RESPONSE OF MUSTARD VARIETIES TO SALICYLIC ACID

MD. ASHRAFUL ALAM

DEPARTMENT OF AGRICULTURAL BOTANY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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MD. ASHRAFUL ALAM

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APPROVED BY:

Prof. Dr. Mohammad Mahbub Islam	**Prof. Dr. Shahnaz Sarkar**
Department of Agricultural Botany	Department of Agricultural Botany
SAU, Dhaka	SAU, Dhaka
Supervisor	Co-Supervisor

Dr. Md. Ashabul Haque
Associate Professor
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled '**Response of Mustard Varieties to Salicylic Acid'** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany,** embodies the results of a piece of bonafide research work carried out by **Md. Ashraful Alam,** Registration No. **09-03542** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Dr. Mohammad Mahbub Islam
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted during the period from November 2014 to March 2015 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to evaluate effort of varieties and salicylic acid(SA) on morphophysiology and yield of mustard. The experiment was laid out in two factors Randomized Complete Block Design (RCBD). Factor A: Mustard varieties (5 varieties)- V_1: Tori 7, V_2: BARI Sarisha 13, V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15, V_5: BARI Sarisha 16. Factors B: Levels of salicylic acid (3 levels)- S_0: 0 mM SA (control), S_1: 0.2 mM SA, S_2: 0.4 mM SA; It replicated three times. The total treatment combinations were 15(5×3). Most of the results of this experiment showed differences to the treatments. The variety showed significant variation on morphophysiology, yield contributing characters and yield of mustard. The highest plant height, leaf number and number of branches per plant were found in V_5(BARI Sarisha 16). The lowest transpirational water loss(%) was recorded in V_5. Due to different mustard varieties, the highest number of siliqua per plant (185.23), the highest length of siliqua (6.89 cm), the highest seed yield (2.15 t/ha) and the highest stover yield (3.08 t/ha) was observed from V_5, whereas the lowest number (85.00), the lowest length of siliqua (4.62 cm), the lowest seed yield (1.18 t/ha) and the lowest stover yield (2.24 t/ha) was found from V_2.The salicylic acid also improved the morphophysiology and yield contributing characters. The salicylic acid showed significant reduction of days required to flowering and harvesting. The highest number of siliqua per plant (113.88), the highest length of siliqua (6.16 cm), the highest seed yield (1.74 t/ha) and the highest stover yield (2.85 t/ha) was found from S_2, while the lowest number (107.78), the lowest length of siliqua (5.58 cm), the lowest seed yield (1.47 t/ha) and the lowest stover yield (2.64 t/ha) was observed from S_0. For the interaction effect of mustard varieties and levels of salicylic acid, the highest number of siliqua per plant (192.23), highest length of siliqua (7.33 cm), the highest seed yield (2.30 t/ha) and the highest stover yield (3.37 t/ha) was observed from S_2V_5 and the lowest number of siliqua per plant (73.33), the lowest seed yield (1.01 t/ha) and the lowest stover yield (2.20 t/ha) and from S_0V_4 treatment combination. Therefore, this experiment result suggested that, exogenous salicylic acid improve the mustard seed yield by changing the morphophysiology and yield contributing characters different mustard varieties.

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CHAPTER I

INTRODUCTION

Mustard belongs to the family Cruciferae, is one of the most important oil crop of the world after soybean and groundnut (FAO, 2012). *Brassica napus, B. campestris* and *B. juncea* are the three species of mustard those produce edible oil. It is one of the most important and widely grown oilseed crops in Bangladesh which occupying 0.483 million hectare of land and the total production was 0.525 million metric ton (AIS, 2013). Vegetable oils and fats (lipids) constitute an important component of human diet and oils of plant origin are nutritionally superior to that of animal origin (Singh, 2000). It is not only a high energy food but also a carrier of fat soluble vitamins including vitamin A, D, E and K in the body. In Bangladesh it is an important source of cooking oil that meet the one third of edible oil requirement of the country (Ahmed, 2008).

Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka are the major mustard growing districts of Bangladesh (BBS, 2011). Bangladesh has been facing acute shortage of edible oil for the last several decades. For that it needs to import oil and oilseeds to meet up the deficit of edible oil. Our internal production can meet only about 21% of our consumption which can meet only a fraction of the cooking oil, requirement of the country and the rest 79% is needed to import (Begum *et al.,* 2012). Due to insufficient oil production, a huge amount of foreign exchange involving over 160 million US$ is being spent every year for importing edible oils in Bangladesh (Rahman, 2002). Mustard seed contains about 40-45% oil and by increasing production of mustard we can meet the shortage of edible oil. The average yield of mustard (1,087 kg ha^{-1}) in our country 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}, 3,076 kg ha^{-1}, respectively. At present the world average yield of mustard is 1,575 kg ha^{-1} (FAO, 2012).

Mustard is the principal oil crop in Bangladesh. Other than 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 good manure. 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 we are loosing in an area of 104,000 hectare and production 68,000 tons of mustard and rapeseed in last ten years (Anon., 2006).

In farmer's field average yield of mustard is much lower due to lack of improved agricultural techniques of which different bioregulators application is an important determinant for better performance of mustard. Plant growth regulators (PGR's) 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). Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimate enhance productivity of the crops (Solaimani *et al.,* 2001). Reports so far been made to indicate a promising results on yield of mustard and other oil crops due to the use of bio-chemical substances or hormone such as Salicylic acid, Gibberelic acid (GA_3), Kinetin etc.

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 movement, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al.*, 2003 and Shakirove *et al.*, 2003). Foliar application of salicylic acid exerted a significant effect on plant growth

metabolism when applied at physiological concentration (Kalarani *et al*., 2002). Salicylic acid increased the number of flowers, pods/plant and seed yield of mustard (Gutierrez-Coronado *et al*., 1998). It also plays a significant role in plant water relations (Barkosky and Einhelling, 1993), photosynthesis, growth and stomatal regulation under abiotic stress conditions (Khan *et al*., 2003; Arfan *et al*., 2007). Therefore, it is suggesting that salicylic acid improve morphology, development and yield of mustard. However, to my knowledge no study has elucidated whether exogenous salicylic acid improves morphology, development and yield of mustard.

It is well known that variety plays an important role in producing high yield of mustard because different varieties perform differently for their genotypic characters. 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 by the Sher-e-Bangla Agricultural University (SAU), Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA). Yield contributing characters and yield of different variety varied significantly (Mamun *et al*., 2014, BARI, 2001). The yield of mustard in Bangladesh has been increased obviously with the introduction of high yielding varieties and improvement of management practices as well as application of plant growth regulators.

Under the above perspective and above all situation the present experiment was conducted to find out the morphological change and seed yield of different mustard varieties by the effect of salicylic acid with the following specific objectives-

- To study the individual effects of variety and salicylic acid regulation of morphological characters and seed yield of mustard.;
- To find out the interaction effect between different mustard variety and different levels of salicylic acid on change of morphology and seed yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oil seed crop in Bangladesh and as well as many countries of the world although the crop has conventional less attention by the researchers on various aspects because normally it grows without or minimum care or management practices. Based on this a very few research works related to morphological changes and yield of mustard have been carried out in our country. However, research works are pursued by scientist in home and abroad to maximize the yield of mustard. Salicylic acid and variety play an important role in improving mustard yield. But research works related to application of salicylic acid and variety of mustard are limited in Bangladesh context. However, some of the important and informative works and research findings related to the salicylic acid and variety so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of different varieties

2.1.1 Plant height

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels (0, 2, 4, 6, 8 and 10 kg Zn ha^{-1}) and reported that S-9 ranked 1^{st} with 216.50 cm plant height, while variety Early Mustard resulted 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 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 per 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.

2.1.2 Number of branches plant^{-1}

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels(0, 2, 4, 6, 8 and 10 kg Zn ha^{-1}) and reported that S-9 ranked 1st with 10.84 branches plant^{-1}, while variety Early Mustard resulted 9.25 branches plant^{-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 branches plant^{-1} (6.14).

BARI (2000) reported that under poor management number of branch plant^{-1} was higher (4.2) in the variety SS-75 and lower (2.1) in the variety BARI Sarisha-8. Under medium management, best performance was Dhali (5.5) and worst

performance was BARI Sarisha-8. Under higher management, highest was in Dhali (5.9) and lowest in (3.0) Nap-248.

Jahan and Zakaria (1997) found that the local varieties Tori and Rapseed produced the highest number of primary branches plant^{-1} (4.07). The minimum number of primary branches plant^{-1} (2.90) was found in Jatarai which was identical to those found in Hyola-401 and BARI Sarisha-8 varieties.

Hussain *et al.* (1996) reported that the varieties were statistically different with respect to number of primary branches plant^{-1}. The maximum number of primary branches was recorded in the Hyola-401 (5.0) and the minimum number was recorded in Semu-249/84.

Khaleque (1989) observed 3.9 and 3.1 branches plant^{-1} in TS-72 and Sonali sarisha, respectively.

2.1.3 Days to flowering

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 produced early flower than the others.

BARI (2001) concluded that there was significant variation of days to flowering of mustard found in different varieties and highest days to flowering (32 days) was found in Jamalpur-1 variety and lowest in BARI Sarisha-10.

Karim *et al.* (2000) stated that varieties showed significant influence in days to flowering. They found maximum days to flowering in J-3023 variety.

2.1.4 Number of siliqua plant^{-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 siliqua plant^{-1} (126.90).

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels(0, 2, 4, 6, 8 and 10 kg Zn ha^{-1}) and reported that S-9 ranked 1st with 581.11 pods plant^{-1}, while variety Early Mustard resulted 484.67 pods plant^{-1}.

Pooran *et al.* (2000) found the highest number of siliqua plant^{-1} (180) in GM-1. Jahan and Zakaria (1997) reported that in case of number of siliqua plant^{-1}, the highest number was recorded in BLN-900 (130.9) which was identical to Dhali (126.3). Tori-7 had the lowest (46.3) number of siliqua per plant.

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.

Mondal *et al.* (1992) obtained maximum number of siliquas plant^{-1} (136) in the variety J-5004, which was identical with the variety Tori-7. The lowest number of siliqua plant^{-1} (45.9) was found in the variety SS-75.

2.1.5 Siliqua length

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 sharisha-8, BARI sharisha-9 and BARI sharisha-11. BARI sharisha-11 and BARI sharisha-8 performed better in terms of siliqua length.

BARI (1999) reported that varieties had significant variation in 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.

2.1.6 Number of seeds siliqua^{-1}

Laxminarayana and Pooranchand (2000) found no significant variations in seeds siliqua^{-1} among the cultivars. Das *et al.* (1999) reported that MM 7 (Mutant) produced the highest number of seeds siliqua^{-1} (29.2) followed by MM 20 (Mutant) (28.0) and BINA sarisha-4 (27.8) at Dinajpur.

Hussain *et al.* (1996) stated that there were significant differences among the varieties in respect of number of seeds siliqua^{-1}. The maximum number of seeds siliqua^{-1} was produced in the hybrid BLN-900 (29.5) and the minimum number was recorded in Tori-7 as well as in Semu-249/84.

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 seeds siliqua^{-1} (25.36).

Mondal *et al.* (1992) found highest number of seeds siliqua^{-1} (27.6) in SS-75 which was significantly different from all other varieties. The lowest number of seeds siliqua^{-1} (13.8) was found in J-5004.

2.1.7 1000 seed weight

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 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 Jamalpur-1 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).

Hussain *et al.* (1998) observed significant variation in case of 1000-seed weight as influenced by different varieties. They found Hyola-401 had the highest 1000-seed weight (3.4 g) and the lowest 1000-seed weight was recorded in Tori-7 (2.1 g) among the mustard variety. Jahan and Zakaria (1997) found variation in 1000-seed weight and the highest weight was in the variety BCN-900 (3.37 g) and the lowest in Tori-7 (2.27 g).

2.1.8 Seed yield

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 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.

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}).

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).*

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.

2.1.9 Stover yield

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 recorded 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.

2.1.10 Harvest index

Islam *et al.* (1994) showed that varieties had significant effect on harvest index of mustard. They found highest harvest index in variety TS-72 which was identical to Daulat and lowest in Sonali sarisha (21.9%) followed by Sambal (26.7%).

Bhargava and Tomer (1982) analyzed the biomass production of harvest index and yield of four *Brassica* genotypes. They noticed variation in harvest index varies from 27 to 40 percent with maximum in early maturing mustard.

Mendham *et al.* (1981) stated that a low harvest index of rapeseed might be due to excessive siliqua and seed losses during flowering.

2.2 Effect of salicylic acid on changes of morphology and yield of mustard

2.2.1 Plant height

A field experiment was conducted by Muhal *et al.* (2014) to evaluate the effect of planting duration and salicylic acid application on yield, quality and nutrient uptake of *Brassica* species. The result revealed that foliar application of salicylic acid produced significantly longest plant at different days after sowing compared to water spray.

Field study was 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 as well as plant height of mustard compared to the application of water.

2.2.2 Days to maturity

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.

2.2.3 Number of siliqua plant^{-1}

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 recorded that 100 ppm SA foliar spray registered significantly higher number of siliqua per plant compared to water spray.

Field study was 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 yield attributes particularly number of siliqua on main shoot.

2.2.4 Number of seeds siliqua^{-1}

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 seeds siliqua^{-1} was significantly higher under 100 ppm SA foliar spray compared to water spray.

Field study was 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 yield attributes and total number of seeds per siliqua improved by 3.2% over the unsprayed control.

2.2.5 Thousand seed weight

Field study was 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 yield attributes and SA spray increased 1000 seed weight in NRCDR-2, Varuna and RH-10 than the others genotypes.

