EVALUATION OF THE APHID INFESTATION ON SOME OF SELECTED MUSTARD VARIETIES AND ITS CHEMICAL CONTROL

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CERTIFICATE

This is to certify that thesis entitled, "**EVALUATION OF THE APHID INFESTATION ON SOME OF SELECTED MUSTARD VARIETIES AND ITS CHEMICAL CONTROL**" 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 (MS)** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **ABIDUR RAHMAN, Registration No. 10-04054** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016

Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2015 to February 2016 to evaluate the infestation level of mustard aphid against the combination of chemical treatment and varieties. The experiment comprised of two factors (4 variety and 3 levels chemical); Factors A: Mustard varieties (4 mustard varieties) i) V_1=BARI Sarisha-11 ii) V_2= BARI Sarisha-14 iii) V_3= BARI Sarisha-15 and iv) V_4= BARI Sarisha-16; and Factor B: chemical treatment (3 levels) viz. i) T_1= Ripcord 10 EC @1mlL^{-1} water ii) T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water The experiment was laid out in a Randomized Complete Block Design with four replications. At early flowering stage, the lowest number of aphid (4.66) observed from V_4 and T_2 (6.12). At late flowering stage, the lowest number of aphid (7.39) observed from V_1 and the lowest number of aphid (7.33) observed from T_2. The lowest number of aphid (5.39) observed from V_4T_2 and the highest number of aphid (13.80) observed from V_4T_1. At early fruiting stage, the lowest number of aphid (4.01) observed from V_4 and the lowest number of aphid (9.00) observed from T_2. The lowest number of aphid (6.61) recorded V_4T_2. At late fruiting stage, the lowest number of aphid (5.67) observed from V_4 and the lowest number of aphid (7.43) recorded from T_2. The lowest number of aphid (5.46) observed from the V_4T_2. At flowering stage, the highest number of healthy plants (31.99) and the lowest infested plant (6.39%) recorded from V_4 and the highest number of healthy plants (28.91) and the lowest infested plant (4.78%) found from T_2. The highest number of healthy plants (33.97) and the lowest infested plant (5.20%) observed V_4T_2. At fruiting stage, the highest number of healthy plants (32.51) recorded from V_4, whereas the lowest number of healthy plants (23.40) found from V_2 again the highest number of healthy plants (29.62) and the lowest infested plant (6.21%) found from T_2. The highest number of healthy plants (33.97) and the lowest infested plant (5.05%) observed V_4T_2. The longest plant (178.78 cm), maximum number of siliqua plant^{-1} (179.57) and longest siliqua (7.39 cm) found from V_4. The longest plant (123.56 cm), maximum number of siliqua plant-1 (119.56), longest siliqua (6.35 cm) observed from T_2. The longest plant, maximum number of siliqua plant^{-1}, longest siliqua found from V_4T_2 , while the shortest observed from V_2T_3. The highest seed yield (2.21 t ha^{-1}) found from V_4 and the lowest seed yield (1.31 t ha^{-1}) observed from V_2. The highest seed yield (1.87 t ha^{-1}) observed from T_2 and the lowest seed yield (1.70 t ha^{-1}) found from T_3. The highest seed yield (2.30 t ha^{-1}) found from V_4T_2.

CONTENTS

LIST OF TABELS

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I
INTRODUCTION

Mustard is one of the important oleiferous crops which constitutes a major source of edible oil for human consumption and cake for animals. Mustard plant belongs to the genus *Brassica* under the family Cruciferae. In our country, mainly three mustard species are cultivated viz, *Brassica campestris*, *Brassica juncea* and *Brassica napus*. This crop is well adapted to almost all agro-climatic zones and grows in Rabi season. It occupies an area of 2,47,000 ha land and produces about 2,27,000 ton of oilseeds per year. The yield of mustard is 947.00 kg/ha in Bangladesh (BBS, 2015).

Among the oil seed crops, mustard ranks first in Bangladesh and its performance in total oilseed production is approximately 70 percent. It occupies first position in the list in respect of area and production among the oilseed crops grown in this country (BBS, 2004). Annual requirement of edible oil for Bangladesh is 0.5 million metric tons. That is, the internal production of edible oil can meet up only less than one-third of the annual requirement of Bangladesh and it has been in short of 65 to 70% of the requirement. As a result, a huge amount of foreign currency is spent every year for importing oil and oilseed from abroad. Mustard seed contain 40-45% oil and 20-25% protein. Using local ghani on average 33% oil may be extracted (Mondal and Wahab, 2001).

It is not only a rich source of energy (about 9 kcal), but also rich in fat soluble vitamins A, D, E and K. The national nutrition council (NCC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day is 6 g of oil for a diet with 2700 kcal, Oil cake is also a nutritious food item for cattle and fish and used as good organic fertilizer.The average yield of mustard per ha is very low in Bangladesh. There are many limiting factors in mustard production such as weather, insufficient nutrient in soil, disease and insect pests is responsible for such low yield. Bangladesh and elsewhere mustard aphid, *Lipaphis erysimi* (Kalt) is the most serious and destructive pest of mustard and a major limiting factor for successful cultivation of mustard seed production (Begum,1995 and Biswas *et al.,* 2000) and has attained the level of key pest. Both nymphs and adults of this pest cause damage to mustard plants from early vegetative to siliqua maturity stage (Verma and Singh, 1987) by de-sapping inflorescence, flower and pods, resulting stunted growth of the plant, flowers wither and pod formation is hindered. Although aphid is a minute insect it may destroy the plants even quicker than larger insects and adversely affects the productivity. Honeydews secreted by aphids are favorite medium for the development of sooty mold on plants. As a result, crop gets black and dies before bearing of seeds. Increase in population beyond 9.45 aphids per plant; reduce the seed yield by 59.3 percent with an economic injury level of 2.04 aphids plants^{-1} and infestation of 37.4 percent (Singh and Malik, 1998).

For increasing the production of mustard every effort is being paid by adopting modern agricultural practices such as use of high yielding varieties, optimum fertilizer application and assured irrigation in order to meet the growing demand of oils although up to date insect pest infestation is a serious problem. More than three dozen of pests are known to be associated with various phenological stages of mustard crops (Singh and Singh, 1983). Among them mustard aphid is the most serious and destructive pest and limiting factor for successfully cultivating of mustard in South Asia (Bakhetia, 1983; Zaman, 1990). The rate of reproduction varies from 5-9 young in a single day by a single female and the total numbers of young produced varies from 76-188 (Nair, 1986). Both the nymph and adult of the aphid suck sap from leaves, stems, inflorescences and pods, as a result the plant show stunted growth, withered flowers and malformed pods (Atwal and Dhaliwal, 1997; Begum 1995; Butane and Jotwani, 1984). The loss in grain weight due to these pests varies greatly within Brassicae; being 35.0-73.3% under different agro climatic regions with a mean loss of 54.2% (Reddy *et al*., 1990).

The use of synthetic chemical pesticides has accounted for astonishing gains in production, as the pesticides have reduced the hidden toll exacted by the aggregated attack of insect-pests. Keeping in view the importance of this crop and its substantial loss by mustard aphids, farmers generally spray insecticides in their field.

The indiscriminate uses of synthetic insecticides cause resistance of this insect pest, destruction of beneficial organisms and environmental pollution (McIntyre *et al*., 1989). Therefore, it is necessary to find out the ecologically sound and environmentally safe methods for this aphid control.

Variety plays an important role in producing high yield of mustard because different varieties perform differently for their genotypic characters, and aphid preferences of different mustard variety also vary from variety to variety. Improved variety is the first and foremost requirement for initiation and accelerated crop production program. There are some HYVs of mustard, which have been released Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA). The yield of mustard in Bangladesh has been increased obviously by using high yielding mustard varieties and improvement of management practices with the judicious use of some selected insecticides.

Considering these facts as stated above, the present investigation was undertaken with the following objectives:

1. To find out the level of infestation caused by aphids on different mustard varieties.
2. To evaluate the best variety(ies) against the infestation of mustard aphid.
3. To evaluate the effectiveness of insecticide on the reduction of aphid on mustard.

CHAPTER II
REVIEW OF LITERATURE

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

2.1 General review on mustard aphid and ladybird beetle

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

2.1.1. Taxonomy of mustard aphid

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

Taxonomic position of mustard aphid

Kingdom: Animalia

Class: Insecta

Sub-Class: Pterygota

Division: Exopterygota

Order: Homoptera

Family: Aphididae

Subfamily: Aphinidae

Genus: *Lipaphis*

Species: *Lipaphis erysimi (*Kalt.)

2.1.2. Distribution of mustard aphid

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

2.1.3. Host range of mustard aphid

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

(Dixon 1982) Vegetable crops viz turnip, Chinese kale, mustard, flowering cabbage and Chinese cabbage possess 63.43, 10.04, 24.93, 23.32 and 114.31 aphids plant^{-1}, respectively. In temperate climate, many aphid species are host alternating and have a primary host, which is usually a woody plant and secondary hosts, which are generally herbaceous.

Lipaphis erysimi is well known as a serious pest of mustard, cauliflower, turnip, kohlrabi, radish, Chinese cabbage, rai, tori, Brussels sprout, broccoli, kale and rutabaga and a minor pest of bean, beet spinach, pea celery, onion, stock, cucumber and potato (Scmutterer 1978).

2.1.4. Seasonal abundance of mustard aphid and its predators

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

Aphids are an important group of plant insect pests. They have a high biological potential with some of aphid's species (Aphididae) having more than ten generations in one year (Iversen and Harding, 2007). Because of their direct (sucking) and indirect (transmission of viruses and honeydew secretion) damage on cultivated and wild growing plants, the producers of food plant, ornamental plants and feed for livestock and control them in different ways.

Vekaria and Patel (2005) conducted an experiment during Rabi 1993-94 and 1994-95 revealed that the incidence of aphid commenced from 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AT) at 14 weeks after sowing coinciding with second week of February during 1993-94, however, during

(1994-95) aphid incidence commenced at late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AT) at 13 WAS coinciding with first week of February. The aphid population exceed above economic threshold level (ETL) between 11 and 14 WAS coinciding with the third week of January to second week of February. The predominant coccinellid predator *Coccinella septempunctata* was active between last week of January and last week of February with maximum population (5.52 and 3.07 beetles/plant) during third week of February in both the years.

Panda *et al.* (2000) conducted an experiment during the 1998-99 winter seasons to study the intensity and population fluctuation of *Lipaphis erysimi* on *Brassica juncea* in relation to the prevailing abiotic and biotic conditions. The aphid species infested the crop from the 2nd to the 14th standard week (SW) with its peak (302.10 aphids per plant) during 7th SW in 70 day old crops. The minimum temperature between 7.1 and 15.1°C, maximum temperature between 24.9 and 29°C were found to be congenial for the proper development of aphid population. The natural enemies like *Menochilus sexmaculatus* influenced the aphid population during their activity period from January to February.

Nayak *et al.* (2000) studied during the Rabi season of 1996-97 to determine the seasonal abundance of the *L. erysimi* pest. The highest aphid population was observed on the second week of January, when it reached 42.95, 22.95, 22.30, 17.35, 16.32 and 11.72 on Indian mustard, cabbage, cauliflower, knolkhol, radish and turnip respectively. Thereafter, the aphid numbers declined. Overall, the mean aphid population during the season was highest (10.59) on radish and lowest (6.97) on turnip.

