EFFECTS OF VARIETY AND HUMIC ACID ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD OF MUSTARD

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CERTIFICATE

*This is to certify that the thesis entitled '**Effects of Variety and Humic Acid on Morpho-physiological Parameters 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 bona fide research work carried out by **CHAMELY AKTER**, Registration No. **12-05084** 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

Prof. Dr. Mohammad Mahbub Islam
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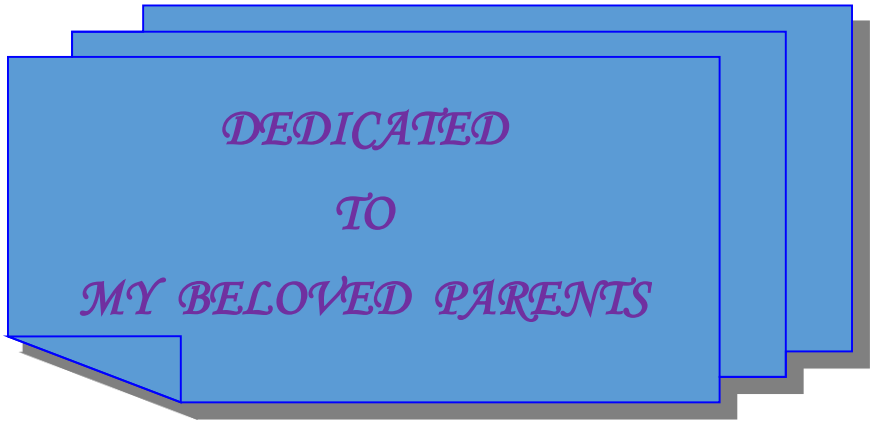
DEDICATED
TO
MY BELOVED PARENTS

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EFFECTS OF VARIETY AND HUMIC ACID ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD OF MUSTARD

ABSTRACT

The experiment was conducted in the Research Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period of October 2017 to February 2018 to study effects of variety and humic acid on morpho-physiological parameters and yield of mustard. The experiment comprised of two factors; Factor A: Different mustard varieties (4 varieties)- i) V_1: BARI Sarisha 9, ii) V_2: BARI Sarisha 11, iii) V_3: BARI Sarisha 14, iv) V_4: BARI Sarisha 15; and Factors B: Different levels of humic acid (H) (4 levels)- i) H_0: 0 kg fertilizer (control condition), ii) H_1: Recommended dose of organic + inorganic fertilizer, iii) H_2: 12 kg HA ha^{-1}, iv) H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on morpho-physiological characters, yield attributes and yield of mustard and observed statistically significant differences for different treatments. In case of different varieties, the tallest plant at 30, 40, 50 DAS (days after sowing) and at harvest 50.69, 97.65, 113.16 and 128.19 cm were recorded from V_2, BARI Sarisha 11, while the shortest plant 28.64, 67.59, 75.58 and 84.87 cm, from V_3, BARI Sarisha 14, respectively. The highest number of siliqua $plant^{-1}$ (149.22) was found from V_2, while the lowest number (78.47) from V_4 BARI Sarisha 15. The highest seed yield (2.45 t ha^{-1}) was found from V_2, while the lowest (1.36 t ha^{-1}) from V_1, BARI Sarisha 9. For different humic acid, the tallest plant 39.32, 80.72, 94.61 and 105.91 cm were found from H_3, Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}, whereas the shortest plant 32.70, 72.91, 79.54 and 92.22 cm from H_0, 0 kg fertilizer (control condition) at 30, 40, 50 DAS and at harvest, respectively. The highest number of siliqua $plant^{-1}$ (112.00) was recorded from H_3, whereas the lowest (93.55) from H_0. The highest seed yield (2.04 t ha^{-1}) was observed from H_3, whereas the lowest (1.32 t ha^{-1}) from H_0. Due to the interaction effect of varieties and humic acid, the tallest plant 55.64, 103.32, 122.42 and 139.39 cm were recorded V_2H_3, BARI Sarisha 11 and Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}, while the shortest plant 27.40, 67.66, 68.56 and 77.81 cm from V_3H_0 treatment combination, BARI Sarisha 14 and 0 kg fertilizer (control condition) at 30, 40, 50 DAS and at harvest, respectively. The highest number of siliqua $plant^{-1}$ (163.27) was recorded from V_2H_3, while the lowest (72.27) from V_4H_0 treatment combination. The highest seed yield (2.85 t ha^{-1}) was recorded from V_2H_3 and the lowest (1.03 t ha^{-1}) from V_1H_0 treatment combination. BARI Sarisha 11 and recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1} gave the highest yield by improving morpho-physiological traits and yield contributing characters of mustard under the climatic and edaphic condition of SAU.

