PERFORMANCE OF SALICYLIC ACID ON THE SUPPRESSION OF MUSTARD INSECT PESTS IN FIELD CONDITION

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JUNE, 2015

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REG. NO. : 09-03681

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2015

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CERTIFICATE

This is to certify that the thesis entitled **'Performance of Salicylic Acid on the Suppression of Mustard Insect Pests in Field Condition'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in Entomology, embodies the result of a piece of *bonafide* research work carried out by **Ferdous Habib**, Registration number: **09-03681** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2015
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DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises to Almightly and kindfull trust on to "Omnipotent Allah" for His never-ending blessings. The author deems it a great pleasure to express his profound gratefulness to his respected parents, who entiled much hardship inspiring for prosecuting his studies, receiving proper education.

The author also expresses his gratefulness to his respected Supervisor Dr. Mohammed Sakhawat Hossain, Associate Professor and Chairman, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author likes to express his deepest sense of gratitude to his respected Co-supervisor Dr. Mohammad Mahbub Islam, Professor, Department of Agricultural Botany, SAU, Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and helpful support in conducting and successfully completing the research work and in the preparation of the manuscript including data analysis.

The author also expresses heartfelt thanks to all the teachers of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the study period.

The author expresses his sincere appreciation to his brothers, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

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ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during November, 2014 to March, 2015 to assess the performance of salicylic acid on the suppression of mustard insect pests in the field. The experiment comprised of two factors; Factors A: levels of salicylic acid (3 levels)- S_0: 0 mM SA (control), S_1: 0.2 mM SA, S_2: 0.4 mM SA and Factor B: Mustard varieties (5 varieties)- V_1: BARI Sarisha-1, V_2: BARI Sarisha-13, V_3: BARI Sarisha-14, V_4: BARI Sarisha-15 and V_5: BARI Sarisha-16. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on the insect pests incidence, insect infestation, yield contributing characters and yield of mustard. Statistical analysis was performed for interpreting the effect of different treatments. Aphid, sawfly, leaf miner and hairy caterpillar were recorded as the major insect pests in mustard field. Different levels of salicylic acid, at flowering stage, the lowest plant infestation (3.70%) was found from S_2 treated plot, while the highest infestation (8.19%) was observed in S_0 (control plot). At fruiting stage, the lowest plant infestation (4.42%) was observed in S_2 (treated plot) whereas the highest infestation (8.92%) was observed in S_0. The highest seed yield (1.72 t ha^{-1}) was found in S_2, whereas the lowest seed yield (1.54 t ha^{-1}) was observed in S_0. For different mustard varieties, at fruiting stage, the lowest plant infestation (4.94%) was found in V_5, while the highest plant infestation (7.83%) was found in V_1. The highest seed yield (2.13 t ha^{-1}) was found in V_5, while the lowest seed yield (1.22 t ha^{-1}) was observed in V_1 variety. Due to the interaction effect of levels of salicylic acid and different mustard varieties, at flowering stage, the lowest plant infestation (2.48%) was found in S_2V_5 and the highest infestation (9.82%) was recorded in S_0V_1. At fruiting stage, the lowest plant infestation (3.35%) was recorded in S_2V_5 and the highest infestation (11.22%) was recorded in S_0V_1. The highest seed yield (2.26 t ha^{-1}) was recorded in S_2V_5 and the lowest seed yield (1.02 t ha^{-1}) was harvested in S_0V_1. From the above findings it may be concluded that 0.4 mM SA and BARI Sarisha-16 was superior for suppressing insect pests of mustard and ensure better yield.

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CHAPTER I

INTRODUCTION

Mustard (*Brassica campestris* L.) belongs to the genus *Brassica* of the family Cruciferae, is one of the most important oil seed crops of the world after soybean and groundnut (FAO, 2012). It is mainly a self-pollinating crop, although on an average 7.5 to 30% out-crossing does occur under natural field conditions (Abraham, 1994). *Brassica napus, B. campestris* and *B. juncea* are the three species of mustard those produce edible oil. In Bangladesh mustard occupies 0.483 million hectare of land and the total production was 0.525 million metric ton (AIS, 2013). It is not only a high energy food but also a carrier of fat soluble vitamins like A, D, E and K in the body. Mustard oil meet the one third of edible oil requirement of the country (Ahmed, 2008). It is used as a condiment, salad, green manure, fodder crop, and a leaf and stem as vegetable in the various mustard growing countries.

Bangladesh has been facing acute shortage of edible oil for the last several decades and for that it needs to import oil and oil seeds to meet up the deficit. The internal production can meet only about 21% of our consumption and the rest 79% is needed to import (Begum *et al.,* 2012). A huge amount of foreign exchange involving over 160 million US$ is being spent every year for importing edible oils due to insufficient oil production in Bangladesh (Rahman, 2002). In Bangladesh the major mustard growing districts are Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka (BBS, 2011). Mustard is the principal oil crop in Bangladesh and besides edible oil mustard oil also serves as an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Its oil is also used by the villagers for hair dressing and body massage before bath. Dry mustard straw is also used as fuel. Moreover, mustard oil cake is also used as a feed for cattle and fish and as a manure.

Mustard seed contains about 40-45% oil and for that by increasing production of mustard we can meet the shortage of edible oil. The average per hectare yield of mustard in Bangladesh is alarmingly very poor compared to the advanced countries like Germany, France, UK and Canada which producing 6,667 kg ha^{-1}, 5,070 kg ha^{-1}, 3,264 kg ha^{-1} and 3,076 kg ha^{-1}, respectively. At present the world average yield of mustard is 1,586 kg ha^{-1} (FAO, 2013). Although it is an important crop but the cultivation of mustard has to compete with other grain crops and it has been shifted to marginal lands of poor productivity. With increasing population, the demand of edible oil is increasing day by day and it is, therefore, highly accepted that the production of edible oil should be increased considerably to fulfill the demand. The area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of *boro* rice and on an average country loosing an area of 104,000 hectare and production of 68,000 tons of mustard and rapeseed in last ten years (Anon., 2006).

Every efforts is being made to raise the productivity of mustard crops 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 insect pests is a serious problems. 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, sawfly, mustard leaf eating caterpillar etc. are the very important insect pests. Mustard aphid is the most serious and destructive pest and limiting factors for successful cultivation of mustard in South Asia (Bakhetia, 1983 and Zaman *et al*., 1990). Both the nymph and adult of the aphid suck sap from leaves, steams, inflorescences and pods, as a result the plant show stunted growth, flowers wither and pod formation is hindered (Atwal, 1997; Begum, 1995 and Butani 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 an average grain weight loss of 54.2% (Reddy and Joshi, 1990).

Plant growth regulators (PGRs) are organic compounds, which plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). The PGRs can improve the physiological efficiency including photosynthetic ability and enhance the effective partitioning of accumulates from source and sink in the field crops (Solaimani *et al.*, 2001). Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, inhibition of ethylene biosynthesis, transpiration and stress tolerance. It also plays a significant role in plant water relations, photosynthesis, growth and stomatal regulation under abiotic stress conditions and also creating defense mechanism against insect pests (Khan *et al*., 2003; Arfan *et al*., 2007).

Varietal characteristics play important role in producing high yield of mustard because different varieties perform differently for their genotypic characters and insect sensitivity of different mustard genotype also vary from genotype to genotype. Improved variety is the first and foremost requirement for initiation and accelerated crop production program. There are some high yielding varieties (HYVs) of mustard, which have been released by the Sher-e-Bangla Agricultural University (SAU), 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 as well as application of plant growth regulators.

Considering the above situation the present experiment was conducted with the following specific objectives:

- to assess the performance of salicylic acid on the suppression of mustard insect pests in mustard field; and
- to assess the infestation level of different insect pests in mustard due to the application of salicylic acid on different mustard varieties and it effects on the seed yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oil seed crop in Bangladesh and as well as in many countries of the world although the crop conventionally was less attended by the researchers because the crop normally grows without or minimum care or management practices. Plant growth regulators and variety play an important role in improving mustard yield. But research works related to plant growth regulators and varieties of mustard in relation to its effect on insect pests defense mechanisms are limited in Bangladesh as well as in the World. However, some of the important and informative works and research findings related to the performance of salicylic acid on the suppression of mustard insect pests and growth and yield of mustard so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Insect population in mustard

Among the insect pests considered important are listed below with their common and scientific name, order and family:

Common name	Scientific name	Order	Family
Aphid	*Lipaphis erysimi* (Kaltenbach)	Homoptera	Aphididae
Sawfly	*Athalia lugens proxima* (Klug.)	Hymenoptera	Tenthredinidae
Leaf miner	*Phytomyza horticola*	Diptera	Agromyzidae
Hairy caterpillar	*Spilosoma obliqua*	Lepidoptera	Arctiidae
Leaf webber	*Crocidolomia binotalis* Zell.	Lepidoptera	Pyralidae
Flea beetle	*Phyllotreta cruciferae* Goeze	Coleoptera	Chrysomelidae
Butterfly	*Pieris brassicae* (Linn.)	Lepidoptera	Pieridae
Black cutworm	*Agrotis ipsilon* (Hufun.)	Lepidoptera	Noctuidae
Butterfly	*Delias eucharis* Dr.	Lepidoptera	Pieridae

Among the above listed insect pests, aphids, sawfly, hairy caterpillar and leaf miner are the most common and damaging insect pests of mustard in Bangladesh (Singh and Singh, 1983).

