MORPHOLOGICAL CHARACTERS AND YIELD OF MUSTARD AS INFLUENCED BY DIFFERENT SOWING TIMES AND SALICYLIC ACID

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CERTIFICATE

This is to certify that the thesis entitled '**MORPHOLOGICAL CHARACTERS AND YIELD OF MUSTARD AS INFLUENCED BY DIFFERENT SOWING TIMES AND SALICYLIC ACID'**submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany,** embodies the result of a piece of *bonafide* research work carried out by **Md. Mizanur Rahman, Registration number: 11-04639** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
Dhaka, Bangladesh

Prof. Dr. Mohammad Mahbub Islam
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Dedicated

To

My Beloved Parents

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The Author

ABSTRACT

The experiment was conducted during the period from October, 2016 to March, 2016 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the morpho-physiology, yield and quality of mustard as influenced by different sowing times and salicylic acid. The experiment comprised of two factors- Factor A: Different sowing times (4) - S_1: 25 October, 2016; S_2: 05 November, 2016; S_3: 15 November, 2016 and S_4: 25 November, 2016; Factors B: Different concentration of salicylic acid (3 levels)- SA_0: 0 mM (control), SA_1: 0.2 mM, SA_2: 0.4 mM;. 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. For different sowing dates, the maximum number of siliqua plant^{-1}, seeds siliqua^{-1}, seed and stover yield (91.53, 24.23, 2.18 and 3.38 t ha^{-1} respectively) was recorded from S_1 while the minimum number of siliqua plant^{-1}, seeds siliqua^{-1}, seed and stover yield (58.58, 20.27, 1.43 and 2.50 t ha^{-1} respectively) was found from S_4 treatment. In case of salicylic acid, the maximum number of siliqua plant^{-1}, the longest siliqua, seed and stover yield (102.9, 4.57 cm, 1.88 and 3.06 t ha^{-1} respectively) was recorded from SA_2 (0.4 mM salicylic acid) whereas the minimum number of siliqua plant^{-1}, the shortest siliqua, seed and stover yield (38.58, 3.80 cm, 1.65 and 2.79 t ha^{-1} respectively) was found from SA_0 (0 mM salicylic acid). For the interaction effect of sowing date and levels of salicylic acid of mustard, At 30, 40, 50 DAS and at harvest, the highest plant height (120.1 cm, 126.8 cm, 135.8 cm and 103.0 cm, respectively) was observed from the S_1SA_2 treatment and the lowest (14.33 cm, 55.30 cm. 77.27 cm and 50.90 cm, respectively) plant height was observed from S_4SA0 treatment combination. The highest number of siliqua plant^{-1}, seeds siliqua^{-1}, seed and stover yield (144.1, 26.40, 2.28 and 3.43 t ha^{-1}respectively) was observed from the S_1SA_2 treatment and the lowest number of siliqua plant^{-1}, seeds siliqua^{-1}, seed and stover yield (32.90, 19.50, 1.32 and 2.32 t ha^{-1} respectively) was observed from S_4SA_0 treatment combination. Sowing on 20 November and salicylic acid concentration 0.4 mM followed by 0.2 mM was more potential in regards to yield contributing characters and yield of mustard.

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CHAPTER I

INTRODUCTION

Mustard is one of the most important and widely grown oilseed crops of Bangladesh occupying 0.483 million ha and the production was 0.525 million metric ton and yield 0.109 million ton per hectare (AIS, 2013). Mustard is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). It has three species those produce edible oil, namely *Brassica napus, B. campestris* and *B. juncea.* Vegetable oils and fats (lipids) constitute an important component of human diet. Oils of plant origin are nutritionally superior to that of animal origin (Singh, 2000). It is an important source of cooking oil in Bangladesh meeting one third of the edible oil requirement of the country (Ahmed, 2008). It is not only a high energy food but also a carrier of fat soluble vitamins (A, D, E and K) in the body.

Mustard is the principal oilseed crop in Bangladesh. It 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. 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. Moreover, mustard oil cake is also used as a feed for cattle and fish and as a good manure. With increasing population, the demand of edible oil is increasing day by day. 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 loosing in an area of 104,000 hectare and production 68,000 tons of mustard and rapeseed in last ten years (Anon., 2006). The major reasons for low yield of rapeseed-mustard in our country are due to lack of high yielding variety, appropriate population density and want of knowledge of sowing date and proper management practices etc.

Mustard is grown particularly in the districts of Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka (BBS, 2011). Bangladesh has been facing acute shortage of edible oil for the last several decades. 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). It needs to import oil and oilseeds to meet up the deficit every year spending huge foreign exchange. Due to insufficient oil production, a huge amount of foreign exchange involving over 160 million US Dollar is being spent every year for importing edible oils in Bangladesh (Rahman, 2002). Mustard seed contains about 40-45% oil and 20-25% protein which can meet the shortage of oil. The average per hectare yield of mustard in this country is alarmingly very poor compared to that of advanced countries like Germany, France, UK and Canada producing 6,667 kg /ha, 5,070 kg/ha, 3,264 kg/ ha, 3,076 kg/ ha, respectively. The world average yield of mustard is 1,575 kg/ ha.

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.

In Bangladesh, mustard is sown in early October to November. The temperature in the country remains fairly high up to mid October which gradually comes down afterwards. Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield and modify the undesirable effect of drought stress. Sowing either too early or too late has been reported to be unfavorable (Hocking and Stapper, 2001; Robertson *et al*., 2004; Uzun *et al*., 2009). Delay on sowing date causes flowering period falls when evapo-transpiration reaches high values and the crop experiences water stress (Yau, 2007). For producing high yield, it is important that the plant flowers as early as possible. By bringing forward the date of flowering, yield can ultimately be increased (Koutroubas *et al*., 2004; Yau, 2007; Dordas *et al*., 2008). Seed yield of mustard declined gradually by 11.7, 21.5, 43.4 and 62.9%, respectively, for each week delay after 1

November sowing (Rahman *et al.*, 1993). Yield reduction due to late sowing is of common occurrence owing to low level of dry matter accumulation accompanied by pod abortion and decrease in seed set.

Considering the above situations the present experiment was conducted to find out the effect of sowing dates and variety on the yield of mustard with the following objectives-

To study the individual effects of sowing dates and salicylic acid regulation of morphological characters and seed yield of mustard; and

To find out the interaction effect between different sowing dates and different levels of salicylic acid on change of morphology and seed yield of mustard

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oilseed crop in Bangladesh and as well as many countries of the world. The crop is grown conventionally and less attention is given 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 growth, yield and development of newly developed mustard varieties have been carried out in our country. However, research works are pursued by scientist in home and abroad to maximize the yield of mustard. Sowing date and variety play an important role in improving mustard yield. But research works related to sowing date as a management practices and variety on mustard are limited in Bangladesh context. However, some of the important and informative works and research findings related to the sowing date and variety so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of sowing dates on mustard

2.1.1 Plant height

A study was carried out by Singh *et al*. (2014) to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea* L.). Results revealed that all the growth and plant height were increased significantly after 30 October sowing.

According to Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the tallest plant was recorded under 01 November sowing followed by 21 October sowing.

Afroz *et al*. (2011) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with two varieties; three sowing date viz. 10, 20 and 30 November and recorded the longest plant in 10 November sowing and the shortest plant in 30 November sowing.

Mondal and Islam (1993) found that the longest plants were found in the plots of November 1 sowing which was followed by November 15, and October 15 sowing. The shortest plant height was found in the plots of December 1 sowing. In case of late sowing in December 1 plants faced higher temperature during later stages of growth, so the plants were shorter than the other sowing dates.

Angrej *et al.* (2002) found that, early sowing was showed higher value for the different plant height.

2.1.2 Number of branches per plant

Gawariya *et al*. (2015) found that four dates of sowing (1st October, 16th October, 31st October and 15th November) and six crop geometry reported sowing during 1st October recorded significantly higher crop yield attributing characters viz. no. of primary, secondary and tertiary branches compared to 31st October and 15th November.

Rahman *et al*. (1993) found that the number of primary branches per plant has a very low direct effect on seed yield but it has an indirect positive effect via pods per plant.

Islam *et al*. (1994) found that early sown crop produced more primary branches than late plant crop on end October and mid November and he also observed that delayed sowing significantly reduced branches per plant except that the difference was similar between sowing of November 4 and November 18 over the varieties. The maximum (4.55) number of branches per plant produced on October 20 and minimum (3.31) on December 2.

2.1.3 Days to flowering

A study was conducted by Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the minimum days to flowering was recorded under 01 November sowing followed by 21 October sowing.

Robertson *et al.* (2004) conducted experiment with three cultivars viz. an early and late flowering canola and an advanced breeding line of Indian mustard. They found that a delay in sowing shortened the time to 50% flowering for all the genotypes. Seeds sowing

in May 15, 1 day delay in sowing delayed flowering by 0.42, 0.42 and 0.37 days in Indian mustard, Monty and Oscar, respectively.

Mondal *et al.* (1999) stated that, seeding date significantly influenced days to flowering and delayed sowing reduced days to flowering.
Mondal and Islam (1993) found that maximum days to flowering (38 days) were required by the October 15 sown plant which was followed by November 1, November 15, and December 1 sowing. Delay in sowing reduced the number of days to flowering. In case of early sowing plant experienced little warm temperature during vegetative stage as a result the growth became slow that is why maturity periods were longer, and later sowing plants completed vegetative growth earlier than the plant of early sowing.

2.1.4 Days to maturity

Islam *et al.* (1994) stated that delayed sowing curtailed the period of crop duration in all varieties. In all sowings, varieties Tori-7 and TS-72 matured much earlier (75-78 days) than the other (90-107 days). It appears that rise of temperature from January onwards might have greatly influenced the post flowering developments, particularly for late sown crops resulting in the shorter maturity periods.

Mondal and Islam (1993) found that maximum days to maturity of mustard (115 days) were required by the October 15 sown plant which was followed by November 1, November 15, and December 1 sowing. Delay in seeding reduced the number of days to maturity. In case of early sowing plant faced little warm temperature during vegetative stage and the growth was slow that is why maturity periods were longer and later sowing plants completed vegetative growth earlier than the plant of early sowing.
Mondal *et al.* (1992) observed that there was a trend of reduction in days to maturity with delayed plantings. In the first planting it took 89 days to mature and in the last planting, this was 83 days.

2.1.5 Number of siliquae plant^{-1}

A field experiment was conducted by Gawariya *et al*. (2015) with four dates of sowing (1st October, 16th October, 31st October and 15th November) and six crop geometry reported sowing during 1st October recorded significantly higher crop yield attributing characters viz. siliquae/plant compared to 31st October and 15th November.

A field experiment was conducted by Singh *et al*. (2014) to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea* L.). Results revealed that all the growth and yield attributes were increased significantly under 30 October sowing.

Shivani *et al.* (2002) experimented sowing on September 25 and October 5 recorded significantly higher number of siliquae per plant and number of siliquae plant^{-1} was significantly influenced by sowing date.

Buttar and Aulakh (1999) found pods per plant were higher in October 25 (1stdate) sowing. This was due to the fact that under earlier sown crop, the temperature and other climatological parameters played a major role for growth and yield attributes.