2.2.6 Seed yield

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 recorded that 100 ppm SA foliar spray registered significantly higher seed yield basis compared to water spray.

A field experiment was conducted by Muhal *et al.* (2014) to evaluate the effect of planting duration and salicylic acid application on yield, quality and nutrient uptake of *Brassica* species. The result revealed that foliar application of salicylic acid produced significantly higher seed yield compared to water spray.

Field study was 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 RB-10 and NPJ-93 followed by CS-1900-2 registered higher seed yield with SA during the two years of study.

As per the above cited reviews, it may be concluded that variety and salicylic acid are the important factors for attaining optimum growth and as well as highest yield 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 find out the morphological change and seed yield of mustard by the effect of salicylic acid. 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 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 of two factors

Factor A: Different mustard varieties (5 varieties)

i) V_1: Tori 7

ii) V_2: BARI Sarisha 13

iii) V_3: BARI Sarisha 14

iv) V_4: BARI Sarisha 15

v) V_5: BARI Sarisha 16

Factors B: 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

There were in total 15 (3×5) treatment combinations such as V_1S_0, V_2S_0, V_3S_0, V_4S_0, V_5S_0, V_1S_1, V_2S_1, V_3S_1, V_4S_1, V_5S_1, V_1S_2, V_2S_2, V_3S_2, V_4S_2 and V_5S_2.

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 plot 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

Tori 7, BARI Sarisha 13, BARI Sarisha 14, BARI Sarisha 15 and BARI Sarisha 16, were used as plating materials in this experiment. All of these high yielding varieties of mustard 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

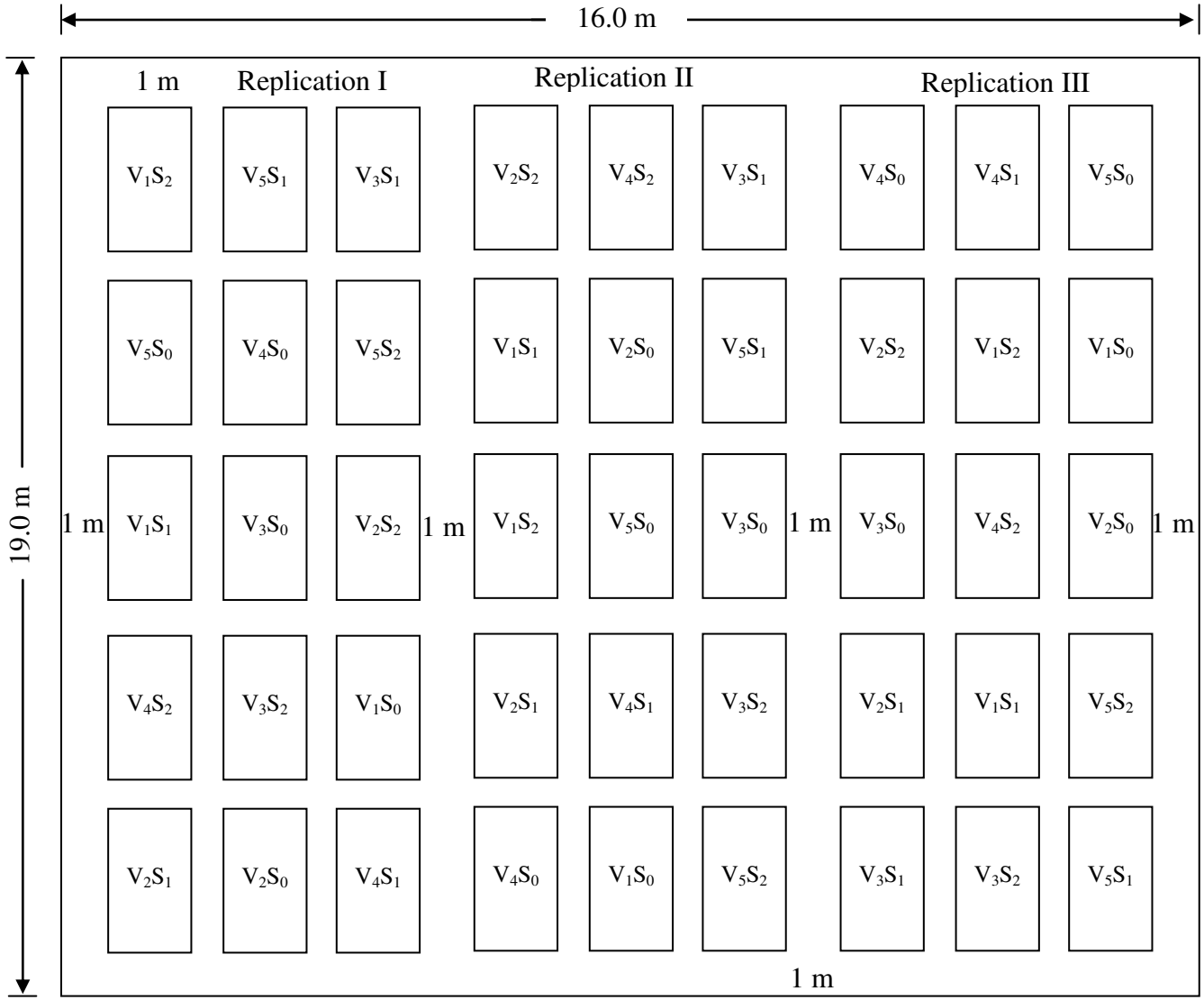
Salicylic acid collected from Merck India. Three levels of salicylic acid S_0: 0 mM SA (control), S_1: 0.2 mM SA, S_2: 0.4 mM of SA. 0.03 gm SA was dissolved in 1 liter of water to make 0.2mM SA and .06 gm SA was dissolved in 1 liter of water to make 0.4mM of SA. Tween-20 detergent was used as surfactant to prevent dropout of salicylic acid solution from leaves and it was applied as treatment combinations at 20, 30, 40 days after sowing (DAS) by a sprayer.

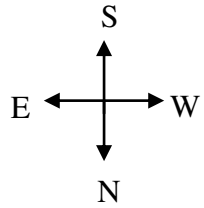
3.3.3 Land preparation

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 25th 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 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 of urea fertilizer were applied at 25 and 45 DAS, respectively.





Plot size = 2.0 m × 1.0 m

Plot spacing = 0.5 m

Between replication= 1.0 m

Factor A: Different mustard varieties (5 varieties)

i) V_1: Tori 7

ii) V_2: BARI Sarisha 13

iii) V_3: BARI Sarisha 14

iv) V_4: BARI Sarisha 15

v) V_5: BARI Sarisha 16

Factors B: 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

Figure 1. Layout of the experimental plot

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 germination started after four different 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 as per the treatment of plant density.

3.3.6.2 Irrigation and weeding

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

3.3.6.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plants. Ripcord 10 EC was sprayed at the rate of 1 ml with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.4 Crop sampling and data collection

Five plants from each treatment and each replication were randomly selected and marked with sample card. Plant height and branches plant^{-1} was recorded from selected plants at an interval of 10 days started from 30 DAS to 50 DAS and at harvest and other parameters were recorded during harvest and post harvest operations.

3.5 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.

3.6 Data collection

The following data were recorded

i. Plant height(cm)

ii. Number of branches per plant

iii. Transpirational water loss (%)

iv. Days required to flowering(d)

v. Days required to harvest(d)

vi. Number of siliqua per plant

vii. Length of siliqua (cm)

viii. Number of seeds per siliqua

ix. Weight of 1000 seeds(g)

x. Seed yield per plot(g)

xi. Stover yield per plot(g)

xii. Seed yield per hectare(ton)

xiii. Stover yield per hectare(tha^{-1})

xiv. Biological yield per hectare(tha^{-1})

xv. Harvest index (%)

3.7 Procedure of data collection

3.7.1 Plant height(cm)

The plant height was measured at 30, 40, 50 DAS and 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 per plant

The number of branches per plant was counted at 30, 40, 50 DAS and at harvest from selected plants. The average number of branches per plant was determined and recorded.

3.7.3 Transpirational water loss(%)

Five younger leaves were collected from each plot initial weight was taken and kept in a clean and dry place. After 30, 60, 90 and 120 minutes moisture loss was calculated and recorded.

$$TWL = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.7.4 Days to 1st flowering

Days to 1st flowering were recorded by counting the number of days required to start flower initiation of mustard plant in each plot.

3.7.5 Days to harvest

Days to harvest were recorded by counting the number of days required to harvest of mustard plant in each plot.

3.7.6 Dry matter content per plant

After harvesting, five plant samples were put into envelop and placed in oven maintained at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and it was recorded as dry matter content per plant.

3.7.7 Number of siliqua per plant

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as per plant basis. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.7.8 Length of siliqua

Length of siliqua was taken from randomly selected ten siliqua and the mean length was expressed on per siliqua basis.

3.7.9 Number of seeds per siliqua

The number of seeds per siliqua was recorded from randomly selected 10 siliqua at the time of harvest. Data were recorded as the average and express in sedds per siliqua.

3.7.10 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).

3.7.11 Seed yield per plot

The seeds collected from 2 (2 m × 1 m) square meter area of each plot were sun dried properly, weighted and data were recorded seed yield of gm/plot.

3.7.12 Stover yield per plot

The stover collected from 2 (2 m × 1 m) square meter area of each plot was sun dried properly, weighted and data were recorded stover yield of gm/plot.

3.7.13 Seed yield per hectare(ton)

The seeds yield of each plot were converted into yield per hectare and express in seed yield of t/ha.

3.7.14 Stover yield per hectare(tha^{-1})

The stover yield of each plot were converted into yield per hectare and express in stover yield of t/ha.

3.7.15 Biological yield (tha^{-1})

Grain yield and stover yield together were regarded as biological yield of mustard. The biological yield was calculated with the following formula:

Biological yield (t/ha) = Grain yield + Stover yield

3.7.16 Harvest index

Harvest index was calculated from the seed and stover yield of mustard and expressed in percentage.

$$HI = \frac{\text{Economic yield (seed weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the morphophysiology and seed yield with or without salicylic acid. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test 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).

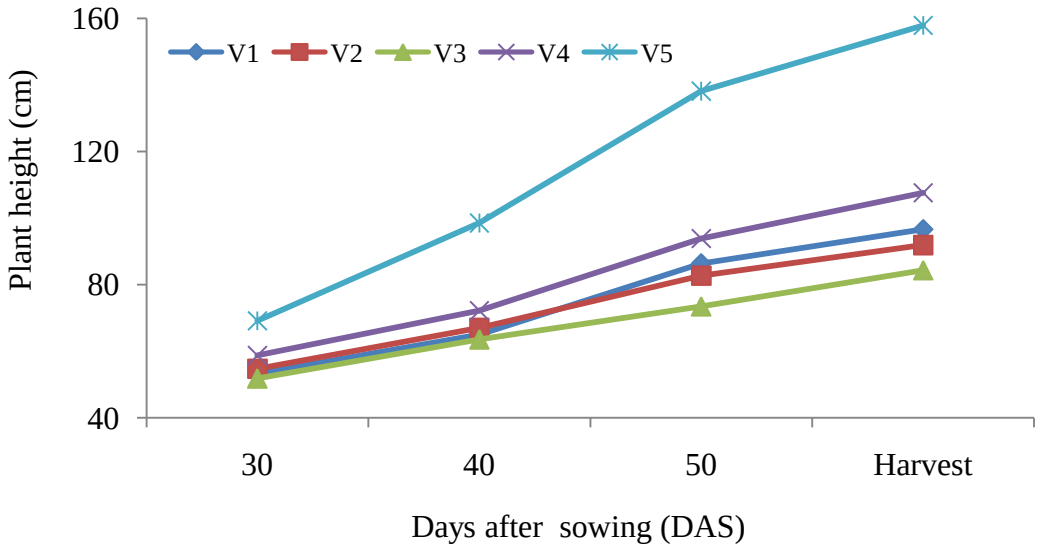
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the morphophysiology and seed yield with or without salicylic acid. The analyses of variance (ANOVA) of the data on different morphological characters, yield contributing parameters and yield are presented in Appendix III-VII. The results have been presented and discussed in the different tables and graphs and possible interpretations given under the following headings:

4.1 Plant height

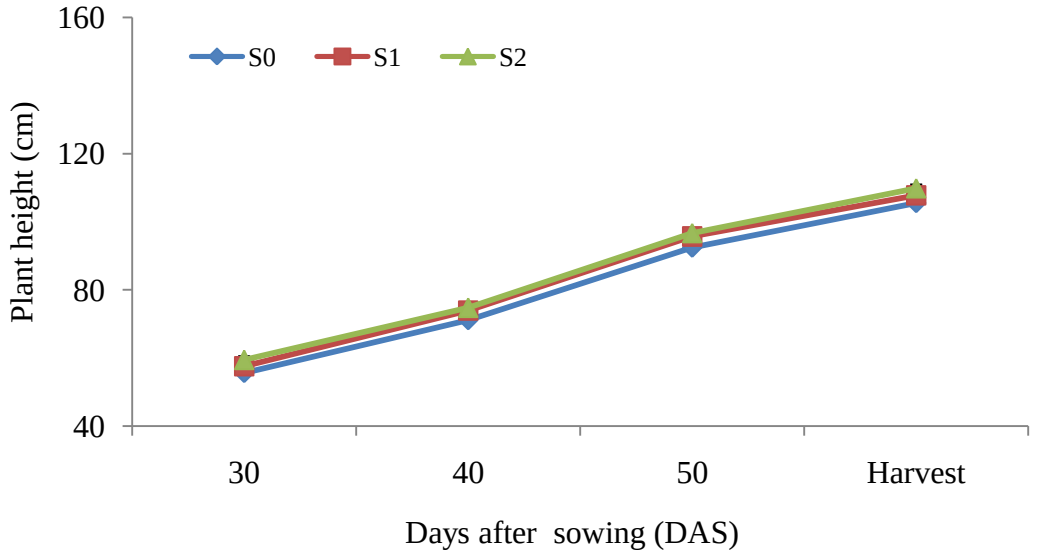
Plant height at 30, 40, 50 days after sowing (DAS) and at harvest showed statistically significant variation due to different mustard varieties under the present trial (Appendix III). The tallest plant (69.17, 98.54, 138.16 and 157.87 cm, respectively) was observed from V_5 (BARI Sarisha 16), which was followed (58.77, 72.20, 93.86 and 107.66 cm, respectively) by V_4 (BARI Sarisha 15), while the shortest plant (51.84, 63.55, 73.52 and 84.40 cm, respectively) was recorded from V_3 (BARI Sarisha 14) which was statistically similar (53.29, 65.04, 82.76 and 91.92 cm, respectively) to V_2 (BARI Sarisha 13) and followed (54.78, 67.10, 86.35 and 96.69 cm, respectively) by V_1 (Tori 7) at 30, 40, 50, DAS and at harvest, respectively (Figure 2). Different varieties produced different plant height based on their varietal characters but environmental and management factor also influences plant height also. 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.



