EFFECT OF HUMIC ACID AND SALICYLIC ACID ON MORPHOLOGY AND YIELD OF MUSTARD

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BY

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CERTIFICATE

*This is to certify that the thesis entitled '**Effect of Humic Acid and Salicylic Acid on Morphology and Yield of Mustard**' submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the results of a piece of bonafide research work carried out by **TANZINA AKTER**, Registration No. **12-04823** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June 2018
Dhaka, Bangladesh

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TO

MY BELOVED PARENTS

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The Author

EFFECT OF HUMIC ACID AND SALICYLIC ACID ON MORPHOLOGY AND YIELD OF MUSTARD

BY

TANZINA AKTER

ABSTRACT

The experiment was conducted during the period of October 2017 to February 2018 in the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the effect of humic acid and salicylic acid on morphology and yield of mustard. BARI Sarisha 15 was used as planting material in this experiment. The experiment comprised of two factors- Factor A: Levels of humic acid (HA): 4 levels - i) HA_0: 0 kg/ha (control), ii) HA_1: 8.0 kg/ha, iii) HA_2: 16.0 kg/ha, iv) HA_3: 24.0 kg/ha and Factors B: Levels of salicylic acid (SA): 4 levels - i) SA_0: 0 mM SA (control), ii) SA_1: 0.2 mM SA, iii) SA_2: 0.4 mM SA, iii) SA_3: 0.6 mM SA. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different morphological characters, yield contributing parameters and yield of mustard and significant variation was observed for different treatments. For humic acid, at 30, 40, 50, days after sowing (DAS) and at harvest, the tallest plant (63.35, 85.31, 97.21 and 103.99 cm, respectively) was recorded from HA_3, whereas the shortest plant (57.77, 75.02, 86.91 and 94.83 cm, respectively) from HA_0. The highest number of siliqua (48.26) was recorded from HA_3, whereas the lowest number (40.21) from HA_0. The highest seed yield (1.89 t/ha) was recorded from HA_3, whereas the lowest (1.34 t/ha) from HA_0. In case of levels of salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant (64.22, 89.09, 101.43 and 108.24 cm, respectively) was recorded from SA_3, while the shortest plant (55.91, 71.20, 80.88 and 89.54 cm, respectively) from SA_0. The highest number of siliqua (47.36) was recorded from SA_3, while the lowest number (40.11) from SA_0. The highest seed yield (1.79 t/ha) was recorded from SA_3, while the lowest (1.36 t/ha) from SA_0. Due to the interaction effect of different levels of humic acid and salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant (69.77, 96.82, 111.49 and 114.98 cm, respectively) was found from HA_3SA_3 and the shortest plant (52.11, 62.00, 72.91 and 83.78 cm, respectively) from HA_0SA_0. The highest number of siliqua (52.07) was found from HA_3SA_3 and the lowest number (32.00) from HA_0SA_0 treatment combination. The highest seed yield (1.97 t/ha) was found from HA_3SA_3 and the lowest (1.06 t/ha) from HA_0SA_0 treatment combination. Among the combination of different levels of humic acid and salicylic acid, 24.0 kg/ha humic acid with 0.6 mM salicylic acid induced superior growth, yield contributing characters and yield of mustard.

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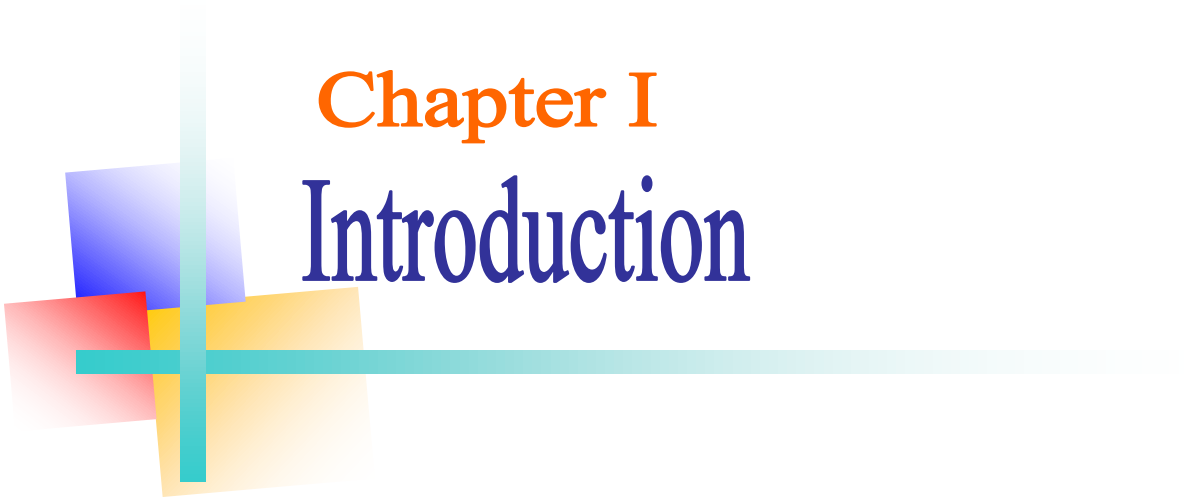


Chapter I

Introduction

CHAPTER I

INTRODUCTION

Mustard (*Brassica* sp.) belongs to the family Brassicaceae, is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Mustard *Brassica napus, B. campestris* and *B. juncea* are the three species of mustard those produce edible oil. Oil of plant origin constitute important component of human diet, ranking third after cereals and animal products and are nutritionally superior to animal oil (Alam *et al*., 2015). About 13.2 percent of the annual world edible oil supply comes from this crop (FAO, 2007). It is one of the most important and widely grown oil seed crops in Bangladesh which occupying 0.495 million hectare of land and the total production was 0.534 million metric ton (AIS, 2017). It is not only a high energy food but also a carrier of fat soluble vitamins including vitamin A, D, E and K in the body. In Bangladesh it is an important source of cooking oil that meet the one third of edible oil requirement of the country (Ahmed, 2008).

Bangladesh has been facing acute shortage of edible oil for the last several decades and for that it needs to import both oil and oilseeds to meet up the deficit. Our internal production can meet only about 21% of our consumption and the rest 79% is needed to import (Begum *et al.*, 2012). Due to insufficient oil production, a huge amount of foreign exchange involving over 160 million US$ is being spent every year for importing edible oils in Bangladesh (Rahman, 2002). Mustard seed contains about 40-45% oil and by increasing production of mustard we can meet the shortage of edible oil. Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka are the major mustard growing districts of Bangladesh (BBS, 2016). The average yield of mustard (1.09 t ha^{-1}) in our country is alarmingly very poor compared to the advanced countries like Germany, France, UK and Canada which producing 6.67 t ha^{-1}, 5.07 t ha^{-1}, 3.26 t ha^{-1}, 3.08 t ha^{-1}, respectively with world average yield is 1,575 kg ha^{-1} (FAO, 2012).

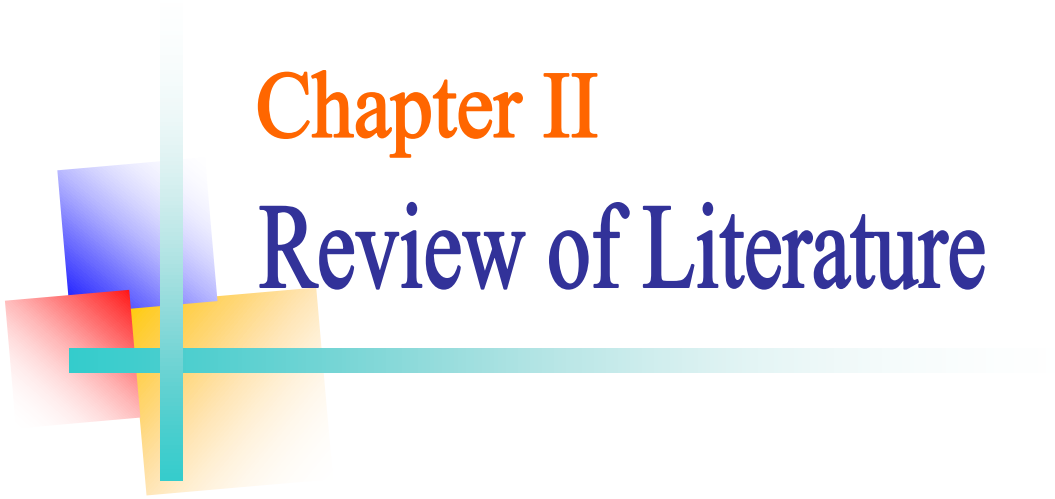
With increasing population, the demand of edible oil is increasing day by day and it is, therefore, highly accepted that the production of edible oil should be increased considerably to fulfill the demand. The area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of *boro* rice and on an average we are loosing in an area of 104,000 hectare and production 68,000 tons of mustard and rapeseed in last ten years (Anon., 2012). In farmer's field average yield of mustard is much lower due to lack of improved agricultural techniques of which different bio-regulators application is an important determinant for better performance of mustard. Reports so far been made to indicate a promising results on yield of mustard and other oil crops due to the use of bio-chemical substances such as humic acid, salicylic acid etc. (Nasiri *et al*., 2017; Muhal *et al*., 2014; Rajpar *et al*., 2011).

Humic acid efficiently improves soil fertility and crop productivity, especially on poorly fertile and alkaline-calcareous soils (Rajpar *et al*., 2011). Humic acid is an organically charged bio-stimulant that significantly affects plant growth and development, yield attributes and increases crop yield. It has been extensively investigated that humic acid improves physical, chemical and biological properties of soils (Keeling *et al*., 2003; Nardi *et al*., 2004; Mikkelsen, 2005). The role of humic acid is well known for improving soil health and nutrient uptake by plants, mineral availability, fruit quality (Mauromicale *et al*., 2011). Humic acid based fertilizers increase crop yield and improve soil fertility (Sarir *et al*., 2005; Mart, 2007; Mohamed *et al*., 2009). Enhanced nutrient uptake by plants as a result of humic acid application is also well established (Day *et al*., 2000; Mackowiak *et al*., 2001; Sharif *et al*., 2004). Likewise, the increased yield attributes and yield is also observed in brassica due to the application of humic acid in different amount (Peng *et al*., 2001; Vetayasuporn, 2006). However, to my knowledge no study has elucidated whether exogenous humic acid improves morphology, development and yield of mustard.

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). Salicylic acid (SA) has recently been recognized as a plant growth hormone and plays diverse physiological roles in plants including thermogenesis generate a wide range of metabolic and physiological responses thereby affecting their growth and development (Hayat *et al*., 2010). 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.

Under the above mention situation and context, the present experiment was conducted with the following objectives:

- To investigate the independent effects of humic acid and salicylic acid on morphology and yield of mustard under the climatic and edaphic condition of Sher-e-Bangla Agricultural University (SAU);
- To find the interaction effect between humic acid and salicylic acid on morphology and yield of mustard under the climatic and edaphic condition of SAU.



Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oil seed crop in Bangladesh and as well as in many countries of the world although the crop conventionally was less attended by the researchers because the crop normally grows without or minimum care or management practices. The potential yield of mustard is determined by appropriate husbandry practices and the surrounding environment that was provided to the cultivation of this crop. Among the husbandry practices, organic culture especially application of humic acid and salicylic acid may play an important role but a very few studies on the growth and yield of mustard have been carried out in our at home and also abroad. However, some of the important and informative works and research findings related to humic acid and salicylic acid so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of humic acid on mustard

2.1.1 Plant height

Nasiri *et al*. (2017) conducted a field experiment to study the different plant densities and humic acid (HA) applications on some rapeseeds cultivars. The experiment was designed with three plant densities, two HA applications (+HA and –HA) as main plots and six rapeseeds varieties. The analysis variance showed that HA, varieties, plant density and interaction effect of plant density and varieties had significant effect on the studied traits. Applications of HA produced longest plant in comparison with non-HA applications.

A pot experiment was conducted by El-Agrodi *et al*. (2016) during winter season at Sakha Agricultural Research Station, Kafr ElSheikh Governorate. The experiment aimed to investigate the effect of disodium ethylene-diaminetetra-acetic acid, citric acid and humic acid (HA) (0.0, 0.2, 0.4 and 0.6 g kg^{-1} soil) on the phytoextraction of Cu, Zn and Pb from Al-Gabal Al-Asfar contaminated soil

using Indian mustard and the leaching behavior of these metals from soil. The obtained results revealed that HA application increased plant height.

Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @ 0, 3.17, 6.35, and 9.35 kg $acre^{-1}$. Overall varieties, compared to control, the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected plant height. The variety S-9 responded comparatively tallest plant to all the application rates of humic acid than its other two counterparts.

Rastghalam *et al*. (2011) conducted an experiment to study the effect of humic acid and nanosuperabsorbent (hydrogel) on plant height, number of pods per plant, shoot dry weight and root dry weight. The treatments (with and without nano-superabsorbent, with and without humic acid) caused significant differences between treated and control plants. The usage of humic acid showed significantly negative effect on plant height.