Mondal *et al*. (1999) stated that the highest number of siliquae per plant was found in the plants of third planting (1 November). The number of siliquae was less in the last two plantings and first planting.

Brar *et al*. (1998) stated that early sown crop produced higher number of siliquae per plant compared to late sowing. Sowing at October 30 and November 15 were at par with each other but further delay in sowing caused significant reduction in number of siliquae per plant.

Shahidullah *et al*. (1997) reported that number of siliquae per plant was decreased with delay in sowing among the three sowing dates on October 27, November 6 and November 16.

Monndal and Islam (1993) found that the highest number of siliquae per plant was in the plants of November 1 sowing and the lowest number of siliquae per plant was in the plants of December 1 sowing.

Mondal *et al*. (1992) stated that number of siliquae per plant decreased in late planting.

According to Saran and Giri (1987) pods plant^{-1} decreased gradually from early (October 15) to later (October 25; November 5 and November 15) sowings. Ghosh and Chatterjee

(1988) also reported that fifteen days to one month delay in sowing produced 24 to 57% reduced pods sqare m.

Uddin *et al*. (1986) reported that numbers of siliqua per plant were generally reduced with delay in sowing among the four sowing dates on October 25, November 14 and November 24.

2.1.6 Number of seeds siliqua^{-1}

A field experiment was conducted by Singh *et al*. (2014) to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea* L.). Results revealed that all the growth and yield attributes were increased significantly under 30 October sowing.

A study was carried out by Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the highest number of seeds siliqua (5.67) was recorded under 01 November sowing followed by 21 October sowing.

Shivani *et al*. (2002) experimented sowing on September 25 and October 5 recorded significantly higher number of seeds per siliquae than that on October 15, October 25 and November 4. Number of seeds per siliqua decreased progressively with delay in planting. Number of seeds per siliqua was significantly influenced by sowing date.

Angrej *et al*. (2002) observed that early sowing gives higher values of seeds per siliqua in mustard.

Mondal *et al*. (1999) stated that the highest number of seeds per siliqua was found in the plants of third planting (November 1).

Shahidullah *et al.* (1997) reported that number of seeds per siliqua was decreased with delay in sowing among the three sowing dates on October 27, November 6 and November 16.

2.1.7 Length of siliqua

A field experiment was conducted by Singh *et al*. (2014) to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard

(*Brassica juncea* L.). Results revealed that all the growth and yield attributes were increased significantly under 30 October sowing.

Hossain *et al*. (1996) found significant variation in siliqua length due to planting time. In each case length decreased from first date to 4th date of sowing. i.e. delayed sowing reduced the siliqua length.

BARI (1992) conducted an experiment during rabi season at Joydepur, Jessore, Ishurdi and Rajshahi. Five dates of planting (October 1, October 16, November 1, November 16 and December 1) and two genotypes of rapeseed were used. Significant variations due to different dates of sowing were found in respect of siliqua length and other traits. Siliqua length showed decreasing tendency with delay in sowing. Highest length (6.8 cm) was found from October 15 sowing and lowest (5.8 cm) in December 1 sowing.

2.1.8 Thousand seed weight

A field experiment was conducted by Singh *et al*. (2014) to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea* L.). Results revealed that all the growth and yield attributes were increased significantly under 30 October sowing.

A study was carried out by Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the highest weight of 1000 seeds (5.02 g) was recorded under 01 November sowing followed by 21 October sowing.

Shivani *et al*. (2002) experimented that, 1000-seed weight was significantly influenced by sowing date. Sowing on September 25 and October 5 recorded significantly higher 1000-seed weight than that on October 15, October 25 and November 4. 1000-seed weight decreased progressively with delay in planting.

Mondal *et al*. (1999) stated that, 1000 seed weight reduced with the delayed planting time.

Ghosh and Chatterjee (1988) reported that one month later planting produced 32% reduction in seed weight. Saran and Giri (1987) observed that sowing in October 25 gave 11% higher 1000-seed weight than that of November 15 sowing.

2.1.9 Grain yield

A field experiment was conducted by Gawariya *et al*. (2015) with four dates of sowing (1st October, 16th October, 31st October and 15th November) and six crop geometry reported sowing during 1st October recorded significantly higher crop yield attributing characters and ultimately seed yield (2013 kg/ha) compared to 31st October and 15th November.

Sattar *et al*. (2013) carried out an experiment with three varieties of canola viz; Bulbul-98, Zafar-2000 and Rainbow sown at three different sowing dates, early (15th October), late (30th October) and very late (15^{th} November). Results indicate that from all these three varieties, seed yield, protein and oil contents of all cultivars were decreased due to delayed sowing. The decline of grain yield with delay in sowing date could be largely explained by the decline in biomass at maturity.

Afroz *et al*. (2011) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the effect of sowing date and seed rate on the yield and yield components of two mustard varieties. The treatments included two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date viz. 10, 20 and 30 November, and three seed rates viz. 8, 10 and 12 kg seeds ha^{-1}. The highest seed yield (1.53 t/ ha) was recorded in 10 November sowing and the lowest one was achieved in 30 November sowing.

A study was carried out by Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the highest seed yield (1727 kg /ha) was recorded under 01 November sowing followed by 21 October sowing.

A study was carried out by Turhan *et al*. (2011) to find out the effect of sowing dates and varieties and significant differences were found between sowing times for most of the traits measured. The lowest average seed yield (1027.40 kg/ ha) was obtained from the latest sowing time, whereas the highest average seed yield (2437.50 kg /ha) was obtained from the earliest sowing time.

Patel *et al*. (2004) observed that Indian mustard seeds were sown on November 8, November 18 and November 28, and December 8 December 18 in field experiment conducted in Indian during winter of 1995-98. The yield of Indian mustard decreased

with delay in sowing. The highest seed yield (1409 kg/ha) was recorded with November 8 sowing.

Panda *et al*. (2004) conducted a field experiment on sandy-loam soil in New Delhi, India, to study the effect of dates of sowing (October 16, October 31 and November 15) on Indian mustard (*B. juncea*). The crop sown on October 16 recorded a higher seed yield (1945 kg ha^{-1}) than the crops sown on October 31 (1556 kg ha^{-1}) and November 15 (872 kg /ha) and delayed sowing beyond October 16 significantly reduced yields.

Sihag *et al*. (2003) found that among the sowing dates October 15, October 30, November 14 and November 29 the highest dry matter accumulation at 90 days of crop growth (31.07 g per plant) and at harvest (42.40 g per plant) was obtained in October 15 sown crops. The highest seed (21.50 q /ha) was obtained in October 15 sown crops.

Razzaque *et al*. (2002) mentioned that, the crop sown on November 15 recorded the highest seed yield (1164.4 kg /ha) but it did not differ significantly from that of November 23 sowing (1001.9 kg /ha). Inferior yield was obtained from December 7 (612 kg /ha) sowing which was identical to that from November 30 (700.6 kg ha^{-1}) due to the high temperature at reproductive stage.

Angrej *et al*. (2002) found that, the highest yield was obtained when the crop was sown between October 10 and October 30. Yield reductions of 26.4 and 40.2% were obtained when sowing was delayed to November 20 and December 10, respectively.

BARI (2001) reported that at Joydebpur location seed yield and other yield contributing characters were significantly varied among the dates of plantings.

Panwar *et al*. (2000) reported that yield of *Brassica* spp. Decreased when sown on November 5 (mean 1.17 t/ ha) compared with October 20 (1.70 and 1.77 t/ha respectively). Brar *et al.* (1998) reported that seed yield was influenced by sowing date. The highest yield was given by sowing on August 13 or September 5.

Buttar and Aulakh (1999) observed that the seed yield of Indian mustard obtained was significantly higher when the crop was sown on October 25 than sown on November 15 and September 5. Shastry and Kumar (1981) and Narang and Singh (1987) also made similar observations.

Mondal *et al.* (1999) showed that, the highest seed yield /ha (1.39 t) was from third planting (November 1) compared with the first and last four planting dates.

BARI (1999) stated that different sowing time significantly influenced the yield of mustard. Significantly highest yield grain yield was obtained from November 19 sowing. Yield reduction was (31 to 72%) when mustard was sown in December and 28% in October 29 sowing.

Brar *et al*. (1998) stated that crops sown on October 30 recorded highest seed yield (16.5 q ha^{-1} than November 30 and December 15 sowings. Chakraborty *et al*. (1991) reported that early sowing (October 16) produced 24% higher seed yield than that of later sowing (November 2). Ghosh and Chatterjee (1988) stated similar results in their experiment with sowing date.

Nair (1998) stated that mean grain yield in both the years among the varieties decreased with later sowing.

Yadav *et al*. (1996) observed that a 2-year field experiment was conducted during the winter seasons at Morena, Madhya Pradesh, to investigate the effects of sowing date (October 17 or October 27, November 6 November 16) on the seed yield of *Brassica juncea cv.* Pusa Bold. Early sowing (October) resulted significantly higher seed compared with later sowing.

Mondal and Islam (1993) found that the highest seed yield plant-^{1} and seed yield per ha^{-1} were obtained from the October 15 sowing which were similar to November 1. Seed yield decreased with delayed sowing.

Mondal *et al*. (1992) reported that the highest seed yield ha^{-1} (1.45 t) was from second planting (Octorber 16) and was significantly different from last planting (November 16.)

Zaman *et al*. (1991) suggested that October 18 and October 28 were better over November 7 for higher yield, and higher yield was attributed by pods per plant and seed per pod. They observed that the seed yield decreased generally with the delay in sowing in all varieties. This view was strengthened by the finding of Uddin *et al*. (1987).

Joshi *et al*. (1989) reported that sowing too early and too late resulted in seed reduction due to natural hazards like insect pest and disease infestation. Early sowing reduced seed yield than in late sowing (mid July-mid August) since the former had a risk of rotting.

2.1.10 Stover yield

Sattar *et al*. (2013) carried out an experiment with three varieties of canola viz; Bulbul-98, Zafar-2000 and Rainbow sown at three different sowing dates, early (15th October), late (30th October) and very late (15th November). Results indicate that from all these three varieties, stover yield were decreased due to delayed sowing. The decline of stover yield with delay in sowing date could be largely explained by the decline in biomass at maturity.

Afroz *et al*. (2011) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the effect of sowing date and seed rate on the yield and yield components of two mustard varieties included two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date viz. 10, 20 and 30 November, and three seed rates viz. 8, 10 and 12 kg seeds ha^{-1} and recorded the highest stover yield (2.68 t/ha) was recorded in 10 November sowing and the lowest one was achieved in 30 November sowing.

BARI (2001) reported that sowing date have effect on stover yield. In sowing time November 16 stover yield (3991 kg/ha^{-1}) was higher than December sowing 3 (2417.56 kg/ha).

Brar *et al*. (1998) stated that straw yield of mustard decreased significantly with the each delay in sowing.

Islam *et al*. (1994) stated that stover yield was significantly influenced by sowing time. Higher stover yield was observed in October 20 sowing that gradually decreased in December 02 sowing.

Chakraborty *et al*. (1991) stated that delayed sowing significantly reduced stover yield. October sown crops produced higher dry matter than in November sown ones.