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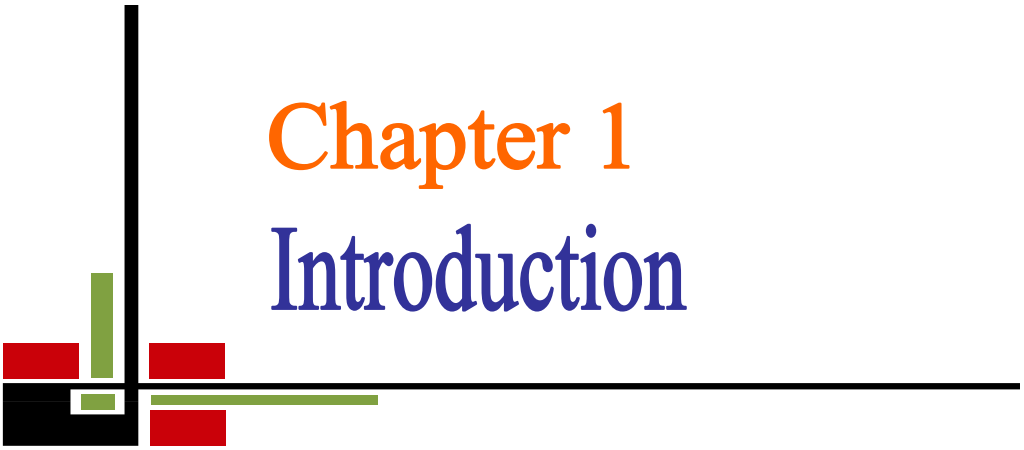
SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Co-efficient of variation	cv
Days After Sowing	DAS
and others	*et al.*
Etcetera	etc
Food and Agriculture Organization	FAO
Humic Acid	H
Journal	J.
Least Significance Difference	LSD
Muriate of Potash	MoP
Non significant	NS
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Triple Superphosphate	TSP
viz.	Namely



Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Mustard belongs to the genus *Brassica* under the family Brassicaceae, is a most important oilseed crops throughout the world after soyabean and groundnut including Bangladesh (FAO, 2004). Worldwide the total annual production of rapeseed and mustard is 63.04 million tons of seed from an area of 34.33 million hectares (FAO, 2013). *Brassica napus, B. campestris* and *B. juncea* are the three species of mustard those produce edible oil. It is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). It is not only a high energy food but also a carrier of fat soluble vitamins like A, D, E and K. In Bangladesh context, mustard is a popular edible oil and is considered important for improving the taste of a number of food items (Aziz *et al*., 2011). It is used as condiment, salad, fodder crop, and its leaf and stem are used as vegetable in the various mustard growing countries. Mustard oil also serves as an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Its oil is also used by the villagers for hair dressing and body massage before bath (Aziz *et al*., 2011). Dry mustard straw is also used as fuel. Moreover, mustard oil cake is also used as a feed for cattle and fish and as a good manure.

In Bangladesh, the total production of mustard was 0.534 million metric ton from 0.495 million hectare of land (AIS, 2017). Bangladesh has been facing acute shortage of edible oil for the last several decades and for that it needs to import a huge amount of oil and oilseeds. Our internal production can meet only about 21% of our consumption and the rest 79% is needed to import (Begum *et al.*, 2012). A huge amount of foreign exchange involving over 160 million US$ is being spent every year for importing edible oils due to insufficient oil production in Bangladesh (Rahman, 2002). The major mustard growing districts are Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka (BBS, 2016).