2.1.2 Days to maturity

Nasiri *et al*. (2017) conducted a field experiment to study the different plant densities and humic acid (HA) applications on some rapeseeds cultivars. The experiment was designed with three plant densities, two HA applications (+HA and –HA) as main plots and six rapeseeds varieties. The analysis variance showed that HA, varieties, plant density and interaction effect of plant density and varieties had significant effect on the studied traits. Applications of HA decreased maturity date in comparison with non-HA applications.

Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @ 0, 3.17, 6.35, and

9.35 kg acre^{-1}. Overall varieties, compared to control, the application of humic acid @ 6.35 kg acre^{-1} positively affected maturity date of mustard. The variety S-9 responded comparatively minimum days to maturity all the application rates of humic acid than its other two counterparts.

2.1.3 Number of siliquae/plant

Lotfi *et al*. (2018) conducted an experiment with aim to evaluate the effect of humic acid (HA) applications on photosynthesis efficiency of rapeseed plants under different watering conditions. Results revealed that application of HA improved plants net photosynthesis under water stress via increasing the rate of gas exchange and electron transport flux in plants that helps for attaining mximum number of siliquae/plant.

Rastghalam *et al*. (2011) conducted an experiment to study the effect of humic acid and nanosuperabsorbent (hydrogel) on plant height, number of siliquae per plant, shoot dry weight and root dry weight. The treatments (with and without nano-superabsorbent, with and without humic acid) caused significant differences between treated and control plants. The usage of humic acid showed significantly negative effect on number of siliquae per plant.

2.1.4 Number of seeds/siliqua

Nasiri *et al*. (2017) conducted a field experiment to study the different plant densities and humic acid (HA) applications on some rapeseeds cultivars. The experiment was designed with three plant densities, two HA applications (+HA and –HA) as main plots and six rapeseeds varieties. The analysis variance showed that HA, varieties, plant density and interaction effect of plant density and varieties had significant effect on the studied traits. Applications of HA increased number of seeds/siliqua in comparison with non-HA applications.

A pot experiment was conducted by El-Agrodi *et al*. (2016) during winter season at Sakha Agricultural Research Station, Kafr ElSheikh Governorate. The experiment aimed to investigate the effect of disodium ethylene-diaminetetra-

acetic acid, citric acid and humic acid (HA) (0.0, 0.2, 0.4 and 0.6 g kg^{-1} soil) on the phytoextraction of Cu, Zn and Pb from Al-Gabal Al-Asfar contaminated soil using Indian mustard and the leaching behavior of these metals from soil. The obtained results revealed that HA application increased plant growth characters number of seeds/siliqua.

Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @ 0, 3.17, 6.35, and 9.35 kg $acre^{-1}$. Overall varieties, compared to control, the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected number of seeds/siliqua of mustard. The variety S-9 responded comparatively maximum number of seeds/siliqua to all the application rates of humic acid than its other two counterparts.

2.1.5 Thousand seed weight

Lotfi *et al*. (2018) conducted an experiment with aim to evaluate the effect of humic acid (HA) applications on photosynthesis efficiency of rapeseed plants under different watering conditions. Results revealed that application of HA improved plants net photosynthesis under water stress via increasing the rate of gas exchange and electron transport flux in plants that helps for attaining highest 1000 seeds weight.

Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @ 0, 3.17, 6.35, and 9.35 kg $acre^{-1}$. Overall varieties, compared to control, the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected 1000 seeds weight of mustard. The variety S-9 responded comparatively highest 1000 seeds weight to all the application rates of humic acid than its other two counterparts.

2.1.6 Seed yield

Lotfi *et al*. (2018) conducted an experiment with aim to evaluate the effect of humic acid (HA) applications on photosynthesis efficiency of rapeseed plants under different watering conditions. Results revealed that application of HA improved plants net photosynthesis under water stress via increasing the rate of gas exchange and electron transport flux in plants that helps for attaining highest yield with producing better yield attributes.

Nasiri *et al*. (2017) conducted a field experiment to study the different plant densities and humic acid (HA) applications on some rapeseeds cultivars. The experiment was designed with three plant densities, two HA applications (+HA and –HA) as main plots and six rapeseeds varieties. The analysis variance showed that HA, varieties, plant density and interaction effect of plant density and varieties had significant effect on the studied traits. Applications of HA increased seed yield and seed oil in comparison with non-HA applications.

A pot experiment was conducted by El-Agrodi *et al*. (2016) during winter season at Sakha Agricultural Research Station, Kafr ElSheikh Governorate. The experiment aimed to investigate the effect of disodium ethylenediaminetetraacetic acid, citric acid and humic acid (HA) (0.0, 0.2, 0.4 and 0.6 g kg^{-1} soil) on the phytoextraction of Cu, Zn and Pb from Al-Gabal Al-Asfar contaminated soil using Indian mustard. The obtained results revealed that HA application increased yield of Indian mustard.

Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @ 0, 3.17, 6.35, and 9.35 kg $acre^{-1}$. Overall varieties, compared to control, the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected yield of mustard. The variety S-9 responded comparatively highest yield to all the application rates of humic acid than its other two counterparts.

2.2 Effect of salicylic acid on mustard

2.2.1 Plant height

Ghasemi *et al*. (2016) conducted a factorial experiments and the factors included five salicylic acid concentrations (0 (control), 1, 10, 25 and 100 mM) and three chamomile cultivars. The physiological traits plant height and other were investigated and recorded significant treatment effect on all the recorded traits.

Kakhki and Fazel (2014) carried out an experiment to study mitigation effects of salicylic acid (SA) on drought stress conditions in mustard plant at the Research Greenhouse of Ferdowsi University of Mashhad Iran. The first factor was three levels (0, 100 and 200 ppm) of salicylic acid (SA) and the second factor was three levels of drought stress. The results showed that the greatest plant height was obtained from application of 200 ppm SA.

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.

Sharma *et al*. (2013) carried out a field study with an assembly of 25 Indian mustard genotypes to test the efficacy of salicylic acid (SA) on different yield attributes, seed filling and seed yield. Results 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.

Kakhki and Fazel (2014) carried out an experiment in order to study mitigation effects of salicylic acid (SA) on drought stress conditions in mustard plant at the Research Greenhouse of Ferdowsi University of Mashhad Iran. The first factor was three levels (0, 100 and 200 ppm) of salicylic acid (SA) and the second factor was three levels of drought stress. The results showed that the significant effects of salicylic acid (SA) and drought stress on all morpho-physiological traits including days to maturity.

2.2.3 Number of siliquae plant^{-1}

Muhal and Solanki (2015) carried out a field experiment 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.

An experiment 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 Godara *et al*. (2016) at Agronomy Farm, S.K.N. College of agriculture, Rajasthan to evaluate the effect of sowing time, varieties and salicylic acid (SA) application on different physiological parameters of Indian mustard. The experiment consisted of three sowing dates, two varieties and four levels of Salicylic acid (Control, SA 50 ppm, SA 100 ppm and SA 150 ppm). Results were revealed that effect of different sowing time, varieties and concentration of SA has shown significant effect on all tested physiological parameters including number of seeds siliqua of Indian mustard and those are associated with high temperature stress tolerance.

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.

Sharma *et al*. (2013) conducted a field study with an assembly of 25 Indian mustard genotypes to test the efficacy of salicylic acid (SA) on yield attributes, seed filling and seed yield. Results revealed that total number of seeds per siliqua improved by 3.2% over the unsprayed control.

2.2.5 Thousand seed weight

Ghasemi *et al*. (2016) conducted an experiments as a factorial and the factors included five salicylic acid concentrations (0 (control), 1, 10, 25 and 100 mM) and three chamomile cultivars (Bushehr, Bona, Bodegold). The physiological traits 1000 grain weight and others were investigated and recorded significant treatment effect on all the traits.

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. Results revealed that SA spray increased 1000 seed weight for all the studied genotypes.

2.2.6 Seed yield

Godara *et al*. (2016) conducted a field experiment at Agronomy Farm, S.K.N. College of agriculture, Rajasthan to evaluate the effect of sowing time, varieties and salicylic acid (SA) application on different physiological parameters of Indian mustard. The experiment consisted of three sowing dates, two varieties and four levels of Salicylic acid (Control, SA 50, SA 100 and SA 150 ppm). Results were revealed that concentration of SA has shown significant effect on all tested physiological parameters including seed yield of Indian mustard.

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.

Kakhki and Fazel (2014) carried out an experiment in order to study mitigation effects of salicylic acid (SA) on drought stress conditions in mustard plant at the Research Greenhouse of Ferdowsi University of Mashhad Iran. The first factor was three levels (0, 100 and 200 ppm) of salicylic acid (SA) and the second factor was three levels of drought stress. The results showed that seed weight per plant and its components were significant.

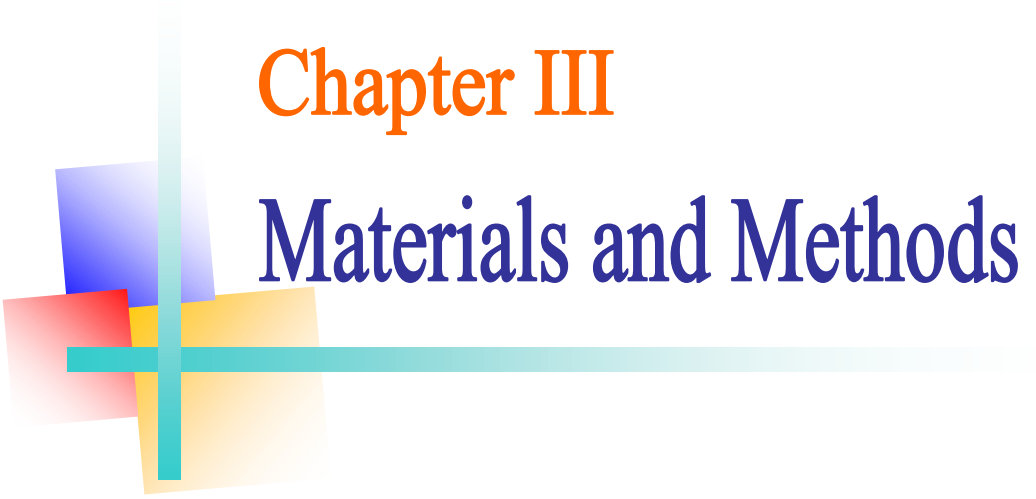
A field experiment was conducted by Muhal *et al*. (2014) to evaluate the effect of planting duration and salicylic acid application on yield, quality and nutrient uptake of *Brassica* species. The result revealed that foliar application of salicylic acid produced significantly higher seed yield compared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

Above cited reviews revealed that humic acid and salicylic acid significantly influences the growth, yield attributes and as well as yield of mustard. The literature revealed that the effects of humic acid and salicylic acid have not been studied well and have no definite conclusion in this aspects for the production of mustard in the agro climatic condition of Bangladesh.

Chapter III

Materials and Methods



CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of humic acid and salicylic acid on morphology and yield of mustard. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of experimental site, soil and climate condition, materials used for the experiment, design of the experiment, data collection procedure and data analysis.

3.1 Description of the experimental site

3.1.1 Experimental period

The field experiment was conducted during the period of October 2017 to February 2018.

3.1.2 Experimental location

The present study was conducted in the Experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is $23^0 74'$N latitude and $90^0 35'$E longitude. A map of the experimental location presented in Appendix I.

3.1.3 Soil characteristics

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 Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. 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 sandy loam with pH and organic matter capacity 5.9 and 0.78%, respectively and the the soil composed of 26% sand, 43% silt, 31% clay. Details descriptions have been presented in Appendix II.

3.1.4 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest of the year. The monthly average temperature, humidity, rainfall and sunshine hour during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III. During the experimental period the maximum temperature (27.7^0C) was recorded in the month of February 2018, whereas the minimum temperature (12.2^0C) in January 2018. The highest humidity (81%) was recorded in the month of October, 2017, while the highest rainfall (30 mm) was recorded in February 2018 and the highest sunshine hour (6.9 hr) in October, 2017.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised of two factors

Factor A: Levels of humic acid (HA): 4 levels

i) HA_0: 0 kg/ha (control)

ii) HA_1: 8.0 kg/ha

iii) HA_2: 16.0 kg/ha

iv) HA_3: 24.0 kg/ha

Factors B: Levels of salicylic acid (SA): 4 levels

i) SA_0: 0 mM SA (control)

ii) SA_1: 0.2 mM SA

iii) SA_2: 0.4 mM SA

iii) SA_3: 0.6 mM SA

There were in total 16 (4×4) treatment combinations such as HA_0SA_0, HA_0SA_1, HA_0SA_2, HA_0SA_3, HA_1SA_0, HA_1SA_1, HA_1SA_2, HA_1SA_3, HA_2SA_0, HA_2SA_1, HA_2SA_2, HA_2SA_3, HA_3SA_0, HA_3SA_1, HA_3SA_2 and HA_3SA_3.