2.1.11 Biological yield

A study was carried out by Turhan *et al*. (2011) to find out the effect of sowing dates and varieties and significant differences were found between sowing times for most of the traits measured. The lowest biological yield (3143.98 kg ha^{-1}) was obtained from the latest sowing time, whereas the highest average stover yield (4231.56 kg ha^{-1}) was obtained from the earliest sowing time.

Sihag *et al*. (2003) a field experiment was conducted in Bikaner, Rajasthan, India, to determine the effect of sowing date date (October 15, October 30, November 14 and November 29) of Indian mustard. The highest biological yield (65.23 q ha^{-1}) was obtained in October 15 sown crops.

Islam and Razzaque (1999) stated that biological yield reduced in general with delaying the day of sowing. Highest biological yield was obtained mainly between the first and second date of sowing. The last date of sowing (December 1) reduced biological yield.

2.1.12 Harvest index

Afroz *et al*. (2011) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the effect of sowing date and seed rate on the yield and yield components of two mustard varieties included two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date viz. 10, 20 and 30 November, and three seed rates viz. 8, 10 and 12 kg seeds per ha and recorded the highest harvest index was recorded in 10 November sowing and the lowest one was achieved in 30 November sowing.

Gfadakar *et al*. (1988) stated that seed yield and dry matter accumulation was positively correlated with heat unit accumulation and accumulation of heat unit varied with growth stage, variety and sowing time. The temperature fluctuation caused the variation in the accumulation of thermal units in plants and it affected harvest index.

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 effect of sowing dates and salicylic acid on the Morpho-physiology, yield and quality of Mustard. 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 experiment was conducted during the period from October, 2016 to November, 2016.

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 lies between $23^0 74^/$N latitude and $88^0 35^/$E longitude with an elevation of 8.2 meter from the sea level.

3.1.3 Climatic condition

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

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 conducting the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix I.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised of two factors

Factors A: Sowing date (4 times)

i) S_1: Sowing at 25 October, 2016

ii) S_2: Sowing at 05 November, 2016

iii) S_3: Sowing at 15 November, 2016

iv) S_4: Sowing at 25 November, 2016

Factor B: Different concentration of salicylic Acid (SA) (3 Concentration)

i) SA_0: 0mM

ii) SA_1: 0.2mM

iii) SA_2: 0.4mM

There were in total 12 (4×3) treatment combinations such as S_1SA_0, S_1SA_1, S_1SA_2, S_2SA_0, S_2SA_1, S_2SA_2, S_3SA_0, S_3SA_1, S_3SA_2, S_4SA_0, S_4SA_1 and S_4SA_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 12 plots where 12 treatments combination were allotted at random. There were 36 unit plot altogether in the experiment. The size of each plot was 2.0 m × 1.5 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 Appendix II.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sarisha-11 was used as plating materials in this experiment. BARI sarisha-11 is high yielding varieties of mustard developed by the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The seeds were collected from 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 12 October, 2016, 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 24 October, 2016.

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, 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 20 and 45 days after sowing (DAS) respectively.

3.3.4 Seed sowing

The seeds of mustard were sown on 25 October, 2016, 05 November, 2016,15 November, 2016 and 25 November,2016 as per treatment in rows in the furrows having a depth of 2-3 cm .

3.3.5 Intercultural operations

3.3.5.1 Thinning

Seeds started of germinate four days after sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain optimum plant population in each plot.

3.3.5.2 Irrigation and weeding

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

3.3.5.3 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. Plants were attacked by aphids at last stage. 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 were randomly selected and marked with sample card. Plant height, branches per plant and leaf area index was recorded from selected plants at an interval of 10 days started from 30 DAS to 60 DAS and at harvest.

3.5 Harvest and post harvest operations

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

3.6 Data collection

i. Plant height(cm)
ii. Number of branches plant^{-1}
iii. Number of siliqua per plant^{-1}
iv. Length of siliqua (cm)
v. Number of seeds siliqua^{-1}
vi. Weight of 1000 seeds
vii. Seed yield hectare^{-1}
viii. Stover yield hectare^{-1}
ix. Biological yield hectare^{-1}
x. Harvest index

3.7 Procedure of data collection

3.7.1 Plant height

The plant height was measured at 30, 40, 50 and 60 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 plant^{-1}

The number of branches per plant was counted at 30, 40, 50 and 60 DAS and at harvest from selected plants. The average number of branches per plant was determined and recorded.

3.7.3 Number of siliqua plant^{-1}

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

3.7.4 Length of siliqua

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

3.7.5 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 per siliqua.

3.7.6 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).

3.7.7 Seed yield

The seeds collected from 6 (2 m × 1 m) square meter of each plot were sun dried properly. The weight of seeds was taken and converted into yield in t ha^{-1}.

3.7.8 Stover yield

The stover collected from 6 (2 m × 1 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted into yield in t ha^{-1}.

3.7.9 Biological yield

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

3.7.10 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 effect of sowing dates and variety on yield contributing characters and yield of mustard. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DICUSSION

The results obtained with different sowing dates (S) and salicylic acid (SA) and their combinations are presented and discussed in this chapter. Data about morphophysiological parameters, yield contributing characters and grain yield of mustard have been presented in both Tables and Figures and analyzes of variance and corresponding degrees of freedom have been shown in Appendix.

4.1 Plant height

4.1.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms of plant height of mustard at 30, 40, 50 DAS and at harvest (Appendix III). At 30, 40, 50 DAS and at harvest, the tallest plant (93.50, 106.1, 120.6, 88.83 and 90.61 cm, respectively) was recorded from S_1 (Sowing at 25 October) whereas the shortest plant (64.87, 72.52, 98.24, 83.79 and 66.19 cm respectively) was found from S_4 (Sowing at 25 November) (Table 1). Management factor, soil moisture content and weather condition influence plant height of mustard and all of these factors are governed by time of seed sowing. In case of delayed planting, the development of plant organs and transfers from source to sink were remarkably affected, which was influenced and also reflected by overall shortening of plant height. In case of late sowing plants faced stress of higher temperature during later stages of growth, so the plants were shorter than the other sowing dates. Mondal and Islam (1993) found that the longest plants were found in November 1 sowing which was followed by November 15, and October 15 sowing and the shortest plant height was found in December 1 sowing. In another experiment Afroz *et al*. (2011) recorded the longest plant in 10 November sowing and the shortest plant in 30 November sowing. But Khatun *et al*. (2011) reported the tallest plant from 01 November sowing followed by 21 October sowing.

Table 1. Effect of different sowing dates on plant height (at different days after sowing) of mustard

Treatments	Plant height (cm)			
	30 DAS	**40DAS**	**50DAS**	**At harvest**
S_1	93.50 a	106.1 a	120.6 a	90.61 a
S_2	87.48 b	86.76 b	113.0 b	82.97 b
S_3	78.92 c	81.43 c	106.6 c	76.02 c
S_4	64.87 d	72.52 d	98.24 d	66.19 d
LSD $_{(0.05)}$	**5.422**	**5.277**	**3.742**	**4.517**
Significant level	*****	******	******	******
CV (%)	**6.83**	**6.23**	**3.49**	**5.85**

S_1: Sowing at 25 October, S_3: Sowing at 15 November,

S_2: Sowing at 05 November, S_4: Sowing at 25 November

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

4.1.2 Effect of salicylic acid

Salicylic acid had significant effect on plant height of mustard at 30, 40, 50 DAS and at harvest (Table 2 and Appendix III). At 30, 40, 50 DAS and at harvest, the tallest plant height (109.5 cm, 105.8 cm, 126.9 cm and 95.89 cm, respectively) was recorded from 0.4 mM salicylic acid (SA_2) whereas the shortest (38.39 cm, 61.32 cm, 89.51 cm and 62.98 cm, respectively) was observed with SA_0 or control. 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.

Table 2. Effect of salicylic acid on plant height (at different days after sowing) of mustard

Treatments	Plant height (cm)			
	30 DAS	**40DAS**	**50DAS**	**At harvest**
SA_0	38.39 c	61.32 c	89.51 c	62.98 c
SA_1	95.67 b	93.01 b	112.4 b	77.97 b
SA_2	109.5 a	105.8 a	126.9 a	95.89 a
LSD $_{(0.05)}$	**4.696**	**4.570**	**3.241**	**3.912**
Significant level	**	**	**	**
CV (%)	**6.83**	**6.23**	**3.49**	**5.85**

SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability

4.1.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on plant height of mustard at 30, 40, 50 DAS and at harvest (Table 3 and Appendix III). At 30, 40, 50 DAS and at harvest, the highest plant height (120.1 cm, 126.8 cm, 135.8 cm and 103.0 cm, respectively) was observed from the S_1SA_2 treatment and the lowest (14.33 cm, 55.30 cm. 77.27 cm and 50.90 cm, respectively) plant height was observed from S_4SA0 treatment combination.

Table 3. Interaction effect of different sowing dates and salicylic acid on plant height (at different days after sowing) of mustard

Treatments	Plant height (cm)			
	30 DAS	**40DAS**	**50DAS**	**At harvest**
S_1SA_0	54.03 f	70.53 e	102.7 f	73.00 c
S_1SA_1	106.3 bc	121.0 a	123.4 bcd	95.83 a
S_1SA_2	120.1 a	126.8 a	135.8 a	103.0 a
S_2SA0	49.83 f	63.30 ef	93.50 g	70.43 cd
S_2SA_1	99.23 cd	92.13 cd	117.1 de	77.93 bc
S_2SA_2	113.4 ab	104.8 b	128.3 b	100.5 a
S_3SA0	35.37 g	56.13 f	84.57 h	57.60 ef
S_3SA_1	90.40 de	87.63 d	110.8 e	74.43 c
S_3SA_2	111.0 ab	100.5 bc	124.5 bc	96.03 a
S_4SA0	14.33 h	55.30 f	77.27 i	50.90 f
S_4SA_1	86.70 e	71.30 e	98.33 fg	63.67 de
S_4SA_2	93.57 de	90.97 d	119.1 cd	84.00 b
LSD $_{(0.05)}$	**9.392**	**9.140**	**6.481**	**7.824**
Significant level	**	**	**	**
CV (%)	**6.83**	**6.23**	**3.49**	**5.85**

S_1: Sowing at 25 October,
S_2: Sowing at 05 November,
S_3: Sowing at 15 November,
S_4: Sowing at 25 November

SA_0: 0 mM Salicylic Acid (control),
SA_1: 0.2 mM Salicylic Acid,
SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability

4.2 Number of branches

4.2.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms of number of branches plant^{-1} of mustard at 30, 40, 50 DAS and at harvest (Table 4 and Appendix IV). At 30, 40, 50 DAS and at harvest, the highest number of branches plant^{-1} (2.40, 5.13, 7.00, and 8.63 respectively) was recorded from S_1 (Sowing at 25 October) whereas the lowest number of branches plant^{-1} (1.43, 2.70, 3.56, and 4.83 respectively) was found from S_4 (Sowing at 25 November) (Table 4). Similarly Gawariya *et al*. (2015) reported that sowing during 1st October recorded significantly higher in no. of primary, secondary and tertiary branches compared to 31st October and 15th November.