Although it is an important crop but the cultivation of mustard has to compete with other crops and it has been shifted to marginal lands of poor productivity. With increasing population, the demand of edible oil is increasing day by day and it is, therefore, highly accepted that the production of edible oil should be increased considerably to fulfill the demand (Meena *et al*., 2017). 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). Deficiency of suitable variety, late sowing and lack of innovative technology as climate smart agriculture techniques with changes climate are the major causes for poor yield of mustard in the country compared to other countries (Alam and Rahman, 2006).

Variety plays an important role in producing high yield of mustard because different varieties perform differently for their genotypic characters. Improved variety is the first and foremost requirement for initiation and accelerated crop production program. Improved varieties plays a crucial role in raising the seed yield of the crop. Development of high yielding varieties (HYV's) of mustard has been one of the major concern of the scientists because use of the improved varieties alone accounts for 15-20% increase in productivity (Singh *et al*., 2017). High yield potential of a variety is the prerequisite for increasing the production of a crop. In the recent years, Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) has developed a number of high yielding varieties of mustard with yield potential up to 2.5 t ha^{-1} (Sharif *et al*., 2016). Yield contributing characters and yield of different varieties varied significantly for different BARI developed mustard varieties (BARI, 2001; Mamun *et al*., 2014) and the yield of mustard will be increased by cultivating of high yielding varieties. Therefore, it is necessary to identify the suitable mustard variety to get the better seed yield under the climatic and edaphic condition of Sher-e-Bangla Agricultural University (SAU). Different variety showed different

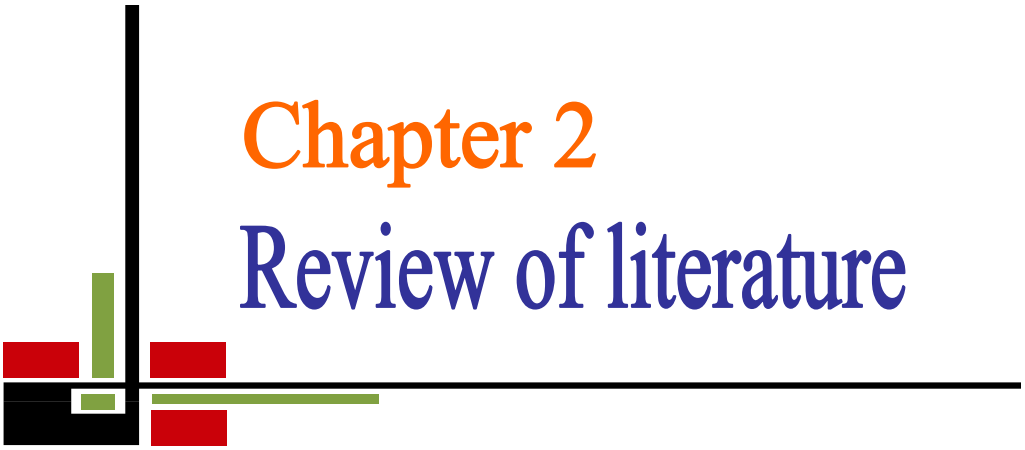
characteristics at various location of Bangladesh. Meanwhile, BARI released *Brassica napus, B. campestris* and *B. juncea* are the main species.

Humic acid is a bio-stimulant that significantly improve 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). Humic acid efficiently improves soil fertility and crop productivity, especially on poorly fertile and alkaline-calcareous soils (Rajpar *et al*., 2011). The role of humic acid is well known for improving soil health and nutrient uptake by plants, mineral availability etc. (Mauromicale *et al*., 2011). 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 and very limited study has conducted to examine the effects of humic acid on morpho-physiological parameters and yield of mustard.

Now it is also necessary to find the interaction effect between variety and humic acid on morpho-physiological parameters and yield of mustard. With this background and situation the present study was conducted for fulfilling the following objectives:

1. To investigate the individual effects of variety and humic acid on changes in morpho-physiological parameters and yield of mustard under the climatic and edaphic condition of SAU,

2. To investigate the interaction effects between variety and humic acid on changes in morpho-physiological parameters and yield of mustard under the climatic and edaphic condition of SAU.



Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the important oil crop in Bangladesh and also in many other countries of the world. Researches are going on in home and abroad to maximize the yield of mustard. However, a very few research work related to growth, yield and development of mustard have been carried out in our country. Variety and nutrient management play an important role in improving mustard yield. But research works related to variety and source of nutrients as a management practices especially use of humic acid on mustard are limited in Bangladesh context. However, some of the important and informative works and research findings related to the variety and humic acid so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Influence of yield attributes and yield of mustard due to different varieties

2.1.1 Plant height

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

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted 186.56 cm plant height.

Mamun *et al*. (2014) evaluated the effect of variety (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and observed that BARI Sarisha-13 performed well in terms of plant height.

An experiment was conducted by Barman *et al*. (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety

on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on plant height and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

A field experiment was conducted by Singh *et al*. (2017) at Faizabad, Uttar Pradesh, India, to assess the response of different mustard varieties (Vardan, Narendra Rai-1 and Narendra Ageti Rai-4 to different nutrient combinations under late sown condition during winter (rabi) season. Results revealed that among the different varieties, Narendra Rai-1 being at par with Vardan recorded significantly higher plant height (except 30 DAS).

2.1.2 Number of branches plant^{-1}

BARI (2001) reputed that under poor management number of branch plant^{-1} was higher (4.2) in the variety SS-75 and lower (2.1) in the variety BARI Sarisha-8. Under medium management, best performance was Dhali (5.5) and worst performance was BARI Sarisha-8. Under higher management, highest was in Dhali (5.9) and lowest in (3.0) Nap-248.

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 10.84 branches plant^{-1}, while variety Early Mustard resulted 9.25 branches plant^{-1}. Similarly, Mamun *et al*. (2014) reported that BARI Sarisha-13 performed well in terms of branches plant^{-1} (6.14) when evaluated the mustard varieties BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3 in different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

An experiment was conducted by Barman *et al*. (2016) at the Agronomy Field Laboratory and Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on number of branches plant^{-1} and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

A field experiment was conducted by Singh *et al*. (2017) at Faizabad, Uttar Pradesh, India, to assess the response of different mustard varieties (Vardan, Narendra Rai-1 and Narendra Ageti Rai-4 to different nutrient combinations under late sown condition during winter (rabi) season. Results revealed that among the different varieties, Narendra Rai-1 being at par with Vardan recorded significantly higher primary branching over Narendra Ageti Rai- 4.

2.1.3 Days to flowering

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

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

Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four

plant densities were applied during the course of study and reported that BARI Sarisha-13 produced early flower than the others.

An experiment was conducted by Barman *et al*. (2016) at the Agronomy Field Laboratory and Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on days to flowering.

2.1.4 Number of siliquae plant^{-1}

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 581.11 pods plant^{-1}, while variety Early Mustard resulted 484.67 pods plant^{-1}. On the other hand Mamun *et al*. (2014) reported that BARI Sarisha-13 performed well in terms of siliqua plant^{-1} (126.90) when they evaluated four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. were applied during the course of study and.

An experiment was conducted by Barman *et al*. (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on number of siliqua plant^{-1} and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

2.1.5 Siliqua length

Hussain *et al*. (2008) conducted an experiment to show the effect of boron application on yield and yield attributes of different mustard varieties. The experiment involved five boron levels and three mustard varieties viz. BARI sharisha-8, BARI sharisha-9 and BARI sharisha-11. BARI sharisha-11 and BARI sharisha-8 performed better in terms of siliqua length.

An experiment was conducted by Barman *et al*. (2016) at the Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments. Results revealed that variety had significant effect on siliqua length (cm) and the best result of the above character was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

Mostafa *et al*. (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 showed highly significant and positive correlation in seed yield with siliqua plant^{-1}.

2.1.6 Number of seeds siliqua^{-1}

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

Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of seeds siliqua^{-1} (25.36).