2.1.1 Aphids

There are six species of aphids that damage the crop. These species include *Rhopalosiphum padi, Schizaphis graminurn, Sitobion avenae, Metopoliphiurn dirhodum, R. Maidis* and *Diuraphis noxia.* Two of those species commonly known as Russian Aphid (*Diuraphis noxia*) and Bird Cherry-Oat Aphid (*Rhopalosiphum padi*) are considered notorious for their direct and indirect losses (Morrison and Peairs, 1998).

Aphid is known to be a sporadic insect causing significant yield losses by spreading from its origin. The centre of origin for aphid is considered to be the central Asian mountains of Caucasus and Tian Shan. The specie could now be found in South Africa, Western United States, Central and Southern Europe and Middle East. The economic impact of aphid include direct and indirect losses that have been estimated to be $893 million in Western United States during 1987 to 1993 whereas 37% yield losses in winter have been reported in Canadian Prairies (Morrison and Peairs, 1998). Direct losses have also been assessed as an increased input cost due to insecticides and indirect losses include reduced yield due to aphid infestation.

Climatic conditions, temperature in particular, plays a significant role in population dynamics of the aphids. A warmer temperature can potentially accelerate the aphid's growth both in terms of number and size, yet, the extreme temperatures can possibly reduce the survival and spread of Aphids (Walker and Peairs, 1998). Aphid is known to be present in its three different morphological types: immature wingless females, mature wingless females and mature winged females. Winged mature adult females spread the population and infested to the surrounding host plants, whereas the wingless types or apterous cause damage by curling and sucking the young leaves. Heavily infested plants may typically look prostrated and/or stunted with yellow or whitish streaks on leaves. These streaks, basically, are formed due to the saliva injected by the aphid (Morrison and Peairs, 1998). The most obvious symptoms due to heavy infestations can be reduced leaf area, loss in dry weight index, and poor cholorophyll concentration. Plant growth

losses could be attributed mainly due to reduced photosynthetic activity to plants aphid infestation. The photochemical activities of the plants were reportedly inhibited by the aphid feeding from leaves and disruption in electron transport chain. Spikes can have bleached appearance with their awns tightly held in curled flag leaf. Yield losses can greatly vary due to infestation at different growth stages, duration of infestation and climatic conditions (wind patterns and temperature). A number of biotypes for aphid have been reported to be present throughout the cereal production areas of the world. These biotypes are classified due to significant genetic differences among them (Morrison and Peairs, 1998).

A number of strategies have been deployed to mitigate aphid. Among these strategies, the host plant resistance has been the most effective and economic method to induce antixenosis, antibiosis and/or tolerance against aphid. Its host plant resistance is well known to be qualitative in nature, and about nine resistance genes have been documented so far. A number of alternate methods to control this pest has been suggested and practiced that include cultural, biological and chemical control methods (Morrison and Peairs, 1998). Cultural control strategies involved eradication of volunteer and alternate host plants is generally recommended. Another strategy is grazing the volunteer plants which significantly reduce the aphid infestation. Adjusting planting dates to de-synchronize the insect population dynamics and favourable environmental conditions of any particular area can also help to control aphid. The enhanced fertigation of infested field and biological control of aphid is also possible with 29 different species of insects and 6 fungus species, of the predator insects, 4 different species of wasps have become adopted to United States. Besides these cultural practices, chemical control method is also widely practiced with equivocal cost efficiency (Walker and Peairs, 1998).

Life cycle

Most aphids reproduce asexually throughout most or all of the year with adult females giving birth to live offspring often as many as 12 day^{-1} without mating. Young aphids are called nymphs. They molt, shedding their skin about four times

before becoming adults. There is no pupal stage. Some species produce sexual forms that mate and produce eggs in fall or winter, providing a more hardy stage to survive harsh weather in the absence of foliage on deciduous plants. In some cases, aphids lay these eggs on an alternative host, usually a perennial plant, for winter survival. When the weather is warm, many species of aphids can develop from newborn nymph to reproducing adult in seven to eight days. Because each adult aphid can produce up to 80 offspring in a matter of a week, aphid populations can increase with great speed (Flint, 1998).

Nature of damage

Low to moderate numbers of leaf-feeding aphids are not usually damaging in gardens or on trees. However, large populations can turn leaves yellow and stunt shoots; aphids can also produce large quantities of sticky exudates known as honeydew, which often turns black with the growth of a sooty mold fungus. Some aphid species inject a toxin into plants, which causes leaves to curl and further distorts growth. A few species cause gall formations (Cannon, 2008).

Squash, cucumber, pumpkin, melon, bean, potato, lettuce, beet, chard, and bok choy are crops that often have aphid-transmitted viruses associated with them. The viruses mottle, yellow, or curl leaves and stunt plant growth. Although losses can be great, they are difficult to prevent by controlling aphids, because infection occurs even when aphid numbers are very low; it takes only a few minutes for the aphid to transmit the virus, while it takes a much longer time to kill the aphid with an insecticide (Cannon, 2008).

2.1.2 Sawfly

The sawfly is a serious pest of crops at seedling stage (Gupta and Sing, 1984). The adult bean fly deposits eggs in punctures of the leaf tissue, the first pair of leaves of bean seedlings being favorite sites for oviposition. The maggot bores into young stem and damages the stem. In young plants the larvae of the fly cause extensive tunneling. The freshly formed tunnels are silvery-white and difficult to locate. The older tunnels are dark brown in colour and contained faeces. Due to

the decaying of the surrounding pith area around the zig-zag tunnels, the old tunnels turned into straight ones (Singh and Singh, 1990). They do not make any exit hole (Sehgal *et al*., 1980). Infested seedlings frequently wilt and subsequently die. The growth of older plants become slowly stunted (Prodhan *et al*., 2000).

Life cycle

The adult is black with yellowish femora and thorax. The female possesses a saw-like ovipositor and inserts the eggs very near the leaf margin. A female on an average lays about 60 eggs. The larva is cylindrical and dark gray with three pairs of thoracic legs and seven pairs of prolegs on abdominal segments 2-8. Its body surface is hairless. Young larva is greenish grey in colour and its colour becomes darker in the later instar. It measures about 15-20 mm long and pupates in an earthen cocoon in the soil. The egg, larval and pupal periods occupy 4-5, 13-18 and 10-15 days, respectively. Parthenogenetic development is also observed (Prodhan *et al*., 2000).

Nature of damage

The larvae feed voraciously on leaves. Apart from mustard it also attacks radish and allied plants. It feeds during mornings and evenings from the margin of the leaf towards the centre. During day time it prefers to stay in the soil (Sehgal *et al*., 1980).

2.1.3 Hairy caterpillar

The name of the insect denotes that there are plenty of hairs on the body of the larval stage of the insect. Adult moth is straw colored and the front pair of wings contains black spot. The body of the larvae is orange colored with both ends are black. In about 15 to 20 days, the caterpillar is fully-grown and it measures 2.5 to 4.0 cm (Bakr, 1998). Hairy caterpillar is a widely distributed polyphagous insect pest. The hairy caterpillar attacks the tender leaves of the seedling after hatching and as a result, the growth of the seedling is ceased.

2.1.4 Leaf miner

The leaf miner is considered as the most important insect pest of groundnut in India and particularly in rainfed situations (Reddy, 1988). The pest initially appears as a leaf miner causing short blister like mines. Older larvae fold the leaflets and feed within. As a result, the leaflets turn brown, shrivel and dry up. Severely infested crop gives a burnt up appearance and yield losses can reach upto 76 per cent (Anon., 1986).

Oloan *et al*. (2003) reported that the population of leaf miner on selected highland crops was assessed and the percent leaf injury caused by adult and larval leaf miner and effect of leaf miner population and leaf injury on the yield of garden pea, potato, onion, and tomato. Larval count was highest in onion (3.03 leaf^{-1}) and leaf injury by leaf miner larva was highest in garden pea (31.25%). Tomato had the lowest count of adult and larval leaf miner and the lowest leaf injury of all the crops tested. An increase in leaf injury by leaf miner adult and larva decreases yield by 0.26% and 0.87%, respectively.

2.2 Yield attributes and yields of mustard due to salicylic acid and variety

2.2.1 Effect of salicylic acid on mustard

Field studies were conducted by Sharma *et al*. (2013) on an assembly of 25 Indian mustard genotypes to test the efficacy of salicylic acid (SA) on yield attributes, seed filling and seed yield and further to visualize the extent of genotypic variations in mitigating the yield losses with SA due to terminal heat stress under late sown conditions and revealed that foliar application of SA improved growth parameters and revealed that foliar application of SA improved yield attributes particularly number of siliqua on main shoot. It was also observed that foliar application of SA improved yield attributes and total number of seeds siliqua^{-1} improved by 3.2% over the unsprayed control.

A field experiment was conducted by Muhal and Solanki (2015) at Udaipur to evaluate the effect of seeding dates and salicylic acid (SA) application on growth attributes, phenology and agro-meteorological indices of *Brassica* species and

observed that number of days taken to attain physiological maturity was significantly higher under 100 ppm SA foliar spray compared to water spray and number of seeds siliqua^{-1} was significantly higher under 100 ppm SA foliar spray compared to water spray.

2.2.2 Effect of different varieties on mustard

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) against six Zn levels and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted 186.56 cm plant height and reported that S-9 ranked 1st with 10.84 branches plant^{-1}, while variety Early Mustard resulted 9.25 branches plant^{-1}. They also reported that 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 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 and maximum seed yield (1.60 t ha^{-1}) was recorded for BARI Sarisha-13.

Afroz *et al*. (2011) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, 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 Sarisha-7, BARI Sarisha-8 and BARI Sarisha11 (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.

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.

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).