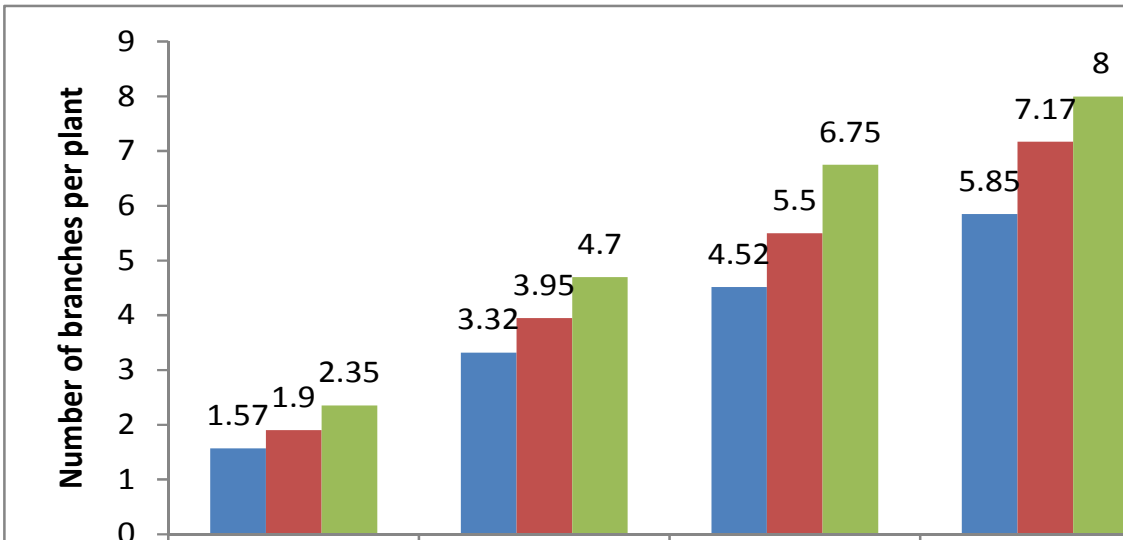
Table 4. Effect of different sowing dates on number of branches plant^{-1} (at different days after sowing) of mustard

Treatments	Number of branches plant^{-1}			
	30 DAS	40DAS	50DAS	At harvest
S_1	2.40 a	5.13 a	7.00 a	8.63 a
S_2	2.10 b	4.43 b	6.53 b	7.63 b
S_3	1.83 c	3.70 c	5.26 c	6.93 c
S_4	1.43 d	2.70 d	3.56 d	4.83 d
LSD $_{(0.05)}$	**0.138**	**0.138**	**0.098**	**0.116**
Significant level	**	**	**	**
CV (%)	**3.43**	**4.24**	**3.48**	**6.13**

S_1: Sowing at 25 October, S_3: Sowing at 15 November,
S_2: Sowing at 05 November, S_4: Sowing at 25 November
** Significant at 0.01 level of probability;

4.2.2 Effect of salicylic acid

Salicylic acid had significant effect on number of branches plant^{-1} of mustard at 30, 40, 50 DAS and at harvest (Figure 1 and Appendix IV). At 30, 40, 50 DAS and at harvest, the maximum number of branches plant^{-1} (2.35, 4.70, 6.75, and 8.00 respectively) was found from 0.4 mM salicylic acid (SA_2) whereas the minimum number of branches plant^{-1} (1.57, 3.32, 4.52, and 5.85 respectively) was observed with SA_0 or control treatment. Similar results was found with Muhal *et al.* (2014) who reported that foliar application of salicylic acid produced significantly the maximum branches plant^{-1} at different days after sowing.



SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid

Figure 1. Effect of salicylic acid on number of branches plant^{-1} (at different days after sowing) of mustard

4.2.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on number of branches plant^{-1} of mustard at 30, 40, 50 DAS and at harvest (Table 5 and Appendix IV). At 30, 40, 50 DAS and at harvest, the maximum number of branches plant^{-1} (2.90, 5.80, 7.90, and 9.40 respectively) was observed from the S_1SA_2 treatment and the lowest number of branches plant^{-1} (1.00, 1.80, 2.00, and 3.00 respectively) was observed from S_4SA0 treatment combination.

Table 5. Interaction effect of different sowing dates and salicylic acid on number of branches plant^{-1} (at different days after sowing) of mustard

Treatments	Number of branches plant^{-1}			
	30 DAS	**40DAS**	**50DAS**	**At harvest**
S_1SA_0	1.90 cd	4.30 d	5.90 e	7.50 e
S_1SA_1	2.40 b	5.30 b	7.20 c	9.00 b
S_1SA_2	2.90 a	5.80 a	7.90 a	9.40 a
S_2SA0	1.80 de	4.00 ef	5.40 g	6.90 g
S_2SA_1	2.00 cd	4.30 d	6.80 d	7.30 f
S_2SA_2	2.50 b	5.00 c	7.40 b	8.70 c
S_3SA0	1.60 ef	3.20 h	4.80 i	6.00 h
S_3SA_1	1.80 de	3.70 g	5.00 h	7.00 g
S_3SA_2	2.10 c	4.20 de	6.00 e	7.80 d
S_4SA0	1.00 g	1.80 j	2.00 k	3.00 j
S_4SA_1	1.40 f	2.50 i	3.00 j	5.40 i
S_4SA_2	1.90 cd	3.80 fg	5.70 f	6.10 h
LSD $_{(0.05)}$	**0.239**	**0.239**	**0.169**	**0.193**
Significant level	**	**	**	**
CV (%)	**3.43**	**4.24**	**3.48**	**6.13**

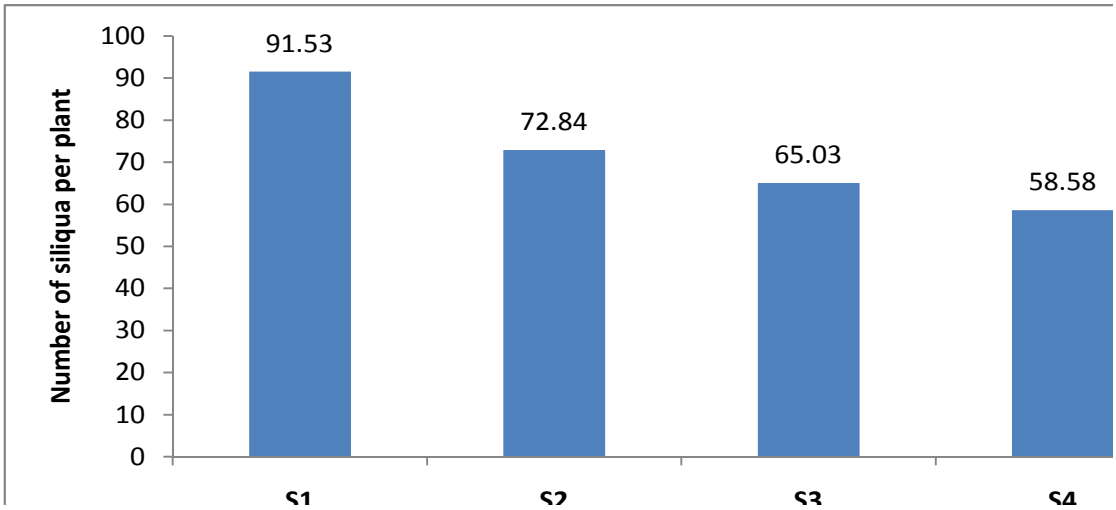
S_1: Sowing at 25 October,
S_2: Sowing at 05 November,
S_3: Sowing at 15 November,
S_4: Sowing at 25 November

SA_0: 0 mM Salicylic Acid (control),
SA_1: 0.2 mM Salicylic Acid,
SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability;

4.3. Number of siliqua

4.3.1 Effect of sowing date

Number of siliqua plant^{-1} of mustard was significantly influenced by different sowing dates (Figure 2 and Appendix V). The highest number of siliqua plant^{-1} (91.53) was recorded from S_1 (Sowing at 25 October) whereas the lowest number of siliqua plant^{-1} (58.58) was found from S_4 (Sowing at 25 November). This result is similar with Gawariya *et al*. (2015) who reported that sowing during 1st October recorded significantly higher crop yield attributing characters viz. siliqua per plant compared to 31st October and 15th November.



S_1: Sowing at 25 October, S_3: Sowing at 15 November,
S_2: Sowing at 05 November, S_4: Sowing at 25 November

Figure 2. Effect of different sowing dates on number of siliqua plant^{-1} of mustard

4.3.2 Effect of salicylic acid

Salicylic acid had significant effect on number of siliqua plant^{-1} of mustard (Table 6 and Appendix V). The maximum number of siliqua plant^{-1} (102.9) was recorded from SA_2 (0.4 mM salicylic acid) whereas the minimum number of siliqua plant^{-1} (38.58) was found from SA_0 (0 mM salicylic acid). This result is agreed with Muhal and Solanki (2015) who reported that 100 ppm SA foliar spray registered significantly higher number of siliqua per plant compared to water spray.

Table 6. Effect of salicylic acid on number of siliqua plant^{-1}, number of seeds siliqua^{-1}and weight of 1000 seeds of mustard

SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid

Treatments	Number of siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000 seeds weight (g)
SA_0	38.58 c	20.90 c	3.72 c
SA_1	74.48 b	22.23 b	4.05 b
SA_2	102.9 a	24.45 a	4.33 a
LSD $_{(0.05)}$	**3.268**	**0.026**	**0.026**
Significant level	**	**	**
CV (%)	**5.36**	**3.64**	**3.29**

**

Significant at 0.01 level of probability

4.3.3 Interaction effect of sowing date and salicylic acid

Significant influence was observed on number of siliqua plant^{-1} of mustard due to the interaction of sowing date and salicylic acid (Table 7 and Appendix V). The highest number of siliqua plant^{-1} (144.1) was observed from the S_1SA_2 treatment and the lowest number of siliqua plant^{-1} (32.90) was observed from S_4SA_0 treatment combination. Similarly, Sharma *et al*. (2013) found that 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.

Table 7. Interaction effect of different sowing dates and salicylic acid on number of siliqua plant^{-1}, length of siliqua, number of seeds siliqua^{-1}and weight of 1000 seeds of mustard

Treatments	Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	1000 seeds weight (g)
S_1SA_0	51.30 g	4.30 e	22.10 f	4.28 d
S_1SA_1	79.20 d	4.80 b	24.20 d	4.37 c
S_1SA_2	144.1 a	5.20 a	26.40 a	4.690 a
S_2SA_0	35.40 h	4.10 g	21.30 h	3.90 f
S_2SA_1	78.50 de	4.30 e	22.60 e	4.20 e
S_2SA_2	104.6 b	4.50 c	25.50 b	4.53 b
S_3SA_0	34.70 h	3.50 h	20.70 j	3.38 h
S_3SA_1	69.60 f	4.20 f	21.90 g	3.90 f
S_3SA_2	90.80 c	4.40 d	24.80 c	4.21 e
S_4SA_0	32.90 h	3.30 i	19.50 l	3.30 i
S_4SA_1	70.63 f	4.10 g	20.20 k	3.72 g
S_4SA_2	72.20 ef	4.20 f	21.10 i	3.89 f
LSD $_{(0.05)}$	**6.536**	**0.053**	**0.054**	**0.053**
Significant level	**	**	**	**
CV (%)	**5.36**	**5.23**	**3.64**	**3.29**

S_1: Sowing at 25 October,
S_2: Sowing at 05 November,
S_3: Sowing at 15 November,
S_4: Sowing at 25 November

SA_0: 0 mM Salicylic Acid (control),
SA_1: 0.2 mM Salicylic Acid,
SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability

4.4. Length of siliqua

4.4.1 Effect of sowing date

Significant influence was observed on length of siliqua (cm) of mustard due to the different sowing dates (Table 8 and Appendix V). S_1 (Sowing at 25 October) gave the highest length of siliqua (4.77 cm) whereas S_4 (Sowing at 25 November) gave the lowest length of siliqua (3.87 cm). Siliqua length showed decreasing tendency with delay in sowing. This result is agreed with Hossain *et al*. (1996) who found that the significant variation in siliqua length in mustard due to planting time.