V_1: Tori 7 V_2: BARI Sarisha 13 V_3: BARI Sarisha 14

V_4: BARI Sarisha 15 V_5 BARI Sarisha 16

Figure 2. Effect of different variety on plant height of mustard. ($LSD_{0.05}$ = 3.399, 3.716, 4.193 and 4.397 at 30, 40, 50 DAS and harvest, respectively)



S_0: 0 mM SA S_1: 0.2 mM SA

S_2: 0.4 mM SA

Figure 3. Effect of salicylic acid on plant height of mustard. ($LSD_{0.05}$ = 2.633, 2.879, 3.248 and 3.406 at 30, 40, 50 DAS and harvest, respectively)

Statistically significant variation was recorded in terms of plant height of mustard at 30, 40, 50 DAS and at harvest due to different levels of salicylic acid (SA) (Appendix III). The tallest plant (59.46, 74.74, 96.66 and 109.85 cm, respectively) was recorded from S_2 (0.4 mM SA) which was statistically similar (57.61, 73.96, 95.71 and 107.78 cm, respectively) to S_1 (0.2 mM SA), whereas the shortest plant (55.64, 71.16, 92.41 and 105.49 cm, respectively) was found from S_0 (0 mM SA i.e. control condition) at 30, 40, 50 DAS and at harvest, respectively (Figure 3). Data revealed that with the application of salicylic acid plant height showed an increasing trend. Muhal *et al.* (2014) reported that foliar application of salicylic acid produced significantly longest plant at different days after sowing compared to water spray plays a significant role in photosynthesis and growth of plant that leads to the production of longest plant as well as vegetative growth. Sharma *et al.* (2013) revealed that foliar application of SA improved growth parameters as well as plant height of mustard compared to the application of water.

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on plant height at 30, 40, 50, DAS and at harvest (Appendix III). At 30, 40, 50 DAS and at harvest, the tallest plant (74.95, 102.90, 143.57 and 160.00 cm, respectively) was found from V_5S_2 (BARI Sarisha 16 with 0.4 mM SA), while the shortest plant (48.10, 57.24, 72.27 and 81.77 cm, respectively) was recorded from V_3S_0 (BARI Sarisha 14 with 0 mM SA i.e. control) treatment combination (Table 1).

4.2 Number of branches per plant

Different mustard varieties showed significant variation in terms of number of branches per plant at 30, 40, 50 DAS and at harvest (Appendix IV). The maximum number of branches per plant (6.00, 7.18, 8.41 and 8.41, respectively) was found from V_5, which was statistically similar (5.56, 7.07, 7.92 and 8.22, respectively) to V_2. On the other hand, the minimum number of branches per plant (4.18, 4.85, 5.48 and 6.19, respectively) was observed from V_1 at 30, 40, 50 DAS and at harvest, respectively (Figure 4). Mamun *et al.* (2014) reported that BARI Sarisha-13 performed well in terms of branches plant^{-1} (6.14).

Table 1. Interaction effect of variety and salicylic acid on plant height of mustard

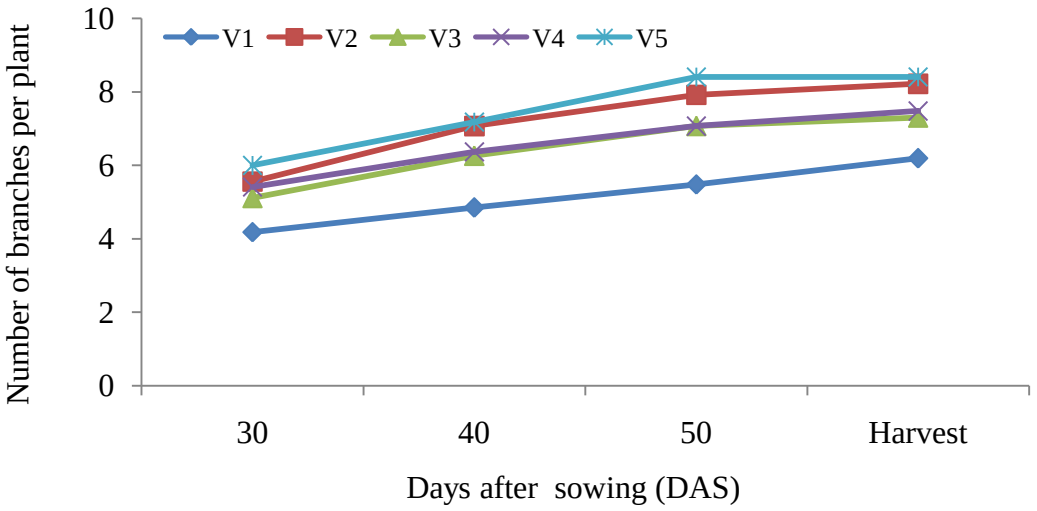
Treatment	Plant height (cm) at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1S_0	51.83 ef	62.51 ef	88.33 de	97.85 de
V_1S_1	54.45 d-f	67.61 de	87.35 de	94.77 d-f
V_1S_2	53.60 ef	65.00 e	83.37 d-f	97.44 de
V_2S_0	60.67 cd	75.00 c	80.35 ef	92.99 d-f
V_2S_1	55.26 de	69.06 c-e	83.93 de	89.34 e-g
V_2S_2	60.38 cd	72.55 cd	84.01 de	93.44 d-f
V_3S_0	48.10 f	57.24 f	72.27 g	81.77 g
V_3S_1	54.84 d-f	67.95 de	75.81 fg	88.57 fg
V_3S_2	52.59 ef	65.47 de	72.48 g	82.85 g
V_4S_0	53.97 d-f	65.90 de	90.22 d	99.67 d
V_4S_1	54.58 d-f	67.61 de	91.48 d	107.77 c
V_4S_2	55.79 de	67.80 de	99.87 c	115.53 b
V_5S_0	63.64 bc	95.15 b	130.90 b	155.17 a
V_5S_1	68.92 b	97.57 ab	140.00 a	158.43 a
V_5S_2	74.95 a	102.90 a	143.57 a	160.00 a
$LSD_{(0.05)}$	5.887	6.437	7.263	7.616
Level of significance	*	*	*	*
CV(%)	6.11	5.25	4.57	4.23

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

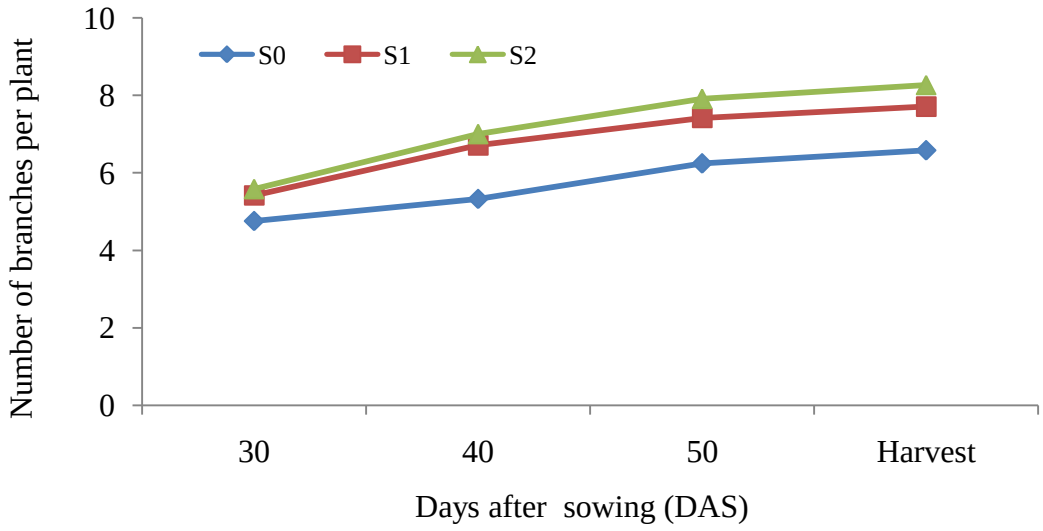
* Significant at 0.05 level of significance



V_1: Tori 7 V_2: BARI Sarisha-13 V_3: BARI Sarisha-14

V_4: BARI Sarisha-15 V_5 BARI Sarisha-16

Figure 4. Effect of different variety on number of branches per plant of mustard. ($LSD_{0.05}$ = 0.587, 0.591, 0.584 and 0.614 at 30, 40, 50 DAS and harvest, respectively)



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

S_2: 0.4 mM SA

Figure 5. Effect of salicylic acid on number of branches per plant of mustard. ($LSD_{0.05}$ = 0.455, 0.458, 0.453 and 0.475 at 30, 40, 50 DAS and harvest, respectively)

Number of branches per plant of mustard at 30, 40, 50 DAS and harvest showed statistically significant variation due to different levels of salicylic acid (Appendix IV). The maximum number of branches per plant (5.58, 7.00, 7.91 and 8.27, respectively) was observed from S_2 which was statistically similar (5.42, 6.71, 7.42 and 7.71, respectively) to S_1, while the minimum number of branches per plant (4.76, 5.33, 6.24 and 6.58, respectively) was recorded from S_0 at 30, 40, 50 DAS and at harvest, respectively (Table 1).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on number of branches per plant at 30, 40, 50, DAS and at harvest (Appendix IV). At 30, 40, 50 DAS and at harvest, the maximum number of branches per plant (6.89, 8.67, 9.45 and 9.56 respectively) was recorded from V_5S_2 and the minimum number of branches per plant (3.67, 4.34, 4.67 and 5.56, respectively) was observed from V_1S_0 treatment combination (Table 2).

4.3 Transpirational water loss(%)

Different mustard varieties showed significant variation in terms of transpirational water loss from leaf of mustard after 30, 60, 90 and 120 minutes (Appendix V). The lowest losses (11.34%, 5.92%, 3.58% and 1.99%, respectively) was found from V_5, whereas the highest losses (15.62%, 7.91%, 5.08% and 2.77%, respectively) was observed from V_1 after 30, 60, 90 and 120 minutes, respectively (Table 3).

Statistically significant variation was recorded in terms of moisture loss from leaf of mustard after 30, 60, 90 and 120 minutes due to different levels of salicylic acid (Appendix V). The lowest losses of water from leaf (13.26%, 6.89%, 4.08% and 2.05%, respectively) was observed from S_2 which was statistically similar (14.02%, 7.26%, 4.25% and 2.30%, respectively) to S_1. On the other hand, the highest losses (14.90%, 7.79%, 4.90% and 3.14%, respectively) from S_0 after 30, 60, 90 and 120 minutes, respectively (Table 3). Barkosky and Einhelling (1993) reported that salicylic acid plays a significant role in plant water relations.

Table 2. Interaction effect of variety and salicylic acid on number of branches per plant of mustard

Treatment	Number of branches/plant at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1S_0	3.67 f	4.34 h	4.67 f	5.56 e
V_1S_1	4.78 de	5.56 e-g	6.11 de	6.67 de
V_1S_2	4.11 ef	4.67 gh	5.67 ef	6.33 e
V_2S_0	5.33 b-d	6.89 cd	7.55 c	7.89 c
V_2S_1	5.22 b-e	6.44 d-f	7.33 c	7.67 cd
V_2S_2	6.11 a-c	7.89 a-c	8.89 ab	9.11 ab
V_3S_0	5.00 c-e	5.44 f-h	6.11 de	6.33 e
V_3S_1	5.67 b-d	6.78 cd	7.56 c	7.55 cd
V_3S_2	4.67 d-f	6.56 de	7.56 c	8.00 bc
V_4S_0	4.89 de	5.22 gh	6.00 de	6.56 de
V_4S_1	5.22 b-e	6.67 de	7.22 c	7.56 cd
V_4S_2	6.11 a-c	7.22 b-d	8.00 bc	8.33 bc
V_5S_0	4.89 de	4.78 gh	6.89 cd	6.56 de
V_5S_1	6.22 ab	8.11 ab	8.89 ab	9.11 ab
V_5S_2	6.89 a	8.67 a	9.45 a	9.56 a
$LSD_{(0.05)}$	1.017	1.024	1.012	1.063
Level of significance	*	**	*	*
CV(%)	11.58	9.65	8.41	8.46

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

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

Table 3. Effect of variety and salicylic acid on transpirational water loss(%) from leaf of mustard

Treatment	Moisture loss (%)			
	After 30 minutes	After 60 minutes	After 90 minutes	After 120 minutes
Mustard variety				
V_1	15.62 a	7.91 a	5.08 a	2.77 a
V_2	15.25 ab	7.87 a	4.69 ab	2.55 b
V_3	13.94 b	7.21 a	4.26 b	2.51 b
V_4	14.15 b	7.66 a	4.44 b	2.66 ab
V_5	11.34 c	5.92 b	3.58 c	1.99 c
$LSD_{(0.05)}$	1.281	0.749	0.431	0.173
Level of significance	0.01	0.01	0.01	0.01
Levels of salicylic acid				
S_0	14.90 a	7.79 a	4.90 a	3.14 a
S_1	14.02 ab	7.26 ab	4.25 b	2.30 b
S_2	13.26 b	6.89 b	4.08 b	2.05 c
$LSD_{(0.05)}$	0.992	0.580	0.334	0.134
Level of significance	0.01	0.01	0.01	0.01
CV(%)	9.43	10.60	10.11	7.17

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on moisture loss from leaf of mustard after 30, 60, 90 and 120 minutes, respectively (Appendix V). After 30, 60, 90 and 120 minutes, the lowest losses of moisture (10.50%, 5.17%, 3.06% and 1.43%, respectively) was obtained from V_5S_2, while the highest losses (17.82%, 8.83%, 5.63% and 3.38%, respectively) was found from V_2S_0 treatment combination (Table 4).