BARI (2000) reported that in case of poor management mustard variety 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 recorded from the same variety and lowest (3702.3 kg ha^{-1}) from PT-303 under high management practices. The highest stover yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg ha^{-1} was obtained from variety Tori-7.

Ahmed *et al.* (1999) stated that the tallest plant (102.56 cm) was recorded 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. 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}).

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.

Bukhtiar *et al.* (1992) showed that *Brassica carinata* yielded best (1578 kg ha^{-1}) followed by RL18 (1092 kg ha^{-1}) and DGL (828 kg ha^{-1}). The poorest yield (683 kg ha^{-1}) was given by Taranira *(Eruca sativa).*

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.

Chakraborty *et al.* (1991) stated that seed yields are different from species to species. Chaudhury *et al.* (1988) in an experiment on irrigation with four cultivars of *B. juncea* obtained the highest yield from cv. RH-7513 without irrigation and from cv. Varuna with irrigation.

As per the above cited reviews, it may be concluded that application of salicylic acid and variety are the important factors for attaining optimum growth as well as highest yield of mustard by controlling insect pest of mustard. The literature revealed that the effects of salicylic acid and variety have not been studied well and have no definite conclusion for the production of mustard in the agro climatic condition of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to assess the performance of salicylic acid on the suppression of mustard insect pests in field. The materials and methods those were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Description of the experimental site

3.1.1 Experimental period

The field experiment was conducted during the period from November, 2014 to March, 2015.

3.1.2 Description of experimental site

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $88^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

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 (27.1^0C) was recorded from February, 2015 and the minimum temperature (12.4^0C) from January, 2015, highest relative humidity (78%) was observed from November, 2014, whereas the lowest relative humidity (67%) and highest rainfall (30 mm) was recorded in February, 2015.

3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. 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. The collected soil was analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised two factors

Factors A: Different levels of salicylic acid-SA (3 levels)

i) S_0: 0 mM SA (control)

ii) S_1: 0.2 mM SA

iii) S_2: 0.4 mM SA

Factor B: Different mustard varieties (5 varieties)

i) V_1: BARI Sarisha-1

ii) V_2: BARI Sarisha-13

iii) V_3: BARI Sarisha-14

iv) V_4: BARI Sarisha-15

v) V_5: BARI Sarisha-16

There were in total 15 (3×5) treatment combinations such as S_0V_1, S_0V_2, S_0V_3, S_0V_4, S_0V_5, S_1V_1, S_1V_2, S_1V_3, S_1V_4, S_1V_5, S_2V_1, S_2V_2, S_2V_3, S_2V_4 and S_2V_5.

3.2.2 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment area was divided into three equal blocks. Each block contained 15 plots where 15 treatments combination were allotted at random. There were 45 unit plots altogether in the experiment. The size of each plot was 2.0 m × 1.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sarisha-1, BARI Sarisha-13, 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 were developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The seeds were collected from the BARI, Joydebpur, Gazipur.

3.3.2 Collection and application of salicylic acid

Salicylic acid was collected from Merck India. Tween 20 detergent was used as surfactant to prevent dropout of salicylic acid solution from leaves and it was applied as per treatments at 20, 30, 40 days after sowing (DAS) by a sprayer.

3.3.3 Land preparation

The experimental plot was opened on 14 November, 2014, with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed for three times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil. Finally land was prepared at 26th November, 2014.

3.3.4 Application of manure and fertilizers

The total amount of urea, triple super phosphate, muriate of potash and borax at the rate of 230, 140, 50 and 10 kg ha^{-1}, respectively were applied at the time of

Figure 1. Layout of the experimental plot

Plot size = 2.0 m × 1.0 m

Plot spacing = 0.5 m

Between replication= 1.0 m

Factors A: Different levels of salicylic acid (3 levels)

i) S_0: 0 mm SA (control)

ii) S_1: 0.2 mm SA

iii) S_2: 0.4 mm SA

Factor B: Mustard varieties (5 varieties)

i) V_1: BARI Sarisha-1

ii) V_2: BARI Sarisha-13

iii) V_3: BARI Sarisha-14

iv) V_4: BARI Sarisha-15

v) V_5: BARI Sarisha-16

final land preparation except urea. Urea was applied in three equal splits. First dose of urea fertilizer was applied at the time of final land preparation, second and third dose were applied at 20 and 45 DAS, respectively.

3.3.5 Seed sowing

The seeds of mustard were sown on 26 November, 2014 in rows in the furrows having a depth of 2-3 cm.

3.3.6 Intercultural operations

3.3.6.1 Thinning

Seeds started germination four Days After Sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain optimum plant population in each plot.

3.3.6.2 Irrigation and weeding

Irrigation was provided for three times after seed sowing, 20 days before flowering and 50 days after sowing for pod development for all experimental plots equally. The crop field was weeded before providing irrigation.

3.4 Crop sampling and data collection

Five plants from each treatment and each replication were randomly selected and tagged with sample card for data collection.

3.5 Monitoring and data collection

The mustard plants of different treatment were closely examined at regular intervals commencing from sowing to harvest. The following data were collected during the course of the study:

- Insect pest 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 branches plant^{-1} at harvest
- Number of siliqua plant^{-1}
- Length of siliqua
- Seed yield hectare^{-1}
- Stover yield hectare^{-1}

3.5.1 Monitoring of insect pest

The mustard plants were closely examined at weekly intervals at flowering and fruiting stage. Insects from 5 plants were recorded at weekly intervals in central rows at flowering and fruiting stage and converted plant^{-1}. The insect population was collected by a camel hair brush in a petridish.

3.5.2 Determination of plant infestation

All the healthy and infested plants were counted from 1m^2 selected area from middle place of each plot and examined. The collected data were divided into flowering and fruiting stage. The healthy and infested plants were counted and the percent plant damage was calculated using the following formula:

$$\text{Plant infestation (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants}} \times 100$$

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 branches plant^{-1}

The number of branches plant^{-1} was counted at harvest from selected plants. The average number of branches plant^{-1} was determined and recorded.

3.7.3 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 recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.7.4 Length of siliqua

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

3.7.5 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^{-1}.

3.7.6 Stover yield

The stover collected from 1 square meter of each plot was sun dried properly. The weight of stover was taken and converted into yield in t ha^{-1}.

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed the performance of salicylic acid on the suppression of mustard insect pests in field condition. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test by using MSTAT-C software. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to assess the performance of salicylic acid on the suppression of mustard insect pests in field condition. Data on observed insect pests were recorded and subsequently their effect on plant infestation and yield contributing characters and yield of mustard were also recorded. The analysis of variance (ANOVA) of the data was given in Appendix III-VII. The results have been presented in Tables and Graphs with possible interpretations given under the following sub-headings:

4.1 Insect population in mustard field

4.1.1 At flowering stage

4.1.1.1 Aphid population

Number of aphid plant^{-1} at flowering stage varied significantly due to different levels of salicylic acid (Table 1). Data revealed that, the lowest number of aphid (3.68) was recorded from S_2 (0.4 mM SA) which was closely followed (4.19) by S_1 (0.2 mM SA), whereas the highest number of aphid (4.95) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of aphid plant^{-1} at flowering stage for different mustard varieties (Table 1). The lowest number of aphid (3.93) was found in V_5 (BARI Sarisha-16) which was statistically similar (4.09 and 4.18) to V_2 (BARI Sarisha-13) and V_3 (BARI Sarisha-14), respectively, while the highest number (4.69) was recorded from V_1 (BARI Sarisha-1) which was statistically similar (4.47) to V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of aphid plant^{-1} at flowering stage (Table 2). The lowest number of aphid (3.07) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the highest number of aphid (5.67) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

Table 1. Effect of salicylic acid and varieties on insect population at flowering stage of mustard

Treatment	Number of insect populations plant^{-1} (at flowering stage)			
	Aphid	Sawfly	Leaf miner	Hairy caterpillar
Levels of salicylic acid				
S_0	4.95 a	2.95 a	3.13 a	3.14 a
S_1	4.19 b	1.91 b	2.32 b	2.09 b
S_2	3.68 c	1.65 c	1.87 c	1.47 c
$LSD_{(0.05)}$	0.340	0.160	0.185	0.232
Level of significance	0.01	0.01	0.01	0.01
Mustard varieties				
V_1	4.69 a	2.38 a	2.78 a	2.76 a
V_2	4.09 bc	2.09 b	2.31 bc	2.07 b
V_3	4.18 bc	2.24 ab	2.49 b	2.24 b
V_4	4.47 ab	2.27 ab	2.49 b	2.57 a
V_5	3.93 c	1.87 c	2.13 c	1.52 c
$LSD_{(0.05)}$	0.439	0.207	0.239	0.299
Level of significance	0.01	0.01	0.01	0.01
CV(%)	10.65	9.87	10.10	13.90

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Table 2. Interaction effect of salicylic acid and varieties on insect population at flowering stage of mustard

Treatment	Number of insect populations plant^{-1} (at flowering stage)			
	Aphid	Sawfly	Leaf miner	Hairy caterpillar
S_0V_1	5.67 a	3.33 a	3.60 a	3.73 a
S_0V_2	5.27 ab	3.27 a	3.40 ab	3.40 ab
S_0V_3	4.33 c	2.47 cd	2.47 de	2.87 bc
S_0V_4	4.73 bc	2.87 b	3.00 bc	3.27 ab
S_0V_5	4.73 bc	2.80 bc	3.20 ab	2.42 cd
S_1V_1	4.53 bc	2.07 ef	2.60 cd	2.67 cd
S_1V_2	3.87 cd	1.73 fg	2.13 e	1.87 e
S_1V_3	4.20 c	2.20 de	2.60 cd	2.13 de
S_1V_4	4.33 c	1.93 efg	2.13 e	2.63 cd
S_1V_5	4.00 c	1.60 gh	2.13 e	1.13 f
S_2V_1	3.87 cd	1.73 fg	2.13 e	1.87 e
S_2V_2	3.13 d	1.27 hi	1.40 f	0.93 f
S_2V_3	4.00 c	2.07 ef	2.40 de	1.73 e
S_2V_4	4.33 c	2.00 ef	2.33 de	1.80 e
S_2V_5	3.07 d	1.20 i	1.07 f	1.00 f
$LSD_{(0.05)}$	0.761	0.359	0.413	0.518
Level of significance	0.05	0.01	0.01	0.05
CV(%)	10.65	9.87	10.10	13.90

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

4.1.1.2 Sawfly population

Different levels of salicylic acid showed statistically significant differences in terms of number of sawfly plant^{-1} at flowering stage (Table 1). The lowest number of sawfly (1.65) was found in S_2 (0.4 mM SA) which was closely followed (1.91) by S_1 (0.2 mM SA) and the highest number of sawfly (2.95) was recorded from S_0 (0 mM SA i.e., control).