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

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

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

The mustard aphid *Lipaphis erysimi* (Kalt.) causes serious losses of yield in Mustard crops and reduces its marketable value. Increase in population beyond 9.45 aphids per plant; reduce the seed yield by 59.3 per cent with an economic injury level of 2.04 aphids/plants with an index of 0.98 and infestation 37.4 per cent (Singh and Malik, 1998).

The yield loss due to aphid infestation in mustard ranged from 87.16 to 98.16% (Anon., 1995). Greatest loss reported in yield only due to mustard aphid, (*Lipaphis eyrsimi* Kalt.) is 83% to rapeseed and mustard in India (Mandal *et al.*, 1994). Losses due to insect pests are estimated to be 70-80% in Pakistan. But in case of severe infestation in years of sporadic attack there may be no grain formation at all (Khattak *et al.*, 2002). The colonies of mustard aphids feed on the new shoots, inflorescence and underside of leaves. Loss in yield up to 91.3 % (Sharma and Kashyap, 1998) and oil contents up to 15 % (Verma and Singh, 1987).

The damage is caused by both nymphs and the adults, these are louse-like and pale greenish insects, is seen feeding in large numbers, often covering the entire surface of the flower buds, shoots, pods etc. (Ahmed and Jalil, 1993). In case of severe aphid infestation, leaves become curled, plant fails to develop pods, the young pods when developed fail to become mature and cannot produce healthy seeds. As a result, plants loss their vigor and growth becomes stunted (Morzia and Huq, 1991).

Khan and Munir (1986) observed the effect of aphid infestation on seed yield and other characteristics of Raya. The number of pods plant^{-1} in the treated (506.25) and in un-treated (187.02) was found significantly different from each other.

2.2. Management of mustard aphid

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

2.2.1. Role of chemical insecticides for the management of mustard aphid

Sarwar (2011) conducted a study to evaluate the effects of new insecticides like, Imidacloprid (Confidor 200 EC), Thiamethoxam (Actara 25 WG) and Acetamiprid (Megamos 20 SL) along with conventional insecticides such as, Chlorpyrifos (Lorsban 40 EC) and Dimethoate (Systoate 40 EC) belonging to Organophosphate group against aphid's population. The study reflected that, newer insecticides were superior in reducing the population of aphids and yield enhancement as compared to conventional insecticides. The best results were achieved with the application of Imidacloprid by recording the lowest number of aphids (2.2 per plant) than obtained with Thiomethoxam and Acetamiprid (3.22 and 4.66, respectively). Other insecticides, viz., Chlorpyrifos and Dimethoatewere also found to be effective in maintaining the aphids' population at lower levels plant-1 (16.2 and 17.5, respectively) over untreated control (227.7).

Amer (2010a) conducted an experiment with conventional and neonicotinoid insecticides to test their toxicity to cabbage aphid, *Brevicoryne brassicae* L. and turnip aphid, *Lipaphis erysimi* (Kalt). Insecticides were Actara 25WG @ 15g a.i/ha, Confidor 20SL @ 0.125 L. a.i/ha, Advantage 20EC @ 0.5 L. a.i/ha, Talstar 10EC @ 0.0625 L. a.i/ha and Methamidophos 60 SL @ 1.5L. a.i/ha. Seven days after application all the insecticides proved to be similarly toxic to aphids and statistically higher numbers of both aphid species were observed in untreated plots. The lowest numbers of aphids were observed in plots where Talstar was applied as compared to Advantage, Actara and Confidor. However, aphid numbers were too high even after three days of application particularly after first spray. Results of this study suggest that insecticides should not be applied at pod-filling stage to manage aphids.

Amer (2010b) studied the effectiveness of nine insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) on mustard as foliar spray. Studies revealed that seventh day of spray; imadacloprid 17.8 SL @ 0.0178% gave most effective control. On seventh day after spray, the order of effectiveness was imadacloprid 0.0178%>oxydemeton methyl 0.025%>monocrotophos 0.036%>dimethoate 0.03%>chloropyriphos 0.05%>malathion 0.05%>endosulfan 0.07%>cypermethrin 0.01%>neemarin, respectively.

Said (2005) also reported that after two weeks of spray of insecticides Karate was found best in suppressing of pest population (9.67 aphid per inch of inflorescence), followed by Actara, Ripcord, Bestox, Curacron, Lorsban, Thiodan, Methamidophos, Advantage and Sevin with reduction of aphid population to 14.44, 18.00, 19.78, 20.33,23.22, 24.78, 24.89, 34.11 and 49.11 per inch of inflorescence respectively. All of insecticides were found effective against aphids on canola crop compared to control (130.00 aphids per inch of inflorescence) at 5% level of significance.

Gami (2002) reported the results of 11 different insecticide treatments with methyl-o-demeton 0.025%, carbosulfan 0.04%, methyl parathion 2% dust @ 25kg/ha and monocrotophos 0.04% were found highly effective against mustard aphid, *Lipaphis erysimi (*Kalt.) Profenophos 0.05% and azadirachtin 0.00075% were found less effective against this pest.

Tong (2001) reported the toxicity baselines and efficacies of primicarb (Pirimor, imidacloprid (Provado), thiamethoxam (Actara) and lambda-cyhalothrin (Warrior) were bioassayed in the laboratory and tested in the field against mustard aphid, *Lipaphis erysimi* (Kalt.) Results showed that the LC_{50} and LD_{50} of the four insecticides for apterous *L. erysimi* adults were comparable with those for other aphid species. Results from field trials showed that primicarb and lambda-cyhalothrin were the most effective among these insecticides, followed by imidacloprid. A field rate (25 gm a.i./ha) of thiamethoxam did not provide satisfactory control of *L. erysimi*, but higher field rate did (50 gm a.i./ha).

Gazi (2001) tested five organophosporus insecticides viz., phosphamdon, quinalphos, malathion, dimethoate and diazinon against mustard aphid, *Lipaphi serysimi* (Kalt.) in the field and net house condition. All these insecticides significantly controlled mustard aphid. Quinalphos was comparatively more effective in controlling mustard aphid followed by phosphamidon. Diethoate, diazinon and malathion showed more or less response against the mustard aphid.

Khan and Akber (1999) stated that significantly high grain yield of 1.44, 1.35, 1.20, 1.05 kg $plot^{-1}$ (3 x 5m size) was obtained in Tamaron 600 SL, Follidole 50 EC, Ripcord and Nuvacron treated plots, respectively, compared to grain yield of 0.75 kg $plot^{-1}$ obtained from untreated plot of the same size.

Phadke (1990) studied that in Bangladesh and other areas of Indo-Pak subcontinent, foliar insecticides generally control insect pest of mustard. Other control methods like cultural, biological are not well known to farmers.

Bhuiyan (1989) conducted an experiment to find out the most effective insecticide (s) for the control of mustard aphid, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae) in the field. Eight different insecticides, namely, Marshal 20 EC, Dimecron 100 EC, Malathion 57 EC, Zolone 35 EC, Perfekthion 40 EC, Ripcord 10 EC, Diazinon 60 EC, and Elsan 50 EC were applied as general application covering the whole plants. The mortality data observed 24 and 48 hours after insecticidal treatments were subjected to statistical analysis. Significant difference was observed among the treatments at 1% level of probability. The results indicated that Marshal 20 EC, Zolone 35 EC and Perfekthion 40 EC – 2 ml/L of water were most effective insecticides in reducing aphid population.

Thakur and Kashyap (1989) tested the toxicity and persistence of different compounds on final instar nymphs of mustard aphid (*L. erysimi*). They noted that malathion retained some toxicity 3 days after spraying on sarson leaves. In laboratory ingestion tests, % toxicity LC50 values to *Apis mellifera* were determined 0.0615.

Karishniah and Mohan (1983) conducted an experiment on mustard aphids and observed that mustard aphid population on cabbage was in considerable number after third spray in November. Quinalphos, methamidophos, chlorpyrifos (0.5kg ai/ha) monocrotophos (both 0.3 and 0.5 kg ai/ha), endosulfan (0.7 kg ai/ha) gave effective control and suppressed the population for over fortnight. Performance of monocrotophos at 0.3 kg ai/ha was equally good as that at 0.5 kg ai/ha phosphamidon. Phenthoate, methomyl, chlorfenvinphos, malathion, fenitrothion, trichlorfon, garlic oil, carbaryl and dicrotophos were also found ineffective.

Gandhale *et al.* (1983) tested endosulfan, quinalphos, fenitrothion, phosalone and malathion at 0.05% and formothion and thiometon at 0.02% for their effectiveness against the aphid on cabbage in field trials and reported that the highest mortality was caused by thiometon (77.28%), while malathion was least effective (62.48%). The mortalities caused by the remaining treatments ranged from 7.50 to 76.57%.

Ahmad (1970) studied systemic activity of four granular insecticides (phorate 10%, Temik 10%, diazinon 5% and Sevidol [8% carbaryl + 8% gamma-BHC]) for the control of mustard aphid, *Lipaphis erysimi* (Kalt). The granules were applied in the soil to one-month old mustard plants transplanted in pots. Mortality counts were made 24 hours after release. Of the insecticides tested, phorate and Temik at 1 lba.i./ac proved most effective. Temik had a quick knockdown effect as compared to phorate, as it gave 100% control within 24 hours, while with phorate 100% kill was obtained only after 72 hours. Diazinon at 4 lba.i./ac gave 83.3% kill after 72 hours. Sevidol proved ineffective as an aphidicide.

A research was carried by Sohail *et al.* (2008) to study the effect of different chemical pesticides on mustard aphid (*L. erysimi*) and their adverse effects on Ladybird beetle in field. The experiments were carried out with eight treatments, Actara (low) @ 5 g/100 L water, Actara (medium) @ 10 g/100 L water, Actara (high) @ 15 g/100 L water, Confidor (low) @ 80 ml/100 ml water, Confidor (medium) @100 ml/100 L water, Confidor (high) @ 120 ml/100L water, Fastkil @ 200 ml/100 L of water with a control. Results showed that Fastkil was more toxic to the mustard aphid (*L. erysimi*) population followed by Actara. Fastkilwas found most lethal for the ladybird beetle population followed by Confidor and Actara. The study recommends the use of Actara for the safe and effective control of mustard aphid (*L. erysimi*). Farmers should use Actara for the control of Aphids (*L. erysimi*) in the field as it is the least toxic to ladybird beetle population (Sohail*et al.*2008).

Mannan (2002) conducted an experiment with Malathion 57 EC and Diazinon 60 EC with different doses (1 ml, 2 ml, 3 ml/L^{-1} water) were tested to evaluate the effect on mustard aphid and their toxicity on the predators and other beneficial insects of mustard aphid. Malathion was more effective then Diazinon for the control of aphids and it was less toxic to the predator and other beneficial insects. The lower dose of insecticides has less adverse effect on the predator and other beneficial insects then the higher dose. Some of the insecticides are fast killing at all the life stages of coccinellids that feed on the treated aphids. Carbaryl and phosmet are slow acting insecticides that cause the greatest mortality. Methomyl did not cause 100% mortality of ladybird beetle feeding on insecticides treated aphids (Hurej and Dutcher, 1994).

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted in 186.56 cm plant height. Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU

Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of plant height.

Laxminarayana and Pooranchand (2000) conducted an experiment during the rabi seasons at Madhira to determine the most suitable mustard (*Brassica juncea*) cultivar and found no significant variations in plant height among the cultivars.