An experiment was conducted by Barman *et al*. (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on number of seeds siliqua^{-1}, and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

2.1.7 Thousand seed weight

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

BARI (2001) concluded that there was significant variation in 1000-seed weight of mustard found in different varieties and highest weigh of 1000-seed was found in Jamalpur-1 variety and lowest in BARI Sarisha-10.

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

Mamun *et al*. (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four

plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of 1000 seed weight (4.00) considering the other variety.

Mostafa *et al*. (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results recorded results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 showed highly significant and positive correlation in seed yield with 1000 seed weight of mustard.

An experiment was conducted by Barman *et al*. (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on 1000 seed weight and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

2.1.8 Seed yield

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

BARI (2001) showed that seed yield and other yield contributing characters significantly varied among the varieties. Rahman (2002) stated that yield variation existed among varieties and the highest seed yield was observed in BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha11 (2.00-2.50 t ha^{-1}) and lowest yield in variety Tori-7 (0.95-1.10 t ha^{-1}).

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

Mamun *et al*. (2014) evaluated the effect of four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that maximum seed yield (1.60 t ha^{-1}) was recorded for BARI Sarisha-13.

Hakim *et al*. (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 1960.30 seed yield kg ha^{-1}, while variety Early Mustard resulted 1677.90 seed yield kg ha^{-1}.

The experiment was conducted by Sharif *et al*. (2016) at the field laboratory of the Patuakhali Science and Technology University, Patuakhali, Bangladesh under the tidal Floodplain region to find out optimum sowing time for the selected three cultivars (BARI Sharisha-15, BINA Sharisha-5 and BARI Sharisha-9). Results showed that the highest grain yield (1.73 t ha^{-1}) was obtained from the first sowing (30 November) with BINA Sharisha-5 and it was significantly different from the yields of all other combination.

Singh and Singh (2017) carried out an experiment with four dates of sowing and two varieties viz. Pusa Bold and Pusa Jaikisan (Bio-902). Highest yield was produced by mustard cv. Pusa Bold among the two varieties tested. The analysis of variance showed that the difference in seed yield were statistically significant for both the varieties.

2.1.9 Stover yield

BARI (2001) reported that in case of poor management Isd-local gave the highest straw yield (3779 kg ha^{-1}) and lowest yield (1295 kg ha^{-1}) was found from Nap-248. In case of medium management, highest weight (6223.3 kg ha^{-1}) was recorded from the same variety and lowest (3702.3 kg ha^{-1}) from PT-303 under high management practices. The highest straw yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg ha^{-1} was obtained from variety Tori-7.

Mostafa *et al*. (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 and their growth parameters were also highly significant.

2.2 Influence of yield attributes and yield of mustard due to humic acid

2.2.1 Plant height

An experiment was conducted by Rastghalam *et al*. (2011) 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.

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.

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.

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.

2.2.2 Days to maturity

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.

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.

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 optimum maturity period.

2.2.3 Number of siliquae plant^{-1}

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.

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2.2.4 Number of seeds siliqua^{-1}

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^{-1} of mustard. The variety S-9 responded comparatively maximum number of seeds siliqua^{-1} to all the application rates of humic acid than its other two counterparts.

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^{-1}.

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^{-1} in comparison with non-HA applications.

2.2.5 Thousand seed 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.

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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 for attaining highest 1000 seeds weight.