4.4 Days required to flowering

Different mustard varieties showed significant variation in terms of days required to flowering (Appendix VI). The minimum days required to flowering (31.67) was recorded from V_4, which was statistically similar (31.78 and 33.00) to V_3 and V_2, while the maximum days (38.22) was obtained from V_5 (Figure 6). BARI (2001) reported the highest days to flowering (32 days) was found in Jamalpur-1 variety and lowest in BARI Sarisha-10.

Days required to flowering of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The minimum days required to flowering (32.87) was found from S_2 which was statistically similar (33.80) to S_1 and the maximum days to flowering (35.00) was recorded from S_0 (Figure 7).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on days required to flowering (Appendix VI). The minimum days required to flowering (30.00) was observed from V_4S_2 and the maximum days required to flowering (39.33) was found from V_5S_0 treatment combination (Figure 8).

4.5 Days required to harvest

Different mustard varieties showed significant variation in terms of days required to harvest (Appendix VI). The minimum days required to harvest (78.44) was observed from V_4, which was statistically similar (79.00) to V_3, while the maximum days required to harvest (108.33) was recorded from V_5 (Figure 6).

Table 4. Interaction effect of variety and salicylic acid on transpirational water loss(%) from leaf of mustard

Treatment	Moisture loss (%)			
	After 30 minutes	After 60 minutes	After 90 minutes	After 120 minutes
V_1S_0	14.54 b-e	7.30 bc	4.88 a-c	3.19 a
V_1S_1	15.84 a-c	8.17 ab	5.06 ab	2.67 b
V_1S_2	16.48 ab	8.27 ab	5.29 a	2.45 bc
V_2S_0	17.82 a	8.83 a	5.63 a	3.38 a
V_2S_1	14.78 b-d	7.44 a-c	4.22 b-e	2.24 cd
V_2S_2	13.17 d-g	7.33 a-c	4.21 b-e	2.03 de
V_3S_0	15.19 b-d	8.10 ab	4.88 a-c	3.11 a
V_3S_1	14.39 b-f	7.53 ab	4.35 b-d	2.40 bc
V_3S_2	12.24 e-h	5.99 c-e	3.56 d-f	2.04 de
V_4S_0	14.96 b-d	7.93 ab	4.88 a-c	3.35 a
V_4S_1	13.54 c-g	7.37 a-c	4.15 c-e	2.33 cd
V_4S_2	13.94 b-g	7.67 ab	4.28 b-e	2.30 cd
V_5S_0	11.99 f-h	6.80 b-d	4.22 b-e	2.69 b
V_5S_1	11.53 gh	5.80 de	3.47 ef	1.83 e
V_5S_2	10.50 h	5.17 e	3.06 f	1.43 f
$LSD_{(0.05)}$	2.219	1.297	0.746	0.299
Level of significance	0.05	0.05	0.01	0.05
CV(%)	9.43	10.60	10.11	7.17

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

V_1: Tori 7
V_2: BARI Sarisha -13
V_3: BARI Sarisha -14
V_4: BARI Sarisha -15
V_5: BARI Sarisha -16

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

Days required to harvest of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The minimum days required to harvest (89.53) was observed from S_2 which was statistically similar (90.67) to S_1, whereas the maximum days required to harvest (95.00) from S_0 (Figure 11). Muhal and Solanki (2015) reported that number of days taken to attain physiological maturity was significantly higher under 100 ppm SA foliar spray compared to water spray.

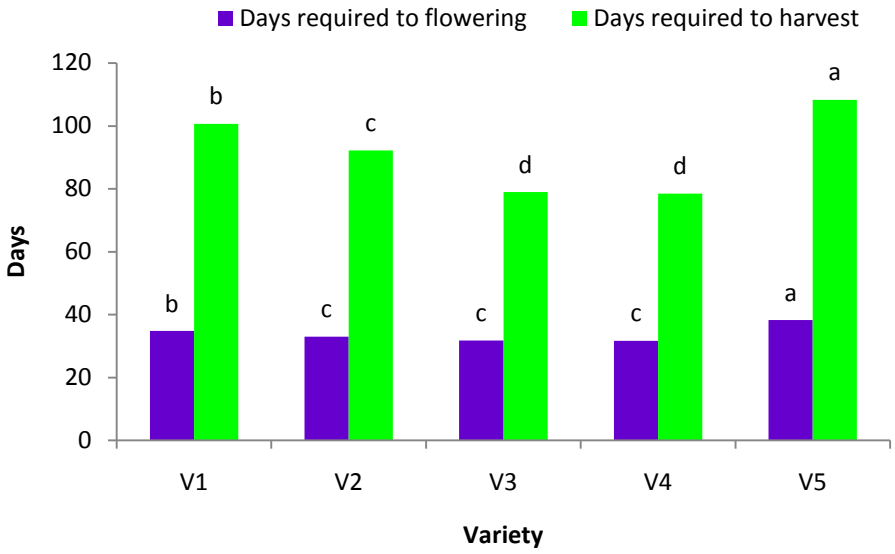
Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on days required to harvest (Appendix VI). The minimum days required to harvest (76.00) was found from V_4S_1, whereas the maximum days (112.67) was recorded from V_5S_0 treatment combination (Figure 12).

4.6 Number of siliqua per plant

Different mustard varieties showed significant variation in terms of number of siliqua per plant (Appendix VI). The highest number of siliqua per plant (185.23) was observed from V_5, which was followed (105.62) by V_1, whereas the lowest number of siliqua per plant (85.00) was obtained from V_2 (Table 3). 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 per plant of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The highest number of siliqua per plant (113.88) was found from S_2 which was statistically similar (112.49) to S_1, while the lowest number (107.78) was recorded from S_0 (Table 3). Muhal and Solanki (2015) reported that 100 ppm SA foliar spray registered significantly higher number of siliqua per plant compared to water spray.

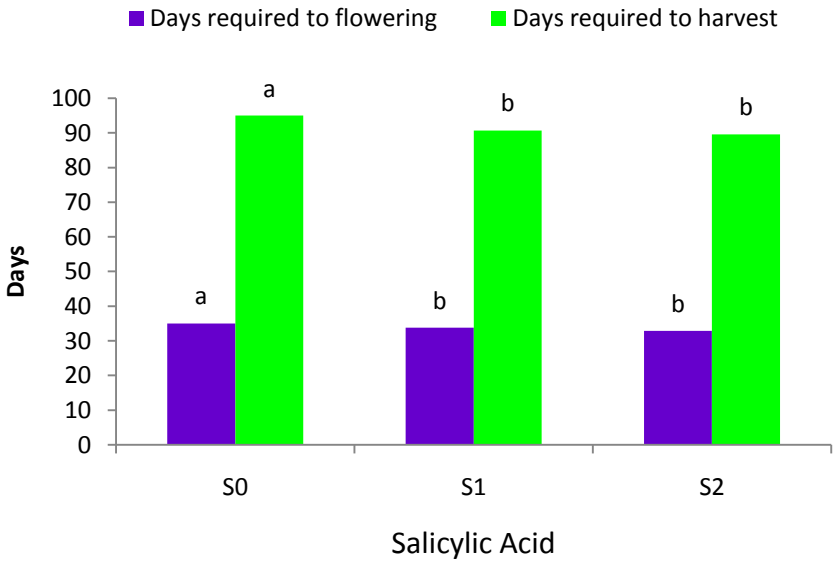
Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on number of siliqua per plant (Appendix VI). The highest



V_1: Tori 7 V_2: BARI Sarisha 13 V_3: BARI Sarisha 14

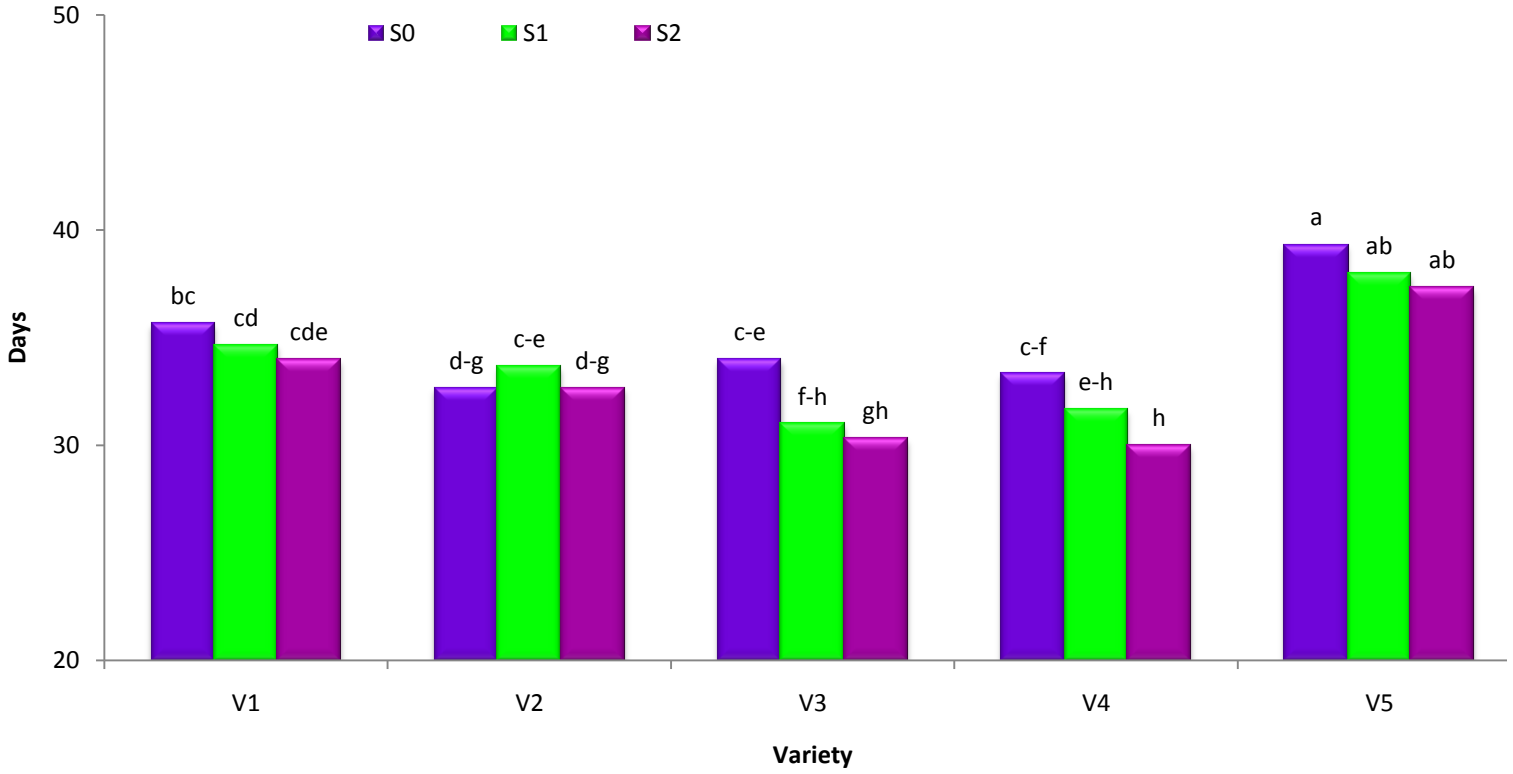
V_4: BARI Sarisha 15 V_5 BARI Sarisha 16

Figure 6. Effect of different variety on Days required to flowering & harvest of mustard. (LSD= 1.354 and 2.826)