Ahmed *et al.* (1999) stated that the tallest plant (102.56 cm) was observed in the variety Daulat. No significant difference was observed in plant height of Dhali and Nap-8509. Jahan and Zakaria (1997) reported that Dhali was the tallest plant (142.5 cm) which was at par with Sonali (139.5) and Japrai (138.6 cm). The shortest plant was observed in Tori-7 (90.97 cm) which was significantly shorter than other varieties. The exotic varieties were of intermediate types of plants.

Hussain *et al.* (1996) observed the highest plant height in Narendra (175 cm) which was identical with AGA-95-21 (166 cm) and Hyola-51 (165 cm). The shortest variety was Tori-7. Mondal *et al.* (1992) found that variety had significant effect on plant height. They found the highest plant height (134.4 cm) in the variety J-5004, which was identical with SS-75 and significantly taller than JS-72 and Tori-7.

Ali *et al.* (1986**)** observed significant variation in plant height in different varieties of mustard and rape.

Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at SAU, Dhaka, Bangladesh. Four varieties (BARI Sarisha13, BARI Sarisha 15, BARI Sarisha 16 and SAU Sarisha 3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of siliqua plant^{-1} (126.90).

Hussain *et al*. (2008) conducted an experiment to show the effect of boron application on yield and yield attributes of different mustard varieties. The experiment involved five boron levels and three mustard varieties viz. BARI sharisha8, BARI Sharisha 9 and BARI Sharisha 11. BARI sharisha11 and BARI sharisha8 performed better in terms of siliqua length.

BARI (1999) reported that varieties had significant variation in of siliqua length. The highest siliqua length was found in Daulat and lowest in Dhali. Hussain *et al.* (1996) observed the longest siliqua (8.07 cm) in BLN-900 and the shortest (4.83 cm) in Hyola-401.Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at SAU, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of 1000 seed weight (4.00) considering the other variety.

Mondal and Wahab (2001) observed that thousand seed weight ranged 2.5- 2.65 g in improved Tori-7 *(B. campestris)* and 1.5-7.8 g in *Rai (B. juncea).*

BARI (2001) concluded that there was significant variation in 1000-seed weight of mustard found in different varieties and highest weigh of 1000-seed was found in Jamalpur1 variety and lowest in BARI Sarisha 10.

Karim *et al.* (2000) stated that varieties showed significant influence in weight of thousand seeds. They found higher weight of 1000-seed in J-3023 (3.43 g) J-3018 (3.42 g) and J-4008 (3.50 g).

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 1960.30 seed yield kg ha^{-1}, while variety Early Mustard resulted 1677.90 seed yield kg ha^{-1}. Mamun *et al*. (2014) evaluated the effect of four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha 16 and SAU Sarisha 3) and four plant densities were applied during the course of study and reported that maximum seed yield (1.60 t ha^{-1}) was observed for BARI Sarisha-13.

Afroz *et al*. (2011) conducted an experiment at the Agronomy Field Laboratory, BAU, Mymensingh with two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date and three seed rates and higher seed yield was obtained by the variety BARI Sarisha-9.

Rahman (2002) stated that yield variation existed among varieties and the highest seed yield was observed in BARI Sarisha7, BARI Sarisha 8 and BARI Sarisha 11 (2.00-2.50 t ha^{-1}) and lowest yield in variety Tori-7 (0.95-1.10 t ha^{-1}). BARI (2001) showed that seed yield and other yield contributing characters significantly varied among the varieties.

BARI (2000) reported that in case of poor management Isd-local gave the highest straw yield (3779 kg ha^{-1}) and lowest yield (1295 kg ha^{-1}) was found from Nap-248. In case of medium management, highest weight (6223.3 kg ha^{-1}) was observed from the same variety and lowest (3702.3 kg ha^{-1}) from PT-303 under high management practices. The highest straw yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg ha-1 was obtained from variety Tori-7.

Pooran *et al.* (2000) studied 6 cultivars of mustard and observed that among the mustard cultivars, GM-1 gave the highest seed yield (1050 kg ha^{-1}), followed by Kranti and Pusa Bold (790 and 760 kg ha^{-1}, respectively) and Varuna and Sita produced comparable yields (680 and 610 kg ha^{-1}, respectively).

Jahan and Zakaria (1997) stated that yield variation is present in different varieties. They found highest yield in the exotic variety BLN-400 (2013 kg ha^{-1}) and the lowest seed yield was in AGA-95-21 (819 kg ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The present experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2015 to February 2016 to evaluate the infestation level of mustard aphid against the combination of chemical treatment and varieties. The details of different experimental materials and methodologies followed during the course of the investigation are described under the following sub-headings:

3.1. Location and duration of the experimental site

The research work was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the Rabi season of 2015-16 (from November 2015 to February 2016).

3.1.2 Soil of the experimental site

The soil of the experimental field belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. It was medium high land, fertile, well drained, fairly leveled and slightly acidic with pH varying from 5.8 to 6.5, CEC 25-28 (Haider *et al.*, 1991). The results have been presented in Appendix II.

3.1.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (27.1 °C) was observed from February 2015 and the minimum temperature (12.4 °C) from

January 2015, highest relative humidity(78%) was observed from November 2014, whereas the lowest relative humidity(67%) and highest rainfall (30 mm) was observed in February 2015.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised of two factors Randomized Complete Block Design with four replication.

Factors A: Mustard varieties (4 mustard varieties)

i) V_1=BARI Sarisha-11

ii) V_2= BARI Sarisha-14

iii) V_3= BARI Sarisha-15

iv) V_4= BARI Sarisha-16

Factor B: Chemical treatment (3 levels)

i) T_1= Ripcord 10 EC @1mlL^{-1} water at 7 days interval

ii) T_2= Imitaf 20 SL @1mlL^{-1} water at 7 days interval

iii) T_3= Marshal 20 EC @1mlL^{-1} water at 7 days interval

There were in total 12 (3×4) treatment combinations such as V_1T_1,V_1T_2,V_1T_3,V_2T_1,V_2T_2,V_2T_3,V_3T_1,V_3T_2,V_3T_3,V_4T_1,V_4T_2 and V_4T_3.

3.2.2 Design of the experiment and layout

The experiment was laid out in a Randomized Complete Block Design with four replications. The total numbers of plots were 48 for 2 factor (Treatment and variety) each measuring 2 m × 3 m (6 m^2). The adjacent block and neighboring plots were separated by 0.75 m and 0.5 m, respectively.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sarisha-11, BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-16, were used as plating materials in this experiment. All of the high yielding varieties of mustard developed by Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The seeds were collected from the BARI, Joydebpur, Gazipur.

3.3.2 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator, afterwards the land was ploughed and cross-ploughed followed by laddering to obtain a good tilt. The corners of the field were spaded, weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilt of soil for sowing of seeds. The target land was leveled and the experimental field was divided into 48 equal plots with a plot size of 2.0 m x 3.0 m and plot to plot distance 0.5 m; block to block distance 0.75m.

3.3.3 Application of fertilizers

Recommended doses of N, P, Zn and B (35 kg N from urea, 35 kg P from TSP and 2.2 kg Zn from ZnO respectively) were applied as Fertilizer guideline. The whole amount of TSP and ZnO, half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 22-25 days of germination.

3.3.4 Seed sowing

The seeds of mustard were sown on 24 November, 2015 in rows in the furrows having a depth of 2-3 cm.

3.3.5 Intercultural operations

3.3.5.1 Thinning

Seeds started of germination four Days After Sowing (DAS). Thinning was done two times; first thinning was done at 7 DAS and second was done at 14 DAS to maintain optimum plant population in each plot as per the treatment of plant density.

3.3.5.2 Irrigation and weeding

Irrigation was provided for three times after seed sowing, 20 days before flowering and 45 days after sowing for pod development for all experimental plots equally. The crop field was weeded before providing irrigation.

3.4 Application of the treatments

The selected treatments comprising different insecticides with their assigned doses were started to apply in the respective plots when the aphids were first appeared in the mustard field. The first appearance or incidence of aphids was determined by visit and daily direct visual observation of mustard plants. Therefore, considering the first appearance of the aphids in the field, treatment applications were started at 45 days after sowing (DAS) of the mustard seeds. The treatments were applied at 7 days interval and continued up to the siliqua were formed.

3.5 Crop sampling and data collection

Five plants from each treatment and each replication were randomly selected and marked with sample card for data collection. The mustard plants of different treatments were closely examined at regular intervals commencing from sowing to harvest. The following data were collected during the course of the study-

- Number of aphid at flowering and fruiting stages
- Number of healthy plants at flowering and fruiting stages
- Number of infested plants at flowering and fruiting stages
- Plant height at harvest
- Number of siliqua plant^{-1}
- Length of siliqua

- Weight of 1000 seeds
- Seed yield ha^{-1}

3.5.1 Counting of aphid

The mustard plants were closely examined at regular intervals at flowering and fruiting stage. Aphid from 10 plants were observed at early, mid and late flowering and fruiting stage and converted per plant. The insect population was collected by a needle brush in a Petri dish.

3.6 Harvest and post harvest operations

Harvesting was done when 90% of the siliqua became brown in color which was estimated by eye observation**.** The matured pods were collected by hand picking from each plot.

3.7 Procedure of data collection

3.7.1 Plant height

The plant height was measured at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.7.2 Number of siliqua $plant^{-1}$

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as $plant^{-1}$ basis. Data were observed as the average of 5 plants selected at random from the inner rows of each plot.

3.7.3 Length of siliqua

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

3.7.4 Weight of 1000 seeds

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

3.7.5 Seed yield

The seeds collected from 1 square meter of each plot were sun dried properly. The weight of seeds was taken and converted into yield in t/ha.

3.8 Statistical analysis

The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. Data were analyzed using the analysis of variance (ANOVA) technique with the help of computer package programme MSTAT and the means were compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to find out the infestation status of aphid on selected mustard variety and its chemical control. Data were observed on aphid infestation at flowering and fruiting stage, plant infestation at flowering and fruiting stage, yield contributing characters and yield of mustard. The analysis of variance (ANOVA) table is given in Appendix III-VII. The results have been presented and possible interpretations are given under the following headings:

4.1 Abundance of aphid

4.1.1 Early flowering stage

Number of aphid plant^{-1} at early flowering stage varied significantly due to different mustard variety (Table 4.1 and Figure 4.1). The lowest number of aphid (4.66) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (8.08) was observed from V_2 (BARI Sarisha-14).

Effect of different treatment showed statistically significant differences in terms of number of aphid plant^{-1} at early flowering stage (Table 4.2 and Figure 4.2). The lowest number of aphid (6.12) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (6.69) was found from T_3 (Marshal 20 EC @1mlL^{-1} water).
Said *et al.,* (2005) reported that chemical insecticides reduced aphid population on mustard with application of Curacron (43.45 aphid per inch of inflorescence), followed by Ripcord, Actara, Bestox, Karate, Thiodan, Lorsban, Advantage, Methamidophos and Sevin with 26.31, 26.92, 27.68, 30.45, 31.26, 33.79, 37.32, 42.32 and 43.77 aphid per cm of inflorescence respectively. Amer *et al., (*2010) reported that the lowest numbers of aphids were observed where Talstar was applied as compared to Advantage, Actara and Confidor. Bakhetia (1984) and Khurana *et al.* (1989) also reported that good control of mustard aphid has been obtained by spraying traditional organic insecticides. Mannan *et al.,* (2002) reported that different doses (1 ml, 2 ml, 3 ml/L water) of

Malathion 57 EC were more effective than same doses of Diazinon 60 EC for the control of aphids.