Number of sawfly plant^{-1} varied significantly at flowering stage for different mustard varieties (Table 1). The lowest number of sawfly (1.87) was obtained from V_5 (BARI Sarisha-16) which was closely followed (2.09) by V_2 (BARI Sarisha-13). On the other hand, the highest number of sawfly (2.38) was found in V_1 (BARI Sarisha-1) which was statistically similar (2.27 and 2.24) to V_4 (BARI Sarisha-15) and V_3 (BARI Sarisha-14), respectively.

Statistically significant variation was recorded due to the interaction effect of levels of salicylic acid and different mustard varieties in terms of number of sawfly plant^{-1} at flowering stage (Table 2). The lowest number of sawfly (1.20) was recorded from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number (3.33) was found in S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.1.1.3 Leaf miner population

Number of leaf miner plant^{-1} at flowering stage varied significantly due to different levels of salicylic acid (Table 1). Data revealed that, the lowest number of leaf miner (1.87) was found in S_2 (0.4 mM SA) which was closely followed (2.32) by S_1 (0.2 mM SA), while the highest number of leaf miner (3.13) was recorded from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of leaf miner plant^{-1} at flowering stage for different mustard varieties (Table 1). The lowest number of leaf miner (2.13) was recorded from V_5 (BARI Sarisha-16) which was statistically similar (2.31) to V_2 (BARI Sarisha-13), whereas the highest number of leaf miner (2.78) was found in V_1 (BARI Sarisha-1) which was closely followed (2.49) by and V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of leaf miner plant^{-1} at flowering stage (Table 2). The lowest number of leaf miner (1.07) was recorded from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number of leaf miner (3.60) was found in S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.1.1.4 Hairy caterpillar population

Number of hairy caterpillar plant^{-1} at flowering stage varied significantly due to different levels of salicylic acid (Table 1). Data revealed that, the lowest number of hairy caterpillar (1.47) was recorded from S_2 (0.4 mM SA) which was closely followed (2.09) by S_1 (0.2 mM SA), whereas the highest number of hairy caterpillar (3.14) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of hairy caterpillar plant^{-1} at flowering stage for different mustard varieties (Table 1). The lowest number of hairy caterpillar (1.52) was observed from V_5 (BARI Sarisha-16) which was closely followed (2.07 and 2.24) by V_2 (BARI Sarisha-13) and V_3 (BARI Sarisha-14), respectively and they were statistically similar. On the other hand, the highest number of hairy caterpillar (2.76) was recorded from V_1 (BARI Sarisha-1) which was statistically similar (2.57) to V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties varied significantly in terms of number of hairy caterpillar plant^{-1} at flowering stage (Table 2). The lowest number of hairy caterpillar (1.00) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number of hairy caterpillar (3.73) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

Mustard aphid, sawfly, mustard leaf eating caterpillar etc. are the serious and destructive pest and limiting factors for successful cultivation of mustard (Bakhetia, 1983 and Zaman, 1990). Both the nymph and adult of the aphid suck sap from leaves, stems, inflorescences and pods (Atwal, 1997; Butani and Jotwani, 1984).

4.1.2 At fruiting stage

4.1.2.1 Aphid population

Number of aphid plant^{-1} at fruiting stage varied significantly due to different levels of salicylic acid (Table 3). The lowest number of aphid (4.76) was recorded from S_2 (0.4 mM SA) which was closely followed (5.04) by S_1 (0.2 mM SA), whereas the highest number (6.32) was recorded from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of aphid plant^{-1} at fruiting stage for different mustard varieties (Table 3). The lowest number of aphid (5.07) was found in V_5 (BARI Sarisha-16) which was statistically similar (5.13 and 5.29) to V_2 (BARI Sarisha-13) and V_3 (BARI Sarisha-14), while the highest number of aphid (5.89) was recorded from V_1 (BARI Sarisha-1) which was closely followed (5.49) by V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of aphid plant^{-1} at fruiting stage (Table 4). The lowest number of aphid (4.07) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the highest number of aphid (6.93) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.1.2.2 Sawfly population

Number of sawfly plant^{-1} at fruiting stage varied significantly due to different levels of salicylic acid (Table 3). The lowest number of sawfly (2.33) was observed from S_2 (0.4 mM SA) which was closely followed (2.71) by S_1 (0.2 mM SA) and the highest number (3.67) was recorded from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of sawfly plant^{-1} at fruiting stage for different mustard varieties (Table 3). The lowest number of sawfly (2.60) was recorded from V_5 (BARI Sarisha-16) which was closely followed (2.84) by V_2 (BARI Sarisha-13), whereas the highest number (3.13) was found in V_1 (BARI Sarisha-1) which was statistically similar (3.04) to V_3 (BARI Sarisha-14) and closely followed (2.89) by V_4 (BARI Sarisha-15).

Table 3. Effect of salicylic acid and varieties on insect population at fruiting stage of mustard

Treatment	Number of insect populations plant^{-1} (at fruiting stage)			
	Aphid	Sawfly	Leaf miner	Hairy caterpillar
Levels of salicylic acid				
S_0	6.32 a	3.67 a	3.08 a	3.15 a
S_1	5.04 b	2.71 b	2.24 b	2.24 b
S_2	4.76 c	2.33 c	1.92 c	1.35 c
$LSD_{(0.05)}$	0.279	0.140	0.132	0.245
Level of significance	0.01	0.01	0.01	0.01
Mustard varieties				
V_1	5.89 a	3.13 a	2.67 a	2.64 a
V_2	5.13 bc	2.84 c	2.31 bc	2.07 bc
V_3	5.29 bc	3.04 ab	2.40 bc	2.24 b
V_4	5.49 b	2.89 bc	2.44 b	2.38 ab
V_5	5.07 c	2.60 d	2.24 c	1.89 c
$LSD_{(0.05)}$	0.360	0.181	0.170	0.316
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.95	6.46	7.28	14.56

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Table 4. Interaction effect of salicylic acid and varieties on insect population at fruiting stage of mustard

Treatment	Number of insect populations plant^{-1} (at fruiting stage)			
	Aphid	Sawfly	Leaf miner	Hairy caterpillar
S_0V_1	6.93 a	4.07 a	3.40 a	3.87 a
S_0V_2	6.60 ab	4.00 a	3.20 ab	2.80 b
S_0V_3	5.87 cde	3.33 b	2.60 c	2.53 bc
S_0V_4	5.93 cd	3.40 b	3.13 ab	3.83 a
S_0V_5	6.27 bc	3.53 b	3.07 b	2.67 bc
S_1V_1	5.40 def	2.93 c	2.53 c	2.60 bc
S_1V_2	4.67 gh	2.40 ef	2.00 de	2.40 bc
S_1V_3	5.07 fg	3.00 c	2.53 c	2.53 bc
S_1V_4	5.20 efg	2.73 cde	2.20 d	2.13 cd
S_1V_5	4.87 fg	2.47 def	1.93 de	1.53 ef
S_2V_1	5.33 d-g	2.40 ef	2.07 d	1.47 ef
S_2V_2	4.13 h	2.13 f	1.73 e	1.00 f
S_2V_3	4.93 fg	2.80 cd	2.07 d	1.67 de
S_2V_4	5.33 d-g	2.53 de	2.00 de	1.13 ef
S_2V_5	4.07 h	1.80 g	1.73 e	1.47 ef
$LSD_{(0.05)}$	0.624	0.313	0.295	0.547
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.95	6.46	7.28	14.56

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of sawfly plant^{-1} at fruiting stage (Table 4). The lowest number of sawfly (1.80) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number of sawfly (4.07) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.1.2.3 Leaf miner population

Number of leaf miner plant^{-1} at fruiting stage varied significantly due to different levels of salicylic acid (Table 3). Data revealed that, the lowest number of leaf miner (1.92) was recorded from S_2 (0.4 mM SA) which was closely followed (2.24) by S_1 (0.2 mM SA) and the highest number of leaf miner (3.08) was recorded from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of leaf miner plant^{-1} at fruiting stage for different mustard varieties (Table 3). The lowest number of leaf miner (2.24) was recorded from V_5 (BARI Sarisha-16) which was statistically similar (2.31 and 2.40) to V_2 (BARI Sarisha-13) and V_3 (BARI Sarisha-14), respectively while the highest number (2.67) was recorded from V_1 (BARI Sarisha-1) which was closely followed (2.44) by V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of leaf miner plant^{-1} at fruiting stage (Table 4). The lowest number of leaf miner (1.73) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16), whereas the highest number of leaf miner (3.40) was found from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.1.2.4 Hairy caterpillar population