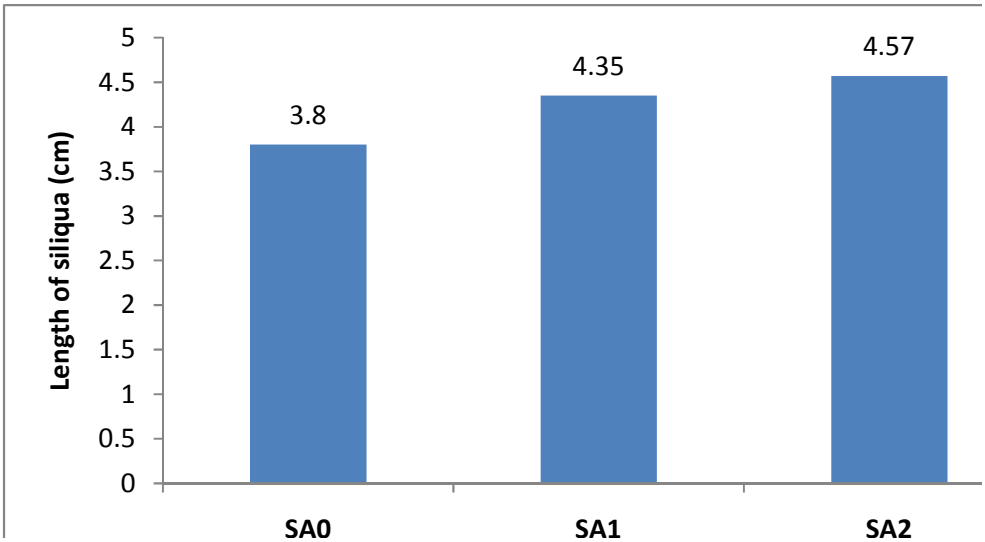
Table 8. Effect of different sowing dates on length of siliqua, number of seeds siliqua^{-1} and weight of 1000 seeds of mustard

Treatments	Length of siliqua (cm)	Number of seeds siliqua^{-1}	1000 seeds weight (g)
S_1	4.77 a	24.23 a	4.45 a
S_2	4.30 b	23.13 b	4.21 b
S_3	4.03 c	22.47 c	3.83 c
S_4	3.87 d	20.27 d	3.64 d
LSD $_{(0.05)}$	**0.031**	**0.031**	**0.032**
Significant level	**	**	**
CV (%)	**5.23**	**3.64**	**3.29**

S_1: Sowing at 25 October, S_3: Sowing at 15 November,
S_2: Sowing at 05 November, S_4: Sowing at 25 November
** Significant at 0.01 level of probability

4.4.2 Effect of salicylic acid

Salicylic acid had significant effect on length of siliqua of mustard (Figure 3 and Appendix V). The longest siliqua (4.57 cm) was recorded from SA_2 (0.4 mM salicylic acid) whereas the shortest siliqua (3.80 cm) was found from SA_0. Similar result found by Alam, M. A. (2015).



SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid

Figure 3. Effect of salicylic acid on length of siliqua of mustard

4.4.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on length of siliqua of mustard (Table 7 and Appendix V). The highest length of siliqua (5.20 cm) was observed from the S_1SA_2 treatment and the lowest length of siliqua (3.30 cm) was observed from S_4SA0 treatment combination.

4.5 Number of seeds

4.5.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms of number of seeds siliqua^{-1} of mustard (Table 8 and Appendix V). The maximum number of seeds siliqua^{-1} (24.23) was recorded from S_1 (Sowing at 25 October) whereas the minimum number of seeds siliqua^{-1} (20.27) was found from S_4 (Sowing at 25 November). Number of seeds siliqua^{-1} decreased progressively with delay in planting. Khatun *et al*. (2011) to find out the effect of sowing dates and varieties and reported the highest number of seeds siliqua^{-1} (5.67) was recorded under 01 November sowing followed by 21 October sowing.

4.5.2 Effect of salicylic acid

Salicylic acid had significant effect on number of seeds siliqua^{-1} in plant of mustard (Table 6 and Appendix V). SA_2 treatment gave the highest number of seeds siliqua^{-1} (24.45) while SA_0

gave the lowest number of seeds siliqua^{-1} (20.90). Similar result was found by Sharma *et al*. (2013) who reported that Salicylic Acid improved yield attributes and total number of seeds siliqua^{-1} improved by 3.2% over the control.

4.5.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on number of seeds siliqua^{-1} of mustard (Table 7 and Appendix V). The highest number of seeds siliqua^{-1} (26.40) was observed from the S_1SA_2 treatment and the lowest number of seeds siliqua^{-1} (19.50) was observed from S_4SA_0 treatment combination. Muhal and Solanki (2015) evaluate the effect of sowing dates and salicylic acid (SA) application on growth attributes, phenology and agro-meteorological indices of *Brassica* species and observed that mitigating the yield losses with SA due to late sown conditions number of seeds siliqua^{-1} was significantly higher compared to control.

4.6 Weight of 1000 seeds

4.6.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms of weight of 1000 seeds of Mustard (Table 8 and Appendix V). The maximum weight of 1000 seeds (4.45 g) was recorded from S_1 (Sowing at 25 October) whereas the minimum weight of 1000 seeds (3.64 g) was found from S_4 (Sowing at 25 November). This result is similar with Ghosh and Chatterjee (1988) who reported that one month later planting produced 32% reduction in seed weight. Similarly, Saran and Giri (1987) observed that sowing in October 25 gave 11% higher 1000-seed weight than that of November 15 sowing.

4.6.2 Effect of salicylic acid

Salicylic acid had significant effect on weight of 1000 seeds of Mustard (Table 6 and Appendix V). The highest weight of 1000 seeds (4.33 g) was recorded from SA_2 (0.4 mM salicylic acid) whereas the lowest weight of 1000 seeds (3.72 g) was found from SA_0 (control) treatment. Weight of 1000 seeds is increased with increasing the volume os salicylic acid and this result is agreed with Alam, M. A. (2015).

4.6.3 Interaction effect of sowing date and salicylic acid

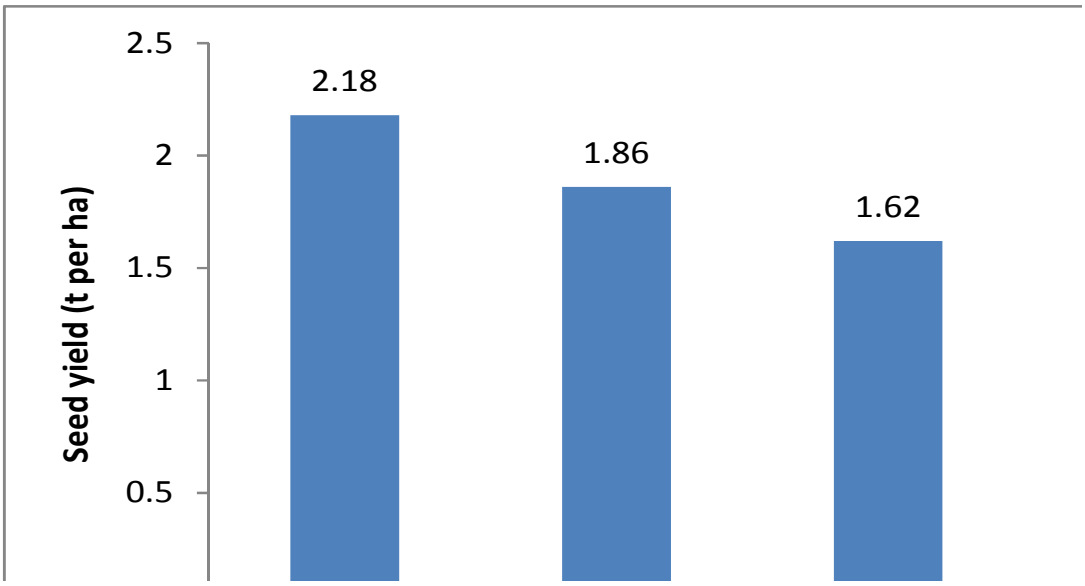
Interaction of sowing date and salicylic acid showed significant variation on weight of 1000 seeds of mustard (Table 7 and Appendix V). The maximum weight of 1000 seeds (4.69 g) was observed from the S_1SA_2 treatment and the minimum weight of 1000 seeds (3.30 g) was

observed from S_4SA_0 treatment combination. Similarly, Muhal and Solanki (2015) reported that mitigating the yield losses with SA due to late sown conditions weight of 1000 seeds of mustard was significantly higher compared to unsprayed.

4.7 Seed yield

4.7.1 Effect of sowing date

Seed yield (t ha^{-1}) of mustard was significantly influenced by different sowing dates (Figure 4 and Appendix VI). The maximum seed yield (2.18 t ha^{-1}) was recorded from S_1 (Sowing at 25 October) whereas the minimum seed yield (1.43 t ha^{-1}) was found from S_4 (Sowing at 25 November. Similar result was found by Gawariya *et al*. (2015) who recorded that significantly higher crop yield attributing characters and ultimately seed yield (2013 kg/ha) compared to 31st October and 15th November.



S_1: Sowing at 25 October, S_3: Sowing at 15 November,
S_2: Sowing at 05 November, S_4: Sowing at 25 November

Figure 4. Effect of different sowing dates on seed yield of mustard

4.7.2 Effect of salicylic acid

Seed yield (t ha^{-1}) of mustard showed significant variation due to different levels of salicylic acid (Table 9 and Appendix VI). The maximum seed yield (1.88 t ha^{-1}) was recorded from SA_2 (0.04 mM salicylic acid) whereas the minimum seed yield (1.65 t ha^{-1}) was found from SA_0. Similar result was found by Muhal and Solanki (2015) who reported that 100 ppm SA foliar spray registered significantly higher seed yield basis compared to water spray. Muhal *et al*.

(2014) also revealed that foliar application of salicylic acid produced significantly higher seed yield compared to water spray.

Table 9. Effect of salicylic acid on seed yield, stover yield, biological yield and harvest index of mustard

Treatments	Seed yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
SA_0	1.65 c	4.45 c	36.94 c
SA_1	1.78 b	4.70 b	37.75 b
SA_2	1.88 a	4.95 a	37.96 a
LSD $_{(0.05)}$	**0.027**	**0.026**	**0.026**
Significant level	**	**	**
CV (%)	**4.42**	**6.63**	**5.22**

SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability

4.7.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on seed yield (t ha^{-1}) of mustard (Table 10 and Appendix IV). The maximum seed yield (2.28 t ha^{-1}) was observed from the S_1SA_2 treatment and the minimum seed yield (1.32 t ha^{-1}) was observed from S_4SA_0 treatment combination. Sharma *et al*. (2013) reported that reducing the yield losses with SA due to terminal heat stress under late sown conditions.