Statistically significant variation was observed due to the combined effect of mustard variety and chemical treatment in terms of number of aphid plant^{-1} at early flowering stage (Table 4.3). The lowest number of aphid (4.49) was observed from the treatment combination of V_4T_2 (Imitaf 20 SL @1mlL^{-1} water and BARI Sarisha-16) and the highest number of aphid (8.65) from the treatment combination of V_2T_3 (Marshal 20 EC @1mlL^{-1} water and BARI Sarisha-14).

4.1.2 Mid flowering stage

Number of aphid plant^{-1} at mid flowering stage varied significantly due to different mustard variety (Table 4.1 and Figure 4.1). The lowest number of aphid (4.85) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (8.40) was observed from V_2 (BARI Sarisha-14).

Chemical treatment showed statistically significant differences in terms of number of aphid plant^{-1} at mid flowering stage (Table 4.2 and Figure 4.2). The lowest number of aphid (6.36) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (6.96) was found from T_3 (Marshal 20 EC @1mlL^{-1} water).

Statistically significant variation was observed due to the combined effect of mustard variety and chemical treatment in terms of number of aphid plant^{-1} at mid flowering stage (Table 4.3). The lowest number of aphid (4.67) was observed from the treatment combination of V_4T_2 and the highest number of aphid (9.00) was observed from the treatment combination of V_2T_3.

Table 4.1 Effect of varieties on number of aphid plant^{-1} at flowering stage of mustard

Variety	Number of aphid plant^{-1}		
	Early flowering stage	Mid flowering stage	Late flowering stage
V_1	6.17c	6.41c	7.39c
V_2	8.08a	8.40a	9.68a
V_3	6.80b	7.08b	8.15b
V_4	4.66d	4.85d	8.32b
LSD $_{(0.05)}$	0.069	0.074	0.722
LS	**	**	**
CV (%)	6.54	7.43	8.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

Table 4.2 Effect of treatments on number of aphid plant^{-1} at flowering stage of mustard

Treatment	Number of aphid plant^{-1}		
	Early flowering stage	Mid flowering stage	Late flowering stage
T_1	6.48b	6.74b	9.81a
T_2	6.12c	6.36c	7.33c
T_3	6.69a	6.96a	8.02b
LSD $_{(0.05)}$	0.020	0.022	0.217
LS	**	**	**
CV (%)	6.54	7.43	8.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

Table 4.3 Combined effect of variety and treatment on number of aphid plant^{-1} at flowering stage of mustard

Combination of variety and treatment	Number of aphid plant^{-1}		
	Early flowering stage	Mid flowering stage	Late flowering stage
$V_1\times T_1$	5.20 g	5.40 g	6.23 d
$V_1\times T_2$	7.93 c	8.25 c	9.50 bc
$V_1\times T_3$	5.38 f	5.59 f	6.44 d
$V_2\times T_1$	8.38 b	8.72 b	10.04 b
$V_2\times T_2$	7.20 e	7.49 e	8.63 f
$V_2\times T_3$	8.65 a	9.00 a	10.37 b
$V_3\times T_1$	7.65 d	7.96 d	9.17 bc
$V_3\times T_2$	4.84 h	5.03 h	5.80 d
$V_3\times T_3$	7.91 c	8.23 c	9.48bc
$V_4\times T_1$	4.68 i	4.86 i	13.80 a
$V_4\times T_2$	4.49 j	4.67 j	5.39 d
$V_4\times T_3$	4.82 h	5.01 h	5.77 d
LSD $_{(0.05)}$	0.120	0.128	1.251
LS	**	**	**
CV (%)	6.54	7.43	8.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water
V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

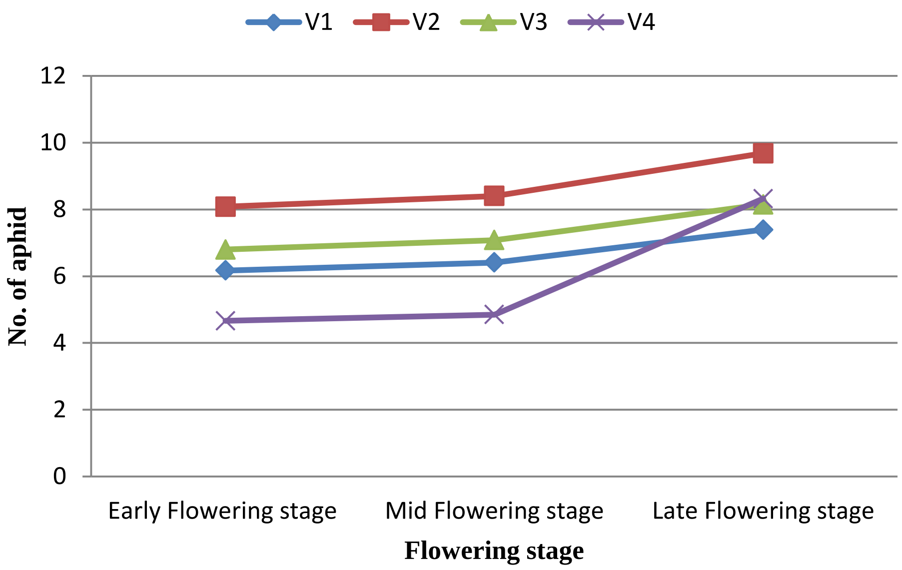

Figure 4.1 Showing varietal effects on number of aphid at different flowering stage

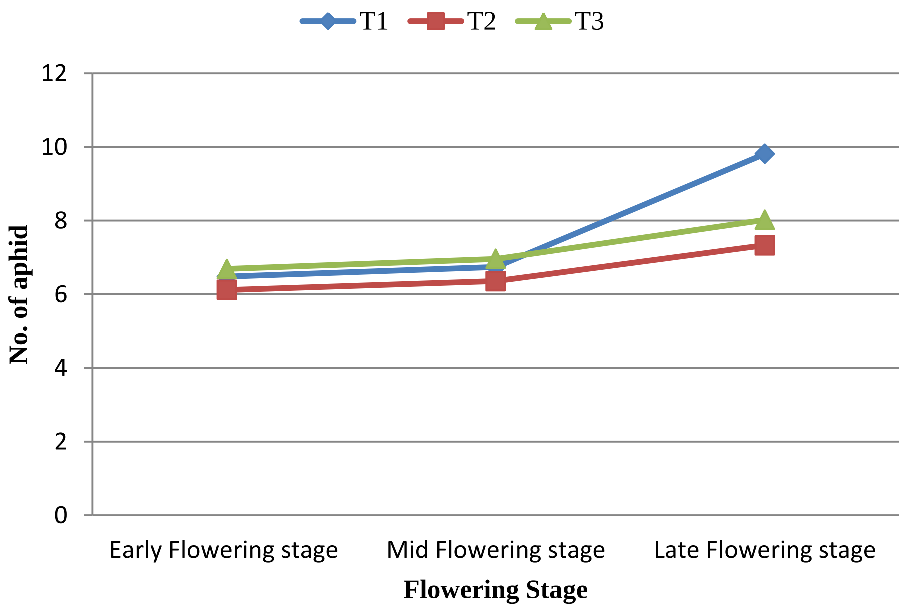

Figure 4.2 Showing treatment effect on number of aphid at different flowering stage

4.1.3 Late flowering stage

Number of aphid plant^{-1} at late flowering stage varied significantly due to different mustard variety (Table 4.1 and Figure 4.1). The lowest number of aphid (7.39) was observed from V_1 (BARI Sarisha-11), whereas the highest number of aphid (9.68) was observed from V_2 (BARI Sarisha-15).

Chemical treatment showed statistically significant differences in terms of number of aphid plant^{-1} at late flowering stage (Table 4.2 and Figure 4.2). The lowest number of aphid (7.33) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (9.81) was found from T_1.

Statistically significant variation was observed due to the combined effect of mustard variety and treatment in terms of number of aphid plant^{-1} at late flowering stage (Table 4.3). The lowest number of aphid (5.39) was observed from the treatment combination of V_4T_2 and the highest number of aphid (13.80) was observed from the treatment combination of V_4T_1.

4.1.4 Early fruiting stage

Number of aphid plant^{-1} at early fruiting stage varied significantly due to different mustard variety (Table 4.4 and Figure 4.3). The lowest number of aphid (4.01) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (9.07) was observed from V_1(BARI Sarisha-11)which was statistically similar (11.88) to V_2 (BARI Sarisha-14).

Effect of chemical treatment showed statistically not significant in terms of number of aphid plant^{-1}at early fruiting stage (Table 4.5 and Figure 4.4). The lowest number of aphid (9.00) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (12.04) was found from T_1. Said *et al.*, (2005) also reported that after two weeks of spray of insecticides Karate was found effective in suppressing of pest population (9.67 aphid per inch of inflorescence), followed by Actara, Ripcord, Bestox, Curacron, Lorsban, Thiodan, Methamidophos, Advantage and Sevin with reduction of aphid population to 14.44, 18.00, 19.78, 20.33,23.22, 24.78, 24.89, 34.11 and 49.11 per inch of inflorescence, respectively.

Statistically significant variation was observed due to the combined effect of chemical treatment and mustard variety in terms of number of aphid plant^{-1}at early fruiting stage (Table 4.6). The lowest number of aphid (6.61) was observed from the treatment combination of V_4T_2 and the highest number of aphid (16.94) from the treatment combination of V_4T_1.

4.1.5 Mid fruiting stage

Number of aphid plant^{-1} at mid fruiting stage varied significantly due to different mustard variety (Table 4.4 and Figure 4.3). The lowest number of aphid (6.55) was observed from V_4 (BARI Sarisha-16), while the highest number of aphid (11.34) was observed from V_2 (BARI Sarisha-14).

Chemical treatment showed statistically significant differences in terms of number of aphid plant^{-1} at mid fruiting stage (Table 4.5 and Figure 4.4). The lowest number of aphid (8.59) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (9.40) was found from T_3.

Statistically no significant variation was observed due to the combined effect of mustard variety and chemical treatment in terms of number of aphid plant^{-1} at mid fruiting stage (Table 4.6). The lowest number of aphid (6.31) was observed from the treatment combination of V_4T_2 and the highest number of aphid (12.15) was observed from the treatment combination of V_2T_3.