Number of hairy caterpillar plant^{-1} at fruiting stage varied significantly due to different levels of salicylic acid (Table 3). Data revealed that, the lowest number of hairy caterpillar (1.35) was recorded from S_2 (0.4 mM SA) which was closely followed (2.24) by S_1 (0.2 mM SA), while the highest number of hairy caterpillar (3.15) was recorded from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of hairy caterpillar plant^{-1} at fruiting stage for different mustard varieties (Table 3). The lowest number of hairy caterpillar (1.89) was found in V_5 (BARI Sarisha-16) which was statistically similar (2.07) to V_2 (BARI Sarisha-13) and closely followed (2.24) by V_3 (BARI Sarisha-14). On the other hand, the highest number of hairy caterpillar (2.64) was recorded from V_1 (BARI Sarisha-1) which was statistically similar (2.38) to V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of hairy caterpillar plant^{-1} at fruiting stage (Table 4). The lowest number of hairy caterpillar (1.47) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the highest number of hairy caterpillar (3.87) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.2 Healthy and infested plant and infestation status

4.2.1 At flowering stage

4.2.1.1 Healthy plant

Healthy plant m^{-2} area at flowering stage varied significantly due to different levels of salicylic acid (Table 5). The highest number of healthy plant m^{-2} (30.85) was observed from S_2 (0.4 mM SA) which was closely followed (26.07) by S_1 (0.2 mM SA), whereas the lowest number (23.53) was found in S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of healthy plant m^{-2} area at flowering stage for different mustard varieties (Table 5). The highest number of healthy plant m^{-2} (32.47) was recorded from V_5 (BARI Sarisha-16) which was closely followed (29.91) by V_2 (BARI Sarisha-13), while the lowest number of healthy plant m^{-2} (21.98) was observed from V_1 (BARI Sarisha-1) which was closely followed (24.40 and 25.33) by V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15), respectively and they were statistically similar.

Table 5. Effect of salicylic acid and varieties on healthy, infested plant and plant infestation at flowering stage of mustard

Treatment	At flowering stage		
	Healthy plant (No.)	Infested plant (No.)	Infestation (%)
Levels of salicylic acid			
S_0	23.53 c	2.08 a	8.19 a
S_1	26.07 b	1.37 b	5.16 b
S_2	30.85 a	1.15 c	3.70 c
$LSD_{(0.05)}$	1.024	0.063	0.289
Level of significance	0.01	0.01	0.01
Mustard varieties			
V_1	21.98 d	1.62 a	7.00 a
V_2	29.91 b	1.56 ab	5.07 c
V_3	24.40 c	1.53 b	6.05 b
V_4	25.33 c	1.51 bc	5.79 b
V_5	32.47 a	1.44 c	4.50 d
$LSD_{(0.05)}$	1.322	0.081	0.373
Level of significance	0.01	0.01	0.01
CV(%)	5.10	5.48	6.80

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of healthy plant m^{-2} area at flowering stage (Table 6). The highest number of healthy plant m^{-2} area (39.53) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the lowest number (20.20) was observed from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.2.1.2 Infested plant

Infested plant m^{-2} area at flowering stage varied significantly due to different levels of salicylic acid (Table 5). The lowest number of infested plant m^{-2} (1.15) was recorded from S_2 (0.4 mM SA) which was closely followed (1.37) by S_1 (0.2 mM SA), whereas the highest number (2.08) was recorded from S_0 (0 mM SA i.e. control).

Statistically significant variation was recorded in terms of number of infested plant m^{-2} area at flowering stage for different mustard varieties (Table 5). The lowest number of infested plant m^{-2} (1.44) was found in V_5 (BARI Sarisha-16) which was statistically similar (1.51) to V_4 (BARI Sarisha-15). On the other ahnd, the highest number of infested plant m^{-2} (1.62) was recorded from V_1 (BARI Sarisha-1) which was statistically similar (1.56) to V_2 (BARI Sarisha-13) and closely followed (1.53) by V_3 (BARI Sarisha-14).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of infested plant m^{-2} area at flowering stage (Table 6). The lowest number of infested plant m^{-2} area (1.00) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number (2.20) was found in S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.2.1.3 Percentage of plant infestation

Percentage of plant infestation at flowering stage varied significantly due to different levels of salicylic acid (Table 5). The lowest plant infestation (3.70%) was found in S_2 (0.4 mM SA) which was followed (5.16%) by S_1 (0.2 mM SA), while the highest infestation (8.19%) was found in S_0 (0 mM SA i.e., control).

Table 6. Interaction effect of salicylic acid and varieties on healthy, infested plant and plant infestation at flowering stage of mustard

Treatment	At flowering stage		
	Healthy plant (No.)	Infested plant (No.)	Infestation (%)
S_0V_1	20.20 h	2.20 a	9.82 a
S_0V_2	26.80 de	2.27 a	7.85 c
S_0V_3	20.87 h	1.60 b	7.13 de
S_0V_4	22.27 gh	2.13 a	8.74 b
S_0V_5	27.53 d	2.20 a	7.41 cd
S_1V_1	20.87 h	1.47 bc	6.56 ef
S_1V_2	30.87 bc	1.33 cd	4.14 hi
S_1V_3	23.40 fg	1.60 b	6.41 f
S_1V_4	24.87 ef	1.33 cd	5.09 g
S_1V_5	30.33 bc	1.13 ef	3.60 ij
S_2V_1	24.87 ef	1.20 de	4.61 gh
S_2V_2	32.07 b	1.07 ef	3.22 j
S_2V_3	28.93 cd	1.40 c	4.62 gh
S_2V_4	28.87 cd	1.07 ef	3.56 ij
S_2V_5	39.53 a	1.00 f	2.48 k
$LSD_{(0.05)}$	2.290	0.140	0.646
Level of significance	0.01	0.01	0.01
CV(%)	5.10	5.48	6.80

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Significant variation was recorded in terms of percentage of plant infestation at flowering stage for different mustard varieties (Table 5). The lowest plant infestation (4.50%) was found in V_5 (BARI Sarisha-16) which was closely followed (5.07%) by V_2 (BARI Sarisha-13), whereas the highest plant infestation (7.00%) was recorded from V_1 (BARI Sarisha-1) which was followed (6.05% and 5.79%) by V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15), respectively and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of percentage of plant infestation at flowering stage (Table 6). The lowest plant infestation (2.48%) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the highest infestation (9.82%) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.2.2 At fruiting stage

4.2.2.1 Healthy plant

Healthy plant m^{-2} area at fruiting stage varied significantly due to different levels of salicylic acid (Table 7). The highest number of healthy plant m^{-2} (29.73) was found in S_2 (0.4 mM SA) which was closely followed (25.13) by S_1 (0.2 mM SA), whereas the lowest number (22.90) was found in S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of healthy plant m^{-2} area at fruiting stage for different mustard varieties (Table 7). The highest number of healthy plant m^{-2} (31.63) was recorded from V_5 (BARI Sarisha-16) which was closely followed (28.59) by V_2 (BARI Sarisha-13), while the lowest number of healthy plant m^{-2} (21.29) was recorded from V_1 (BARI Sarisha-1) which was closely followed (23.71 and 24.39) by V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15), respectively and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of healthy plant m^{-2} area at fruiting stage (Table 8). The highest number of healthy plant m^{-2} area (38.43) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the lowest number (19.53) was observed from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

Table 7. Effect of salicylic acid and varieties on healthy, infested plant and plant infestation at fruiting stage of mustard

Treatment	At fruiting stage		
	Healthy plant (No.)	Infested plant (No.)	Infestation (%)
Levels of salicylic acid			
S_0	22.90 c	2.21 a	8.92 a
S_1	25.13 b	1.55 b	5.94 b
S_2	29.73 a	1.35 c	4.42 c
$LSD_{(0.05)}$	0.947	0.162	0.560
Level of significance	0.01	0.01	0.01
Mustard varieties			
V_1	21.29 d	1.78 a	7.83 a
V_2	28.59 b	1.73 a	5.81 c
V_3	23.71 c	1.69 a	6.77 b
V_4	24.39 c	1.73 a	6.81 b
V_5	31.63 a	1.58 b	4.94 d
$LSD_{(0.05)}$	1.223	0.198	0.723
Level of significance	0.01	0.01	0.01
CV(%)	4.88	12.76	11.63

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Table 8. Interaction effect of salicylic acid and varieties on healthy, infested plant and plant infestation at fruiting stage of mustard

Treatment	At fruiting stage		
	Healthy plant (No.)	Infested plant (No.)	Infestation (%)
S_0V_1	19.53 i	2.47 a	11.22 a
S_0V_2	26.10 ef	2.47 a	8.66 bc
S_0V_3	20.33 i	1.73 cd	7.86 cd
S_0V_4	21.60 hi	2.33 ab	9.74 b
S_0V_5	26.93 de	2.07 bc	7.13 d
S_1V_1	20.47 i	1.60 def	7.23 d
S_1V_2	28.67 cd	1.40 def	4.65 fg
S_1V_3	23.00 gh	1.73 cd	7.00 d
S_1V_4	24.00 fg	1.67 de	6.51 de
S_1V_5	29.53 bc	1.33 def	4.33 fg
S_2V_1	23.87 g	1.27 ef	5.05 f
S_2V_2	31.00 b	1.33def	4.11 fg
S_2V_3	27.80 cde	1.60 def	5.44 ef
S_2V_4	27.57 cde	1.20f	4.18 fg
S_2V_5	38.43 a	1.33 def	3.35 g
$LSD_{(0.05)}$	2.118	0.363	1.252
Level of significance	0.01	0.01	0.01
CV(%)	4.88	12.76	11.63