3.2.2 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block contained 16 plots where 16 treatments combination were allotted at random. There were 48 unit plot altogether in the experiment. The size of each plot was 3.0 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 Figure 1.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sarisha 15 was used as plating materials in this experiment. It is a high yielding variety of mustard developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The seeds were collected from the BARI, Joydebpur, Gazipur.

3.3.2 Land preparation

The experimental plot was opened on 20 October 2017, 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 3 November 2017.

3.3.3 Application of manure and fertilizers

Urea, triple super phosphate, muriate of potash and borax was applied at the rate of 230, 140, 50 and 10 kg ha^{-1}, respectively. Humic acid were applied as per treatment. All of the fertilizers and humic acid were applied during 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 40 DAS, respectively.

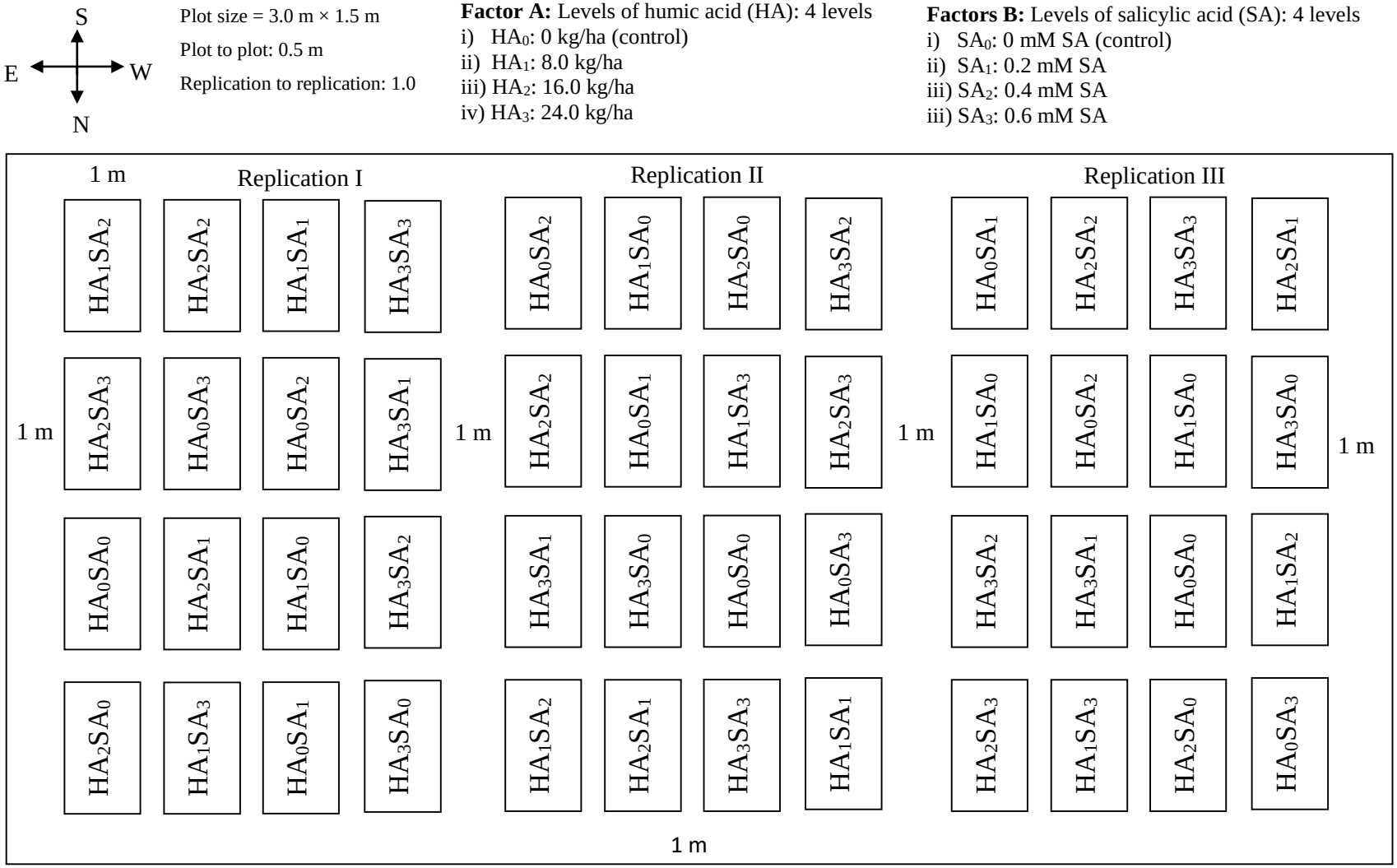


Figure 1. Layout of the experimental plot

3.3.4 Collection and application of humic acid

Humic acid were collected from local market and it was applied as per treatments at basal dose during final land preparation.

3.3.5 Collection and application of salicylic acid

Salicylic acid (SA) collected from Merck India. Three levels of salicylic acid was SA_0: 0 mM SA (control), SA_1: 0.2 mM SA, SA_2: 0.4 mM SA and SA_3: 0.6 mM SA. For the preparation of 0.2, 0.4 and 0.6 mM SA, respectively 0.03, 0.06 and 0.08 gm SA was dissolved in 01 liter water. Tween-20 detergent was used as surfactant to prevent dropout of SA solution from leaves and it was applied as treatment combinations at 20, 30, 40 days after sowing (DAS) by a sprayer.

3.3.6 Seed sowing

The seeds of mustard were sown on 3 November, 2017 in rows in the furrows having a depth of 2-3 cm.

3.3.7 Intercultural operations

3.3.7.1 Thinning

Seeds germination started after four DAS. Thinning was done two times; first thinning was done at 8 DAS and second was done at 20 DAS to maintain optimum plant population in each plot as per the treatment of plant density.

3.3.7.2 Irrigation and weeding

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

3.3.7.3 Protection against insect and pest

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

3.4 Crop sampling and data collection

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

3.5 Harvest and post-harvest operations

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

3.6 Data collection

The following data were recorded

i. Plant height (cm)
ii. Number of branches per plant
iii. Total dry matter content per plant (g)
iv. Days to 1st flowering
v. Days to harvest
vi. Number of siliqua per plant
vii. Length of siliqua (cm)
viii. Number of seeds per siliqua
ix. Weight of 1000 seeds (g)
x. Seed yield per hectare (t/ha)
xi. Stover yield per hectare (t/ha)
xii. Biological yield per hectare (t/ha)

3.7 Procedure of data collection

3.7.1 Plant height (cm)

The plant height was measured at 30, 40, 50 DAS and at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.7.2 Number of branches per plant

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

3.7.3 Total dry matter (g)

Total dry matter hill^{-1} was recorded at 30, 50 and 70 DAT by drying plant sample. Data were recorded as the average of 5 sample hill^{-1} collected at random from the inner rows of each plot and expressed in gram (g).

3.7.6 Days to 1st flowering

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

3.7.7 Days to harvest

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

3.7.8 Number of siliqua per plant

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

3.7.9 Length of siliqua (cm)

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

3.7.10 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 seeds per siliqua.

3.7.11 Weight of 1000 seeds (g)

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).

3.7.12 Seed yield per hectare (t/ha)

The seeds collected from 2 (2 m × 1 m) square meter area of each plot were sun dried properly, weighted and data were recorded. The seeds yield of each plot were converted into yield per hectare and express in seed yield of t/ha.

3.7.13 Stover yield per hectare (t/ha)

The stover collected from 2 (2 m × 1 m) square meter area of each plot was sun dried properly, weighted and data were recorded stover yield. The stover yield of each plot were converted into yield per hectare and express in stover yield of t/ha.

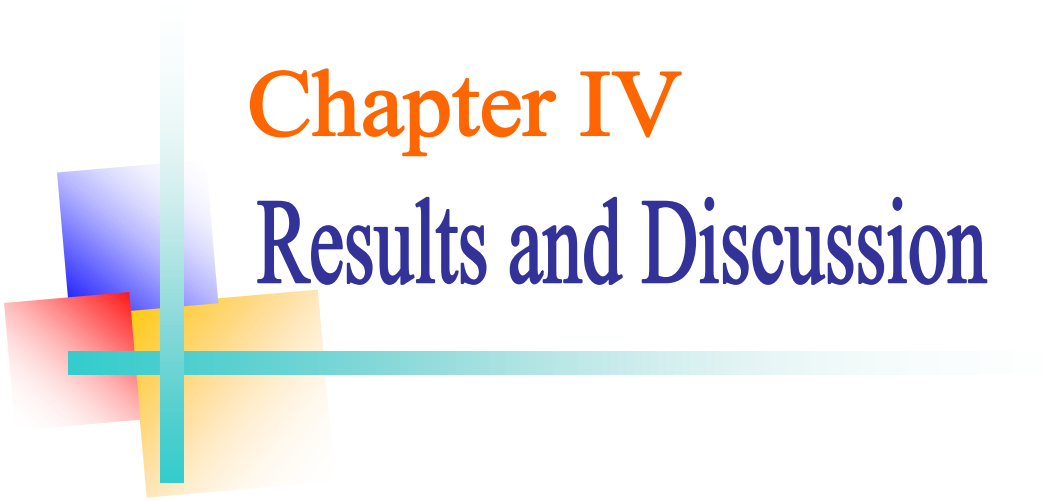
3.7.14 Biological yield (t/ha)

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

3.8 Statistical analysis

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



Chapter IV

Results and Discussion

CHAPTER IV

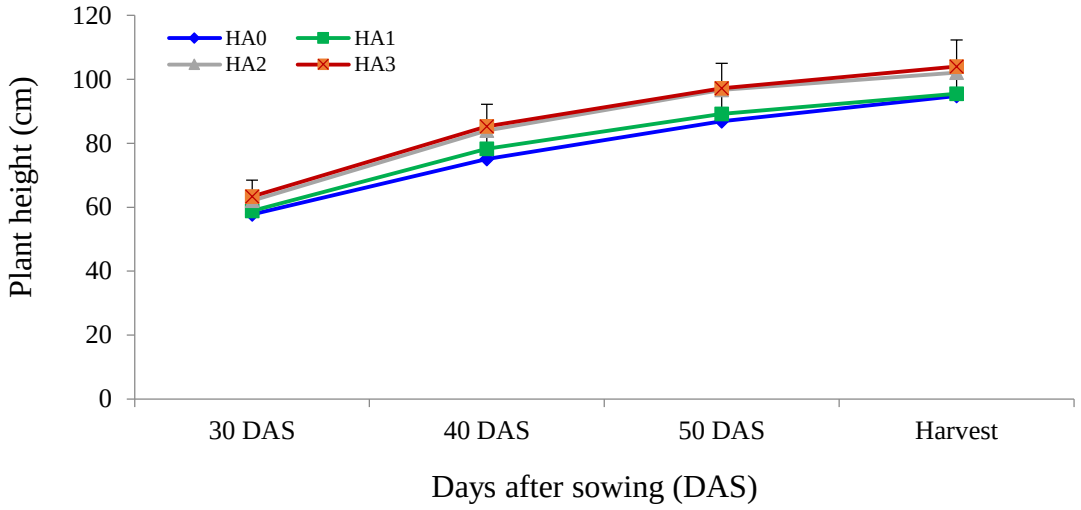
RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of humic acid and salicylic acid on morphology and yield of mustard. The analyses of variance (ANOVA) of the data on different morphological characters, yield contributing parameters and yield of mustard are presented in Appendix IV-VIII. The results have been presented and discussed in the different tables and graphs and possible interpretations given under the following headings:

4.1 Plant height

Plant height at 30, 40, 50 days after sowing (DAS) and at harvest showed statistically significant variation due to different levels of humic acid (Figure 2 and Appendix IV). At 30, 40, 50, DAS and at harvest, the tallest plant (63.35, 85.31, 97.21 and 103.99 cm, respectively) was recorded from HA_3 (24.0 kg/ha), which was statistically similar (62.04, 83.98, 96.64 and 102.08 cm, respectively) by HA_2 (16.0 kg/ha), whereas the shortest plant (57.77, 75.02, 86.91 and 94.83 cm, respectively) was recorded from HA_0 (0 kg/ha i.e. control) which was statistically similar (58.81, 78.31, 89.15 and 95.50 cm, respectively) to HA_1 (8.0 kg/ha). Different varieties produced different plant height based on their varietal characters but environmental and management factor also influences plant height. Rajpar *et al*. (2011) reported that the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected plant height.