Table 4.4 Effect of varieties on number of aphid plant^{-1} at fruiting stage of mustard

Variety	Number of aphid plant^{-1}		
	Early Fruiting stage	Mid Fruiting stage	Late Fruiting stage
V_1	9.07	8.66c	7.49c
V_2	11.88	11.34a	9.81a
V_3	10.00	9.55b	8.27b
V_4	10.21	6.55d	5.67d
LSD $_{(0.05)}$	-	0.098	0.097
LS	NS	*	**
CV (%)	7.42	6.43	5.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

Table 4.5 Effect of treatment on number of aphid plant^{-1} at fruiting stage of mustard

Treatment	Number of aphid plant^{-1}		
	Early fruiting stage	Mid fruiting stage	Late fruiting stage
T_1	12.04a	9.10b	7.87b
T_2	9.00b	8.59c	7.43c
T_3	9.84ab	9.40a	8.13a
LSD $_{(0.05)}$	2.431	0.029	0.071
LS	**	*	*
CV (%)	7.42	6.43	5.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

Table 4.6 Combined effect of variety and treatment on number of aphid plant^{-1} at fruiting stage of mustard

Combination of variety and treatment	Number of aphid plant^{-1}		
	Early fruiting stage	Mid fruiting stage	Late fruiting stage
$V_1 \times T_1$	7.65 d	7.30 c	6.32 g
$V_1 \times T_2$	11.66 bc	11.13 b	9.63 c
$V_1 \times T_3$	7.91 d	7.55 d	6.53 f
$V_2 \times T_1$	12.33 b	11.77 c	10.18 b
$V_2 \times T_2$	10.59 c	10.11 b	8.75 e
$V_2 \times T_3$	12.73 b	12.15 b	10.51 a
$V_3 \times T_1$	11.26 bc	10.75 c	9.30 d
$V_3 \times T_2$	7.12 d	6.80 d	5.89 h
$V_3 \times T_3$	11.64 bc	11.11 c	9.61 c
$V_4 \times T_1$	16.94 a	8.57 h	5.68 i
$V_4 \times T_2$	6.61 d	6.31 e	5.46 j
$V_4 \times T_3$	7.09 d	6.77 e	5.86 h
$LSD_{(0.05)}$	1.531	-	1.654
LS	**	NS	*
CV (%)	7.42	6.43	5.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water
V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15and V_4= BARI Sarisha-16

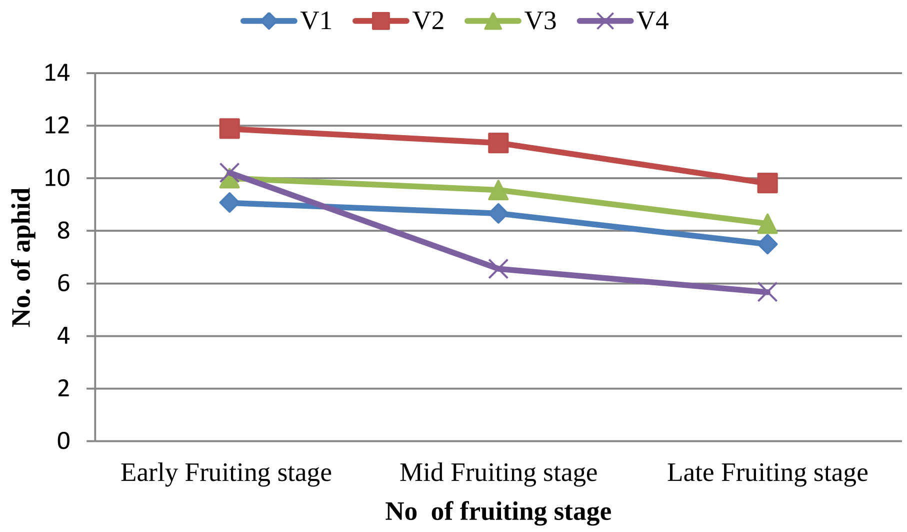

Figure 4.3 Showing varietal effects on number of aphid plant^{-1} at different fruiting stage

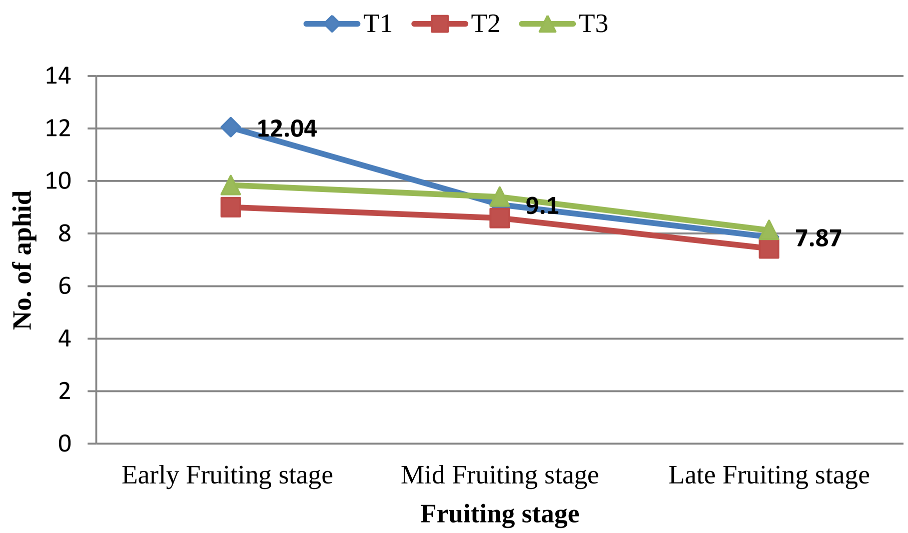

Figure 4.4 Showing treatment effect on number of aphid plant^{-1} at different fruiting stage

4.1.6 Late fruiting stage

Number of aphid $plant^{-1}$ at late fruiting stage varied significantly due to different mustard variety (Table 4.4 and Figure 4.3). The lowest number of aphid (5.67) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (9.81) was observed from V_2 (BARI Sarisha-14).

Chemical treatment showed statistically significant differences in terms of number of aphid $plant^{-1}$at late fruiting stage (Table 4.5 and Figure 4.4). The lowest number of aphid (7.43) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (8.13) was found from T_3 (Marshal 20 EC @1mlL^{-1} water).

Statistically significant variation was observed due to the combined effect of chemical treatment and mustard variety in terms of number of aphid $plant^{-1}$ at late fruiting stage (Table 4.6). The lowest number of aphid (5.46) was observed from the treatment combination of V_4T_2 and the highest number of aphid (10.51) was observed from the treatment combination of V_2T_3.

4.2 Healthy and infested plants and infestation status

4.2.1 Healthy plants at flowering stage

Different mustard variety showed statistically significant differences in terms of number of healthy plants per m^{-2} area at flowering stage (Table 4.7 and Figure 4.5). The highest number of healthy plants (31.99) was observed from V_4 (BARI Sarisha-16) whereas the lowest number of healthy plants (22.88) was found from V_2 (BARI Sarisha-14).

Statistically significant variation was observed in terms of healthy plants m^{-2} at flowering stage due to chemical treatment (Table 4.8 and Figure 4.6). The highest number of healthy plants (28.91) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water), while the lowest number (26.16) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of chemical mustard variety and treatment showed statistically significant variation in terms of number of healthy plants m^{-2} at flowering stage (Table 4.9). The highest number of healthy plants (33.97) was observed from the treatment combination of V_4T_2, while the lowest number (22.42) was observed from the treatment combination of V_2T_3.

Table 4.7 Effect of varieties on healthy and infested plant m^{-2} at flowering stage

Variety	Flowering stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
V_1	30.62b	1.92c	7.92c
V_2	22.88d	2.30a	6.44b
V_3	25.32c	1.91d	7.04a
V_4	31.99a	2.15b	6.39b
LSD $_{(0.05)}$	2.321	0.002	0.135
LS	*	**	*
CV (%)	4.54	5.45	6.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

Table 4.8 Effect of treatment on healthy and infested plant m^{-2} at flowering stage

Treatment	Flowering stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
T_1	28.03b	1.97b	6.69b
T_2	28.91a	2.01b	4.78c
T_3	26.16c	2.23a	7.88a
LSD $_{(0.05)}$	0.178	0.051	0.112
LS	*	**	*
CV (%)	4.54	5.45	6.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

Table 4.9 Combined effect of variety and treatment on healthy and infested plant m^{-2} at flowering stage of mustard

Combination of variety and treatment	Flowering stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
$V_1 \times T_1$	30.90 c	1.73 l	5.31
$V_1 \times T_2$	31.94 bc	2.07 e	6.10
$V_1 \times T_3$	29.01 d	1.97 g	6.36
$V_2 \times T_1$	23.00 h	2.57 b	9.91
$V_2 \times T_2$	23.24 gh	2.28 c	8.93
$V_2 \times T_3$	22.42 h	2.05 f	8.38
$V_3 \times T_1$	25.30 f	1.77 k	6.55
$V_3 \times T_2$	26.48 e	1.85 i	6.54
$V_3 \times T_3$	24.17 g	2.11 d	8.04
$V_4 \times T_1$	32.94 ab	1.82 j	5.24
$V_4 \times T_2$	33.97 a	1.87 h	5.20
$V_4 \times T_3$	29.05 d	2.77 a	8.72
$LSD_{(0.05)}$	1.108	0.015	-
LS	*	*	NS
CV (%)	4.54	5.45	6.43

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

4.2.2 Infested plants at flowering stage

Different mustard variety showed statistically significant differences in terms of number of infested plants per m^{-2} at flowering stage (Table 4.7 and Figure 4.5). The lowest number of infested plants (1.91) was observed from V_3, whereas the highest number of infested plants (2.30) was found from V_2 (BARI Sarisha-14)

Statistically significant variation was observed in terms of infested plants m^{-2} at flowering stage due to chemical treatment (Table 4.8 and Figure 4.6). The lowest number of infested plants (1.97) was found from T_1 which was statistically similar to T_2 (Imitaf 20 SL @1mlL^{-1} water) (2.01), while the highest number (2.23) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of number of infested plants m^{-2} at flowering stage (Table 4.9). The lowest number of infested plants (1.73) was observed from the treatment combination of V_1T_1, while the lowest number (2.77) was observed from the treatment combination of V_4T_3.

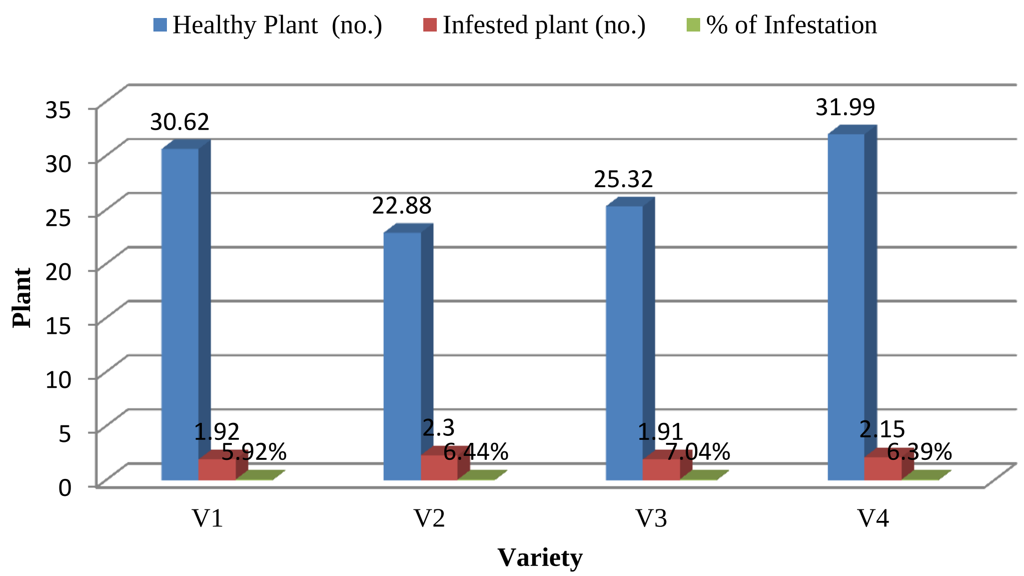

Figure 4.5 Showing varietal effects on healthy and infestation plant at flowering stage of mustard