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

4.2.2.2 Infested plant

Infested plant m^{-2} area at fruiting stage varied significantly due to different levels of salicylic acid (Table 7). The lowest number of infested plant m^{-2} (1.35) was recorded from S_2 (0.4 mM SA) which was closely followed (1.55) by S_1 (0.2 mM SA) and the highest number (2.21) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of infested plant m^{-2} area at fruiting stage for different mustard varieties (Table 7). The lowest number of infested plant m^{-2} (1.58) was found in V_5 (BARI Sarisha-16) which was statistically different from all other varieties, whereas the highest number (1.78) was recorded from V_1 (BARI Sarisha-1) which was statistically similar (1.73 and 1.69) to V_2 (BARI Sarisha-13), V_4 (BARI Sarisha-15) and (1.53) by V_3 (BARI Sarisha-14).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of infested plant m^{-2} area at fruiting stage (Table 8). The lowest number of infested plant m^{-2} area (1.33) was recorded from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the highest number (2.47) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.2.2.3 Percentage of plant infestation

Percentage of plant infestation at fruiting stage varied significantly due to different levels of salicylic acid (Table 7). The lowest plant infestation (4.42%) was observed from S_2 (0.4 mM SA) which was closely followed (5.94%) by S_1 (0.2 mM SA), whereas the highest infestation (8.92%) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of percentage of plant infestation at fruiting stage for different mustard varieties (Table 7). The lowest plant infestation (4.94%) was found in V_5 (BARI Sarisha-16) which was closely followed (5.81%) by V_2 (BARI Sarisha-13), while the highest plant infestation (7.83%) was found in V_1 (BARI Sarisha-1) which was followed (6.81% and

6.77%) by V_4 (BARI Sarisha-15) and V_3 (BARI Sarisha-14), respectively and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of percentage of plant infestation at fruiting stage (Table 8). The lowest plant infestation (3.35%) was recorded from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the highest infestation (11.22%) was found in S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.3 Yield contributing characters and yield of mustard

4.3.1 Plant height at harvest

Plant height at harvest varied significantly due to different levels of salicylic acid (Figure 2). The longest plant (112.86 cm) was recorded from S_2 (0.4 mM SA) which was statistically similar (110.83 cm) to S_1 (0.2 mM SA), while the shortest plant (102.76 cm) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of plant height at harvest for different mustard varieties (Figure 3). The longest plant (158.46 cm) was found in V_5 (BARI Sarisha-16) which was followed (107.97 cm) by V_4 (BARI Sarisha-15). On the other hand, the shortest plant (86.17 cm) was recorded from V_3 (BARI Sarisha-14) which was followed (93.50 cm and 97.99 cm) by V_2 (BARI Sarisha-13) and V_1 (BARI Sarisha-1), respectively and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of plant height of mustard (Figure 4). The longest plant (162.78 cm) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16), whereas the shortest plant (85.52 cm) was observed from S_0V_3 (0 mM SA i.e., control and BARI Sarisha-14).

4.3.2 Number of branches plant^{-1} at harvest

Number of branches plant^{-1} at harvest varied significantly due to different levels of salicylic acid (Table 9). The maximum number of branches plant^{-1} (7.77) was found in S_2 (0.4 mM SA) which was statistically similar (7.61) to S_1 (0.2 mM SA), whereas the minimum number of branches plant^{-1} (7.16) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of number of branches plant^{-1} at harvest for different mustard varieties (Table 9). The maximum number of branches plant^{-1} (8.38) was found in V_5 (BARI Sarisha-16) which was statistically similar (8.27) to V_2 (BARI Sarisha-13), while the minimum number of branches plant^{-1} (6.18) was recorded from V_1 (BARI Sarisha-1) which was closely followed (7.36 and 7.40) by V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15), respectively and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of branches plant^{-1} of mustard (Table 10). The maximum number of branches plant^{-1} (8.73) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the minimum number of branches plant^{-1} (5.33) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.3.3 Number of siliqua plant^{-1}

Number of siliqua plant^{-1} varied significantly due to different levels of salicylic acid (Table 9). The maximum number of siliqua plant^{-1} (116.53) was found in S_2 (0.4 mM SA) which was statistically similar (115.40) to S_1 (0.2 mM SA) and the minimum number of siliqua plant^{-1} (107.13) was obtained from S_0 (0 mM SA i.e., control).

Table 9. Effect of salicylic acid and varieties on yield contributing characters and yield of mustard

Treatment	Number of branches plant^{-1} at harvest	Number of siliqua plant^{-1}	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Levels of salicylic acid				
S_0	7.16 b	107.13 b	1.54 c	2.53 b
S_1	7.61 a	115.40 a	1.64 b	2.75 a
S_2	7.77 a	116.53 a	1.72 a	2.84 a
$LSD_{(0.05)}$	0.278	3.660	0.047	0.132
Level of significance	0.01	0.01	0.01	0.01
Mustard varieties				
V_1	6.18 c	106.44 b	1.22 d	2.29 c
V_2	8.27 a	86.67 d	2.05 b	2.83 ab
V_3	7.36 b	89.56 cd	1.38 c	2.76 b
V_4	7.40 b	93.67 c	1.39 c	2.69 b
V_5	8.38 a	188.78 a	2.13 a	2.99 a
$LSD_{(0.05)}$	0.359	4.725	0.061	0.170
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.94	4.33	4.85	6.50

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Table 10. Interaction effect of salicylic acid and varieties on yield contributing characters and yield of mustard

Treatment	Number of branches plant^{-1} at harvest	Number of siliqua plant^{-1}	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0V_1	5.33 j	94.00 c-f	1.02 i	1.86 e
S_0V_2	8.00 b-e	79.67 h	1.95 bc	2.71 bc
S_0V_3	7.33 e-h	96.67 cde	1.51 de	2.76 bc
S_0V_4	7.00 gh	80.67 gh	1.35 fg	2.47 cd
S_0V_5	8.13 a-d	184.67 a	1.88 c	2.87 ab
S_1V_1	6.33 i	109.00 b	1.25 gh	2.35 d
S_1V_2	8.40 ab	89.00 efg	2.00 b	2.87 ab
S_1V_3	7.60 c-g	86.33 fgh	1.41 ef	2.88 ab
S_1V_4	7.47 d-h	99.67 cd	1.30 fgh	2.74 bc
S_1V_5	8.27 abc	193.00 a	2.23 a	2.93 ab
S_2V_1	6.87 hi	116.33 b	1.40 ef	2.65 bcd
S_2V_2	8.40 ab	91.33 def	2.21 a	2.89 ab
S_2V_3	7.13 fgh	85.67 fgh	1.23 h	2.64 bcd
S_2V_4	7.73 b-f	100.67 c	1.53 d	2.85 ab
S_2V_5	8.73 a	188.67 a	2.26 a	3.17 a
$LSD_{(0.05)}$	0.621	8.184	0.106	0.295
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.94	4.33	4.85	6.50

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

S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1
V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15
V_5: BARI Sarisha-16

Statistically significant variation was recorded in terms of number of siliqua plant^{-1} for different mustard varieties (Table 9). The maximum number of siliqua plant^{-1} (188.78) was found in V_5 (BARI Sarisha-16) which was followed (106.44) by V_1 (BARI Sarisha-1), whereas the minimum number of siliqua plant^{-1} (86.67) was found in V_2 (BARI Sarisha-13) which was statistically similar (89.56) to V_3 (BARI Sarisha-14) and closely followed (93.67) by V_4 (BARI Sarisha-15).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of number of siliqua plant^{-1} of mustard (Table 10). The maximum number of siliqua plant^{-1} (188.67) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the minimum number of siliqua plant^{-1} (79.67) from S_0V_2 (0 mM SA i.e., control and BARI Sarisha-13).

4.3.4 Length of siliqua

Length of siliqua varied significantly due to different levels of salicylic acid (Figure 5). The longest siliqua (6.36 cm) was observed from S_2 (0.4 mM SA) which was closely followed (6.06 cm) by S_1 (0.2 mM SA) and the shortest siliqua (5.32 cm) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of length of siliqua for different mustard varieties (Figure 6). The longest siliqua (6.77 cm) was found in V_2 (BARI Sarisha-13) which was statistically similar (6.60 cm) to V_5 (BARI Sarisha-16) and closely followed (6.02 cm) by V_4 (BARI Sarisha-15). On the other hand, the shortest siliqua (4.80 cm) was found in V_1 (BARI Sarisha-1) which was closely followed (5.38 cm) by V_3 (BARI Sarisha-14).

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of length of siliqua of mustard (Figure 7). The longest siliqua (7.43 cm) was observed from S_2V_5 (0.4 mM SA and BARI Sarisha-16), while the shortest siliqua (4.50 cm) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.3.5 Seed yield

Seed yield varied significantly due to different levels of salicylic acid (Table 9). The highest seed yield (1.72 t ha^{-1}) was found in S_2 (0.4 mM SA) which was closely followed (1.64 t ha^{-1}) by S_1 (0.2 mM SA), whereas the lowest seed yield (1.54 t ha^{-1}) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of seed yield for different mustard varieties (Table 9). The highest seed yield (2.13 t ha^{-1}) was found in V_5 (BARI Sarisha-16) which was followed (2.05 t ha^{-1}) by V_2 (BARI Sarisha-13), while the lowest seed yield (1.22 t ha^{-1}) was observed from V_1 (BARI Sarisha-1) which was followed (1.38 t ha^{-1} and 1.39 t ha^{-1}) by V_3 (BARI Sarisha-14) and V_4 (BARI Sarisha-15) and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varieties showed statistically significant variation in terms of seed yield of mustard (Table 10). The highest seed yield (2.26 t ha^{-1}) was recorded from S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the lowest seed yield (1.02 t ha^{-1}) was found in S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

4.3.6 Stover yield

Stover yield varied significantly due to different levels of salicylic acid (Table 9). The highest stover yield (2.84 t ha^{-1}) was observed from S_2 (0.4 mM SA) which was statistically similar (2.75 t ha^{-1}) to S_1 (0.2 mM SA), while the lowest stover yield (2.53 t ha^{-1}) was observed from S_0 (0 mM SA i.e., control).