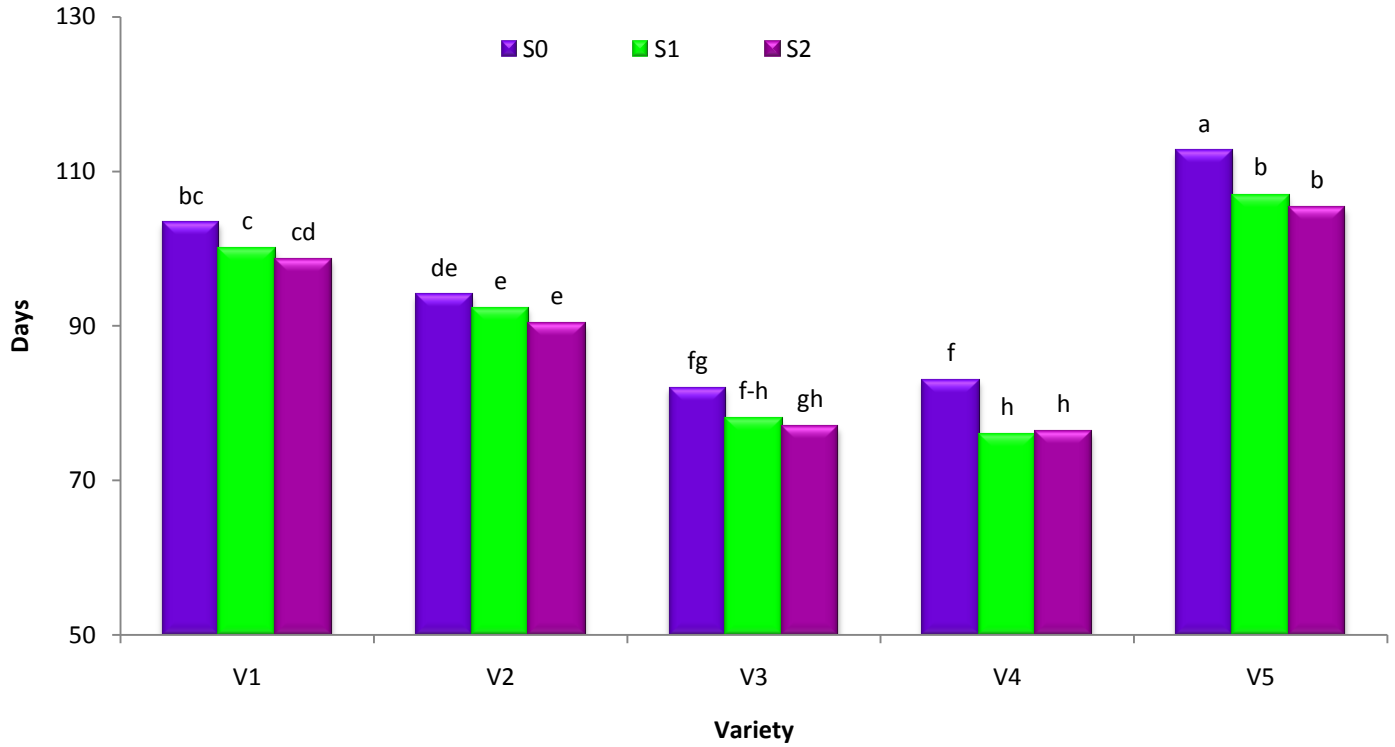
S_0: 0 mM SA S_1: 0.2 mM SA S_2: 0.4 mM SA

Figure 7. Effect of salicytlic acid on Days required to flowering & harvest of mustard. (LSD= 1.048 and 2.189)



V_1: Tori 7 V_2: BARI Sarisha 13 V_3: BARI Sarisha 14 V_4: BARI Sarisha 15 V_5 BARI Sarisha 16

Figure 8.Interaction effect of variety and salicylic acid on Days required to flowering of mustard. (LSD= 2.345)



V_1: Tori 7 V_2: BARI Sarisha 13 V_3: BARI Sarisha 14 V_4: BARI Sarisha 15 V_5 BARI Sarisha 16

Figure 9.Interaction effect of variety and salicylic acid on Days required to harvestingof mustard. (LSD= 4.895)

number of siliqua per plant (192.23) was observed from V_5S_2 and the lowest number of siliqua per plant (73.33) was recorded from V_4S_0 treatment combination (Table 5).

4.7 Length of siliqua (cm)

Different mustard varieties showed significant variation in terms of length of siliqua (Appendix VI). The highest length of siliqua (6.89 cm) was observed from V_2, which was statistically similar (6.62 cm) to V_5 and closely followed (6.00 cm and 5.46 cm) by V_4 and V_3 and they were statistically similar, while the lowest length of siliqua (4.62 cm) was recorded from V_1 (Table 5). 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 of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The highest length of siliqua (6.16 cm) was recorded from S_2 which was statistically similar (6.02 cm) to S_1 and the lowest length of siliqua (5.58 cm) was found from S_0 (Table 5).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on length of siliqua (Appendix VI). The highest length of siliqua (7.33 cm) was found from V_2S_2, whereas the lowest length of siliqua (4.29 cm) was recorded from V_1S_0 treatment combination (Table 6).

4.8 Number of seeds per siliqua

Different mustard varieties showed significant variation in terms of number of seeds per siliqua (Appendix VI). The highest number of seeds per siliqua (23.73) was observed from V_2, which was closely followed (21.67 and 21.30) by V_4 and V_3 and they were statistically similar, whereas the lowest number of seeds per siliqua (15.22) was found from V_1 (Table 5).

Number of seeds per siliqua of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The highest number of

Table 5. Effect of variety and salicylic acid on yield contributing characters of mustard

Treatment	Number of siliqua per plant	Length of siliqua (cm)	Number of seeds per siliqua
Mustard variety			
V_1	105.62 b	4.62 c	15.22 d
V_2	85.00 d	6.89 a	23.73 a
V_3	88.18 cd	5.46 b	21.30 b
V_4	92.89 c	6.00 b	21.67 b
V_5	185.23 a	6.62 a	18.30 c
$LSD_{(0.05)}$	6.470	0.603	1.456
Level of significance	**	**	**
Levels of salicylic acid			
S_0	107.78 b	5.58 b	19.05 b
S_1	112.49 ab	6.02 ab	20.42 a
S_2	113.88 a	6.16 a	20.67 a
$LSD_{(0.05)}$	5.011	0.467	1.128
Level of significance	*	*	**
CV(%)	6.02	10.55	7.52

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

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

Table 6. Interaction effect of variety and salicylic acid on yield contributing characters of mustard

Treatment	Number of siliqua per plant	Length of siliqua (cm)	Number of seeds per siliqua
V_1S_0	113.33 c	4.29 e	14.93 d
V_1S_1	84.43 de	4.67 de	15.70 d
V_1S_2	119.10 c	4.89 c-e	15.03 d
V_2S_0	86.67 d	7.29 a	24.00 ab
V_2S_1	83.90 de	6.04 bc	22.50 a-c
V_2S_2	84.43 de	7.33 a	24.70 a
V_3S_0	88.90 d	5.26 c-e	20.40 c
V_3S_1	85.00 de	5.34 c-e	22.10 a-c
V_3S_2	90.63 d	5.79 b-d	21.40 bc
V_4S_0	73.33 e	5.27 c-e	20.80 c
V_4S_1	122.33 c	6.83 ab	22.10 a-c
V_4S_2	83.00 de	5.90 bc	22.10 a-c
V_5S_0	176.67 b	5.79 b-d	15.10 d
V_5S_1	186.80 ab	7.21 a	19.70 c
V_5S_2	192.23 a	6.87 ab	20.10 c
$LSD_{(0.05)}$	11.21	1.044	2.522
Level of significance	*	*	*
CV(%)	6.02	10.55	7.52

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

* Significant at 0.05 level of significance

seeds per siliqua (20.67) was observed from S_2 which was statistically similar (20.42) to S_1, while the lowest number of seeds per siliqua (19.05) from S_0 (Table 5). Sharma *et al.* (2013) reported that SA improved yield attributes and total number of seeds per siliqua improved by 3.2% over the unsprayed control.

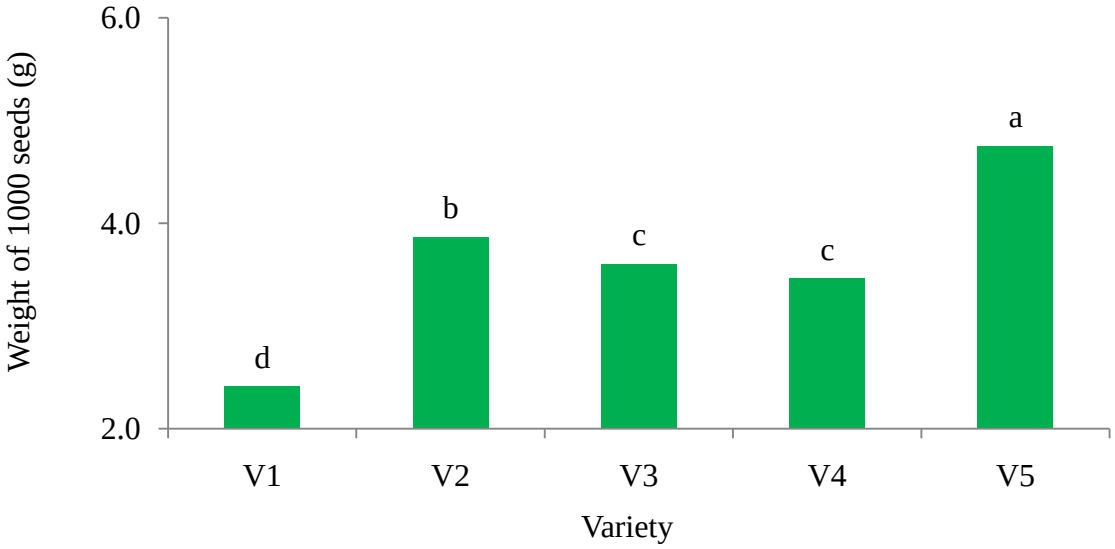
Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on number of seeds per siliqua (Appendix VI). The highest number (24.70) was found from V_2S_2 and the lowest number of seeds per siliqua (14.93) was recorded from V_1S_0 treatment combination (Table 6).

4.9 Weight of 1000 seeds (g)

Different mustard varieties showed significant variation in terms of weight of 1000 seeds (Appendix VI). The highest weight of 1000 seeds (4.75 g) was recorded from V_5, which was closely followed (3.87 g) by V_2 and the lowest weight of 1000 seeds (2.41 g) was found from V_1 (Figure 10). 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 of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VI). The highest weight of 1000 seeds (3.75 g) was recorded from S_2 which was statistically similar (3.59 g) to S_1, whereas the lowest weight of 1000 seeds (3.52 g) was found from S_0 (Figure 11).

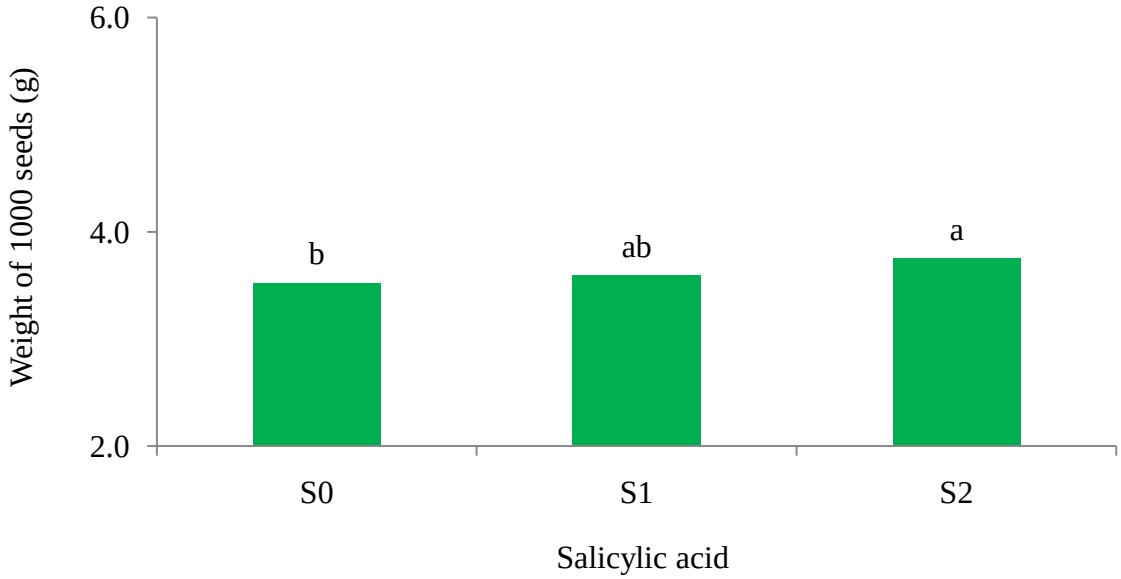
Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on weight of 1000 seeds (Appendix VI). The highest weight of 1000 seeds (4.89 g) was recorded from V_5S_2, while the lowest weight of 1000 seeds (2.38 g) was observed from V_1S_0 treatment combination (Figure 12).