Table 10. Interaction effect of different sowing dates and salicylic acid on seed yield, stover yield, biological yield and harvest index of mustard

Treatments	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
S_1SA_0	2.10 b	3.31 b	5.41 c	38.81 b
S_1SA_1	2.15 b	3.40 a	5.55 b	38.74 c
S_1SA_2	2.28 a	3.43 a	5.71 a	39.93 a
S_2SA0	1.71 e	2.89 e	4.60 g	37.17 f
S_2SA_1	1.88 d	2.97 d	4.85 e	38.76 bc
S_2SA_2	2.00 c	3.25 c	5.25 d	38.09 d
S_3SA0	1.47 h	2.67 g	4.14 i	35.50 k
S_3SA_1	1.65 f	2.75 f	4.40 h	37.50 e
S_3SA_2	1.73 e	2.94 de	4.67 f	37.04 g
S_4SA_0	1.32 i	2.32 i	3.64 k	36.26 i
S_4SA_1	1.44 h	2.56 h	4.00 j	36.00 j
S_4SA_2	1.53 g	2.63 g	4.16 i	36.78 h
LSD $_{(0.05)}$	**0.053**	**0.053**	**0.054**	**0.053**
Significant level	**	**	**	**
CV (%)	**4.42**	**3.22**	**6.63**	**5.22**

S_1: Sowing at 25 October,
S_2: Sowing at 05 November,
S_3: Sowing at 15 November,
S_4: Sowing at 25 November

SA_0: 0 mM Salicylic Acid (control),
SA_1: 0.2 mM Salicylic Acid,
SA_2: 0.4 mM Salicylic Acid
** Significant at 0.01 level of probability

4.8 Stover yield

4.8.1 Effect of sowing date

Stover yield (t ha^{-1}) of mustard was significantly influenced by different sowing dates (Table 11 and Appendix VI). The maximum stover yield (3.38 t ha^{-1}) was recorded from S_1 (Sowing at 25 October) whereas the minimum stover yield (2.50 t ha^{-1}) was found from S_4 (Sowing at 25 November). This result is agreed with Sattar *et al*. (2013) who reported that stover yield was decreased due to delayed sowing. The decline of stover yield with delay in sowing date could be largely explained by the decline in biomass at maturity. Islam *et al*. (1994) also stated that stover yield was significantly influenced by sowing time and higher stover yield was observed in October 20 sowing that gradually decreased in December 02 sowing.

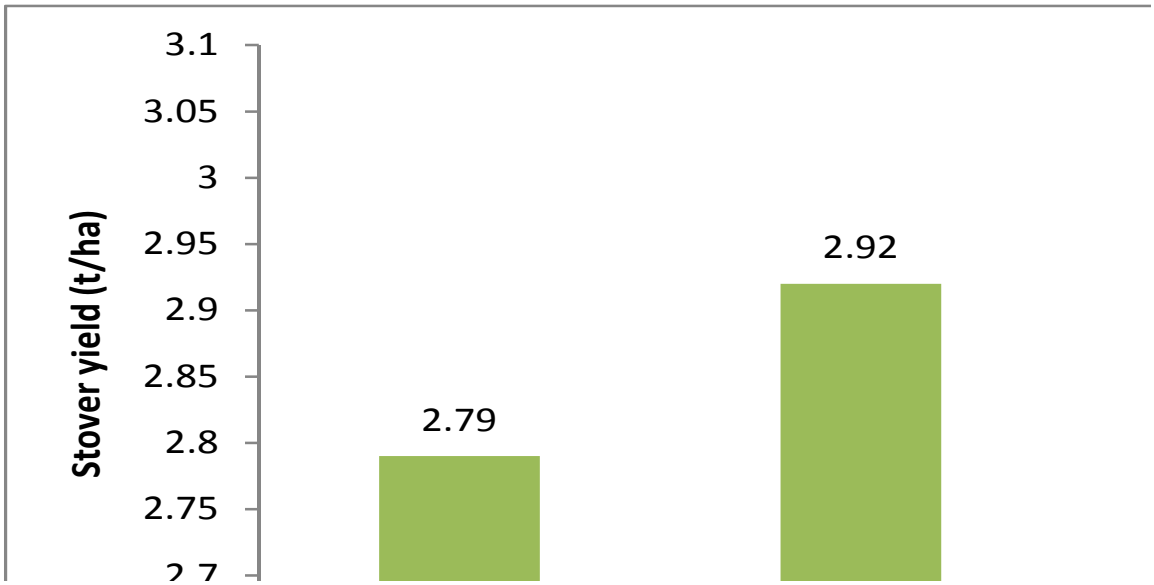
Table 11. Effect of different sowing dates on stover yield, biological yield and harvest index of mustard

Treatments	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	3.38 a	5.56 a	39.16 a
S_2	3.04 b	4.90 b	38.01 b
S_3	2.79 c	4.40 c	36.68 c
S_4	2.50 d	3.93 d	36.35 d
LSD $_{(0.05)}$	**0.033**	**0.031**	**0.032**
Significant level	**	**	**
CV (%)	**3.22**	**6.63**	**5.22**

S_1: Sowing at 25 October, S_3: Sowing at 15 November,
S_2: Sowing at 05 November, S_4: Sowing at 25 November
** Significant at 0.01 level of probability

4.8.2 Effect of salicylic acid

Salicylic acid had significant effect on stover yield (t ha^{-1}) of mustard (Figure 5 and Appendix VI). The maximum stover yield (3.06 t ha^{-1}) was recorded from SA_2 (0.04 mM salicylic acid) whereas the minimum stover yield (2.79 t ha^{-1}) was found from SA_0. Stover yield is increased with increasing the volume of salicylic acid and this result is agreed with Alam, M. A. (2015).



SA_0: 0 mM Salicylic Acid (control), SA_1: 0.2 mM Salicylic Acid, SA_2: 0.4 mM Salicylic Acid

Figure 5. Effect of different sowing dates on stover yield of mustard

4.8.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on stover yield (t ha^{-1}) of mustard (Table 10 and Appendix VI). The maximum stover yield (3.43 t ha^{-1}) was observed from the S_1SA_2 treatment and the minimum stover yield (2.32 t ha^{-1}) was observed from S_4SA_0 treatment combination. This result is ageed with Muhal and Solanki (2015) who reported that the effect of sowing dates and salicylic acid (SA) application on yield attributes of *Brassica* species and observed that stover yield was significantly higher under 100 ppm SA foliar spray compared to water spray.

4.9 Biological yield

4.9.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms biological yield (t ha^{-1}) of mustard (Table 11 and Appendix VI). The highest biological yield (5.56 t ha^{-1}) was recorded from S_1 (Sowing at 25 October) whereas the lowest biological yield (3.93 t ha^{-1}) was found from S_4 (Sowing at 25 November). Similarly, Sihag *et al*. (2003) recorded that the highest biological yield (65.23 q / ha) was obtained in October 15 sown crops.

4.9.2 Effect of salicylic acid

Salicylic acid had significant effect on biological yield (t ha^{-1}) of mustard (Table 9 and Appendix VI). The highest biological yield (4.95 t ha^{-1}) was recorded from 0.4 mM salicylic acid (SA_2) whereas the lowest biological yield (4.45 t ha^{-1}) was found from SA_0. Biological yield is increased with increasing the amount of salicylic acid and this result is agreed with Alam, M. A. (2015).

4.9.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on biological yield (t ha^{-1}) of mustard (Table 10 and Appendix VI). The maximum biological yield (5.71 t ha^{-1}) was observed from the S_1SA_2 treatment and the minimum biological yield (3.64 t ha^{-1}) was observed from S_4SA_0 treatment combination.

4.10 Harvest index

4.10.1 Effect of sowing date

Different sowing dates showed statistically significant variation in terms harvest index (%) of mustard (Table 11 and Appendix VI). The highest harvest index (39.16 %) was recorded from S_1 (Sowing at 25 October) whereas the lowest number of harvest index (36.35 %) was found from S_4 (Sowing at 25 November). Seed yield and dry matter accumulation was positively correlated with heat unit accumulation and accumulation of heat unit varied with growth stage, variety and sowing time. The temperature fluctuation caused the variation in the accumulation of thermal units in plants and it affected harvest index of mustard (Gfadakar *et al*., 1988).

4.10.2 Effect of salicylic acid

Salicylic acid had significant effect on harvest index (%) of mustard (Table 9 and Appendix VI). The highest harvest index (37.96 %) was recorded from 0.4 mM salicylic acid (SA_2) whereas the lowest harvest index (36.94 %) was found from SA_0.

4.10.3 Interaction effect of sowing date and salicylic acid

Interaction of sowing date and salicylic acid showed significant variation on harvest index (%) of mustard (Table 10 and Appendix VI). The highest Harvest index (39.93 %) was observed from the S_1SA_2 treatment and the lowest harvest index (36.26%) was observed from S_4SA_0 treatment combination. Alam, M. A. (2015) found that the statistically significant variation of harvest index of mustard due to different levels of salicylic acid.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from October, 2016 to March, 2016 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the morpho-physiology, yield and quality of mustard as influenced by different sowing times and salicylic acid. The experiment comprised of two factors- Factor A: Different sowing times (4) - S_1: 25 October, 2016; S_2: 05 November, 2016; S_3: 15 November, 2016 and S_4: 25 November, 2016; Factors B: Different concentration of salicylic acid (3 levels)- SA_0: 0 mM (control), SA_1: 0.2 mM, SA_2: 0.4 mM;. 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.

For different sowing dates, at 30, 40, 50 DAS and at harvest, the tallest plant (93.50, 106.1, 120.6, 88.83 and 90.61 cm, respectively) was recorded from S_1 whereas the shortest plant (64.87, 72.52, 98.24, 83.79 and 66.19 cm respectively) was found from S_4 treatment. At 30, 40, 50 DAS and at harvest, the highest number of branches plant^{-1} (2.40, 5.13, 7.00, and 8.63 respectively) was found from S_1 (Sowing at 25 October) whereas the lowest number of branches plant^{-1} (1.43, 2.70, 3.56, and 4.83 respectively) was found from S_4. The maximum number of siliqua plant^{-1} (91.53) was recorded from S_1 while the minimum number of siliqua plant^{-1} (58.58) was found from S_4 treatment. S_1 gave the highest length of siliqua (4.77 cm) whereas S_4 gave the lowest length of siliqua (3.87 cm). The maximum number of seeds siliqua^{-1} (24.23) was recorded from S_1 (Sowing at 25 October) whereas the minimum number of seeds siliqua^{-1} (20.27) was found from S_4 (Sowing at 25 November). The maximum weight of 1000 seeds (4.45 g) was recorded from S_1 whereas the minimum weight of 1000 seeds (3.64 g) was found from S_4 treatment. The maximum seed yield and stover yield (2.18 and 3.38 t ha^{-1} respectively) was recorded from S_1 (Sowing at 25 October) whereas the minimum seed yield and stover yield (1.43 and 2.50 t ha^{-1} respectively) was found from S_4 (Sowing at 25 November). The highest biological yield and harvest index (5.56 t ha^{-1} and 39.16 % respectively) was recorded from S_1 whereas the lowest biological yield and harvest index (3.93 t ha^{-1} and 36.35 % respectively) was found from S_4 treatment.

