whereas, the population of mustard aphid was increased in control, which indicated that all the treatments were found effective in controlling mustard aphid. However, cultivation of BARI sharisha-14 along with Confidor 70 WG (imidacloprid) @ 0.2 g/L of water application (V_3P_1) recorded lower infestation of sawfly and aphid and was found superior overall other varieties and botanical up to 15 days after spraying.

In case of yield and yield contributing characteristics different varieties of mustards, biorational pesticides and their combination had showed significant effect. In case of varieties the highest number of healthy siliqua plant^{-1} (109.38), seeds siliqua^{-1}(32.08), 1000 seeds weight plot^{-1} (3.52 g) and seed yield plot^{-1} (0.51 kg) were observed in V_3 (BARI sharisha-14) treatment. While the lowest number of healthy siliqua plant^{-1} (76.89), seed siliqua^{-1}of mustard (25.73), 1000 seeds weight plot^{-1} (3.19 g) and seed yield plot^{-1} (0.36 kg) were observed in V_1 treatment.

Among different biorational pesticides, the highest number of healthy siliqua plant^{-1} (99.22), seeds siliqua^{-1}(34.21), 1000 seeds weight plot^{-1} (3.52 g) and seed yield plot^{-1} (0.51 kg) were observed in P_1 treatment, whereas the lowest number of healthy siliqua plant^{-1} (86.16), seeds siliqua^{-1}of mustard (21.79), 1000 seeds weight plot^{-1} (3.14 g) and seed yield plot^{-1} (0.39 kg) were observed in P_0 treatment.

Among different tr eatment combination, V_3P_1 treatment combination performed best and recorded the highest number of healthy siliqua plant^{-1} (116.33), seeds siliqua^{-1}(40.34), and significantly higher seed yield plot^{-1} (1.57 ton/ha) which gave (37.21 %) more yield comparable to control treatment (V_3P_0), while the lowest seed yield (0.88 ton/ha) was obtained from V_1P_0 treatment combination.

5.2 Conclusion:

- Mustard field infested with various types of insect pest. Among them major pests of mustard aphid of this area started appearing in the field from 51 SW (3rd week of December 2020-2021) and reached up to maximum population on 10th SW (2nd standard week of March, 2021). However minor pests such as mustard sawfly started appeared in the field from 49th SW and reached up to the maximum at 1^{s} SW respectively. The predators *viz*; the coccinellids appeared in the field from 3th to 14th SW, syrphid fly 1th SW and 8th SW, and spider 49 SW to 11th standard week. The major pest *i.e.* mustard aphid showed a significant positive correlation with coccinellids, spidersand others.However, a non-significant correlation of mustard sawfly appeared with coccinellids, syrphid flies, spiders and others.

- ❖ The population of mustard sawfly and aphid reduced due to the application of biorationals pesticide and different mustard varieties treatments whereas, the population of mustard aphid was increased in control, which indicated that all the treatments were found effective in controlling mustard aphid. However, cultivation of BARI sharisha-14 along with Confidor 70WG (imidacloprid) @ 0.2 g/L of water application (V_3P_1) recorded lower infestation of sawfly and aphid and was found superior overall other varieties and botanical up to 15 days after spraying.
- ❖ The highest seed yield plot^{-1} (0.36 kg) were observed in V_3 (BARI sharisha-14) treatment.
- ❖ Among different biorational pesticide, application of Confidor 70WG (imidacloprid) @ 0.2 g/L of water recorded the highest the seed yield plot^{-1} (0.51 kg)
- ❖ Among different treatment combination, V_3P_1 treatment combination performed best and recorded the highest number of healthy siliqua plant^{-1} (116.33), seeds siliqua^{-1}(40.34) and significantly higher seed yield plot^{-1} (1.57 ton/ha) which gave (37.21 %) more yield comparable to control treatment (V_3P_0), while the lowest seed yield plot^{-1} (0.88 ton/ha) was obtained from V_1P_0 treatment combination.