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 10. Effect of different variety on weight of 1000 seeds mustard. ($LSD_{0.05}$ = 0.220)



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

S_2: 0.4 mM SA

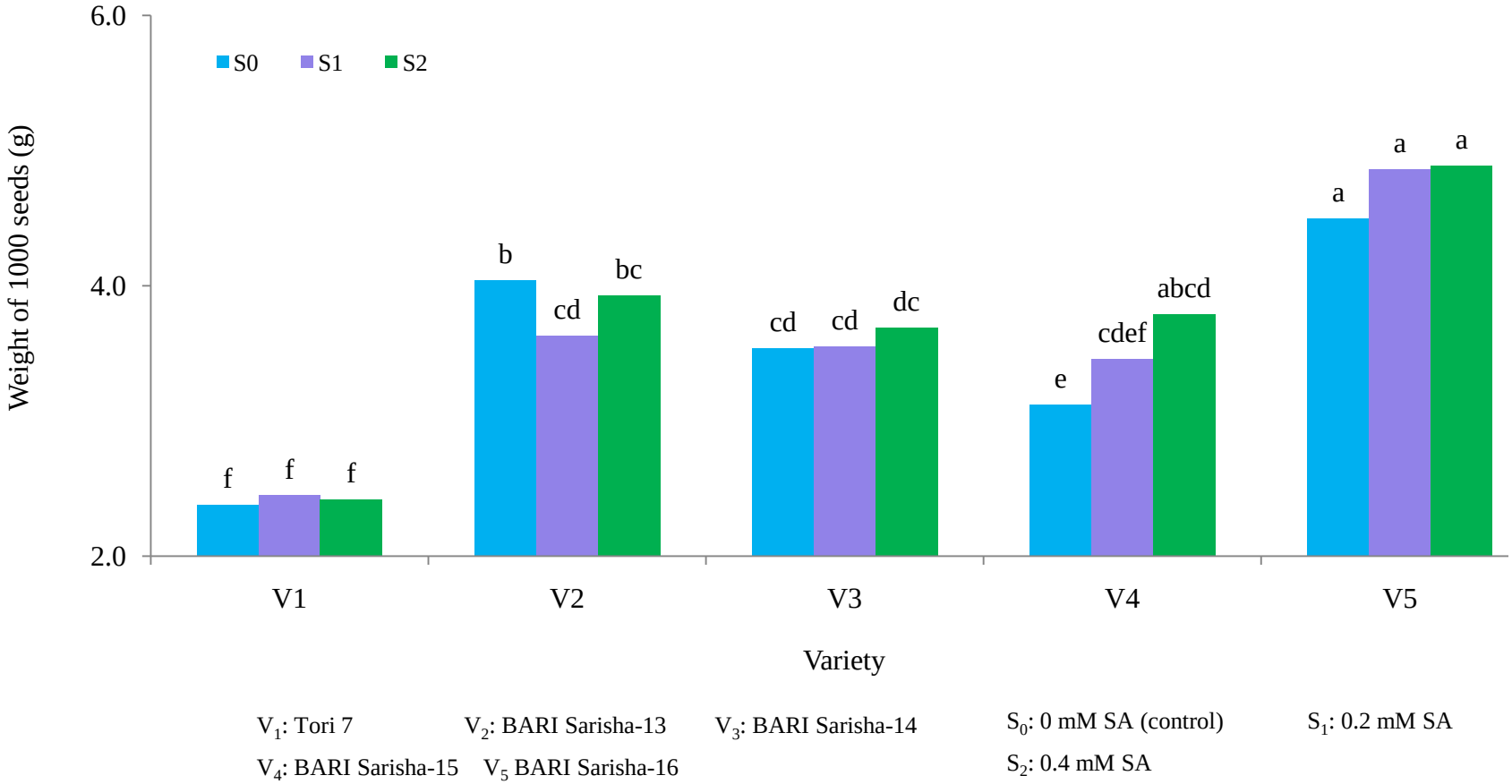


Figure 12. Interaction effect of variety and salicylic acid on weight of 1000 seeds of mustard. ($LSD_{0.05}$ = 0.381)

4.10 Seed weight per plot

Different mustard varieties showed significant variation in terms of seed weight per plot (Appendix VII). The highest seed weight per plot (430.05 g) was observed from V_5, which was statistically similar (412.05 g) to V_2 and closely followed (280.70 g and 279.19 g) by V_4 and V_3 and they were statistically similar, while the lowest seed weight per plot (235.84 g) was found from V_1 (Figure 13).

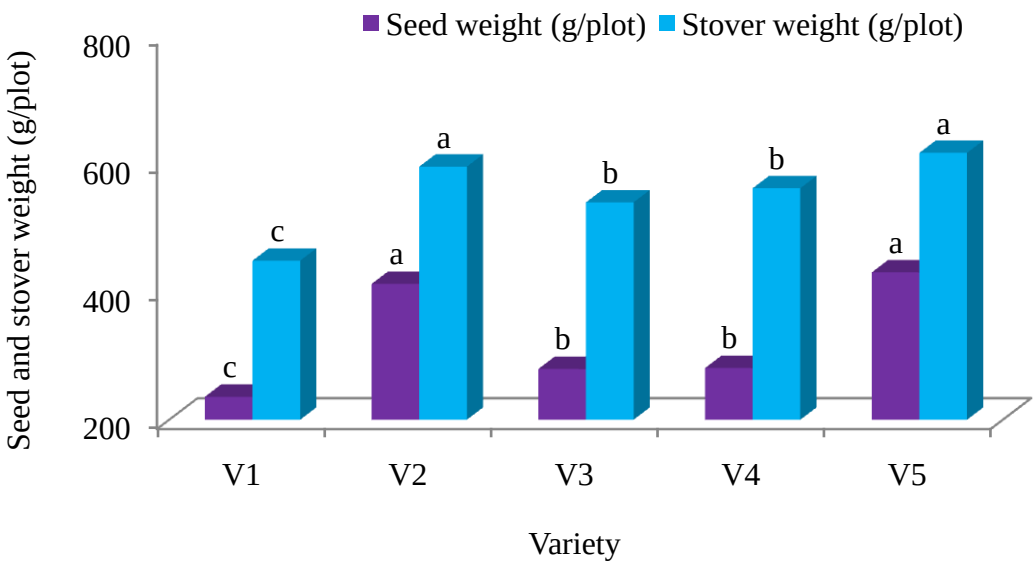
Seed weight per plot of mustard showed statistically significant variation due to different levels of salicylic acid under the present trial (Appendix VII). The highest seed weight per plot (347.28 g) was found from S_2 which was statistically similar (342.18 g) to S_1, whereas the lowest seed weight per plot (293.24 g) was observed from S_0 (Figure 14).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on seed weight per plot (Appendix VII). The highest seed weight per plot (459.43 g) was found from V_5S_2, whereas the lowest seed weight per plot (201.36 g) was recorded from V_1S_0 treatment combination (Table 7).

4.11 Stover yield per plot

Different mustard varieties showed significant variation in terms of stover weight per plot (Appendix VII). The highest stover weight per plot (616.65 g) was observed from V_5, which was statistically similar (595.11 g) to V_2 and closely followed (561.39 g and 539.37 g) by V_4 and V_3 and they were statistically similar, whereas the lowest stover weight per plot (448.33 g) was found from V_1 (Figure 13). BARI (2001) showed that seed yield and other yield contributing characters significantly varied among the varieties.

Stover weight per plot of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VII). The highest stover weight per plot (569.68 g) was found from S_2 which was statistically similar (557.91 g) to S_1, while the lowest stover weight per plot (528.92 g) was found from S_0 (Figure 14).



V_1: Tori 7 V_2: BARI Sarisha 13 V_3: BARI Sarisha 14
V_4: BARI Sarisha 15 V_5 BARI Sarisha 16

Figure 13. Effect of differnt variety on seed and stover weight per plot of mustard. (LSD= 23.22 and 29.92)

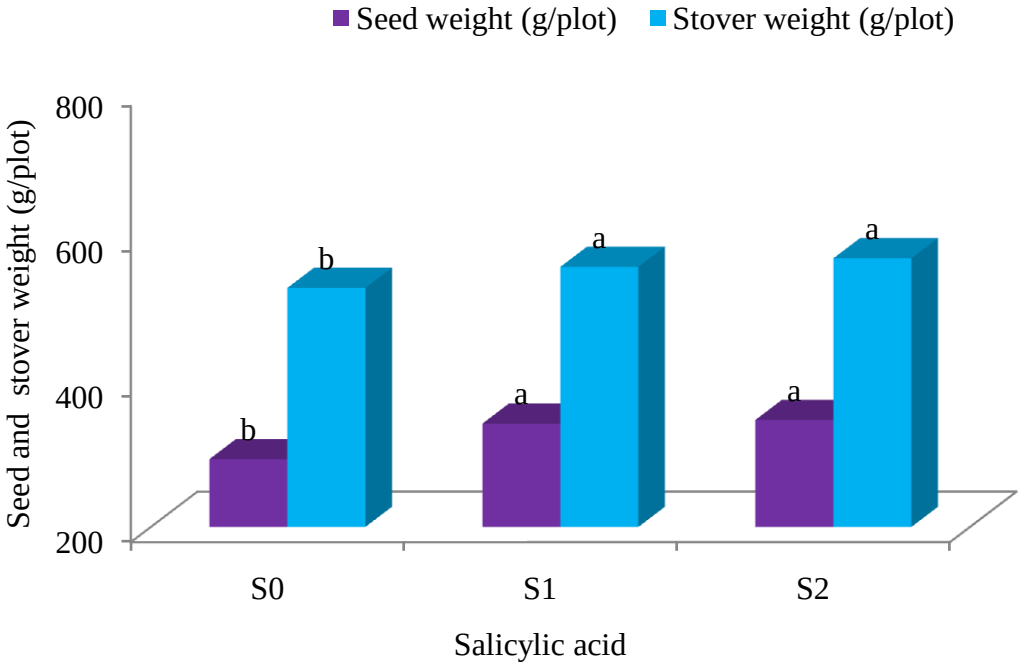


Figure 14. Effect of salicylic acid on seed and stover yield of mustard. (LSD = 17.98 and 23.18)

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on stover weight per plot (Appendix VII). The highest stover yield per plot (673.57 g) was found from V_5S_2 and the lowest stover weight per plot (439.14 g) was observed from V_1S_0 treatment combination (Table 7).

4.12 Seed yield per hectare

Different mustard varieties showed significant variation in terms of seed yield per hectare (Appendix VII). The highest seed weight per hectare (2.15 ton) was observed from V_5, which was statistically similar (2.06 ton) to V_2 and closely followed (1.40 ton) by V_4 and V_3, while the lowest seed yield per hectare (1.18 ton) was recorded from V_1 (Figure 15). Afroz *et al.* (2011) was obtained higher seed yield from variety BARI Sarisha-9. Mamun *et al.* (2014) reported that maximum seed yield (1.60 t ha^{-1}) was recorded for BARI Sarisha-13.

Seed yield per hectare of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VII). The highest seed yield per hectare (1.74 ton) was found from S_2 which was statistically similar (1.71 ton) to S_1, whereas the lowest seed yield per hectare (1.47 ton) was recorded from S_0 (Figure 16). Muhal *et al.* (2014) reported that that foliar application of salicylic acid produced significantly higher seed yield compared to water spray.

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on seed yield per hectare (Appendix VII). The highest seed yield per hectare (2.30 ton) was found from V_5S_2, whereas the lowest seed yield per hectare (1.01 ton) was recorded from V_1S_0 treatment combination (Table 7).

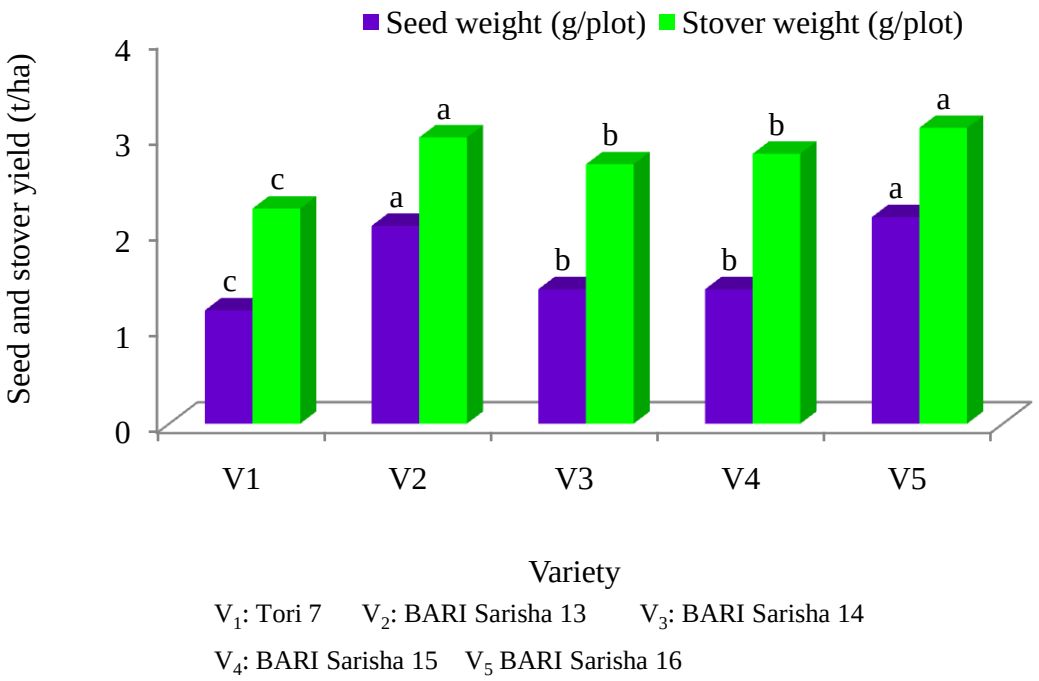


Figure 15. Effect of differnt variety on seed and stover yield per hectare of mustard. (LSD= 0.114 and 0.150)