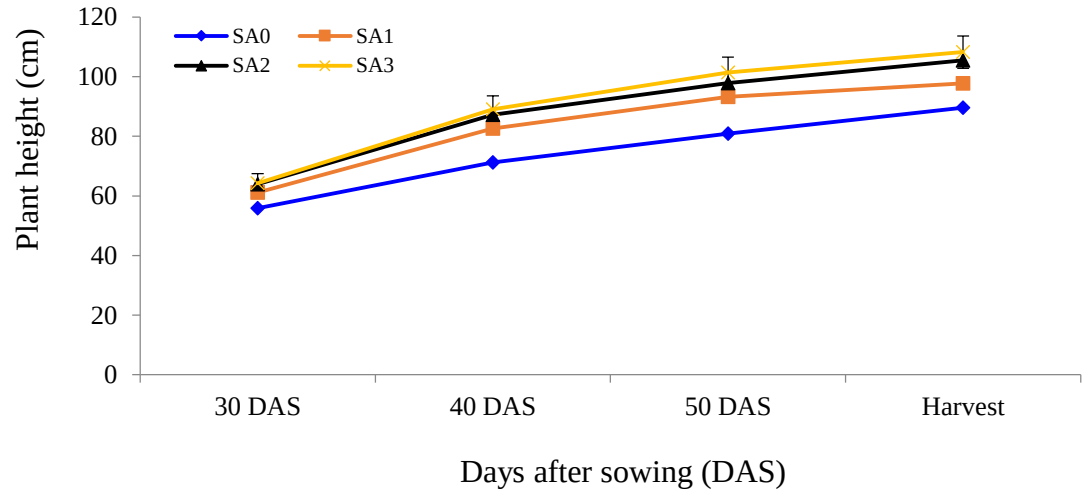
Different levels of salicylic acid varied significantly in terms of plant height of mustard at 30, 40, 50 DAS and at harvest (Figure 3 and Appendix IV). At 30, 40, 50 DAS and at harvest, the tallest plant (64.22, 89.09, 101.43 and 108.24 cm, respectively) was recorded from SA_3 (0.6 mM SA) which was statistically similar (63.95, 87.19, 97.80 and 105.43 cm, respectively) to SA_2 (0.4 mM SA) and followed (61.12, 82.64, 93.24 and 97.69 cm, respectively) by SA_1 (0.2 mM SA), while the shortest plant (55.91, 71.20, 80.88 and 89.54 cm, respectively)



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha

Figure 2. Effect of different levels of humic acid on plant height of mustard. (Vertical bars represent LSD value at 5% level of probability)



SA_0: 0 mM SA (control) SA_1: 0.2 mM SA

SA_2: 0.4 mM SA SA_3: 0.6 mM SA

Figure 3. Effect of different levels of salicylic acid on plant height of mustard. (Vertical bars represent LSD value at 5% level of probability)

was found from SA_0 (0 mM SA i.e. control). Data revealed that with the application of salicylic acid plant height showed an increasing trend upto the highest level. Sharma *et al*. (2013) revealed that foliar application of SA improved plant height of mustard compared to the application of water. Muhal *et al*. (2014) reported that foliar application of salicylic acid produced significantly longest plant at different days after sowing compared to control.

Interaction effect of different levels of humic acid and salicylic acid showed significant variation on plant height at 30, 40, 50, DAS and at harvest (Table 1 and Appendix IV). At 30, 40, 50 DAS and at harvest, the tallest plant (69.77, 96.82, 111.49 and 114.98 cm, respectively) was found from HA_3SA_3 (24.0 kg/ha HA and 0.6 mM SA) and the shortest plant (52.11, 62.00, 72.91 and 83.78 cm, respectively) was recorded from HA_0SA_0 (0 kg/ha and 0 mM SA i.e. control condition) treatment combination (Table 1).

4.2 Number of branches/plant

Number of branches/plant at 30, 40, 50 DAS and at harvest showed statistically significant variation due to different levels of humic acid (Table 2 and Appendix V). At 30, 40, 50, DAS and at harvest, the maximum number of branches/plant (4.33, 5.72, 7.78 and 9.14, respectively) was recorded from HA_3, which was statistically similar (4.25, 5.56, 7.53 and 9.08, respectively) by HA_2, whereas the minimum number (3.91, 5.30, 6.94 and 7.83, respectively) was recorded from HA_0. El-Agrodi *et al*. (2016) also reported similar results.

Different levels of salicylic acid varied significantly in terms of number of branches/plant of mustard at 30, 40, 50 DAS and at harvest (Table 2 and Appendix V). At 30, 40, 50 DAS and at harvest, the maximum number of branches/plant (4.44, 5.92, 7.89 and 9.22, respectively) was recorded from SA_3 which was statistically similar (4.39, 5.80, 7.75 and 8.94, respectively) to SA_2 and followed (4.05, 5.61, 7.47 and 8.78, respectively) by SA_1, while the minimum number (3.64, 4.83, 6.53 and 7.92, respectively) from SA_0. Sharma *et al*. (2013) recorded that SA increased the number of branches/plant of mustard.

Table 1. Interaction effect of different levels of humic acid and salicylic acid on plant height at different days after sowing (DAS) and harvest of mustard

Treatments	Plant height (cm) at			
	30 DAS	40 DAS	50 DAS	Harvest
HA_0SA_0	52.11 f	62.00 d	72.91 d	83.78 e
HA_0SA_1	59.24 c-e	77.40 c	89.08 b-d	88.86 de
HA_0SA_2	60.88 b-d	82.70 bc	90.87 bc	103.61 a-c
HA_0SA_3	62.21 b-d	85.98 a-c	94.80 a-c	103.08 a-d
HA_1SA_0	58.64 d-f	82.65 bc	87.90 b-d	92.04 c-e
HA_1SA_1	59.89 cd	89.67 c	86.89 cd	96.83 b-e
HA_1SA_2	65.59 a-c	86.59 a-c	96.48 a-c	100.07 ab
HA_1SA_3	61.99 b-d	86.32 a-c	99.04 a-c	105.05 a-c
HA_2SA_0	62.11 b-d	76.96 c	89.58 bc	97.90 b-e
HA_2SA_1	61.29 b-d	85.32 a-c	97.87 a-c	99.82 b-d
HA_2SA_2	61.86 b-d	86.40 a-c	98.70 a-c	100.76 a-d
HA_2SA_3	62.90 a-d	87.25 a-c	100.41 a-c	109.84 ab
HA_3SA_0	58.76 ef	63.17 d	83.10 d	84.45 e
HA_3SA_1	64.04 a-d	88.17 a-c	89.12 a-c	105.26 a-c
HA_3SA_2	67.46 ab	93.07 ab	105.14 ab	111.28 ab
HA_3SA_3	69.77 a	96.82 a	111.49 a	114.98 a
$LSD_{(0.05)}$	6.418	11.25	14.85	12.78
Level of significance	0.05	0.05	0.05	0.05
CV(%)	5.55	4.73	4.61	3.33

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Table 2. Effect of different levels of humic acid and salicylic acid on number of branches/plant at different days after sowing (DAS) and harvest of mustard

Treatments	Number of branches/plant at			
	30 DAS	40 DAS	50 DAS	Harvest
Levels of humic acid				
HA_0	3.91 b	5.30 b	6.94 b	7.83 b
HA_1	4.22 a	5.59 a	7.58 a	8.81 a
HA_2	4.25 a	5.56 ab	7.53 a	9.08 a
HA_3	4.33 a	5.72 a	7.58 a	9.14 a
$LSD_{(0.05)}$	0.306	0.261	0.324	0.365
Level of significance	0.05	0.05	0.05	0.05
Levels of salicylic acid				
SA_0	3.64 c	4.83 c	6.53 c	7.92 c
SA_1	4.05 b	5.61 b	7.47 b	8.78 b
SA_2	4.39 a	5.80 ab	7.75 ab	8.94 ab
SA_3	4.44 a	5.92 a	7.89 a	9.22 a
$LSD_{(0.05)}$	0.306	0.261	0.324	0.365
Level of significance	0.01	0.01	0.01	0.01
CV(%)	8.79	5.66	5.25	5.02

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on number of branches/plant at 30, 40, 50, DAS and at harvest (Table 3 and Appendix V). At 30, 40, 50 DAS and at harvest, the maximum number of branches/plant (4.89, 6.33, 8.22 and 9.67, respectively) was found from HA_3SA_3 and the minimum number (3.22, 4.78, 5.78 and 7.45, respectively) was recorded from HA_0SA_0 treatment combination.

4.3 Total dry matter content/plant

Total dry matter content/plant at 30, 40, 50 DAS and at harvest showed statistically significant variation due to different levels of humic acid (Figure 4 and Appendix VI). At 30, 40, 50, DAS and at harvest, the highest total dry matter content/plant (4.18, 7.28, 11.89 and 15.02 g, respectively) was recorded from HA_3, which was statistically similar (3.97, 7.06, 11.60 and 14.41 g, respectively) by HA_2, whereas the lowest (3.65, 6.61, 9.12 and 13.76 g, respectively) was recorded from HA_0. Rajpar *et al*. (2011) recorded the highest dry matter due to the application of humic acid.

Different levels of salicylic acid varied significantly in terms of total dry matter content/plant of mustard at 30, 40, 50 DAS and at harvest (Figure 5 and Appendix VI). At 30, 40, 50 DAS and at harvest, the highest total dry matter content/plant (4.60, 7.47, 11.76 and 15.13 g, respectively) was recorded from SA_3 which was statistically similar (4.37, 7.33, 11.70 and 14.95 g, respectively) to SA_2, while the lowest (2.82, 6.14, 9.28 and 12.87 g, respectively) was found from SA_0. Kakhki and Fazel (2014) recorded the highest dry matter content/plant of mustard due to the application of salicylic acid.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on total dry matter content/plant at 30, 40, 50, DAS and at harvest (Table 4 and Appendix VI). At 30, 40, 50 DAS and at harvest, the highest total dry matter content/plant (5.26, 8.11, 13.10 and 16.27 g, respectively) was found from HA_3SA_3 and the lowest (2.25, 5.44, 7.10 and 12.18 g, respectively) was recorded from HA_0SA_0 treatment combination.

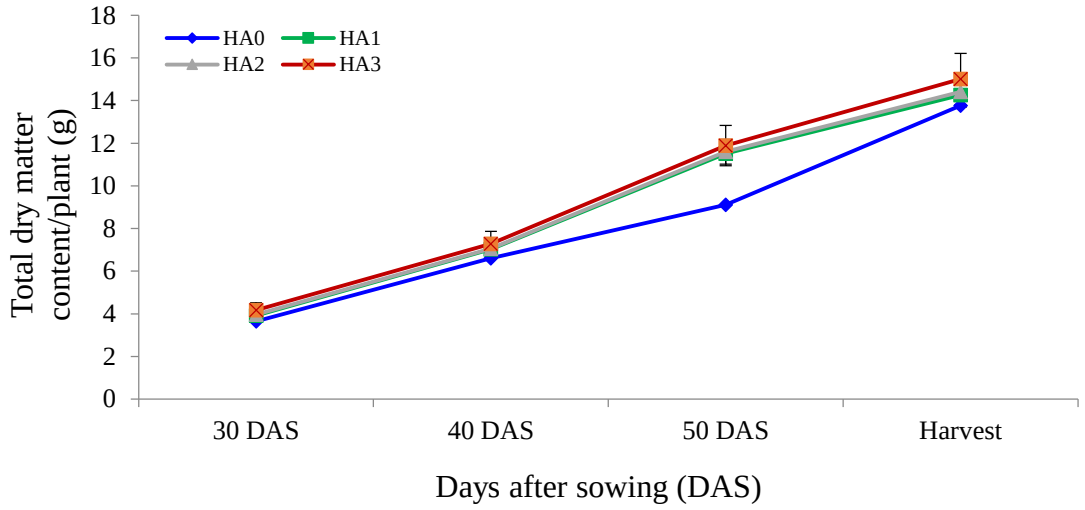
Table 3. Interaction effect of different levels of humic acid and salicylic acid on number of branches/plant at different days after sowing (DAS) and harvest of mustard

Treatments	Number of branches/plant at			
	30 DAS	40 DAS	50 DAS	Harvest
HA_0SA_0	3.22 c	4.78 d	5.78 g	7.45 e
HA_0SA_1	4.11 b	5.44 bc	7.33 c-e	7.78 de
HA_0SA_2	4.11 b	5.44 bc	7.22 de	7.89 de
HA_0SA_3	4.22 ab	5.56 bc	7.44 b-e	8.22 c-e
HA_1SA_0	4.00 b	4.78 d	6.78 ef	7.78 de
HA_1SA_1	4.11 b	5.78 a-c	7.44 b-e	9.11 ab
HA_1SA_2	4.33 ab	5.78 a-c	8.11 ab	9.00 a-c
HA_1SA_3	4.44 ab	6.00 ab	8.00 a-c	9.33 a
HA_2SA_0	4.11 b	5.33 c	7.33 c-e	8.45 b-d
HA_2SA_1	4.11 b	5.33 c	7.22 de	8.89 a-c
HA_2SA_2	4.56 ab	5.78 a-c	7.67 a-d	9.33 a
HA_2SA_3	4.22 ab	5.78 a-c	7.89 a-d	9.56 a
HA_3SA_0	3.22 c	4.44 d	6.22 fg	8.00 de
HA_3SA_1	4.67 ab	5.89 a-c	7.89 a-d	9.33 a
HA_3SA_2	4.56 ab	6.22 a	8.00 a-c	9.56 a
HA_3SA_3	4.89 a	6.33 a	8.22 a	9.67 a
$LSD_{(0.05)}$	0.613	0.522	0.648	0.731
Level of significance	0.05	0.01	0.01	0.05
CV(%)	8.79	5.66	5.25	5.02