In case of salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant height (109.5 cm, 105.8 cm, 126.9 cm and 95.89 cm, respectively) was recorded from 0.4 mM salicylic acid

(SA_2) whereas the shortest (38.39 cm, 61.32 cm, 89.51 cm and 62.98 cm, respectively) was observed with SA_0 or control. At 30, 40, 50 DAS and at harvest, the maximum number of branches plant^{-1} (2.35, 4.70, 6.75, and 8.00 respectively) was found from 0.4 mM salicylic acid (SA_2) whereas the minimum number of branches plant^{-1} (1.57, 3.32, 4.52, and 5.85 respectively) was observed with SA_0 or control treatment. The maximum number of siliqua plant^{-1} (102.9) was recorded from SA_2 (0.4 mM salicylic acid) whereas the minimum number of siliqua plant^{-1} (38.58) was found from SA_0 (0 mM salicylic acid). The longest siliqua and weight of 1000 seeds (4.57 cm and 4.33 g, respectively) was recorded from SA_2 (0.4 mM salicylic acid) whereas the shortest siliqua and weight of 1000 seeds (3.80 cm and 3.72 g, respectively) was found from SA_0 (control) treatment. SA_2 treatment gave the highest number of seeds siliqua^{-1} (24.45) while SA_0 gave the lowest number of seeds siliqua^{-1} (20.90). The maximum seed and stover yield (1.88 and 3.06 t ha^{-1}, respectively) was recorded from SA_2 (0.04 mM salicylic acid) whereas the minimum seed and stover yield (1.65 and 2.79 t ha^{-1}, respectively) was found from SA_0. The highest biological yield and harvest index (4.95 t ha^{-1} and 37.96 %, respectively) was recorded from 0.4 mM salicylic acid (SA_2) whereas the lowest biological yield and harvest index (4.45 t ha^{-1} and 36.94 %, respectively) was found from SA_0 treatment.

For the interaction effect of sowing date and levels of salicylic acid of mustard, At 30, 40, 50 DAS and at harvest, the highest plant height (120.1 cm, 126.8 cm, 135.8 cm and 103.0 cm, respectively) was observed from the S_1SA_2 treatment and the lowest (14.33 cm, 55.30 cm. 77.27 cm and 50.90 cm, respectively) plant height was observed from S_4SA0 treatment combination. At 30, 40, 50 DAS and at harvest, the maximum number of branches plant^{-1} (2.90, 5.80, 7.90, and 9.40 respectively) was observed from the S_1SA_2 treatment and the lowest number of branches plant^{-1} (1.00, 1.80, 2.00, and 3.00 respectively) was observed from S_4SA0 treatment combination. The highest number of siliqua plant^{-1} and seeds siliqua^{-1} (144.1 and 26.40, respectively) was observed from the S_1SA_2 treatment and the lowest number of siliqua plant^{-1} and seeds siliqua^{-1} (32.90 and 19.50, respectively) was observed from S_4SA_0 treatment combination. The highest length of siliqua and weight of 1000 seeds (5.20 cm and 4.69 g, respectively) was observed from the S_1SA_2 treatment and the lowest length of siliqua and weight of 1000 seeds (3.30 cm and 3.30 g, respectively) was observed from S_4SA0 treatment combination. The maximum seed and stover yield (2.28 and 3.43 t ha^{-1}, respectively) was observed from the S_1SA_2 treatment and the minimum seed and stover yield (1.32 and 2.32 t ha^{-1} respectively) was observed from S_4SA_0 treatment combination. The maximum biological yield and harvest index (5.71 t ha^{-1} and 39.93 %, respectively) was observed from the S_1SA_2

treatment and the minimum biological yield and harvest index (3.64 t ha^{-1} and 36.26%. respectively) was observed from S_4SA_0 treatment combination.

From the above results it can be concluded that sowing on 20 November of mustard provided better yield with better yield contributing characters and salicylic acid concentration 0.4 mM followed by 0.2 mM provided better yield for mustard.

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 sowing dates, and
- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

REFERENCES

Afroz, M. M., Sarkar, M. A. R., Bhuiya, M. S. U. and Roy, A. K. (2011). Effect of sowing date and seed rate on yield performance of two mustard varieties. *J. Bangladesh Agril. Univ*. **9**(1): 5–8.

Ahmed, M. (2008). Results of farm level socio-economic study on mustard production. *Bangladesh J. Agril. Res*. **13**(1): 20-23.

AIS (Agricultural Information Service). (2013). Krishi Diary (In Bangla). Agril. Inform. Ser. Khamarbari, Farmgate, Dhaka, Bangladesh. p.16.

Angrej, S., Dhingra, K. K., Jagroop, S and Singh, M. P. (2002).Effect of sowing time and plant density on growth, yield and quality of Ethiopian mustard (*Brassica carinata* A. Br.). *J. Res. Punjab Agril. Univ.* **39**(4): 471-475.

Arfan, M., Athar, H. R. and Ashraf, M. (2007). Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress. *J. Plant. Physiol*. **164**: 685-694.

BARI (Bangladesh Agricultural Research Institute), (1992). Annual Report (1992-93). Bangladesh, Agril. Res. Inst. Joydebpur, pp. 231-298.

BARI (Bangladesh Agricultural Research Institute), (1999). Annual Report (1998-99). Bangladesh, Agril. Res. Inst. Joydebpur, pp. 126-131.

BARI (Bangladesh Agricultural Research Institute), (2001). Annual Report 2000-2001. Oilseed Research Centre.Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. p. 115-118.

Barkosky, R.R. and F.A. Einhelling. (1998). Effect of salicylic acid on plant water relationship. *J. Chem. Ecol*. **19**: 237-247.

Begum F., Hossain F. and Mondal M. R. I. (2012). Influence of Sulphur on morpho-physiological and yield parameters of rapeseed. *Bangladsh J. Agril. Res*. **37**(4): 645-652.

Brar, Z. S. D., Bal, S. and John, A. S. (1998). Influence of sowing dates, nitrogen and planting geometry on the performance of GobhiSarson (*Brassica napus spp. Olefera var. annua*). *Indian J. Agron*. **43**(1): 133-137.

Buttar, G. S. and Aulakh, C. S. (1999).Effect of sowing date, nitrogen and raw spacing on growth, yield attributes and yield of Indian mustard (*Brassica juncea*).*Indian J. Agron.* **44**(4): 813-815.

Chakraborty, P. K. Majumder, A. and Chatterjee, B. N. (1991). Physiological process in Indian mustard (*B. Juncea*) and yellow sarson(*B. napus var.* Glauca) and their organic appraisal in mild and short winter prevailing in Gangetic plain of Eastern India. *Indian J. Agric. Sci.* **61**(11): 851-861.

Dordas, C. A., Lithourgidis, A. S., Matsi,T. H. and Barbayiannis, N. (2008). Application of liquid cattle manure and inorganic fertilizers affect dry matter, nitrogen accumulation, and partitioning in maize. *Nutr.Cycl.Agroecosys*.**80**: 283-296.

FAO (Food and Agriculture Organization). (2012). Production Year Book. Food and Agriculture Organization of the United Nations, Rome. Italy.

Gawariya, S. C., Chopra, N. K., Chopra, N. and Harika, A. S. (2015). Effect of date of sowing and crop geometry on growth and yield parameters of forage mustard. *African J. Agril. Res*. **10**(33): 3292-3295.

Gfadakar, S. R., Morey, D. K. and Zilpe, Y. P. (1988).Effect of transplanting date on dry matter, yield and accumulation of photothermal units in rice (*Oryza sativa*) at Nagput.*Indian J. Agric. Sci.* **58**(5): 339-341.

Ghosh, R. K. and Chatterjee, B. N. (1988).Effect of dates of sowing on oil content and fatty acid profiles of Indian mustard.*Indian J. Oilseed Res.* **5**(2): 144-149.

Hocking, P. J. and Stapper, M. (2001).Effect of sowing time and nitrogen fertilizer on canola and wheat, and nitrogen fertilizer on Indian mustard. I. Dry matter production, seed yield, and yield components. *Australian J. Agric. Res*. **52**: 623-634.

Hussain, M. F, Zakaria, A. K. M. and Jahan, M. H. (1996).Technical report on variety screening, Adaptive research on oilseeds.Rural Development Academy. pp. 6-34.

Islam, N. and Razzaque, A. S. M. A. (1999). Accommodating mustard in the transplant aman rice mustard cropping pattern. 1. Selection of mustard varieties to late sowing. BAU Res. Prog. 10:58.

Islam, N., Choudhury, M. and Karim, M. R. (1994).Effect on sowing date on growth and development of mustard and rapes.*Progress. Agric*. **59**: 23-29.

Joshi, M. L., Ahuja, B. D. and Mathur, B. N. (1989).Loss in seed yield by insect pests and their occurrence on different dates of sowing in Indian mustard. (*B. juncea sub sp. Juncea*) *Indian J. Agric. Sci.* **59**(3): 166-168.

Khan, M.F.R., Pallardy, S.G. and Khan, R.P. (2003). Efficacy of insecticides at controlling insect pests of tomato in South Carolina. *J. Agric. and Urban Entomol*. **16** (3): 165-170.

Khatun, F., Alam, M. S. Hossain, M. A., Malaker, P. K. and Rashid, M. H. (2011). Effect of sowing dates and varieties on the severity of *Alternaria* blight of mustard. *Bangladesh J. Agril. Res*. **36**(4): 583-594.

Koutroubas, S. D., Papakosta, D. K. and Doitsinis, A. (2004). Cultivar and seasonal effects on the contribution of pre-anthesis assimilates to safflower yield. *Field Crop Res*. **90**: 263-274.

Mondal, M. R. I. and Islam, M. A. (1993).Effect of seed rate and date on yield and yield components of rapeseed.*Bangladesh J. Agril. Sci.* **20**(1):29-33.

Mondal, M. R. Islam, M. A. and Khaleque, M. A. (1992). Effect of variety and planting date on the yield performance of mustard and rapseed. *Bangladesh J. Agril. Sci*. **19**(92): 181-188.

Mondal, R. I., Biswas, M. M. K., Hydar-Ali and Akbar, M. A. (1999). Response of rapeseed genotype Dhali to rate and seeding date.*Bangladesh J. Agril.Res.* **24**(1):83-90.

Muhal, S and Solanki, N.S. (2015). Effect of seeding dates and salicylic acid foliar spray on growth, yield, phenology and agrometeorological indices of *Brassica* species. *J. Oilseed Brassica.* **6**(1): 183-190.

Muhal, S., Solanki, N.S., Singh, P. and Shukla, K.B. (2014). Effect of salicylic acid on productivity and nutrient uptake of *Brassica* species under different planting durations. *African J. Agril. Res*. **9**(3): 1101-1106.

Nair, A. K. (1998). Effect of sowing dates, and nitrogen levels on growth and yield of Ethiopian mustard (*Brassica carinata*) in Sikkim.*J. Andaman Sci. Asso.* **14**(2): 37-40.