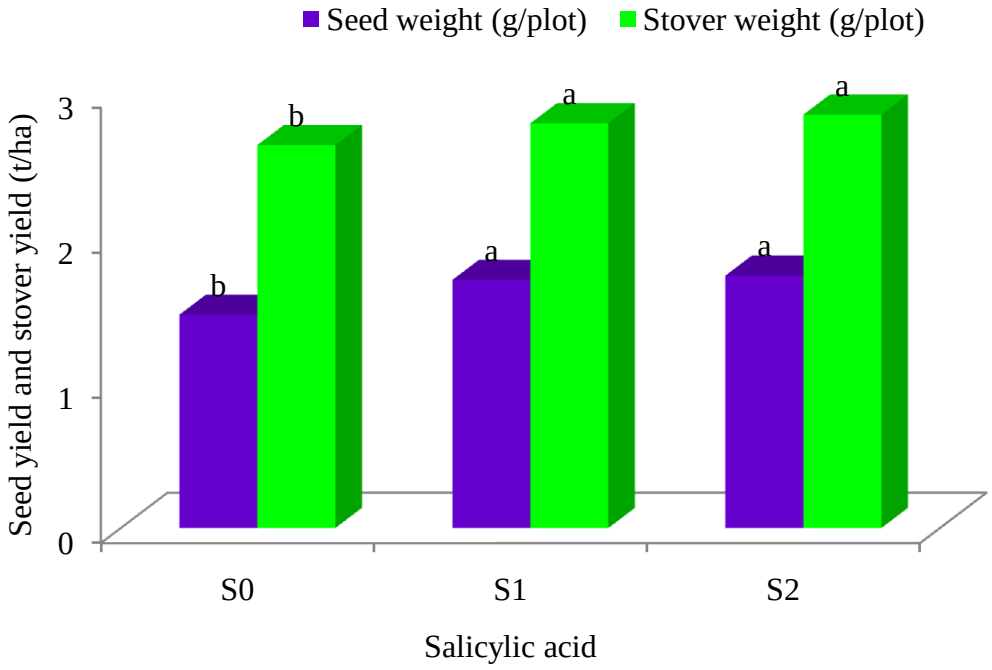


Figure 16. Effect of salicylic acid on seed and stover yield per hectare of mustard. (LSD = 0.09 and 0.116)

Table 7. Interaction effect of salicylic acid and variety on yield of mustard

Treatment	Seed yield (g/plot)	Stover yield (g/plot)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
V_1S_0	201.36 f	439.14 e	1.01 f	2.20 e	31.44 g
V_1S_1	257.38 c-e	456.33 e	1.29 c-e	2.28 e	35.98 d-f
V_1S_2	248.78 de	449.52 e	1.24 de	2.25 e	35.60 d-f
V_2S_0	356.08 b	600.00 bc	1.78 b	3.00 bc	37.27 c-g
V_2S_1	446.67 a	588.67 bc	2.23 a	2.94 bc	43.15a
V_2S_2	433.41 a	596.67 bc	2.17 a	2.98 bc	42.06 ab
V_3S_0	229.37 ef	522.78 d	1.15 ef	2.61 d	30.45 g
V_3S_1	266.75 c-e	544.38 cd	1.33 c-e	2.72 cd	32.91 fg
V_3S_2	341.44 b	550.95 cd	1.71 b	2.75 cd	38.27 b-d
V_4S_0	298.03 c	541.14 cd	1.49 c	2.71 cd	35.54 d-f
V_4S_1	290.74 cd	565.33 cd	1.45 cd	2.83 cd	33.89 e-g
V_4S_2	253.33 de	577.70 b-d	1.41 cd	2.89 b-d	30.38 g
V_5S_0	381.37 b	541.52 cd	1.91 b	2.71 cd	41.33 ab
V_5S_1	449.35 a	634.86 ab	2.25 a	3.17 ab	41.45 ab
V_5S_2	459.43 a	673.57 a	2.30 a	3.37 a	40.53 a-c
$LSD_{(0.05)}$	40.22	51.83	0.198	0.260	3.481
Level of significance	**	**	**	*	**
CV(%)	7.35	5.61	7.35	5.61	5.67

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

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

4.13 Stover yield per hectare

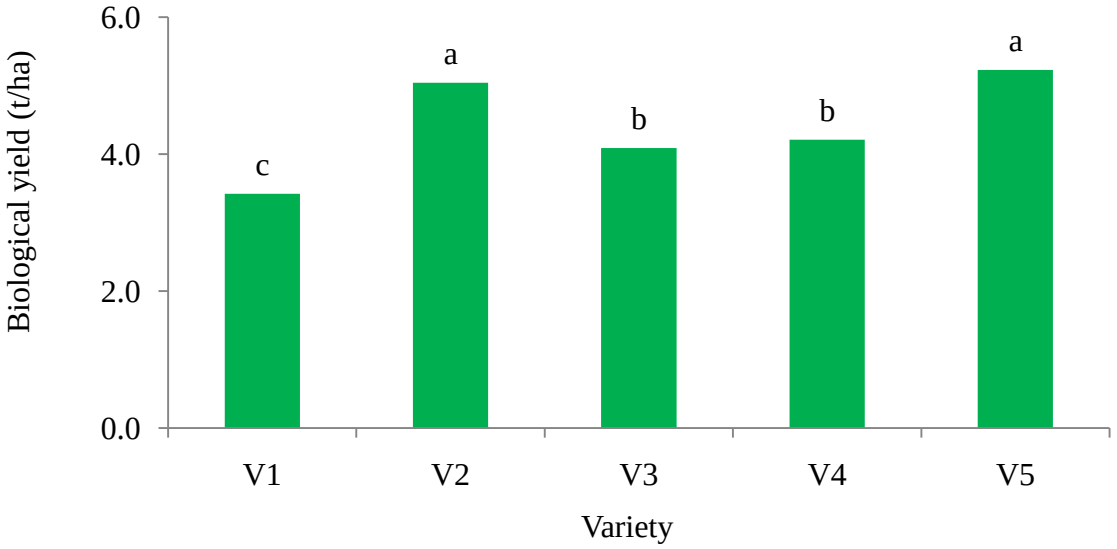
Different mustard varieties showed significant variation in terms of stover yield per hectare (Appendix VII). The highest stover yield per hectare (3.08 ton) was found from V_5, which was statistically similar (2.98 ton) to V_2 and closely followed (2.81 ton and 2.70 ton) by V_4 and V_3 and they were statistically similar, whereas the lowest stover yield per hectare (2.24 ton) was observed from V_1 (Figure 15). BARI (2000) reported the highest straw yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg was obtained from variety Tori-7.

Stover yield per hectare of mustard showed significant variation due to different levels of salicylic acid (Appendix VII). The highest stover yield per hectare (2.85 ton) was recorded from S_2 which was statistically similar (2.79 ton) to S_1, while the lowest stover yield per hectare (2.64 ton) was found from S_0 (Figure 16).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on stover yield per hectare (Appendix VII). The highest stover yield per hectare (3.37 ton) was found from V_5S_2 and the lowest stover yield per hectare (2.20 ton) was recorded from V_1S_0 treatment combination (Table 7).

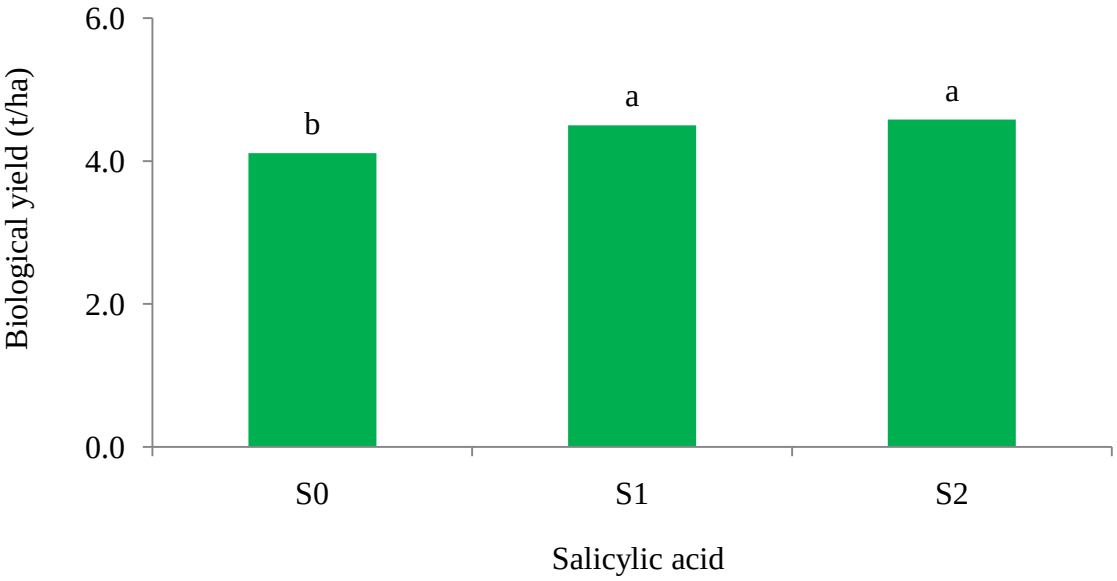
4.14 Biological yield

Different mustard varieties showed significant variation in terms of biological yield (Appendix VII). The highest biological yield (5.23 ton) was observed from V_5, which was statistically similar (5.04 ton) to V_2 and closely followed (4.21 ton and 4.09 ton) by V_4 and V_3 and they were statistically similar, while the lowest biological yield (3.42 ton) was recorded from V_1 (Figure 17). Bhargava and Tomer (1982) analyzed the biomass production, harvest index and yield of four *Brassica* genotypes. They noticed variation in harvest index values from 27 to 40 percent with maximum in early maturing mustard.



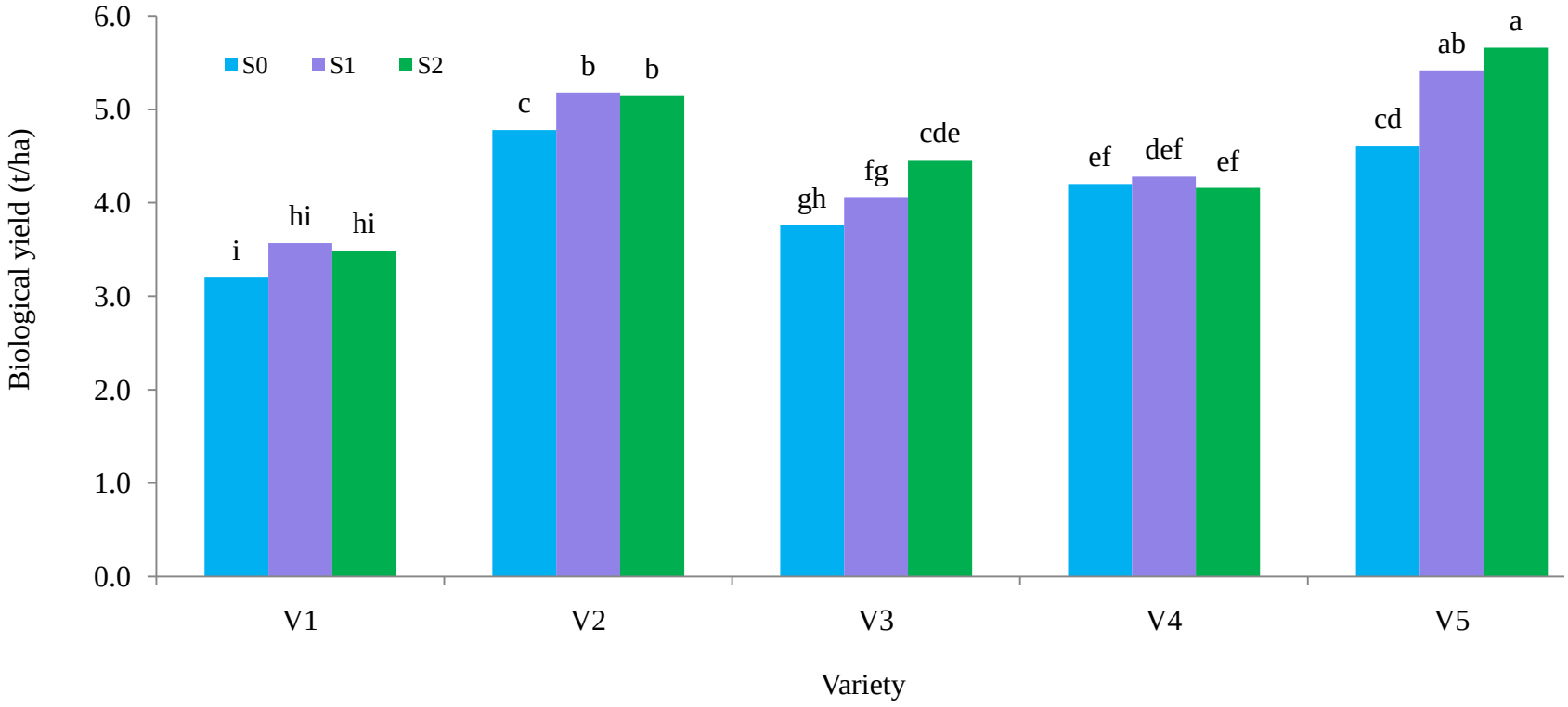
V_1: Tori 7 V_2: BARI Sarisha-13 V_3: BARI Sarisha-14
V_4: BARI Sarisha-15 V_5 BARI Sarisha-16

Figure 17. Effect of different variety on biological yield of mustard. ($LSD_{0.05}$ = 0.212)



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

Figure 18. Effect of salicylic acid on biological yield of mustard. ($LSD_{0.05}$ = 0.164)



V_1: BARI Sarisha-1 V_2: BARI Sarisha-13 V_3: BARI Sarisha-14 S_0: 0 mM SA (control) S_1: 0.2 mM SA

V_4: BARI Sarisha-15 V_5 BARI Sarisha-16 S_2: 0.4 mM SA

Figure 19: Interaction effect of variety and salicylic acid on biological yield seeds of mustard. ($LSD_{0.05}$ = 0.366)

Biological yield of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VII). The highest biological yield (4.58 ton) was found from S_2 which was statistically similar (4.50 ton) to S_1 and the lowest biological yield (4.11 ton) was observed from S_0 (Figure 18).