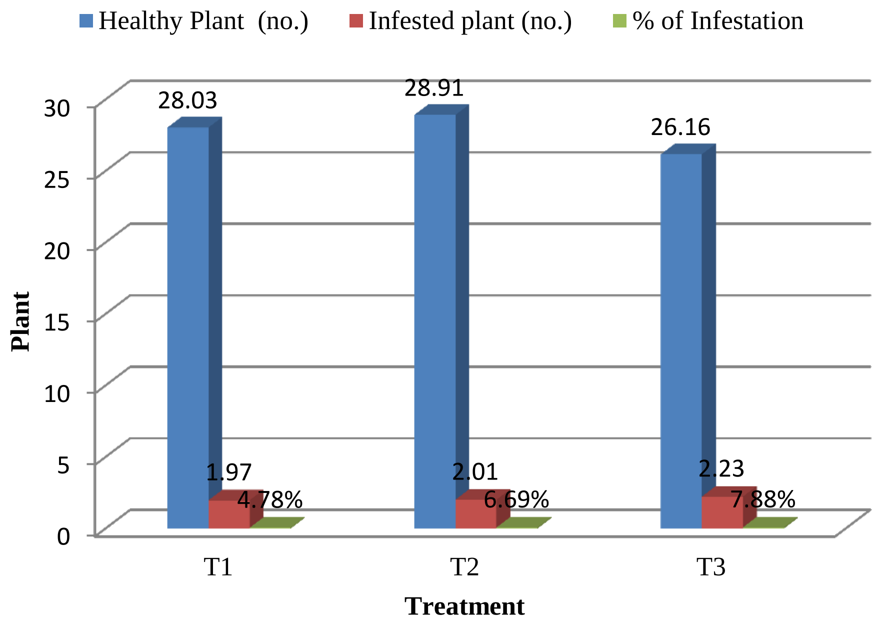

Figure 4.6 Showing treatment effect on healthy and infestation plant at flowering stage of mustard

4.2.3 Percent infestation at flowering stage

Different mustard variety showed statistically significant differences in terms of plant infestation at flowering stage (Table 4.7 and Figure 4.5). The lowest infested plant (6.39%) was observed from V_4 (BARI Sarisha-16) which was statistically similar (6.44%) to V_2 (BARI Sarisha-14), whereas the highest infested plant (7.04%) was found from V_3 (BARI Sarisha-15).

Statistically significant variation was observed in terms of percent plant infestation at flowering stage due to chemical treatment (Table 4.8 and Figure 4.6). The lowest infested plant (4.78) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water), while the highest infested plant (7.88%) was observed from T_1.

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of plant infestation at flowering stage (Table 4.9). The lowest infested plant (5.20%) was observed from the treatment combination of V_4T_2, while the highest (9.87%) was observed from the treatment combination of V_2T_1.

4.2.4 Healthy plants at fruiting stage

Different mustard variety showed statistically significant differences in terms of number of healthy plants m^{-2} at fruiting stage (Table 4.10 and Figure 4.7). The highest number of healthy plants (32.51) was observed from V_4 (BARI Sarisha-16), whereas the lowest number of healthy plants (23.40) was found from V_2 (BARI Sarisha-14).

Statistically significant variation was observed in terms of healthy plants m^{-2} area at fruiting stage due to chemical treatment (Table 4.11 and Figure 4.8). The highest number of healthy plants (29.62) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water) which was closely followed (28.84) by T_1 and the lowest number (27.33) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of number of healthy plants m^{-2} at fruiting stage (Table 4.12). The highest number of healthy plants (33.97) was observed from the treatment combination of V_4T_2, while the lowest number (22.48) was observed from the treatment combination of V_2T_3.

Table 4.10 Effect of variety on healthy and infested plant m^{-2} at fruiting stage of mustard

Variety	Fruiting stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
V_1	32.28b	1.93b	5.66d
V_2	23.40d	2.07a	8.12a
V_3	26.20c	1.82c	6.52b
V_4	32.51a	2.09a	6.08c
LSD $_{(0.05)}$	2.175	0.026	0.146
LS	**	**	*
CV (%)	4.43	5.42	9.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

Table 4.11 Effect of treatment on healthy and infested plant m^{-2} at fruiting stage of mustard

Treatment	Fruiting stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
T_1	28.84b	1.88b	6.26b
T_2	29.62a	1.92b	6.21b
T_3	27.33c	2.14a	7.31a
LSD $_{(0.05)}$	0.609	0.053	0.126
LS	**	**	*
CV (%)	4.43	5.42	9.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

Table 4.12 Combined effect of variety and treatment on healthy and infested plant m^{-2} at fruiting stage of mustard

Combination of variety and treatment	Fruiting stage		
	Healthy Plant (no.)	Infested plant (no.)	% of Infestation
$V_1 \times T_1$	32.31 bc	1.90 e	5.57
$V_1 \times T_2$	33.41 ab	2.00 d	5.64
$V_1 \times T_3$	31.10 cd	1.90 e	5.76
$V_2 \times T_1$	23.60 hi	2.17 b	8.42
$V_2 \times T_2$	24.13 gh	2.13 b	8.10
$V_2 \times T_3$	22.48 i	1.91 e	7.84
$V_3 \times T_1$	26.28 ef	1.68 h	6.01
$V_3 \times T_2$	26.99 e	1.74 g	6.05
$V_3 \times T_3$	25.34 fg	2.05 c	7.49
$V_4 \times T_1$	33.15 ab	1.76 fg	5.04
$V_4 \times T_2$	33.97 a	1.80 f	5.05
$V_4 \times T_3$	30.40 d	2.70 a	8.14
$LSD_{(0.05)}$	1.319	0.049	0.274
LS	**	*	*
CV (%)	4.43	5.42	9.64

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15and V_4= BARI Sarisha-16

4.2.5 Infested plants at fruiting stage

Different mustard variety showed statistically significant differences in terms of number of infested plants m^{-2} area at fruiting stage (Table 4.10 and Figure 4.7). The lowest number of infested plants (1.82) was observed from V_3 (BARI Sarisha-15), whereas the highest number (2.07) was found from V_2 (BARI Sarisha-14) which was statistically similar with V_4 (BARI Sarisha-16).

Statistically significant variation was observed in terms of infested plants m^{-2} area at fruiting stage due to chemical treatment (Table 4.11 and Figure 4.8). The lowest number of infested plants (1.88) was found from T_1 which was statistically similar (1.92) to T_2 (Imitaf 20 SL @1mlL^{-1} water), while the highest number (2.14) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). Sarwar *et al.*, (2011) reported that among some new insecticides like Imidacloprid (Confidor 200 EC, Thiamethoxam (Actara 25 WG) and Acetamiprid (Megamos 20 SL) alongwith conventional insecticides such as, Chlorpyrifos (Lorsban 40 EC) and Dimethoate (Systoate 40 EC) belonging to Organophosphate group gave the best results with the application of Imidacloprid by recording the lowest number of aphids (2.2 per plant) than obtained with Thiomethoxam and Acetamiprid (3.22 and 4.66, respectively). Other insecticides, viz., Chlorpyrifos and Dimethoate were also found to be effective in maintaining the aphids' population at lower levels plant-1 (16.2 and 17.5, respectively) over untreated control (227.7).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of number of infested plants m2 area at fruiting stage (Table 4.12). The lowest number of infested plants (1.74) was observed from the treatment combination of V_3T_2, while the highest number (2.70) was observed from the treatment combination of V_4T_3.

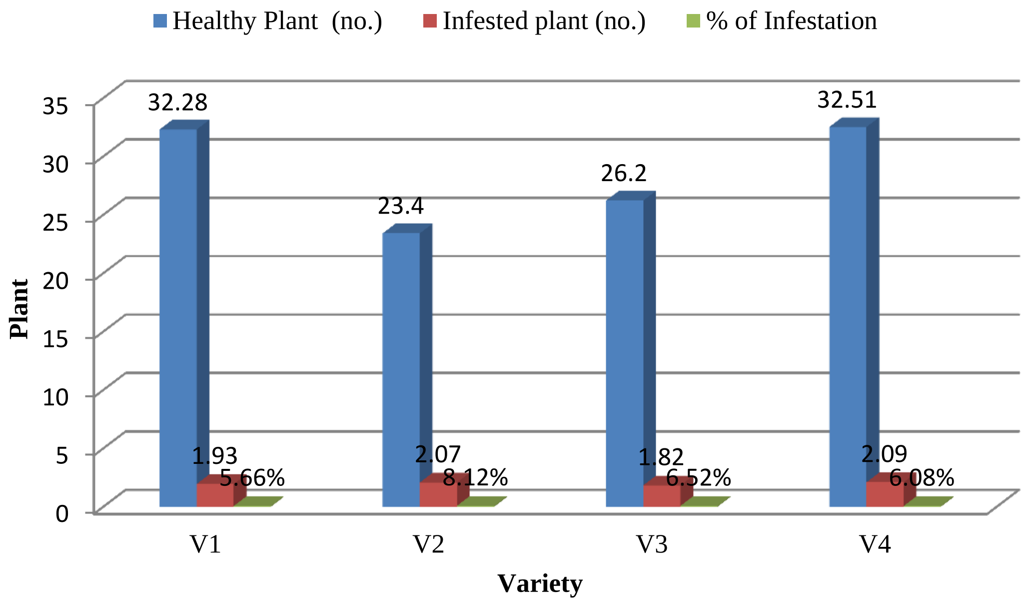

Figure 4.7 Showing varietal effects on healthy and infestation plant at fruiting stage

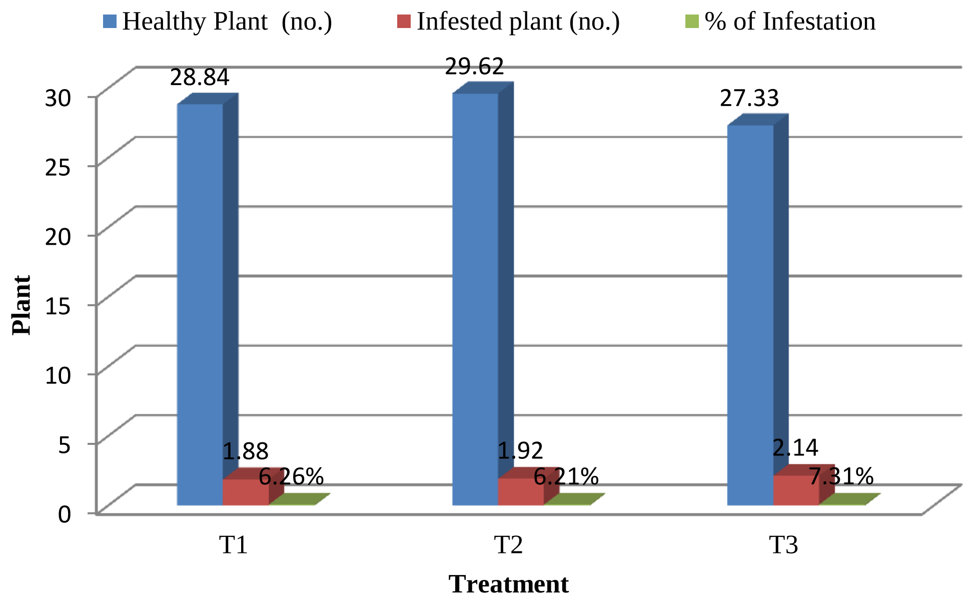

Figure 4.8 Showing treatment effects on healthy and infested plant at fruiting stage

4.2.6 Plant infestation at fruiting stage

Different mustard variety showed statistically significant differences in terms of plant infestation at fruiting stage (Table 4.11 and Figure 4.8). The lowest infested plant (5.66%) was observed from V_1, whereas the highest infested pant (8.12%) was found from V_2 (BARI Sarisha-14).