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

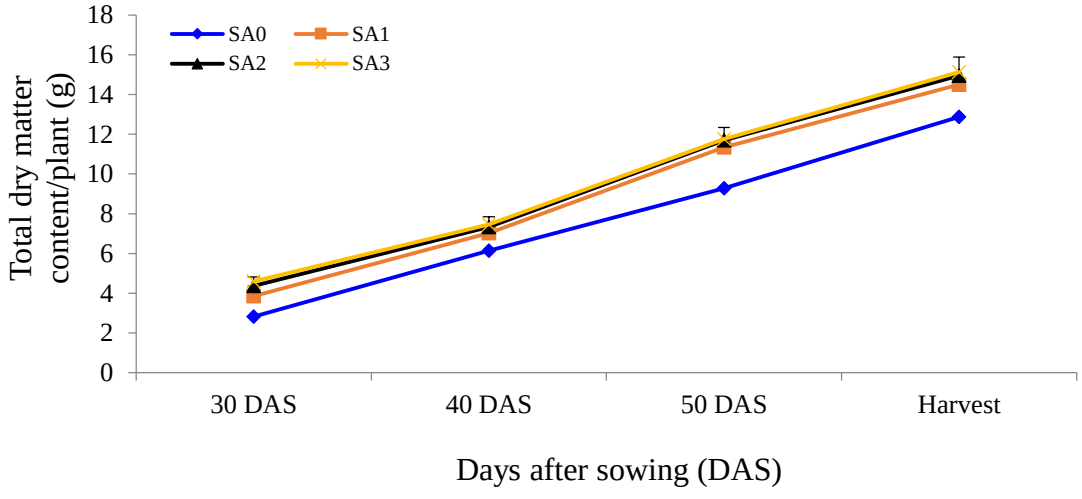
SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha

Figure 4. Effect of different levels of humic acid on total dry matter content/plant of mustard. (Vertical bars represent LSD value at 5% level of probability)



SA_0: 0 mM SA (control) SA_1: 0.2 mM SA

SA_2: 0.4 mM SA SA_3: 0.6 mM SA

Figure 5. Effect of different levels of salicylic acid on total dry matter content/plant of mustard. (Vertical bars represent LSD value at 5% level of probability)

Table 4. Interaction effect of different levels of humic acid and salicylic acid on total dry matter content/plant at different days after sowing (DAS) and harvest of mustard

Treatments	Total dry matter content/plant (g) at			
	30 DAS	40 DAS	50 DAS	Harvest
HA_0SA_0	2.25 h	5.44 d	7.10 e	12.18 e
HA_0SA_1	3.78 c-f	6.78 c	9.59 d	14.08 cd
HA_0SA_2	4.09 b-e	6.89 c	9.88 d	14.41 bc
HA_0SA_3	4.48 bc	7.33 a-c	9.78 d	14.38 b-d
HA_1SA_0	3.13 fg	6.67 c	9.48 d	12.62 de
HA_1SA_1	3.85 c-f	7.00 bc	12.06 a-c	14.66 a-c
HA_1SA_2	4.15 b-e	7.11 bc	12.37 ab	15.16 a-c
HA_1SA_3	4.54 a-c	7.33 a-c	12.02 a-c	14.65 a-c
HA_2SA_0	3.38 ef	6.78 c	11.37 bc	14.34 b-d
HA_2SA_1	3.54 d-f	6.89 c	11.15 c	13.80 c-e
HA_2SA_2	4.54 a-c	7.45 a-c	11.38 bc	14.27 b-d
HA_2SA_3	4.14 b-e	7.11 bc	12.43 ab	15.21 a-c
HA_3SA_0	2.52 gh	5.67 d	9.13 d	12.36 e
HA_3SA_1	4.27 b-d	7.44 a-c	12.59 a	15.47 a-c
HA_3SA_2	4.68 ab	7.89 ab	12.66 a	15.98 ab
HA_3SA_3	5.26 a	8.11 a	13.10 a	16.27 a
$LSD_{(0.05)}$	0.692	0.839	0.996	1.574
Level of significance	0.01	0.05	0.05	0.05
CV(%)	10.60	7.19	7.50	6.57

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

4.4 Days to 1st flowering

Days to 1st flowering of mustard varied significantly due to different levels of humic acid (Table 5 and Appendix VII). The maximum days to 1st flowering (36.17) was recorded from HA_0, which was statistically similar (35.38) to HA_1, while the minimum days (32.58) was recorded from HA_3 which was statistically similar (33.83) to HA_2. Similar findings also stated by Rajpar *et al*., 2011.

Different levels of salicylic acid varied significantly in terms of days to 1st flowering of mustard (Table 5 and Appendix VII). The maximum days to 1st flowering (36.17) was recorded from SA_0 which was followed (34.92 and 34.67) by SA_1 and SA_2 and they were statistically similar, while the minimum days (32.22) from SA_0. Kakhki and Fazel (2014) observed the significant effects of salicylic acid (SA) including days to 1st flowering.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on days to 1st flowering of mustard (Table 6 and Appendix VII). The maximum days to 1st flowering (38.67) was found from HA_0SA_0 and the minimum days (28.67) from HA_3SA_3 treatment combination.

4.5 Days to harvest

Days to harvest of mustard showed statistically significant variation due to different levels of humic acid (Table 5 and Appendix VII). The maximum days to harvest (91.42) was recorded from HA_0, which was statistically similar (89.42) by HA_1, whereas the minimum days (84.67) from HA_3 which was statistically similar (85.08) to HA_2. Nasiri *et al*. (2017) reported that applications of HA decreased maturity date in comparison with non-HA applications.

Different levels of salicylic acid varied significantly in terms of days to harvest of mustard (Table 5 and Appendix VII). The maximum days to harvest (90.42) was recorded from SA_0 which was statistically similar (88.75 and 87.67) to SA_1 and SA_2, while the minimum days (83.75) from SA_0. Muhal and Solanki (2015) reported that number of days taken to attain physiological maturity was significantly higher under 100 ppm SA foliar spray compared to water spray.

Table 5. Effect of different levels of humic acid and salicylic acid on different yield contributing characters of mustard

Treatments	Days to 1st flowering	Days to harvest	Length of siliqua (cm)	Number of seeds/siliqua
Levels of humic acid				
HA_0	36.17 a	91.42 a	5.35 b	15.88 c
HA_1	35.38 a	90.42 ab	5.54 b	17.56 b
HA_2	33.83 b	86.08 b	5.67 a	18.66 a
HA_3	32.58 b	85.67 b	5.76 a	19.49 a
$LSD_{(0.05)}$	0.867	2.651	0.094	1.358
Level of significance	0.05	0.01	0.05	0.01
Levels of salicylic acid				
SA_0	36.17 a	90.42 a	5.21 c	15.44 c
SA_1	34.92 b	88.75 ab	5.37 c	17.40 b
SA_2	34.67 b	87.67 ab	5.68 b	18.23 b
SA_3	32.22 c	83.75 b	6.05 a	20.52 a
$LSD_{(0.05)}$	0.867	1.651	0.094	1.358
Level of significance	0.05	0.05	0.01	0.01
CV(%)	5.51	7.08	5.84	6.93

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Table 6. Interaction effect of different levels of humic acid and salicylic acid on different yield contributing characters of mustard

Treatments	Days to 1st flowering	Days to harvest	Length of siliqua (cm)	Number of seeds/siliqua
HA_0SA_0	38.67 a	98.67 a	4.28 e	11.30 g
HA_0SA_1	35.00 a-d	93.00 ab	5.31 cd	16.07 ef
HA_0SA_2	33.00 a-e	94.00 ab	5.67 b-d	17.43 c-f
HA_0SA_3	38.00 ab	80.00 c-e	6.15 b	18.73 cd
HA_1SA_0	37.33 a-c	89.00 a-d	5.18 d	18.20 c-e
HA_1SA_1	34.00 a-e	84.67 b-e	5.47 cd	18.80 cd
HA_1SA_2	31.67 c-e	78.33 de	5.57 b-d	19.67 bc
HA_1SA_3	32.33 b-e	86.67 b-e	5.88 bc	21.30 ab
HA_2SA_0	36.00 a-c	93.00 ab	5.28 cd	16.77 d-f
HA_2SA_1	34.00 a-e	88.67 a-d	5.43 cd	17.23 d-f
HA_2SA_2	36.67 a-c	85.67 b-e	5.63 b-d	17.50 c-f
HA_2SA_3	31.67 c-e	90.33 a-c	5.82 bc	18.03 c-e
HA_3SA_0	38.33 a	93.00 ab	5.38 cd	15.50 f
HA_3SA_1	36.67 a-c	84.33 b-e	5.58 b-d	17.77 c-f
HA_3SA_2	29.87 de	86.00 b-e	5.83 bc	19.73 bc
HA_3SA_3	28.67 e	77.00 e	6.81 a	22.33 a
$LSD_{(0.05)}$	1.734	3.302	0.188	1.716
Level of significance	0.01	0.01	0.01	0.05
CV(%)	5.51	7.08	5.84	6.93

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on days to harvest of mustard (Table 6 and Appendix VII). The maximum days to harvest (98.67) was found from HA_0SA_0 and the minimum days (77.00) was recorded from HA_3SA_3 treatment combination.

4.6 Number of siliqua/plant

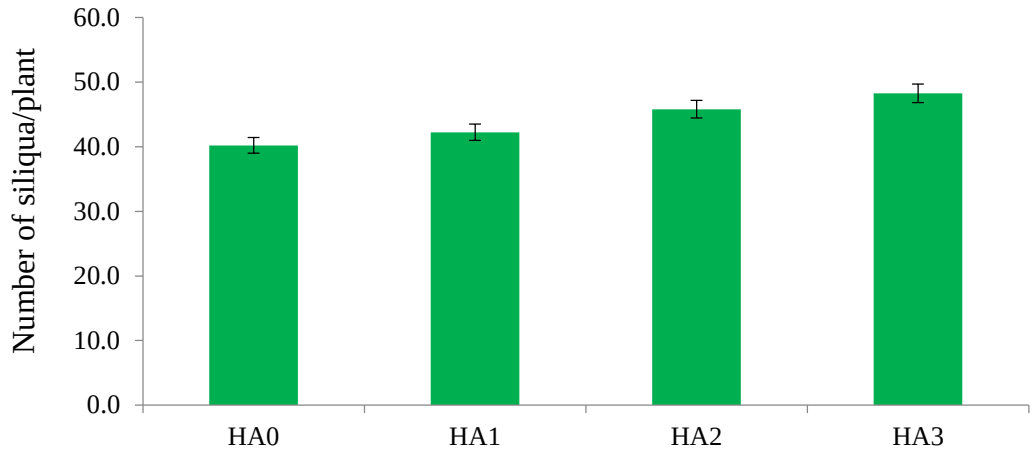
Number of siliqua/plant of mustard varied significantly due to different levels of humic acid (Figure 6 and Appendix VII). The highest number of siliqua/plant (48.26) was recorded from HA_3, which was statistically similar (45.80) by HA_2, whereas the lowest number (40.21) was recorded from HA_0 which was statistically similar (42.23) to HA_1. Rastghalam *et al*. (2011) observed that humic acid showed significantly negative effect on number of siliquae/plant.

Different levels of salicylic acid varied significantly in terms of number of siliqua of mustard (Figure 7 and Appendix VII). The highest number of siliqua/plant (47.36) was recorded from SA_3 which was statistically similar (44.75) to SA_2, while the lowest number (40.11) from SA_0 which was statistically similar (42.28) to SA_1. Muhal and Solanki (2015) reported that 100 ppm SA foliar spray registered significantly higher number of siliqua/plant.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on number of siliqua/plant (Figure 8 and Appendix VII). The highest number of siliqua/plant (52.07) was found from HA_3SA_3 and the lowest number (32.00) was recorded from HA_0SA_0 treatment combination.