Statistically significant variation was recorded in terms of stover yield for different mustard varieties (Table 9). The highest stover yield (2.99 t ha^{-1}) was found in V_5 (BARI Sarisha-16) which was statistically similar (2.83 t ha^{-1}) to V_2 (BARI Sarisha-13). On the other hand, the lowest stover yield (2.29 t ha^{-1}) was recorded from V_1 (BARI Sarisha-1) which was closely followed (2.69 t ha^{-1} and 2.76 t ha^{-1}) by V_4 (BARI Sarisha-15) and V_3 (BARI Sarisha-14) and they were statistically similar.

Interaction effect of levels of salicylic acid and different mustard varietis showed statistically significant variation in terms of stover yield of mustard (Table 10). The highest stover yield (3.17 t ha^{-1}) was found in S_2V_5 (0.4 mM SA and BARI Sarisha-16) and the lowest stover yield (1.86 t ha^{-1}) was recorded from S_0V_1 (0 mM SA i.e., control and BARI Sarisha-1).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2014 to March, 2015 to assess the performance of salicylic acid on the suppression of mustard insect pests in field condition. The experiment comprised of two factors; Factors A: Levels of salicylic acid (3 levels)- S_0: 0 mM SA (control), S_1: 0.2 mM SA,S_2: 0.4 mM SA and Factor B: Mustard varieties (5 mustard varieties)- V_1: BARI Sarisha-1, V_2: BARI Sarisha-13, V_3: BARI Sarisha-14, V_4: BARI Sarisha-15 and V_5: BARI Sarisha-16. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on the insect pests incidence, insect infestation, yield contributing characters and yield.

In case of different levels of salicylic acid, at flowering stage, the lowest number of aphid (3.68) was recorded from S_2, whereas the highest number of aphid (4.95) was observed from S_0. The lowest number of sawfly (1.65) was found in S_2 and the highest number of sawfly (2.95) was recorded from S_0. The lowest number of leaf miner (1.87) was found in S_2, while the highest number of leaf miner (3.13) was observed from S_0. The lowest number of hairy caterpillar (1.47) was recorded from S_2, whereas the highest number of hairy caterpillar (3.14) was observed from S_0. At fruiting stage the lowest number of aphid (4.76) was recorded from, whereas the highest number of aphid (6.32) was observed from S_0. The lowest number of sawfly (2.33) was observed from S_2 and the highest number of sawfly (3.67) was found in S_0. The lowest number of leaf miner (1.92) was recorded from S_2 and the highest number of leaf miner (3.08) was observed from S_0. The lowest number of hairy caterpillar (1.35) was recorded from S_2, while the highest number of hairy caterpillar (3.15) was observed from S_0.

At flowering stage, the highest number of healthy plant m^{-2} (30.85) was observed from S_2, whereas the lowest number (23.53) was found in S_0. The lowest number

of infested plant m^{-2} (1.15) was recorded from S_2, whereas the highest number (2.08) was observed from S_0. The lowest plant infestation (3.70%) was found in S_2 (0.4 mM SA), while the highest infestation (8.19%) was observed from S_0. At fruiting stage, the highest number of healthy plant m^{-2} (29.73) was found in S_2, whereas the lowest number (22.90) was observed from S_0. The lowest number of infested plant m^{-2} (1.35) was recorded from S_2 and the highest number (2.21) was observed from S_0. The lowest plant infestation (4.42%) was observed from S_2, whereas the highest infestation (8.92%) was observed from S_0.

The longest plant (112.86 cm) was recorded from S_2, while the shortest plant (102.76 cm) was observed from S_0. The maximum number of branches $plant^{-1}$ (7.77) was found in S_2, whereas the minimum number of branches $plant^{-1}$ (7.16) was observed from S_0. The maximum number of siliqua $plant^{-1}$ (116.53) was found in S_2 and the minimum number of siliqua $plant^{-1}$ (107.13) was obtained from S_0. The longest siliqua (6.36 cm) was observed from S_2 and the shortest siliqua (5.32 cm) was observed from S_0. The highest seed yield (1.72 t ha^{-1}) was found in, whereas the lowest seed yield (1.54 t ha^{-1}) was observed from S_0. The highest stover yield (2.84 t ha^{-1}) was observed from S_2, while the lowest stover yield (2.53 t ha^{-1}) was observed from S_0.

For different mustard variety, at flowering stage, the lowest number of aphid (3.93) was found in V_5, while the highest number of aphid (4.69) was recorded from V_1. The lowest number of sawfly (1.87) was obtained from V_5 and the highest number of sawfly (2.38) was found in V_1. The lowest number of leaf miner (2.13) was recorded from V_5, whereas the highest number of leaf miner (2.78) was found in V_1. The lowest number of hairy caterpillar (1.52) was observed from V_5 and the highest number of hairy caterpillar (2.76) was recorded from V_1. At Fruiting stage, the lowest number of aphid (5.07) was found in V_5, while the highest number of aphid (5.89) was recorded from V_1. The lowest number of sawfly (2.60) was recorded from V_5, whereas the highest number of sawfly (3.13) was found in V_1. The lowest number of leaf miner (2.24) was found in V_5, while the highest number of leaf miner (2.67) was recorded from V_1. The

lowest number of hairy caterpillar (1.89) was found in V_5 and the highest number of hairy caterpillar (2.64) was recorded from V_1.

At flowering stage, the highest number of healthy plant m^{-2} (32.47) was recorded from V_5, while the lowest number of healthy plant m^{-2} (21.98) was observed from V_1. The lowest number of infested plant m^{-2} (1.44) was found in V_5 and the highest number of infested plant m^{-2} (1.62) was recorded from V_1. The lowest plant infestation (4.50%) was found in V_5, whereas the highest plant infestation (7.00%) was obtained from V_1. At fruiting stage, the highest number of healthy plant m^{-2} (31.63) was recorded from V_5, while the lowest number of healthy plant m^{-2} (21.29) was recorded from V_1. The lowest number of infested plant m^{-2} (1.58) was found in V_5, whereas the highest number of infested plant m^{-2} (1.78) was recorded from V_1. The lowest plant infestation (4.94%) was found in V_5, while the highest plant infestation (7.83%) was found in V_1.

The longest plant (158.46 cm) was found in V_5 (BARI Sarisha-16) and the shortest plant (86.17 cm) was recorded from V_3. The maximum number of branches $plant^{-1}$ (8.38) was found in V_5, while the minimum number of branches $plant^{-1}$ (6.18) was recorded from V_1. The maximum number of siliqua $plant^{-1}$ (188.78) was found in V_5, wheras the minimum number of siliqua $plant^{-1}$ (86.67) was found in V_2. The longest siliqua (6.77 cm) was found in V_2 and the shortest siliqua (4.80 cm) was found in V_1. The highest seed yield (2.13 t ha^{-1}) was found in V_5, while the lowest seed yield (1.22 t ha^{-1}) was observed from V_1. The highest stover yield (2.99 t ha^{-1}) was found in V_5 and the lowest stover yield (2.29 t ha^{-1}) was recorded from V_1.

Due to the interaction effect of levels of salicylic acid and different mustard variety, at flowering stage, the lowest number of aphid (3.07) was observed from S_2V_5 and the highest number (5.67) was recorded from S_0V_1. The lowest number of sawfly (1.20) was recorded from S_2V_5, while the highest number of sawfly (3.33) was observed from S_0V_1. The lowest number of leaf miner (1.07) was recorded from S_2V_5, while the highest number of leaf miner (3.60) was found in

S_0V_1. The lowest number of hairy caterpillar (1.00) was found in S_2V_5, while the highest number of hairy caterpillar (3.73) was recorded from S_0V_1. At fruiting stage, the lowest number of aphid (4.07) was observed from S_2V_5 and the highest number of aphid (6.93) was recorded from S_0V_1. The lowest number of sawfly (1.80) was found in S_2V_5, while the highest number of sawfly (4.07) was recorded from S_0V_1. The lowest number of leaf miner (1.73) was found in S_2V_5, whereas the highest number of leaf miner (3.40) was obtained from S_0V_1. The lowest number of hairy caterpillar (1.47) was observed from S_2V_5 and the highest number of hairy caterpillar (3.87) was recorded from S_0V_1.

At flowering stage, the highest number of healthy plant m^2 area (39.53) was found in S_2V_5, while the lowest number (20.20) was observed from S_0V_1. The lowest number of infested plant m^{-2} area (1.00) was observed from S_2V_5, while the highest number (2.20) was recorded from S_0V_1. The lowest plant infestation (2.48%) was found in S_2V_5 and the highest infestation (9.82%) was recorded from S_0V_1. At fruiting stage, the highest number of healthy plant m^{-2} area (38.43) was found in S_2V_5 and the lowest number (19.53) was observed from S_0V_1. The lowest number of infested plant m^{-2} area (1.33) was observed from S_2V_5, while the highest number (2.47) was recorded from S_0V_1. The lowest plant infestation (3.35%) was recorded from S_2V_5 and the highest infestation (11.22%) was found in S_0V_1.