Statistically significant variation was observed in terms of plant infestation at fruiting stage due to chemical treatment (Table 4.10 and Figure 4.7). The lowest infested plant (6.21%) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water) which was statistically similar with T_1(7.83%), while the highest infested plant (7.31%) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). About similar study was also carried out by Sultana *et al.*, (2009) on the management on mustard aphid (Lipaphis erysimi) using Neem Kernel extract with two chemical insecticides Aktara 25 WG and Diazinon 60 EC. Among the treatments on an average Aktara reduced the highest aphid population (92%) with the highest BCR (4.20) followed by Diazinon (89%) and Neem Kernel extract + Jet powder (65%).

Combined effect of chemical treatment and different mustard variety showed statistically significant variation in terms of plant infestation at fruiting stage (Table 4.12). The lowest infested plant (5.05%) was observed from the treatment combination of V_4T_2, while the highest (8.42%) from V_2T_1.

4.3 Yield contributing characters and yield of mustard

4.3.1 Plant height (cm)

Statistically significant variation was observed in terms of plant height at harvest for different mustard variety (Table 4.13). The longest plant (178.78 cm) was found from V_4(BARI Sarisha-16). On the other hand, the shortest plant (86.07 cm) was observed from V_2 (BARI Sarisha-14). Mamun *et al*. (2014) reported that BARI Sarisha-13 performed well in terms of plant height. Mondal *et al.* (1992) found that variety had significant effect on plant height and they found the highest plant height (134.4 cm) in the variety J-5004, which was identical with SS-75 and significantly taller than JS-72 and Tori-7. On the other hand, Laxminarayana and Pooranchand (2000) found no significant variations in plant height among the cultivars. Ali *et al.* (1986**)** observed significant variation in plant height in different varieties of mustard and rape.

Plant height at harvest varied significantly due to chemical treatment (Table 4.14). The longest plant (123.56 cm) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) which, whereas the shortest plant (112.66 cm) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of plant height of mustard (Table 4.15). The longest plant (186.35 cm) was found from the treatment combination of V_4T_2, while the shortest plant (74.70 cm) was observed from the treatment combination of V_2T_3.

Table 4.13 Effect of variety on yield contributing attributes and yield of mustard

Variety	Plant height (cm)	Sliqua plant^{-1} (no.)	Length of Sliqua (cm)	Weight of 1000 seed (g)	Seed Yield (t ha^{-1})
V_1	124.08b	120.77b	6.33b	4.17b	2.17b
V_2	78.44d	86.07d	5.31d	2.55d	1.31d
V_3	92.90c	71.81c	5.50c	2.85c	1.49c
V_4	178.78a	179.57a	7.39a	4.52a	2.21a
LSD $_{(0.05)}$	4.413	5.32	0.541	0.531	0.037
LS	**	**	**	**	**
CV (%)	6.54	7.86	4.53	3.23	4.56

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15 and V_4= BARI Sarisha-16

Table 4.14 Effect of treatment on yield contributing attributes and yield of mustard

Treatment	Plant height (cm)	Sliqua plant^{-1} (no.)	Length of Sliqua (cm)	Weight of 1000 seed (g)	Seed Yield (t ha^{-1})
T_1	119.43b	115.18b	6.17b	3.53b	1.82b
T_2	123.56 a	119.56a	6.40a	3.68a	1.87a
T_3	112.66c	108.92c	5.83c	3.35c	1.70c
LSD $_{(0.05)}$	1.223	1.143	0.015	0.032	0.031
LS	**	**	**	**	**
CV (%)	6.54	7.86	4.53	3.23	4.56

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water

Table 4.15 Combined effect of variety and treatment on yield contributing attributes and yield of mustard

Combination of variety and treatment	Plant height (cm)	Sliqua plant^{-1} (no.)	Length of Sliqua (cm)	Weight of 1000 seed (g)	Seed Yield (t ha^{-1})
$V_1 \times T_1$	125.18 e	120.78 e	6.34 e	4.18 d	2.19 b
$V_1 \times T_2$	128.96 d	125.69 d	6.60 d	4.34 c	2.26 a
$V_1 \times T_3$	118.11 f	115.84 f	6.05 f	3.99 e	2.06 c
$V_2 \times T_1$	78.54 k	86.71 h	5.33 i	2.53 i	1.33 f
$V_2 \times T_2$	82.07 j	89.80 g	5.55 h	2.68 h	1.36 ef
$V_2 \times T_3$	74.70 l	81.72 i	5.05 k	2.42 j	1.25 g
$V_3 \times T_1$	96.88 g	75.41 j	5.74 g	2.97 f	1.56 d
$V_3 \times T_2$	96.88 g	75.41 j	5.74 g	2.97 f	1.56 d
$V_3 \times T_3$	87.75 i	67.65 l	5.19 j	2.69 h	1.41 e
$V_4 \times T_1$	179.92 b	180.89 b	7.45 b	4.55 b	2.24 ab
$V_4 \times T_2$	186.35 a	187.35 a	7.71 a	4.71 a	2.30 a
$V_4 \times T_3$	170.08 c	170.48 c	7.01 c	4.29 c	2.09 c
$LSD_{(0.05)}$	3.432	2.452	0.901	0.064	0.64
LS	**	**	*	**	**
CV (%)	6.54	7.86	4.53	3.23	4.56

Figures in a column followed by different letter(s) differ significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by DMRT.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least standard deviation, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability, NS = Not Significant.

T_1= Ripcord 10 EC @1mlL^{-1} water, T_2= Imitaf 20 SL @1mlL^{-1} waterand T_3= Marshal 20 EC @1mlL^{-1} water
V_1=BARI Sarisha-11, V_2= BARI Sarisha-14, V_3= BARI Sarisha-15and V_4= BARI Sarisha-16

4.3.2 Siliqua plant^{-1}(no.)

Statistically significant variation was observed in terms of number of siliqua plant^{-1} at harvest for different mustard variety (Table 4.13). The maximum number of siliqua plant^{-1} (179.57) was found from V_4 (BARI Sarisha-16) while minimum number (86.07) was observed from V_2 (BARI Sarisha-14). Hossain *et al.* (1996) observed the highest number of siliqua plant-1 (187.3) in BLN-900 and the lowest (150.4) in Semu 249/84.

Number of siliqua plant^{-1} at harvest varied significantly due to chemical treatment (Table 4.14). The maximum number of siliqua plant^{-1}(119.56) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the minimum number of siliqua plant^{-1}(108.92) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of number of siliqua plant^{-1} of mustard (4.15). The maximum number of siliqua plant^{-1} (187.35) was found from the treatment combination of V_4T_2, while the minimum number of siliqua plant^{-1}(67.65) was observed from the treatment combination of V_3T_3.

4.3.3 Length of siliqua (cm)

Statistically significant variation was observed in terms of length of siliqua for different mustard variety (Table 4.13). The longest siliqua (7.39 cm) was found from V_4 (BARI Sarisha-16). On the other hand, the shortest siliqua (5.31 cm) was observed from V_2. Hussain *et al*. (2008) reported that BARI sharisha-8 performed better in terms of siliqua length. Hussain *et al.* (1996) observed the longest siliqua (8.07 cm) in BLN-900 and the shortest (4.83 cm) in Hyola-401.

Length of siliqua varied significantly due to chemical treatment (Table 4.14). The longest siliqua (6.35 cm) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the shortest siliqua (5.83 cm) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of length of siliqua of mustard (Table 4.15). The longest siliqua (7.71 cm) was found from the treatment combination of V_4T_2, while the shortest siliqua (5.05 cm) was observed from the treatment combination of V_2T_3.

4.3.4 Weight of 1000 seeds (g)

Significant variation was observed in terms of weight of 1000 seeds for different mustard variety (Table 4.13). The highest weight of 1000 seeds (4.52 g) was found from V_4 (BARI Sarisha-16), whereas the lowest weight (2.55 g) was recorded from V_2 (BARI Sarisha-14). Karim *et al.* (2000) stated that the higher weight of 1000-seed in J-3023 (3.43 g) J-3018 (3.42 g) and J-4008 (3.50 g).

Weight of 1000 seeds varied significantly due to chemical treatment (Table 4.14). The highest weight of 1000 seeds (3.68 g) was observed fromT_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the lowest weight (3.35 g) from T_3 (Marshal 20 EC @1mlL^{-1} water).

Combined effect of chemical treatment and different mustard variety showed statistically significant variation in terms of weight of 1000 seeds of mustard (4.15). The highest weight of 1000 seeds (4.71 g) was found from the treatment combination of V_4T_2, while the lowest weight of 1000 seeds (2.42 g) was observed from the treatment combination of V_2T_3.

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

Statistically significant variation was observed in terms of seed yield for different mustard variety (Table 4.13 and Figure 4.9). The highest seed yield (2.21 t ha^{-1}) was found from V_4 (BARI Sarisha-16) while, the lowest seed yield (1.31 t ha^{-1}) was observed from V_2 (BARI Sarisha-14).Mamun *et al*. (2014) reported that maximum seed yield (1.60 t ha-1) was recorded for BARI Sarisha-13.

Seed yield of mustard varied significantly due to chemical treatment (Table 4.14 and Figure 4.10).The highest seed yield (1.87t ha^{-1}) was observed fromT_2 (Imitaf 20 SL

@1mlL^{-1} water)which was followed byT_1(1.82 t ha^{-1}) and the lowest seed yield (1.70t ha^{-1}) was found from T_3.

Combined effect of different mustard variety and chemical treatment showed statistically significant variation in terms of seed yield of mustard (Table 4.15). The highest seed yield (2.30 t ha^{-1}) was found from the treatment combination of V_4T_2, while the lowest seed yield (1.25 t ha^{-1}) was observed from the treatment combination of V_2T_3.