4.7 Length of siliqua

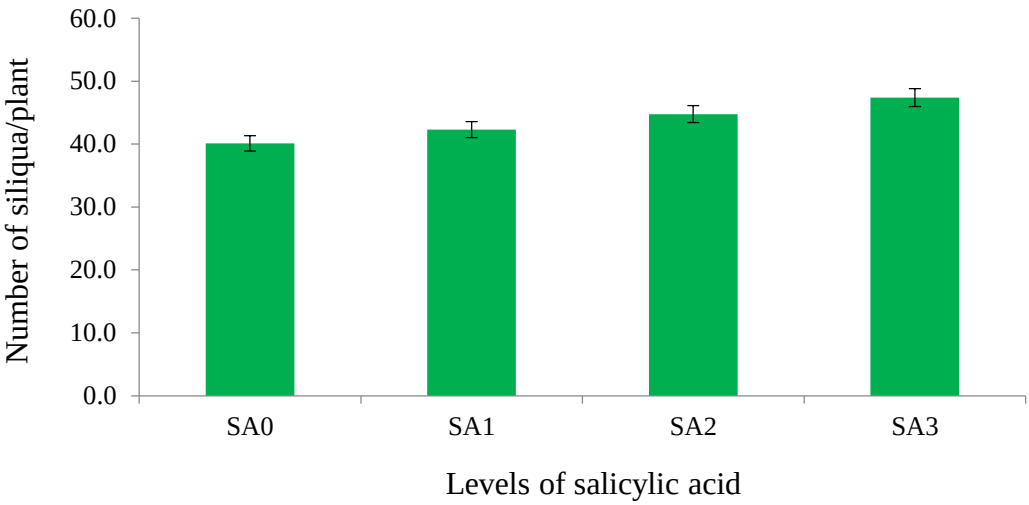
Length of siliqua of mustard showed statistically significant variation due to different levels of humic acid (Table 5 and Appendix VII). The highest length of siliqua (5.76 cm) was recorded from HA_3, which was statistically similar (5.67 cm) by HA_2, whereas the lowest (5.35 cm) was recorded from HA_0 which was statistically similar (5.54 cm) to HA_1. Lotfi *et al*. (2018) also recorded longest siliqua due to the application of humic acid.



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha

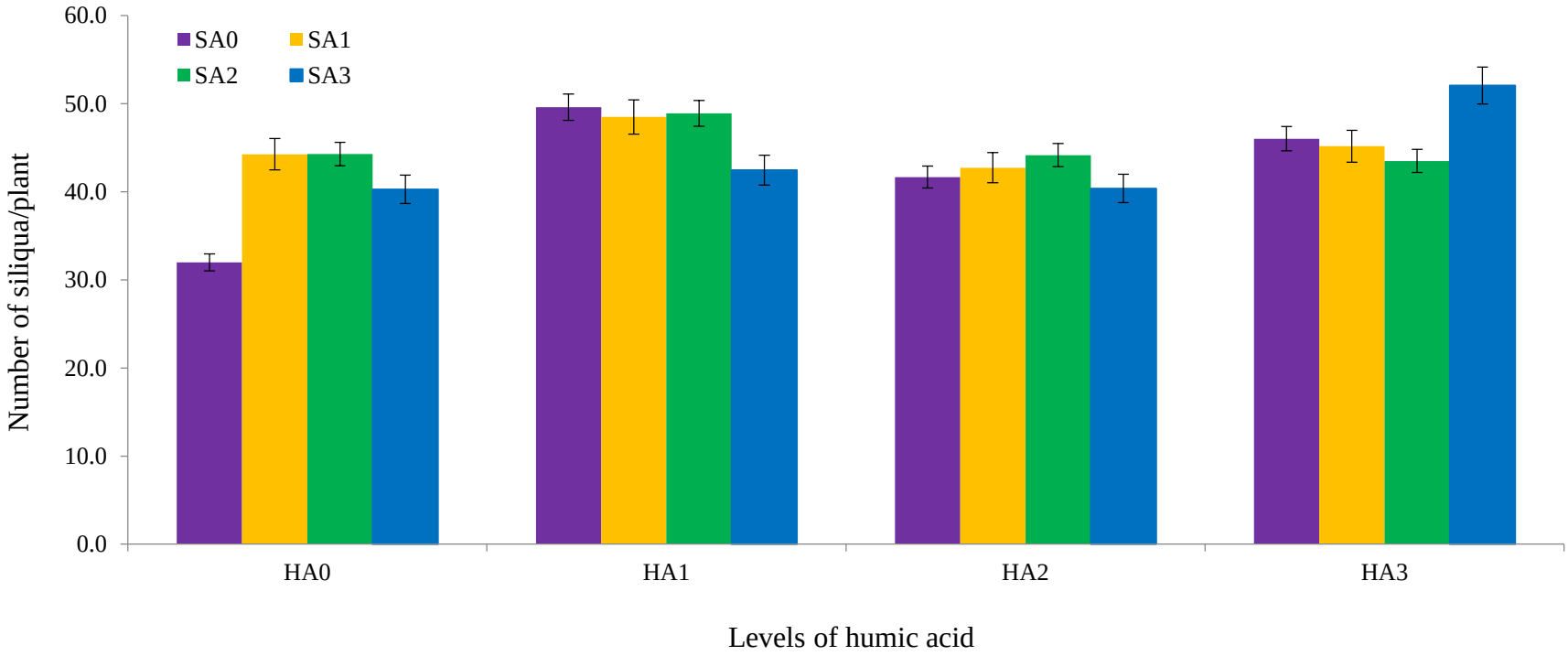
Figure 6. Effect of different levels of humic acid on number of siliqua/plant of mustard. (Vertical bars represent LSD value at 5% level of probability)



SA_0: 0 mM SA (control) SA_1: 0.2 mM SA

SA_2: 0.4 mM SA SA_3: 0.6 mM SA

Figure 7. Effect of different levels of salicylic acid on number of siliqua/plant of mustard. (Vertical bars represent LSD value at 5% level of probability)



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha SA_0: 0 mM SA (control) SA_1: 0.2 mM SA

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha SA_2: 0.4 mM SA SA_3: 0.6 mM SA

Figure 8. Interaction effect of different levels of humic acid and salicylic acid on number of siliqua/plant of mustard. (Vertical bars represent LSD value at 5% level of probability

Different levels of salicylic acid varied significantly in terms of length of siliqua of mustard (Table 5 and Appendix VII). The highest length of siliqua (6.05 cm) was recorded from SA_3 which was followed (5.68 cm) by SA_2, while the lowest (5.21 cm) from SA_0 which was statistically similar (5.37 cm) to SA_1. Sharma *et al*. (2013) recorded longest siliqua due to the application of salicylic acid.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on length of siliqua (Table 6 and Appendix VII). The highest length of siliqua (6.81 cm) was found from HA_3SA_3 and the lowest (4.28 cm) was recorded from HA_0SA_0 treatment combination.

4.8 Number of seeds/siliqua

Number of seeds/siliqua of mustard showed statistically significant variation due to different levels of humic acid (Table 5 and Appendix VII). The highest number of seeds/siliqua (19.49) was recorded from HA_3, which was statistically similar (18.66 g) to HA_2 and followed (17.56) by HA_1, whereas the lowest number (15.88) from HA_0. Nasiri *et al*. (2017) reported that applications of HA increased number of seeds/siliqua in comparison with non-HA applications.

Different levels of salicylic acid varied significantly in terms of number of seeds/siliqua of mustard (Table 5 and Appendix VII). The highest number of seeds/siliqua (20.52) was recorded from SA_3 which was followed (18.23 and 17.40) by SA_2 and SA_1 and they were statistically similar, while the lowest number (15.44) was found from SA_0. Sharma *et al*. (2013) reported that SA improved yield attributes and total number of seeds/siliqua improved by 3.2% over the unsprayed control.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on number of seeds/siliqua (Table 6 and Appendix VII). The highest number of seeds/siliqua (22.33) was found from HA_3SA_3 and the lowest number (11.30) was recorded from HA_0SA_0 treatment combination.

4.9 Weight of 1000 seeds

Weight of 1000 seeds of mustard showed statistically significant variation due to different levels of humic acid (Table 7 and Appendix VIII). The highest weight of 1000 seeds (3.26 g) was recorded from HA_3, which was statistically similar (3.20 g) to HA_2, whereas the lowest (2.89 g) from HA_0 which was statistically similar (2.96 g) to HA_1. Lotfi *et al*. (2018) reported that HA application improved photosynthesis that helps for attaining highest 1000 seeds weight.

Different levels of salicylic acid varied significantly in terms of weight of 1000 seeds of mustard (Table 7 and Appendix VIII). The highest weight of 1000 seeds (3.30 g) was recorded from SA_3 which was similar (3.11 g) to SA_2, while the lowest weight (2.90 g) was found from SA_0 which was similar (3.00 g) to SA_1. Rajpar *et al*. (2011) reported that the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected 1000 seeds weight of mustard.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on weight of 1000 seeds (Table 8 and Appendix VIII). The highest weight of 1000 seeds (3.63 g) was found from HA_3SA_3 and the lowest weight (2.22 g) was recorded from HA_0SA_0 treatment combination.

4.10 Seed yield

Seed yield of mustard showed statistically significant variation due to different levels of humic acid (Table 7 and Appendix VIII). The highest seed yield (1.89 t/ha) was recorded from HA_3, which was followed (1.72 t/ha) by HA_2, whereas the lowest seed yield (1.34 t/ha) was recorded from HA_0 which was followed (1.58 t/ha) by HA_1. This results are consistent with the morphological and yield contributing characters of this study. Lotfi *et al*. (2018) reported that application of HA improved plants net photosynthesis under water stress via increasing the rate of gas exchange and electron transport flux in plants that helps for attaining highest yield with producing better yield attributes. To all together, it suggest that humic acid influence mustard seed yield by improving morphological and yield contributing characters.

Table 7. Effect of different levels of humic acid and salicylic acid on yield attributes and yields of mustard

Treatments	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
Levels of humic acid			
HA_0	2.89 c	1.34 d	2.17 c
HA_1	2.96 bc	1.58 c	2.41 b
HA_2	3.20 ab	1.72 b	2.64 a
HA_3	3.26 a	1.89 a	2.81 a
$LSD_{(0.05)}$	0.087	0.033	0.058
Level of significance	0.01	0.01	0.01
Levels of salicylic acid			
SA_0	2.90 b	1.36 b	2.37 b
SA_1	3.00 b	1.56 a	2.48 a
SA_2	3.11 ab	1.63 a	2.54 a
SA_3	3.30 a	1.79 a	2.64 a
$LSD_{(0.05)}$	0.087	0.033	0.058
Level of significance	0.01	0.01	0.05
CV(%)	9.74	5.86	7.97

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Table 8. Interaction effect of different levels of humic acid and salicylic acid on yield attributes and yields of mustard

Treatments	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
HA_0SA_0	2.22 c	1.06 h	1.69 g
HA_0SA_1	3.28 ab	1.31 g	2.19 f
HA_0SA_2	3.24 ab	1.40 fg	2.35 d-f
HA_0SA_3	2.83 b	1.59 d-f	2.47 b-f
HA_1SA_0	3.37 ab	1.76 b-d	2.64 a-e
HA_1SA_1	3.18 ab	1.90 a-c	2.77 a-c
HA_1SA_2	3.26 ab	1.93 ab	2.81 ab
HA_1SA_3	3.24 ab	1.94 ab	3.02 a
HA_2SA_0	2.87 b	1.50 e-g	2.26 ef
HA_2SA_1	2.95 b	1.52 ef	2.42 b-f
HA_2SA_2	3.06 ab	1.62 de	2.45 b-f
HA_2SA_3	2.96 b	1.66 de	2.49 b-f
HA_3SA_0	3.13 ab	1.57 d-f	2.40 c-f
HA_3SA_1	3.04 b	1.68 de	2.47 b-f
HA_3SA_2	2.98 b	1.72 c-e	2.72 a-d
HA_3SA_3	3.63 a	1.97 a	2.98 a
$LSD_{(0.05)}$	0.173	0.065	0.115
Level of significance	0.05	0.01	0.01
CV(%)	9.74	5.86	7.97

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

HA_0: 0 kg/ha (control)
HA_1: 8.0 kg/ha
HA_2: 16.0 kg/ha
HA_3: 24.0 kg/ha

SA_0: 0 mM SA (control)
SA_1: 0.2 mM SA
SA_2: 0.4 mM SA
SA_3: 0.6 mM SA

Different levels of salicylic acid varied significantly in terms of seed yield of mustard (Table 7 and Appendix VIII). The highest seed yield (1.79 t/ha) was recorded from SA_3, which was similar (1.63 and 1.56 t/ha) to SA_2 and SA_1, while the lowest seed yield (1.36 t/ha) was found from SA_0. This results are consistent with the morphological and yield contributing characters of this study. Muhal *et al*. (2014) reported that that foliar application of salicylic acid produced significantly higher seed yield compared to water spray. To all together, it suggest that salicylic acid influence mustard seed yield by improving morphological and yield contributing characters.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on seed yield (Table 8 and Appendix VIII). The highest seed yield (1.97 t/ha) was found from HA_3SA_3 and the lowest seed yield (1.06 t/ha) was recorded from HA_0SA_0 treatment combination.

4.11 Stover yield

Stover yield of mustard showed statistically significant variation due to different levels of humic acid (Table 7 and Appendix VIII). The highest stover yield (2.81 t/ha) was recorded from HA_3, which was similar (2.64 t/ha) to HA_2, whereas the lowest stover yield (2.17 t/ha) was recorded from HA_0 which was followed (2.41 t/ha) by HA_1. Rajpar *et al*. (2011) recorded similar results in their earlier experiment due to the application of humic acid.