Panda, B.B., Bandyopadhyay, S. K. and Shivay, Y. S. (2004). Effect of irrigation level, sowing dates and varieties on yield attributes, yield, consumptive water use and water-use efficiency of Indian mustard (*Brassica juncea*).*Indian J. Agril. Sci*. **74**(6): 339-342.

Panwar, K. S., Sharma, S. K. and Nanwal, R. K. (2000). Influence of sowing time on the yield of different mustard cultivars (*Brassica sp*.) under conserved soil moisture conditions. *Indian J. Agric. Sci.* **70**(6): 398-399.

Patel, S. R., Awasthi, A. K. and Tomar. R. K. S. (2004). Assessment of yield losses in mustard (*Brassica juncea L.*) due to mustard aphid (*Lipaphiserysimi*Kalt.) under different thermal environments in Eastern Central India.Department of Agricultural Meteorology, Indira Gandhi Agril.Univ. Raipur.492006 (C.G.), India.Applied- Ecology-and-Environmental-Research. **2**(1): 1-15.

Rahman, M. M., Hossain, S. M. A., Islam, N., Uddin, M. J. and Salam, M. U. (1993). Effect of sowing date and boron fertilizer on the yield and oil content of mustard and rapeseed.*Bangladesh J. Agri*. **15**(1&2): 73-78.

Razzaque, M. A., Howlader, M. I. A., Rafiquzzaman. S., Ahsanullah, M. and Uddin, M. N. (2002). Effect of sowing time of sowing on the performance of mustard varieties in the southern region of Bangladesh.*Bangladesh J. Agril. Res.* **27**(3): 479-484.

Robertson M. J., Holland, J. F. and Bambach, R. (2004).Response of canola and Indian mustard to sowing date in the grain belt of north-eastern Australia.*Australian J. Expt. Agric*. **44**: 43-52.

Saran, G. and Giri, G. (1987). Influence of dates of sowing on *Brassica* species under semi-arid rainfed conditions of North-West India. *J. Agric. Sci.* **108**: 561-566.

Sattar, A., Mumtaz, A. Cheema, M. A., Wahid, M., FarrukhSaleem, M. A., Ghaffari, ShabirHussain and Arshad, M. S. (2013).Effect of sowing time on seed yield and oil contents of canola varieties.*J. Glob. Innov. Agric. Soc. Sci.* **1**(1): 1-4.

Shahidullah, M., Islam, U., Karim, M. A. and Hussain, M. (1997). Effect of sowing dates and varieties on yield and yield attributes of mustard .*Bangladesh J. Sci. Ind. Res.* **32(**4): 515-516.

Sharma, P., Sardana, V. and Banga, S.S (2013). Effect of Salicylic Acid on Growth and Seed Filling in Indian Mustard (*Brassica juncea* L.) under High Temperature Stress. *Intl. J. Plant Res*. **26**(1): 243-249.

Shivani, K., Sanjeev, P. and Kumar, S. (2002). Response of Indian mustard (*Brassica juncea*) to sowing date and row spacing in mid-hills of Sikkim under rainfed conditions.*Indian J. Agron*. **47**(3): 405-410.

Sihag, J. S., Manohar, S. S. and Chaudhary, T. (2003). Combined effect of sulphur and time of sowing on yield attributes, yield and quality of mustard (*Brassica juncea L.* Czern and Coss). *J. Eco Physiol.* **6**(2): 65-68.

Singh, A. K., Singh, R. R., and Singh, P. K. (2014). Influence of dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea*L). *Intl. J. Farm Sci.* **4**(2): 80-85.

Singh, B. D. (2000). Plant Breeding, Kalyani Publisher. pp. 574-597.

Turhan, H., Muhammet Kemal, G. U. L., Cem Omer, E. and Kahriman, F. (2011). Effect of sowing time on grain yield, oil content, and fatty acids in rapeseed (*Brassica napus*subsp. oleifera).*Turk J Agric For*. **35**: 225-234.

Uddin, M.M., Samad, A. M. R., Khan, S., Begum and M. A. Salam. (1986). Effect of sowing dates on the yield and some of its components of mustard and rapeseed.*Bangladesh J. Inds. Res.* **21**: 159-166.

Yadav, K. S., Rajput, R. L., Shrivastava, U. K. and Yadav, R.P. (1996).Effect of sowing date and irrigation schedule on productivity of mustard (*Brassica juncea*L.). *Adv. Agril. Res.India.* **8**: 75-79.

Yau, S. K. (2007). Winter versus spring sowing of rain-fed safflower in a semi-arid, high-elevation Mediterranean environment. *European J. Agron*. **26**: 249-256.

Zaman, M. W. Ali, Z., Awal, H. M.A. and Talukder, M. Z. I. (1991). Influence of different stages of harvesting on the yield, oil content and shattering loss in *oleiferous Brassica. Bangladesh. J. Sci. Indus. Res*. **29**(4): 25-32.

APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Characteristics of the experimental field

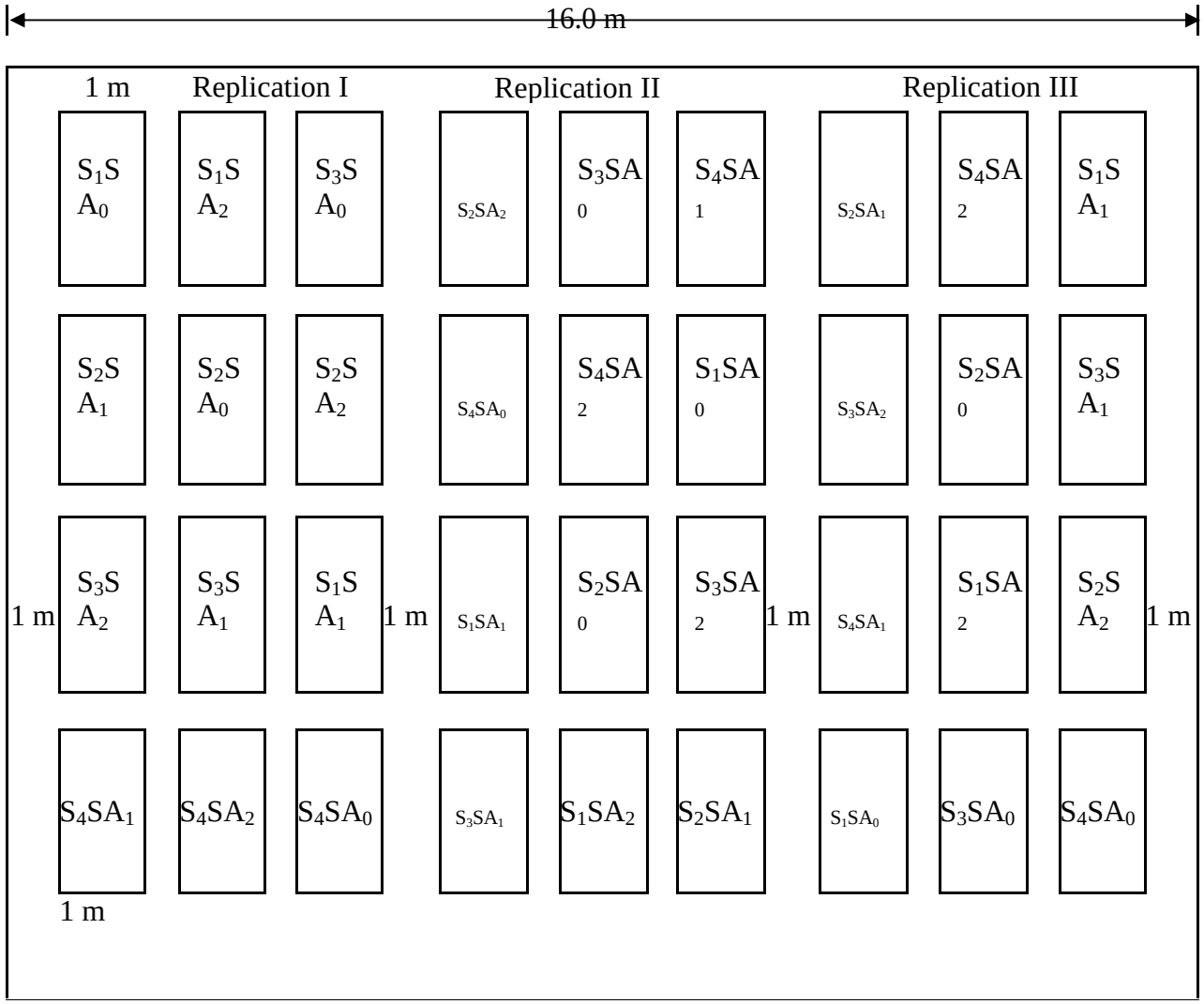
Morphological features	Characteristics
Location	Agricultural Botany field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

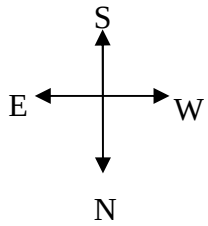
B. Physical and chemical properties of the initial soil

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 II. Layout of the experimental plot





Plot size = 2.0 m × 1.0 m

Plot spacing = 0.5 m
Between replication= 1.0 m

Factor A: Different sowing times (4)

i) S_1: 25 October, 2016
ii) S_2: 05 November, 2016
iii) S_3: 15 November, 2016
iv) S_4: 25 November, 2016

Factors B: Different levels of salicylic acid-SA (3 levels)
SA_0: 0 mM; SA_1: 0.2 mM; SA_2: 0.4 mM;

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

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	78.031	2305.242	950.855	1593.535
Sowing date (A)	3	1387.999*	1815.330**	814.234**	970.599**
Conc. of salicylic acid (B)	2	17062.028**	6289.694**	4272.312**	3257.529**
Interaction (A×B)	6	97.153**	154.446**	21.088**	54.962**
Error	22	30.761	29.138	14.651	21.349

** 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 plant^{-1} of mustard at different days after sowing (DAS) as influenced by different sowing dates and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Number of branches plant^{-1} at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.034	0.076	0.089	0.543
Sowing date (A)	3	1.516**	9.756**	21.229**	23.302**
Conc. of salicylic acid (B)	2	1.818**	5.687**	14.927**	14.117**
Interaction (A×B)	6	0.041**	0.231**	1.184**	0.648**
Error	22	0.045	0.098	0.039	0.346**

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

Appendix V. Analysis of variance of the data on yield contributing characters of mustard as influenced by different sowing dates and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	1000 seeds weight (g)
Replication	2	1102.778	108.000	1200.000	108.000
Sowing date (A)	3	1832.864**	1.389**	25.176**	1.200**
Conc. of salicylic acid (B)	2	12481.613**	1.907**	38.618**	1.134**
Interaction (A×B)	6	626.377**	0.074**	1.461**	0.035**
Error	22	14.899	0.131	0.011	0.021

** 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 as influenced by different sowing dates and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	12.000	48.000	108.000	1200.000
Sowing date (A)	3	0.940**	1.249**	4.349**	15.017**
Conc. of salicylic acid (B)	2	0.166**	0.211**	0.750**	3.518**
Interaction (A×B)	6	0.053**	0.015**	0.021**	1.165**
Error	22	0.011	0.011	0.001	0.012

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

Appendix VII. Some pictorial view of my experiment