The longest plant (162.78 cm) was found in S_2V_5, whereas the shortest plant (85.52 cm) was observed from S_0V_3. The maximum number of branches $plant^{-1}$ (8.73) was observed from S_2V_5 and the minimum number of branches $plant^{-1}$ (5.33) was recorded from S_0V_1. The maximum number of siliqua $plant^{-1}$ (188.63) was observed from S_2V_5, while the minimum number of siliqua $plant^{-1}$ (79.67) was recorded from S_0V_2. The longest siliqua (7.43 cm) was observed from S_2V_5, while the shortest siliqua (4.50 cm) was recorded from S_0V_1. The highest seed yield (2.26 t ha^{-1}) was recorded from S_2V_5 and the lowest seed yield (1.02 t ha^{-1}) was found in S_0V_1. The highest stover yield (3.17 t ha^{-1}) was found in S_2V_5 and the lowest stover yield (1.86 t ha^{-1}) was recorded from S_0V_1.

Conclusion

From the above findings it may be concluded that 0.4 mM SA and BARI Sarisha-16 was superior for controlling insect pests of mustard and also for better yield.

Recommendations

Considering the findings of the present study, further research works in the following areas may be suggested:

1. Some other component of management practices along with salicylic acid may be included for developing environment friendly IPM packages.
2. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2014 to March 2015

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2014	25.8	16.0	78	00	6.8
December, 2014	22.4	13.5	74	00	6.3
January, 2015	24.5	12.4	68	00	5.7
February, 2015	27.1	16.7	67	30	6.7
March, 2015	28.1	19.5	68	00	6.8

* Monthly average,

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

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me 100 g $soil^{-1}$)	0.10
Available S (ppm)	23

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

Appendix III. Analysis of variance of the data on insect population at flowering stage of mustard as influenced by salicylic acid and varieties

Source of variation	Degrees of freedom	Mean square			
		At flowering stage number of insect populations plant^{-1}			
		Aphid	Sawfly	Leaf miner	Hairy caterpillar
Replication	2	0.025	0.012	0.003	0.022
Salicylic acid (A)	2	6.092**	7.046**	6.179**	10.690**
Varieties (B)	4	0.828**	0.352**	0.516**	2.082**
Interaction (A×B)	8	0.562*	0.348**	0.660**	0.261*
Error	28	0.207	0.046	0.061	0.096

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

Appendix IV. Analysis of variance of the data on insect population at fruiting stage of mustard as influenced by salicylic acid and varieties

Source of variation	Degrees of freedom	Mean square			
		At fruiting stage number of insect populations plant^{-1}			
		Aphid	Sawfly	Leaf miner	Hairy caterpillar
Replication	2	0.008	0.014	0.008	0.092
Salicylic acid (A)	2	10.377**	7.098**	5.384**	12.150**
Varieties (B)	4	0.986**	0.379**	0.235**	0.756**
Interaction (A×B)	8	0.519**	0.316**	0.181**	0.677**
Error	28	0.139	0.035	0.031	0.107

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

Appendix V. Analysis of variance of the data on healthy, infested plant and plant infestation at flowering stage of mustard as influenced by salicylic acid and varieties

Source of variation	Degrees of freedom	Mean square		
		At flowering stage		
		Healthy plant (No.)	Infested plant (No.)	Infestation (%)
Replication	2	0.006	0.008	0.045
Salicylic acid (A)	2	207.281**	3.555**	78.803**
Varieties (B)	4	164.145**	0.538*	8.241**
Interaction (A×B)	8	9.285**	0.176**	1.592**
Error	28	1.874	0.007	0.149

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

Appendix VI. Analysis of variance of the data on healthy, infested plant and plant infestation at fruiting stage of mustard as influenced by salicylic acid and varieties

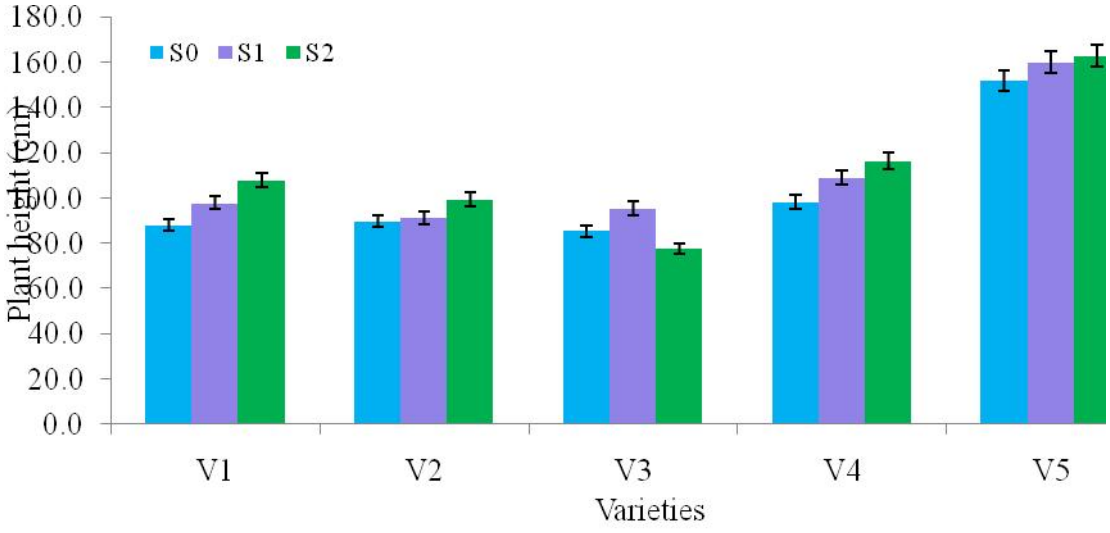
Source of variation	Degrees of freedom	Mean square		
		At fruiting stage		
		Healthy plant (No.)	Infested plant (No.)	Infestation (%)
Replication	2	0.193	0.006	0.081
Salicylic acid (A)	2	182.106**	3.089**	78.557**
Varieties (B)	4	153.981**	0.652**	10.915**
Interaction (A×B)	8	7.656**	0.201**	2.221**
Error	28	1.603	0.047	0.560

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

Appendix VII. Analysis of variance of the data on yield contributing characters and yield of mustard as influenced by salicylic acid and varieties

Source of variation	Degrees of freedom	Mean square					
		Plant height at harvest	Number of branches plant^{-1} at harvest	Number of siliqua plant^{-1}	Length of siliqua (cm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Replication	2	3.345	0.086	5.489	0.014	0.002	0.018
Salicylic acid (A)	2	428.508**	1.518**	394.956**	4.239**	0.126**	0.374**
Varieties (B)	4	7491.029**	7.056**	16654.74**	6.157**	1.592**	0.614**
Interaction (A×B)	8	134.782**	0.334*	163.844**	0.157**	0.070**	0.093**
Error	28	43.539	0.138	23.941	0.048	0.004	0.031

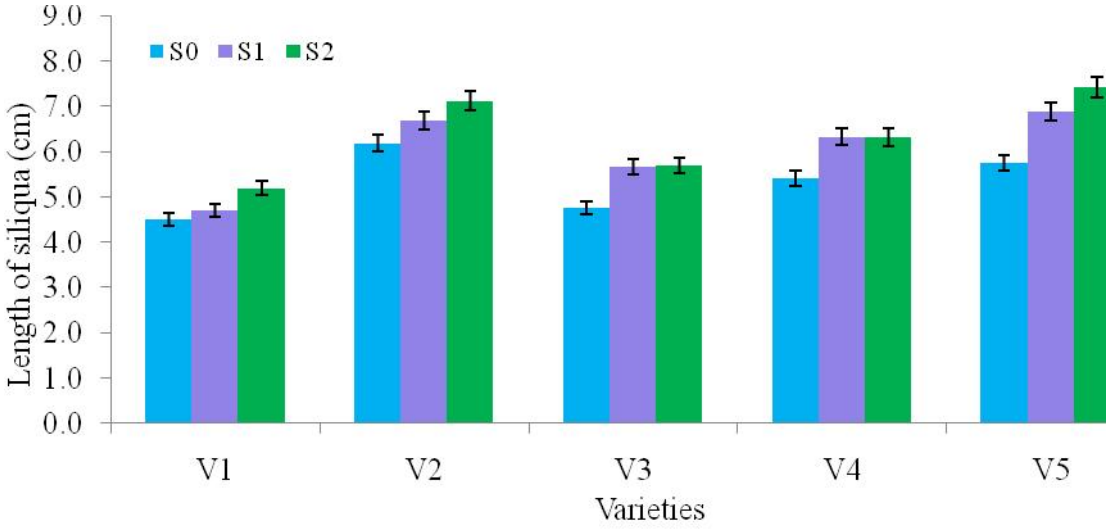
** Significant at 0.01 level of probability;



S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1 V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15 V_5: BARI Sarisha-16

Figure 4. Interaction effect of salicylic acid and varieties on plant height at harvest of mustard.



S_0: 0 mM SA (control)
S_1: 0.2 mM SA
S_2: 0.4 mM SA

V_1: BARI Sarisha-1 V_2: BARI Sarisha-13
V_3: BARI Sarisha-14
V_4: BARI Sarisha-15 V_5: BARI Sarisha-16

Figure 7. Interaction effect of salicylic acid and varieties on length of siliqua of mustard.