Different levels of salicylic acid varied significantly in terms of stover yield of mustard (Table 7 and Appendix VIII). The highest stover yield (2.64 t/ha) was recorded from SA_3, which was similar (2.54 and 2.48 t/ha) to SA_2 and SA_1, while the lowest stover yield (2.37 t/ha) was found from SA_0. Godara *et al*. (2016) observed that concentration of SA has shown significant effect on all tested physiological parameters including seed yield of Indian mustard.

Interaction effect of different levels of humic acid and salicylic acid showed significant differences on stover yield (Table 8 and Appendix VIII). The highest

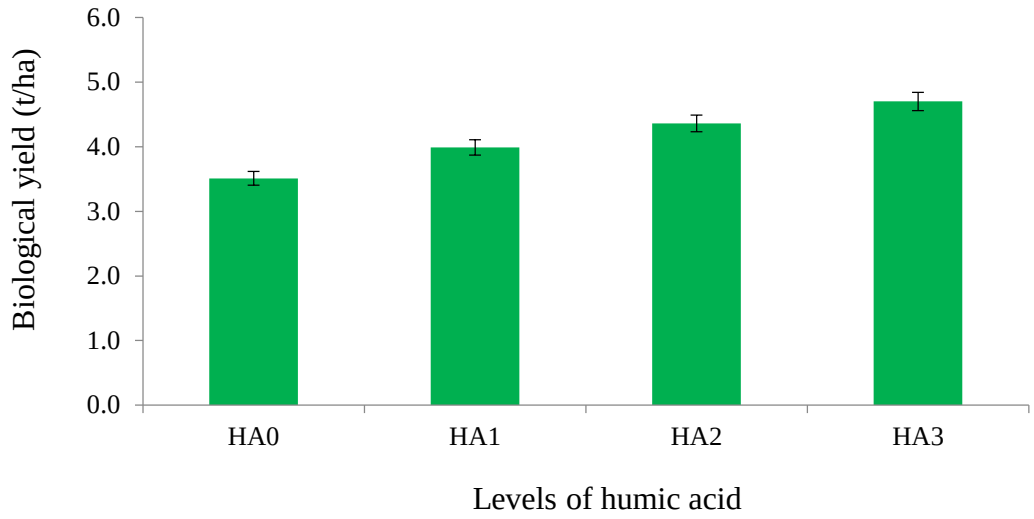
stover yield (2.98 t/ha) was found from HA_3SA_3 and the lowest stover yield (1.69 t/ha) was recorded from HA_0SA_0 treatment combination.

4.12 Biological yield

Biological yield of mustard showed statistically significant variation due to different levels of humic acid (Figure 9 and Appendix VIII). The highest biological yield (4.70 t/ha) was recorded from HA_3, which was similar (4.36 t/ha) to HA_2, whereas the lowest biological yield (3.51 t/ha) was recorded from HA_0 which was followed (3.99 t/ha) by HA_1. Lotfi *et al*. (2018) reported that application of HA improved plants net photosynthesis under water stress via increasing the rate of gas exchange and electron transport flux in plants that helps for attaining highest biological yield with producing taller plants and other yield attributes.

Different levels of salicylic acid varied significantly in terms of biological yield of mustard (Figure 10 and Appendix VIII). The highest biological yield (4.43 t/ha) was recorded from SA_3, which was similar (4.17 and 4.04 t/ha) to SA_2 and SA_1, while the lowest biological yield (3.73 t/ha) was found from SA_0. Muhal *et al*. (2014) found that foliar application of salicylic acid produced significantly higher seed yield compared to water spray.

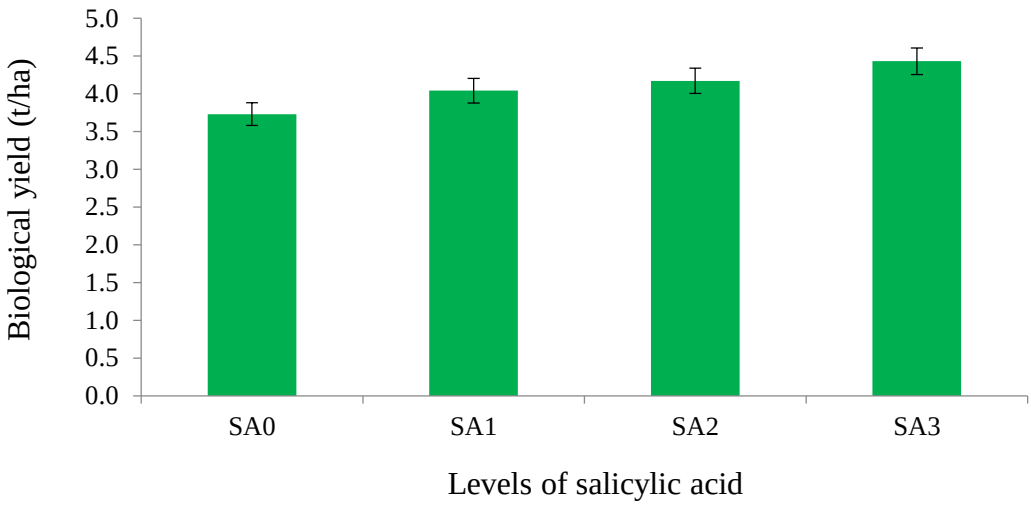
Interaction effect of different levels of humic acid and salicylic acid showed significant differences on biological yield (Figure 11 and Appendix VIII). The highest biological yield (4.81 t/ha) was found from HA_3SA_3 and the lowest biological yield (2.75 t/ha) was recorded from HA_0SA_0 treatment combination.



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha

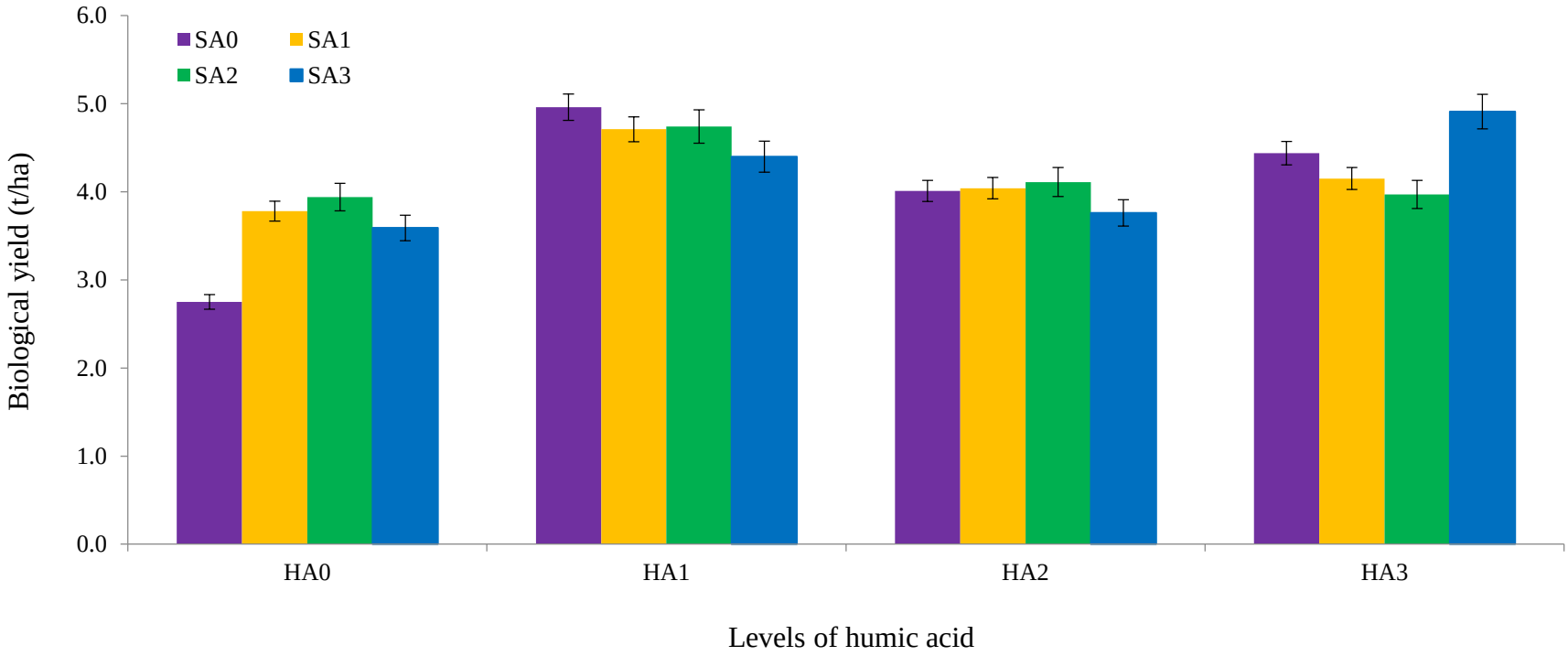
Figure 9. Effect of different levels of humic acid on biological yield of mustard. (Vertical bars represent LSD value at 5% level of probability)



SA_0: 0 mM SA (control) SA_1: 0.2 mM SA

SA_2: 0.4 mM SA SA_3: 0.6 mM SA

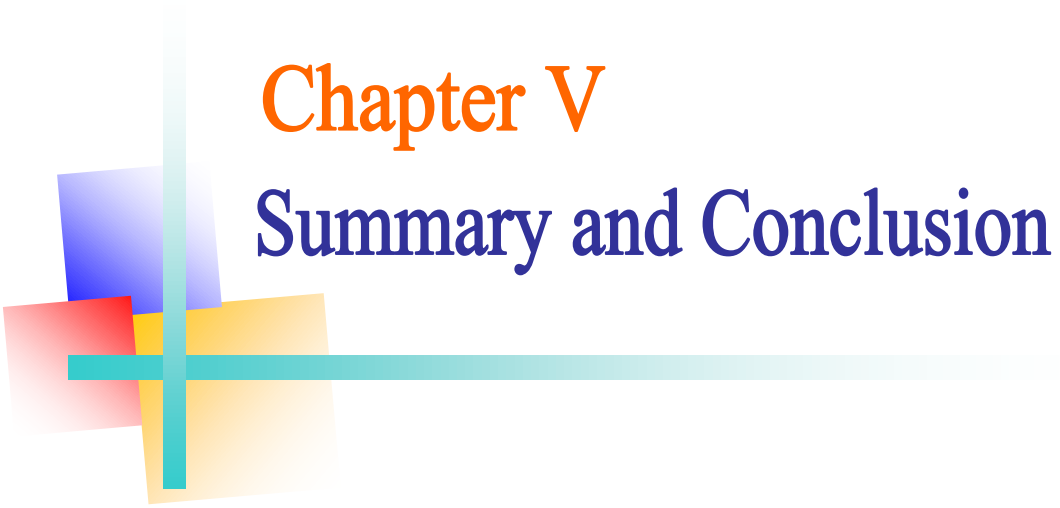
Figure 10. Effect of different levels of salicylic acid on biological yield of mustard. (Vertical bars represent LSD value at 5% level of probability)



HA_0: 0 kg/ha (control) HA_1: 8.0 kg/ha SA_0: 0 mM SA (control SA_1: 0.2 mM SA

HA_2: 16.0 kg/ha HA_3: 24.0 kg/ha SA_2: 0.4 mM SA SA_3: 0.6 mM SA

Figure 11. Interaction effect of different levels of humic acid and salicylic acid on biological yield of mustard. (Vertical bars represent LSD value at 5% level of probability



Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period of October 2017 to February 2018 in the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the effect of humic acid and salicylic acid on morphology and yield of mustard. BARI Sarisha 15 was used as plating material in this experiment. The experiment comprised of two factors- Factor A: Levels of humic acid (HA): 4 levels - i) HA_0: 0 kg/ha (control), ii) HA_1: 8.0 kg/ha, iii) HA_2: 16.0 kg/ha, iv) HA_3: 24.0 kg/ha and Factors B: Levels of salicylic acid (SA): 4 levels - i) SA_0: 0 mM SA (control), ii) SA_1: 0.2 mM SA, iii) SA_2: 0.4 mM SA, iii) SA_3: 0.6 mM SA. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different morphological characters, yield contributing parameters and yield of mustard and significant variation was observed for different treatments.