Therefore, it may be concluded that among all treatment combination, V_3P_1 treatment combination was found effective due to significantly minimum insect-pests incidence, high reduction percent and high seed yield production of mustard.

Recommendation

Further research in the following areas may be suggested based on the results of the current experiment:

i. A similar study in different agro-ecological zones (AEZ) of Bangladesh is required for regional adaptability;

ii. Other insect management practices may be included for additional research.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

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

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

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

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

Appendix III. Monthly meteorological information during the period from November 2020 to April, 2021

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	November	29.6	19.8	53	Nil
	December	28.8	19.1	47	Nil
2022	January	25.5	13.1	41	Nil
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71
		32.7°C	23.8°C	74	168

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

Appendix IV. Analysis of variance of the data on biorationals pesticide against mustard sawfly during *Rabi season* 2020-2021

Source	Df	The population of mustard sawfly (Av. No. larvae/ plant)				
		Pre-treatment	Post-treatment			
		1 DBS	1 DAS	3 DAS	7 DAS	15 DAS
Replication	2	0.01000	0.01210	0.00321	0.00588	0.00401
Variety (V)	2	0.25963**	0.3300**	0.0712**	0.1122**	0.1496**
Pesticide (P)	2	1.02523**	1.0100**	1.2745**	0.4422**	0.6974**
V×P	4	0.03688*	0.1650**	0.1851**	0.2211**	0.0919**
Eror	16	0.02125	0.00985	0.00146	0.00438	0.00141

DBS: Day before spray and DAS: Day after spray
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on reduction (%) in the population of mustard sawfly (larvae/ plant) during Rabi season 2020-2021

Source	Df	Reduction %			
		1 DAS	3 DAS	7 DAS	15 DAS
Replication	2	5.444	5.444	7.111	5.778
Variety (V)	2	178.273**	375.080**	303.761**	109.451**
Pesticide (P)	2	340.248**	586.712**	645.699**	350.004**
V×P	4	157.230**	260.685**	308.128**	137.284**
Eror	16	2.444	2.444	3.361	2.028

DBS: Day before spray and DAS: Day after spray.
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on biorationals pesticide against mustard aphid during Rabi season 2020-2021

Source	Df	The population of mustard aphid (Av. No./10 cm central twig /plant) Post-treatment			
		1 DAS	3 DAS	7 DAS	15 DAS
Replication	2	5.444	0.778	4.000	1.000
Variety (V)	2	52.745**	111.346**	89.999**	32.432**
Pesticide (P)	2	106.987**	181.652**	197.810**	106.964**
V×P	4	49.696**	79.943**	95.614**	41.964**
Eror	16	2.444	1.528	1.750	1.000

DBS: Day before spray and DAS: Day after spray
** : Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on reduction (%) in the population of mustard aphid during *Rabi season* 2020-2021

Source	Df	Reduction %			
		1 DAS	3 DAS	7 DAS	15 DAS
Replication	2	5.444	5.444	7.111	5.778
Variety (V)	2	178.273**	375.080**	303.761**	109.451**
Pesticide (P)	2	340.248**	586.712**	645.699**	350.004**
V×P	4	157.230**	260.685**	308.128**	137.284**
Eror	16	2.444	2.444	3.361	2.028

DBS: Day before spray and DAS : Day after spray.
**: Significant at 0.05 level of probability
*: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characteristics and yield of mustard

Source	Df	Number of infested siliqua plant^{-1}	Number of healthy siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000-seed weight plot^{-1} (g)	Seed yield plot^{-1}
Replication	2	21.78	0.1599	5.444	0.00444	0.00028
Variety (V)	2	2374.9**	71.981**	92.68**	0.25053**	0.0530**
Pesticide (P)	2	387.28**	31.361**	357.59**	0.3346**	0.0325**
V×P	4	11.85*	1.231*	15.02*	0.0264*	0.0017*
Eror	16	9.78	0.3261	1.444	0.00694	0.00014

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

PLATES

Plate 1. Experimental field at the early growing stage of mustard

Plate 2. Fertilizer application in the experimental field

Plate 3. Flower initiation stage in mustard field