Interaction effect of mustard varieties and levels of salicylic acid showed significant differences on biological yield under the present trial (Appendix VII). The highest biological yield (5.66 ton) was observed from V_5S_2, whereas the lowest biological yield (3.20 ton) was recorded from V_1S_0 treatment combination (Figure 19).

4.15 Harvest index

Different mustard varieties showed significant variation in terms of harvest index (Appendix VII). The highest harvest index (41.10%) was found from V_5, which was statistically similar (40.83%) to V_2 and closely followed (33.87% and 33.27%) by V_3 and V_4 and they were statistically similar, whereas the lowest harvest index (34.34%) was observed from V_1 (Table 8).

Harvest index of mustard showed statistically significant variation due to different levels of salicylic acid (Appendix VII). The highest harvest index (37.48%) was recorded from S_1 which was statistically similar (37.37%) to S_2, while the lowest harvest index (35.21%) was found from S_0 (Table 8).

Interaction effect of mustard varieties and levels of salicylic acid showed statistically significant differences in terms of harvest index under the present trial (Appendix VII). The highest harvest index (43.15%) was found from S_1V_2 and the lowest harvest index (30.38%) was recorded from S_2V_4 treatment combination (Table 9).

Table 8. Effect of variety and salicylic acid on harvest index of mustard

Treatment	Harvest index (%)
Mustard variety	
V_1	34.34 b
V_2	40.83 a
V_3	33.87 b
V_4	33.27 b
V_5	41.10 a
$LSD_{(0.05)}$	2.010
Level of significance	**
Levels of salicylic acid	
S_0	35.21 b
S_1	37.48 a
S_2	37.37 a
$LSD_{(0.05)}$	1.557
Level of significance	**
CV(%)	5.67

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

** Significant at 0.01 level of significance;

Table 9. Interaction effect of salicylic acid and variety on yield of mustard

Treatment	Harvest index (%)
V_1S_0	31.44 g
V_1S_1	35.98 d-f
V_1S_2	35.60 d-f
V_2S_0	37.27 c-g
V_2S_1	43.15a
V_2S_2	42.06 ab
V_3S_0	30.45 g
V_3S_1	32.91 fg
V_3S_2	38.27 b-d
V_4S_0	35.54 d-f
V_4S_1	33.89 e-g
V_4S_2	30.38 g
V_5S_0	41.33 ab
V_5S_1	41.45 ab
V_5S_2	40.53 a-c
$LSD_{(0.05)}$	3.481
Level of significance	0.01
CV(%)	5.67

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

V_1: Tori 7
V_2: BARI Sarisha 13
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15
V_5: BARI Sarisha 16

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November, 2014 to March, 2015 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the morphophysiology and seed yield with or without salicylic acid. The experiment comprised of two factors- Factor A: Mustard varieties (5 varieties)- V_1: Tori 7, V_2: BARI Sarisha 13, V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15, V_5: BARI Sarisha 16; Factors B: Levels of salicylic acid (3 levels)- S_0: 0 mM SA (control), S_1: 0.2 mM SA, S_2: 0.4 mM SA;. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different morphological change and seed yield of mustard were recorded and statistically significant variation was observed for different treatment.

Due to different mustard varieties, at 30, 40, 50 DAS and at harvest, the tallest plant (69.17, 98.54, 138.16 and 157.87 cm, respectively) was observed from V_5, while the shortest plant (51.84, 63.55, 73.52 and 84.40 cm, respectively) was recorded from V_3. The maximum number of branches per number of branches per plant (6.00, 7.18, 8.41 and 8.41, respectively) was found from V_5 and the minimum number of branches per plant (4.18, 4.85, 5.48 and 6.19, respectively) was observed from V_1 at 30, 40, 50 DAS and at harvest, respectively. The lowest losses (11.34%, 5.92%, 3.58% and 1.99%, respectively) was found from V_1, whereas the highest losses (15.62%, 7.91%, 5.08% and 2.77%, respectively) was observed from V_5 after 30, 60, 90 and 120 minutes, respectively. The minimum days to flowering (31.67) was recorded from V_4, while the maximum days to flowering (38.22) was obtained from V_5. The minimum days to harvest (78.44) was observed from V_4, while the maximum days to harvest (108.33) was recorded from V_5. The highest dry matter content per plant (7.07 g) was found from V_5, while the lowest dry matter content per plant (5.50 g) was recorded from V_1. The

highest number of siliqua per plant (185.23) was observed from V_5, whereas the lowest number of siliqua per plant (85.00) was obtained from V_2. The highest length of siliqua (6.89 cm) was observed from V_2, while the lowest length of siliqua (4.62 cm) was recorded from V_1. The highest number of seeds per siliqua (23.73) was observed from V_2, whereas the lowest number of seeds per siliqua (15.22) was found from V_1. The highest weight of 1000 seeds (4.75 g) was recorded from V_5 and the lowest weight of 1000 seeds (2.41 g) was found from V_1. The highest seed yield per hectare (2.15 ton) was observed from V_5, while the lowest seed yield per hectare (1.18 ton) was recorded from V_1. The highest stover yield per hectare (3.08 ton) was found from V_5, whereas the lowest stover yield per hectare (2.24 ton) was observed from V_1. The highest biological yield (5.23 ton) was observed from V_5, while the lowest biological yield (3.42 ton) was recorded from V_1. The highest harvest index (41.10%) was found from V_5, whereas the lowest harvest index (34.34%) was observed from V_1.

In case of salicylic acid, the tallest plant (59.46, 74.74, 96.66 and 109.85 cm, respectively) was recorded from S_2, whereas the shortest plant (55.64, 71.16, 92.41 and 105.49 cm, respectively) from S_0 at 30, 40, 50 DAS and at harvest. The maximum number of branches per plant (5.58, 7.00, 7.91 and 8.27, respectively) was observed from S_2, while the minimum number (4.76, 5.33, 6.24 and 6.58, respectively) from S_0 at 30, 40, 50 DAS and at harvest, respectively. After 30, 60, 90 and 120 minutes, the lowest losses of water from leaf (13.26%, 6.89%, 4.08% and 2.05%, respectively) was observed from S_2 and the highest losses (14.90%, 7.79%, 4.90% and 3.14%, respectively) from S_0. The minimum days to flowering (32.87) was found from S_2 and the maximum days (35.00) from S_0. The minimum days to harvest (89.53) was observed from S_2, whereas the maximum days (95.00) from S_0. The highest dry matter content per plant (6.70 g) was recorded from S_2 and the lowest (6.29 g) from S_0. The highest number of siliqua per plant (113.88) was found from S_2, while the lowest number (107.78) from S_0. The highest length of siliqua (6.16 cm) was recorded from S_2 and the lowest length of siliqua (5.58 cm) from S_0. The highest number of seeds per siliqua (20.67) was observed from

S_2, while the lowest number (19.05) from S_0. The highest weight of 1000 seeds (3.75 g) was recorded from S_2, whereas the lowest weight (3.52 g) from S_0. The highest seed yield per hectare (1.74 ton) was found from S_2, whereas the lowest seed yield per hectare (1.47 ton) was recorded from S_0. The highest stover yield per hectare (2.85 ton) was recorded from S_2, while the lowest stover yield per hectare (2.64 ton) was found from S_0. The highest biological yield (4.58 ton) was found from S_2 and the lowest biological yield (4.11 ton) was observed from S_0. The highest harvest index (37.48%) was recorded from S_1, while the lowest harvest index (35.21%) was found from S_0.

For the interaction effect of mustard varieties and levels of salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant (74.95, 102.90, 143.57 and 160.00 cm, respectively) was found from V_5S_2, while the shortest plant (48.10, 57.24, 72.27 and 81.77 cm, respectively) was recorded from V_3S_0. At 30, 40, 50 DAS and at harvest, the maximum number of branches per plant (6.89, 8.67, 9.45 and 9.56 respectively) was recorded from V_5S_2 and the minimum number of branches per plant (3.67, 4.34, 4.67 and 5.56, respectively) was observed from V_1S_0 treatment combination. After 30, 60, 90 and 120 minutes, the lowest losses of moisture (10.50%, 5.17%, 3.06% and 1.43%, respectively) was obtained from V_1S_2, while the highest losses (17.82%, 8.83%, 5.63% and 3.38%, respectively) was found from V_2S_0 treatment combination. The minimum days to flowering (30.00) was observed from V_4S_2 and the maximum days to flowering (39.33) was found from V_5S_0 treatment combination. The minimum days to harvest (76.00) was found from V_4S_1, whereas the maximum days to harvest (112.67) was recorded from V_5S_0 treatment combination. The highest dry matter content per plant (7.49 g) was observed from V_5S_2, whereas the lowest dry matter content per plant (5.38 g) was recorded from V_1S_0 treatment combination. The highest number of siliqua per plant (192.23) was observed from V_5S_2 and the lowest number of siliqua per plant (73.33) was recorded from V_4S_0 treatment combination. The highest length of siliqua (7.33 cm) was found from V_2S_2, whereas the lowest length of siliqua (4.29 cm) was recorded from V_1S_0 treatment combination. The highest number of seeds

per siliqua (24.70) was found from V_2S_2 and the lowest number of seeds per siliqua (14.93) was recorded from V_1S_0 treatment combination. The highest weight of 1000 seeds (4.89 g) was recorded from V_5S_2, while the lowest weight of 1000 seeds (2.38 g) was observed from V_1S_0 treatment combination. The highest seed yield per hectare (2.30 ton) was found from V_5S_2, whereas the lowest seed yield per hectare (1.01 ton) was recorded from V_1S_0 treatment combination. The highest stover yield per hectare (3.37 ton) was found from V_5S_2 and the lowest stover yield per hectare (2.20 ton) was recorded from V_1S_0 treatment combination. The highest biological yield (5.66 ton) was found from V_5S_2, whereas the lowest biological yield (3.20 ton) was recorded from V_1S_0 treatment combination. The highest harvest index (43.15%) was found from V_2S_1 and the lowest harvest index (30.38%) was recorded from V_4S_2 treatment combination.

From the above results it can be concluded that the variety BARI Sarisha 16 provided better yield than the other varieties and salicylic acid 0.4 mM followed by 0.2 mM provided better yield for most of the mustard varieties.

Considering the results obtained from the present experiment, further studies in the following areas may be suggested:

- Other growth regulators with different management practices may be included in future study for more accurate results,
- Future study may be carried out with more varieties/genotypes, and
- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

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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 2013 to March 2014

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	28.1	19.5	68	00	6.8

* Monthly average,

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

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)	0.10
Available S (ppm)	23

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

Appendix III. Analysis of variance of the data on plant height of mustard at different days after sowing (DAS) and at harvest as influenced by different variety and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	3.689	3.250	0.878	13.987
Mustard variety (A)	4	438.497**	1889.665**	5736.746**	7716.988**
Levels of salicylic acid (B)	2	54.741*	53.136*	74.432*	71.417*
Interaction (A×B)	8	28.090*	34.460*	45.407*	49.786*
Error	28	12.391	14.812	18.856	20.737

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

Appendix IV. Analysis of variance of the data on number of branches per plant of mustard at different days after sowing (DAS) and at harvest as influenced by different variety and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Number of branches/plant at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.092	0.152	0.248	0.121
Mustard variety (A)	4	4.128**	7.801**	11.174**	7.004**
Levels of salicylic acid (B)	2	2.853**	11.886**	11.018**	11.104**
Interaction (A×B)	8	0.966*	2.237**	0.828*	1.039*
Error	28	0.370	0.375	0.366	0.404

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

Appendix V. Analysis of variance of the data on moisture loss from leaf of mustard at different days after sowing (DAS) and at harvest as influenced by different variety and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Moisture loss (%)			
		After 30 minutes	After 60 minutes	After 90 minutes	After 120 minutes
Replication	2	0.227	0.487	0.036	0.006
Mustard variety (A)	4	25.401**	6.138**	2.766**	0.823**
Levels of salicylic acid (B)	2	10.045**	3.123**	2.778**	4.947**
Interaction (A×B)	8	4.978**	1.418*	0.541*	0.068*
Error	28	1.760	0.601	0.199	0.032

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

Appendix VI. Analysis of variance of the data on yield contributing characters of mustard at different days after sowing (DAS) and at harvest as influenced by different variety and salicylic acid

Source of variation	Degrees of freedom	Mean square						
		Days required to flowering	Days required to harvest	Dry matter content/ plant (g)	Number of siliqua per plant	Length of siliqua (cm)	Number of seeds per siliqua	Weight of 1000-seeds (g)
Replication	2	0.822	2.400	0.087	6.054	0.308	0.818	0.013
Mustard variety (A)	4	66.944**	1562.26**	3.293**	15893.18**	7.521**	99.252*	6.350**
Levels of salicylic acid (B)	2	17.156**	124.867**	0.680**	153.371*	1.346*	11.428**	0.204*
Interaction (A×B)	8	7.211*	28.672*	0.272*	780.307**	1.068*	4.981**	0.111**
Error	28	1.965	8.567	0.138	44.888	0.390	2.274	0.052

** 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 of mustard at different days after sowing (DAS) and at harvest as influenced by different variety and salicylic acid

Source of variation	Degrees of freedom	Mean square					
		Seed yield (g/plot)	Stover yield (g/plot)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	81.655	0.002	128.288	0.003	0.008	0.543
Mustard variety (A)	4	68831.83**	1.721**	38323.49**	0.958**	4.923**	138.875**
Levels of salicylic acid (B)	2	13351.88**	0.334**	6602.86**	0.165**	0.959**	24.621**
Interaction (A×B)	8	3365.07**	0.084**	2309.043*	0.058*	0.148**	23.322**
Error	28	578.153	0.014	960.294	0.024	0.048	4.331

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