For levels of humic acid, at 30, 40, 50, DAS and at harvest, the tallest plant (63.35, 85.31, 97.21 and 103.99 cm, respectively) was recorded from HA_3, whereas the shortest plant (57.77, 75.02, 86.91 and 94.83 cm, respectively) was recorded from HA_0. At 30, 40, 50, DAS and at harvest, the maximum number of branches/plant (4.33, 5.72, 7.78 and 9.14, respectively) was recorded from HA_3, whereas the minimum number (3.91, 5.30, 6.94 and 7.83, respectively) was recorded from HA_0. At 30, 40, 50, DAS and at harvest, the highest total dry matter content/plant (4.18, 7.28, 11.89 and 15.02 g, respectively) was recorded from HA_3, whereas the lowest (3.65, 6.61, 9.12 and 13.76 g, respectively) was recorded from HA_0. The maximum days to 1st flowering (36.17) was recorded from HA_0, whereas the minimum days (32.58) was recorded from HA_3. The maximum days to harvest (91.42) was recorded from HA_0, whereas the minimum days (84.67) was recorded from HA_3. The highest number of siliqua (48.26) was recorded from HA_3, whereas the lowest number (40.21) was

recorded from HA_0. The highest length of siliqua (5.76 cm) was recorded from HA_3, whereas the lowest (5.35 cm) was recorded from HA_0. The highest number of seeds/siliqua (19.49) was recorded from HA_3, whereas the lowest number (15.88) was recorded from HA_0. The highest weight of 1000 seeds (3.26 g) was recorded from HA_3, whereas the lowest weight (2.89 g) was recorded from HA_0. The highest seed yield (1.89 t/ha) was recorded from HA_3, whereas the lowest seed yield (1.34 t/ha) was recorded from HA_0. The highest stover yield (2.81 t/ha) was recorded from HA_3, whereas the lowest stover yield (2.17 t/ha) was recorded from HA_0. The highest biological yield (4.70 t/ha) was recorded from HA_3, whereas the lowest biological yield (3.51 t/ha) was recorded from HA_0.

In case of levels of salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant (64.22, 89.09, 101.43 and 108.24 cm, respectively) was recorded from SA_3, while the shortest plant (55.91, 71.20, 80.88 and 89.54 cm, respectively) from SA_0. At 30, 40, 50 DAS and at harvest, the maximum number of branches/plant (4.44, 5.92, 7.89 and 9.22, respectively) was recorded from SA_3, while the minimum number (3.64, 4.83, 6.53 and 7.92, respectively) from SA_0. At 30, 40, 50 DAS and at harvest, the highest total dry matter content/plant (4.60, 7.47, 11.76 and 15.13 g, respectively) was recorded from SA_3, while the lowest (2.82, 6.14, 9.28 and 12.87 g, respectively) from SA_0. The maximum days to 1^{st} flowering (36.17) was recorded from SA_0, while the minimum days (32.22) from SA_0. The maximum days to harvest (90.42) was recorded from SA_0, while the minimum days (83.75) was found from SA_0. The highest number of siliqua (47.36) was recorded from SA_3, while the lowest number (40.11) was found from SA_0. The highest length of siliqua (6.05 cm) was recorded from SA_3, while the lowest (5.21 cm) was found from SA_0. The highest number of seeds/siliqua (20.52) was recorded from SA_3, while the lowest number (15.44) was found from SA_0. The highest weight of 1000 seeds (3.30 g) was recorded from SA_3, while the lowest weight (2.90 g) was found from SA_0. The highest seed yield (1.79 t/ha) was recorded from SA_3, while the lowest seed yield (1.36 t/ha) was found from SA_0. The highest stover yield (2.64 t/ha) was recorded

from SA_3, while the lowest stover yield (2.37 t/ha) was found from SA_0. The highest biological yield (4.73 t/ha) was recorded from SA_3, while the lowest (4.03 t/ha) was found from SA_0.

Due to the interaction effect of different levels of humic acid and salicylic acid, at 30, 40, 50 DAS and at harvest, the tallest plant (69.77, 96.82, 111.49 and 114.98 cm, respectively) was found from HA_3SA_3 and the shortest plant (52.11, 62.00, 72.91 and 83.78 cm, respectively) from HA_0SA_0. At 30, 40, 50 DAS and at harvest, the maximum number of branches/plant (4.89, 6.33, 8.22 and 9.67, respectively) was found from HA_3SA_3 and the minimum number (3.22, 4.78, 5.78 and 7.45, respectively) from HA_0SA_0 treatment combination. At 30, 40, 50 DAS and at harvest, the highest total dry matter content/plant (5.26, 8.11, 13.10 and 16.27 g, respectively) was found from HA_3SA_3 and the lowest (2.25, 5.44, 7.10 and 12.18 g, respectively) from HA_0SA_0 treatment combination. The maximum days to 1st flowering (38.67) was found from HA_0SA_0 and the minimum days (28.67) from HA_3SA_3 treatment combination. The maximum days to harvest (98.67) was found from HA_0SA_0 and the minimum days (77.00) from HA_3SA_3 treatment combination. The highest number of siliqua (52.07) was found from HA_3SA_3 and the lowest number (32.00) was recorded from HA_0SA_0 treatment combination. The highest length of siliqua (6.81 cm) was found from HA_3SA_3 and the lowest (4.28 cm) was recorded from HA_0SA_0 treatment combination. The highest number of seeds/siliqua (22.33) was found from HA_3SA_3 and the lowest number (11.30) was recorded from HA_0SA_0 treatment combination. The highest weight of 1000 seeds (3.63 g) was found from HA_3SA_3 and the lowest weight (2.22 g) was recorded from HA_0SA_0 treatment combination. The highest seed yield (1.97 t/ha) was found from HA_3SA_3 and the lowest seed yield (1.06 t/ha) was recorded from HA_0SA_0 treatment combination. The highest stover yield (2.98 t/ha) was found from HA_3SA_3 and the lowest stover yield (1.69 t/ha) was recorded from HA_0SA_0 treatment combination. The highest biological yield (4.81 t/ha) was found from HA_3SA_3 and the lowest biological yield (2.70 t/ha) was recorded from HA_0SA_0 treatment combination.

Conclusion:

- Among the different levels of humic acid, 24.0 kg/ha humic acid induced superior growth, yield contributing characters and yield of mustard. Simailrly 0.6 mM salicylic acid also showed the similar results.

- Among the combination of different levels of humic acid and salicylic acid, 24.0 kg/ha humic acid with 0.6 mM salicylic acid induced superior growth, yield contributing characters and yield of mustard and that can be used for commercial mustard production.

Recommendation:

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

- Response of other variety and other management practices to the treatments under study may be investigated in future.

- Need to conduct advance research how HA and SA increased seed yield of mustered for the development of sustainable agriculture.

- Scope to conduct of that experiment in other crops with HA and SA for enhancing the productivity for in view of increasing demand and changing environment.

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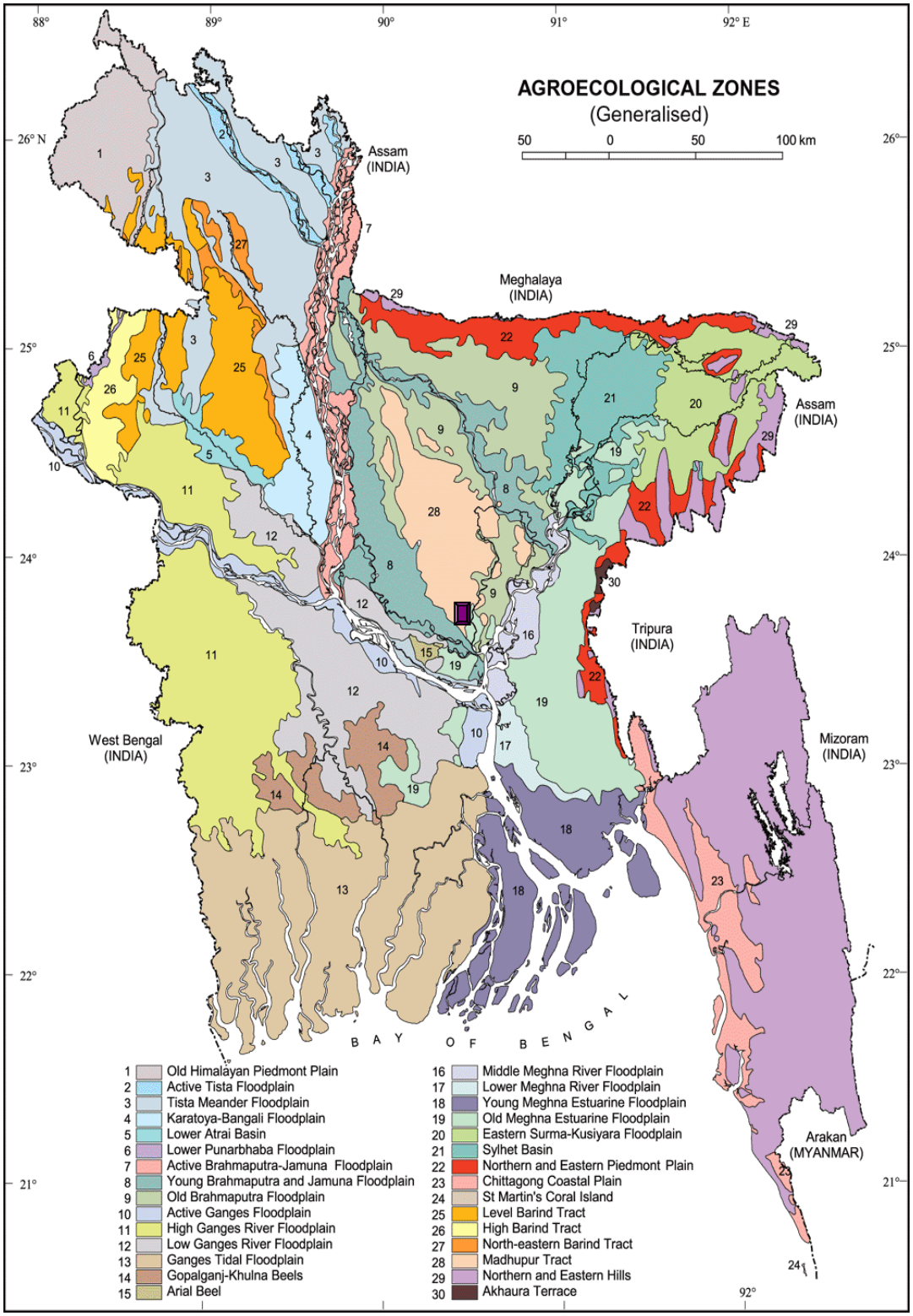
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental farm 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	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2017 to February 2018

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2017	26.5	19.4	81	22	6.9
November, 2017	25.8	16.0	76	00	6.8
December, 2017	22.6	13.4	78	05	6.6
January, 2018	24.9	12.2	64	00	5.8
February, 2018	27.7	16.9	69	30	6.7

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

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

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.165	1.570	30.826	48.756
Humic acid (A)	3	44.854*	167.134*	271.123*	188.156*
Salicylic acid (B)	3	178.617**	773.195**	963.040**	892.025**
Interaction (A×B)	9	34.186*	118.830*	227.143*	194.235*
Error	30	14.812	45.544	79.290	58.747

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

Appendix V. Analysis of variance of the data on number of branches/plant at different days after sowing (DAS) of mustard as influenced by different levels of humic acid and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Number of branches/plant at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.016	0.082	0.030	0.010
Humic acid (A)	3	0.402*	0.361*	1.167**	4.407**
Salicylic acid (B)	3	1.649**	2.866**	4.511**	3.794**
Interaction (A×B)	9	0.324*	0.297**	0.421*	2.424*
Error	30	0.135	0.098	0.151	0.192

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

Appendix VI. Analysis of variance of the data on dry matter content/plant at different days after sowing (DAS) of mustard as influenced by different levels of humic acid and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Total dry matter content/plant (g) at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.001	0.038	0.231	0.410
Humic acid (A)	3	0.571*	0.928*	1.231*	3.197*
Salicylic acid (B)	3	7.486**	4.312**	5.398**	12.700**
Interaction (A×B)	9	0.483**	0.623*	0.819*	1.789*
Error	30	0.172	0.253	0.326	0.891

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

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

Source of variation	Degrees of freedom	Mean square				
		Days to 1st flowering	Days to harvest	Number of siliqua/ plant	Length of siliqua (cm)	Number of seeds/ siliqua
Replication	2	0.141	24.021	0.070	0.035	0.790
Humic acid (A)	3	30.703*	131.19**	155.24**	0.371*	29.17**
Salicylic acid (B)	3	32.770*	96.30*	73.22**	1.622**	53.15**
Interaction (A×B)	9	26.581**	105.47**	32.82*	0.721**	3.929*
Error	30	9.021	32.710	12.680	0.106	1.537

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

Appendix VIII. Analysis of variance of the data on yield attributes and yields of mustard as influenced by different levels of humic acid and salicylic acid

Source of variation	Degrees of freedom	Mean square			
		Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)
Replication	2	0.058	0.008	0.025	0.0123
Humic acid (A)	3	3.266**	0.656**	0.921**	0.874**
Salicylic acid (B)	3	2.334**	0.140**	0.146*	0.132**
Interaction (A×B)	9	2.659**	0.039**	0.171**	0.154**
Error	30	0.374	0.013	0.040	0.028

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