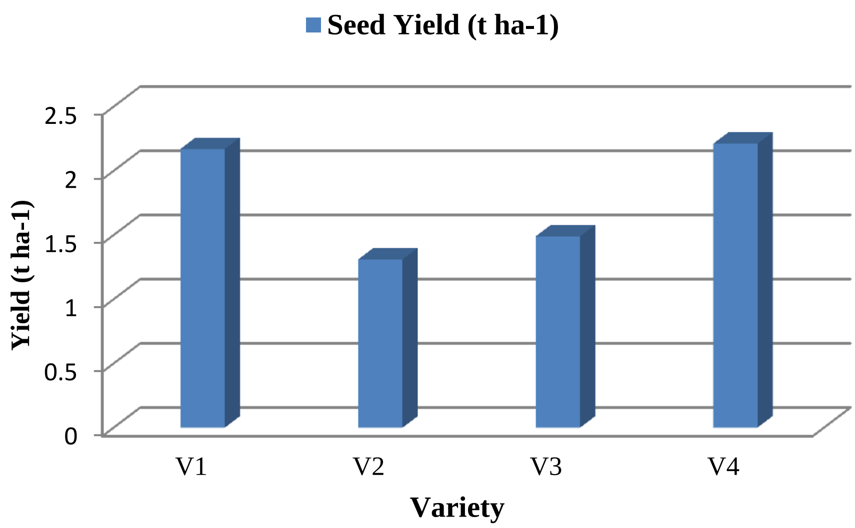

Figure 4.10 Showing effect of variety on seed yield of mustard

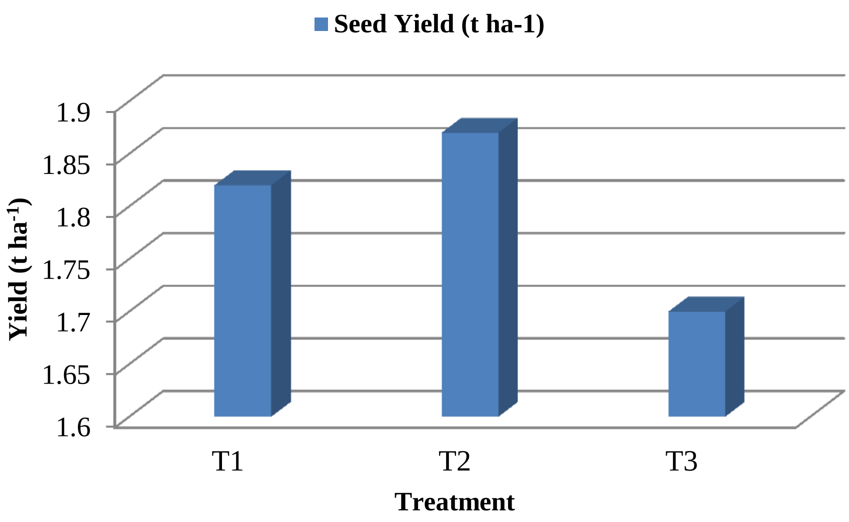

Figure 4.9 Showing effect of treatment on seed yield of mustard

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2015 to February 2016to evaluate the infestation level of mustard aphid against the combination of chemical treatment and varieties. The experiment comprised of two factors (4 variety and 3 levels chemical); Factors A : Mustard varieties (4 mustard varieties) i) V_1=BARI Sarisha-11 ii) V_2= BARI Sarisha-14 iii) V_3= BARI Sarisha-15 and iv) V_4= BARI Sarisha-16; and Factor B : chemical treatment (3 levels) viz. i) T_1= Ripcord 10 EC @1mlL^{-1} water ii) T_2= Imitaf 20 SL @1mlL^{-1} water and T_3= Marshal 20 EC @1mlL^{-1} water. The experiment was laid out in a Randomized Complete Block Design with four replications. The total numbers of plots were 48. The data were collected on number of aphid at flowering and fruiting stages, number of healthy plants at flowering and fruiting stages, number of infested plants at flowering and fruiting stages, plant height at harvest, number of siliqua per plant, length of siliqua, weight of 1000 seedsand seed yield ha^{-1}. Data were analyzed using the analysis of variance (ANOVA) technique with the help of computer package programme MSTAT and the means were compared by Duncan's Multiple Range Test.

At early flowering stage, the lowest number of aphid (4.66) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (8.08) was observed from V_2 (BARI Sarisha-14). The lowest number of aphid (6.12) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (6.69) was found from T_3 (Marshal 20 EC @1mlL^{-1} water). The lowest number of aphid (4.49) was observed from the treatment combination of V_4T_2 (Imitaf 20 SL @1mlL^{-1} water and BARI Sarisha-16) and the highest number of aphid (8.65) from the treatment combination of V_2T_3 (Marshal 20 EC @1mlL^{-1} water and BARI Sarisha-14).

At mid flowering stage, the lowest number of aphid (4.85) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (8.40) was observed from V_2

(BARI Sarisha-14). The lowest number of aphid (6.36) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (6.96) was found from T_3 (Marshal 20 EC @1mlL^{-1} water). The lowest number of aphid (4.67) was observed from the treatment combination of V_4T_2 and the highest number of aphid (9.00) was observed from the treatment combination of V_2T_3.

At late flowering stage, the lowest number of aphid (7.39) was observed from V_1 (BARI Sarisha-11) and whereas the highest number of aphid (9.68) was observed from V_3 (BARI Sarisha-15). The lowest number of aphid (7.33) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (9.81) was found from T_1. The lowest number of aphid (5.39) was observed from the treatment combination of V_4T_2 and the highest number of aphid (13.80) was observed from the treatment combination of V_4T_1.

At early fruiting stage**,** the lowest number of aphid (4.01) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (9.07) was observed from V_1 (BARI Sarisha-11). The lowest number of aphid (9.00) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (12.04) was found from T_1. The lowest number of aphid (6.61) was observed from the treatment combination of V_4T_2 and the highest number of aphid (16.94) from the treatment combination of V_4T_1.

At mid fruiting stage, the lowest number of aphid (6.55) was observed from V_4 (BARI Sarisha-16), while the highest number of aphid (11.34) was observed from V_2 (BARI Sarisha-14). The lowest number of aphid (8.59) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (12.04) was found from T_1. The lowest number of aphid (6.31) was observed from the treatment combination of V_4T_2 and the highest number of aphid (12.15) was observed from the treatment combination of V_2T_3.

At late fruiting stage, the lowest number of aphid (5.67) was observed from V_4 (BARI Sarisha-16), whereas the highest number of aphid (9.81) was observed from V_2 (BARI

Sarisha-14). The lowest number of aphid (7.43) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) and the highest number of aphid (8.13) was found from T_3(Marshal 20 EC @1mlL^{-1} water). The lowest number of aphid (5.46) was observed from the treatment combination of V_4T_2 and the highest number of aphid (10.51) was observed from the treatment combination of V_2T_3.

Healthy plants at flowering stage, the highest number of healthy plants (31.99) was observed from V_4 (BARI Sarisha-16) whereas the lowest number of healthy plants (22.88) was found from V_2 (BARI Sarisha-14). The highest number of healthy plants (28.91) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water), while the lowest number (26.16) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The highest number of healthy plants (33.97) was observed from the treatment combination of V_4T_2, while the lowest number (22.42) was observed from the treatment combination of V_2T_3. The lowest infested plant (6.39%) was observed from V_4 (BARI Sarisha-16) which was statistically similar (6.44%) to V_2 (BARI Sarisha-14), whereas the highest infested pant (7.04%) was found from V_3 (BARI Sarisha-15). The lowest infested plant (4.78%) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water), while the highest infested plant (7.88%) was observed from T_1. The lowest infested plant (5.20%) was observed from the treatment combination of V_4T_2, while the highest (9.87%) was observed from the treatment combination of V_2T_1.

Healthy plants at fruiting stage, the highest number of healthy plants (32.51) was observed from V_4 (BARI Sarisha-16), whereas the lowest number of healthy plants (23.40) was found from V_2 (BARI Sarisha-14). The highest number of healthy plants (29.62) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water) which was closely followed (28.84) by T_1 and the lowest number (27.33) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The highest number of healthy plants (33.97) was observed from the treatment combination of V_4T_2, while the lowest number (22.48) was observed from the treatment combination of V_2T_3. The lowest infested plant (5.66%) was observed from V_1, whereas the highest infested pant (8.12%) was found from V_2 (BARI Sarisha-14). The lowest infested plant (6.21%) was found from T_2 (Imitaf 20 SL @1mlL^{-1} water) which was statistically similar with T_1(7.83%), while the highest infested plant (7.31%)

was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The lowest infested plant (5.05%) was observed from the treatment combination of V_4T_2, while the highest (8.42%) from V_2T_1.

The longest plant (178.78 cm) was found from V_4 (BARI Sarisha-16). On the other hand, the shortest plant (86.07 cm) was observed from V_2 (BARI Sarisha-14).The longest plant (123.56 cm) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) which, whereas the shortest plant (112.66 cm) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The longest plant (186.35 cm) was found from the treatment combination of V_4T_2, while the shortest plant (74.70 cm) was observed from the treatment combination of V_2T_3.

The maximum number of siliqua plant-1 (179.57) was found from V_4 (BARI Sarisha-16) while minimum number (86.07) was observed from V_2 (BARI Sarisha-14). The maximum number of siliqua plant^{-1} (119.56) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the minimum number of siliqua plant^{-1} (108.92) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The maximum number of siliqua plant^{-1} (187.35) was found from the treatment combination of V_4T_2, while the minimum number of siliqua plant^{-1} (67.65) was observed from the treatment combination of V_3T_3.

The longest siliqua (7.39 cm) was found from V_4 (BARI Sarisha-16). On the other hand, the shortest siliqua (5.31 cm) was observed from V_2. The longest siliqua (6.35 cm) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the shortest siliqua (5.83 cm) was observed from T_3 (Marshal 20 EC @1mlL^{-1} water). The longest siliqua (7.71 cm) was found from the treatment combination of V_4T_2, while the shortest siliqua (5.05 cm) was observed from the treatment combination of V_2T_3.

The highest weight of 1000 seeds (4.52 g) was found from V_4 (BARI Sarisha-16), whereas the lowest weight (2.55 g) was recorded from V_2 (BARI Sarisha-14).The highest weight of 1000 seeds (3.68 g) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water), whereas the lowest weight (3.35 g) from T_3 (Marshal 20 EC @1mlL^{-1} water).

The highest weight of 1000 seeds (4.71 g) was found from the treatment combination of V_4T_2, while the lowest weight of 1000 seeds (2.42 g) was observed from the treatment combination of V_2T_3.

The highest seed yield (2.21 t ha^{-1}) was found from V_4 (BARI Sarisha-16) while, the lowest seed yield (1.31 t ha^{-1}) was observed from V_2 (BARI Sarisha-14). The highest seed yield (1.87 t ha^{-1}) was observed from T_2 (Imitaf 20 SL @1mlL^{-1} water) which was followed by T_1 (1.82 t ha^{-1}) and the lowest seed yield (1.70 t ha^{-1}) was found from T_3. The highest seed yield (2.30 t ha^{-1}) was found from the treatment combination of V_4T_2, while the lowest seed yield (1.25 t ha^{-1}) was observed from the treatment combination of V_2T_3.

CONCLUSION

It was revealed from the study that the variety V_4 (BARI Sarisha-16) was superior for better yield contributing characters and yield of mustard and which was also prone to aphid infestation while the lowest aphid infestation was found from the variety V_1 (BARI Sarisha-11).

On the otherhand, the treatment T_2 in which Imitaf 20 SL @1mlL^{-1} water was superior for controlling aphid of mustard. Meanwhile, the effectiveness of Ripcord 10 EC @ 1mlL^{-1} water was next to Imitaf 20 SL in controlling aphid infestation.

RECOMMENDATIONS

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

1. It may be recommended that the use of insecticides in additional with the use of plant derivatives to ensure the environment-friendly pest management of mustard.
2. Further research on systemically acquired resistance in mustard with Imitaf 20 SL @1mlL^{-1} in relation to aphid infestation.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the periodfrom November 2015 to February 2016

Month	*Air temperature (ºc)		*Relative humidity (%)	*Rainfall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.8	16.0	78	00	6.8
December, 2015	22.4	15.5	74	00	6.3
January, 2016	24.5	14.5	68	00	5.7
February, 2016	27.1	16.7	67	10	6.7

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1207

Appendix II. Characteristics of the Experiment field of Sher-e-Bangla Agricultural University,Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomic Farm,SAU,Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow-Mustard

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Source: SRDI,2015