2.2.6 Seed yield

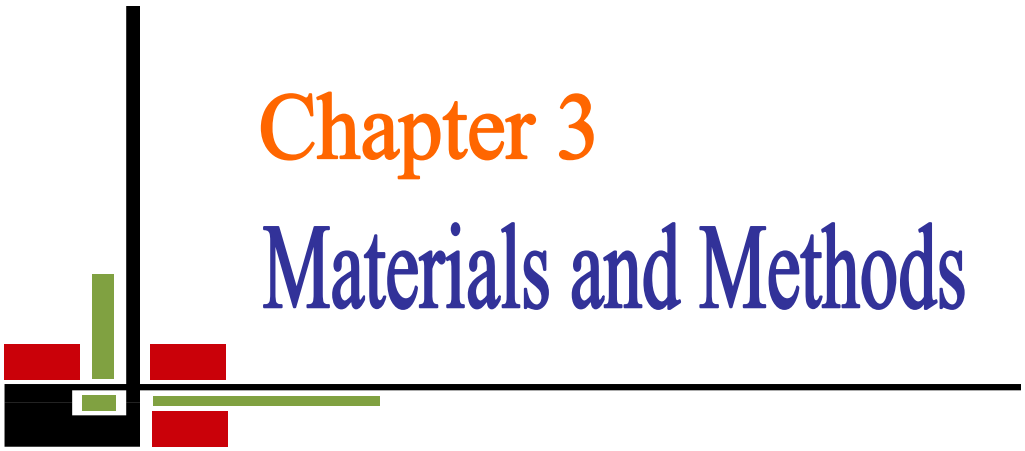
Rajpar *et al*. (2011) conducted a field study to assess the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing @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

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.

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.

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.

Above cited reviews revealed that variety and humic acid are the important factors for attaining optimum growth, yield attributes and yield of mustard. The literature revealed that the effects of variety and humic acid have not been studied well and have no definite conclusion for the production of mustard in the agro climatic condition of Bangladesh.



Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to effects of variety and humic acid on morpho-physiology 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, treatments of the experiments, design of the experiment, crop production, 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 with an elevation of 8.2 meter from sea level. 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. 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. 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.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised of two factors

Factor A: Different mustard varieties (V): 4 varieties

i) V_1: BARI Sarisha 9 under *Brassica campestris*

ii) V_2: BARI Sarisha 11 under *Brassica juncea*

iii) V_3: BARI Sarisha 14 under *Brassica campestris*

iv) V_4: BARI Sarisha 15 under *Brassica campestris*

Factors B: Different levels of humic acid (HA): 4 levels

i) H_0: 0 kg fertilizer (control condition)

ii) H_1: Recommended dose of organic and inorganic fertilizer

iii) H_2: 12 kg HA ha^{-1}

iv) H_3: Recommended dose of organic and inorganic fertilizer also use of 12 kg HA ha^{-1}

There were in total 16 (4×4) treatment combinations as V_1H_0, V_1H_1, V_1H_2, V_1H_3, V_2H_0, V_2H_1, V_2H_2, V_2H_3, V_3H_0, V_3H_1, V_3H_2, V_3H_3 V_4H_0, V_4H_1, V_4H_2 and V_4H_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 2.50 m × 1.25 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

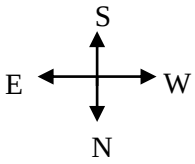
BARI Sarisha 9, BARI Sarisha 11, BARI Sarisha 14 and BARI Sarisha 15 were used as planting materials in this experiment. Both are a high yielding variety of mustard and developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The seeds were collected from the BARI, Joydebpur, Gazipur.

3.3.2 Collection and application of humic acid

Humic acid were collected from local market and it was applied as per treatments of the experiment and 50% as basal dose and 50% at 30 days after sowing (DAS) as broadcast.

3.3.3 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 on 4 November 2017.



Plot size = 2.50 m × 1.25 m

Plot to plot: 0.5 m

Replication to replication: 1.0 m

Factor A: Different mustard varieties (V): 4 varieties

i) V_1: BARI Sarisha 9 under *Brassica campestris*
ii) V_2: BARI Sarisha 11 under *Brassica juncea*
iii) V_3: BARI Sarisha 14 under *Brassica campestris*
iv) V_4: BARI Sarisha 15 under *Brassica campestris*

Factors B: Different levels of humic acid (B) as humic acid (HA): 4 levels

i) H_0: 0 kg fertilizer (control condition)
ii) H_1: Recommended dose of organic and inorganic fertilizer
iii) H_2: 12 kg HA ha^{-1}
iv) H_3: Recommended dose of organic and inorganic fertilizer also use of 12 kg HA ha^{-1}

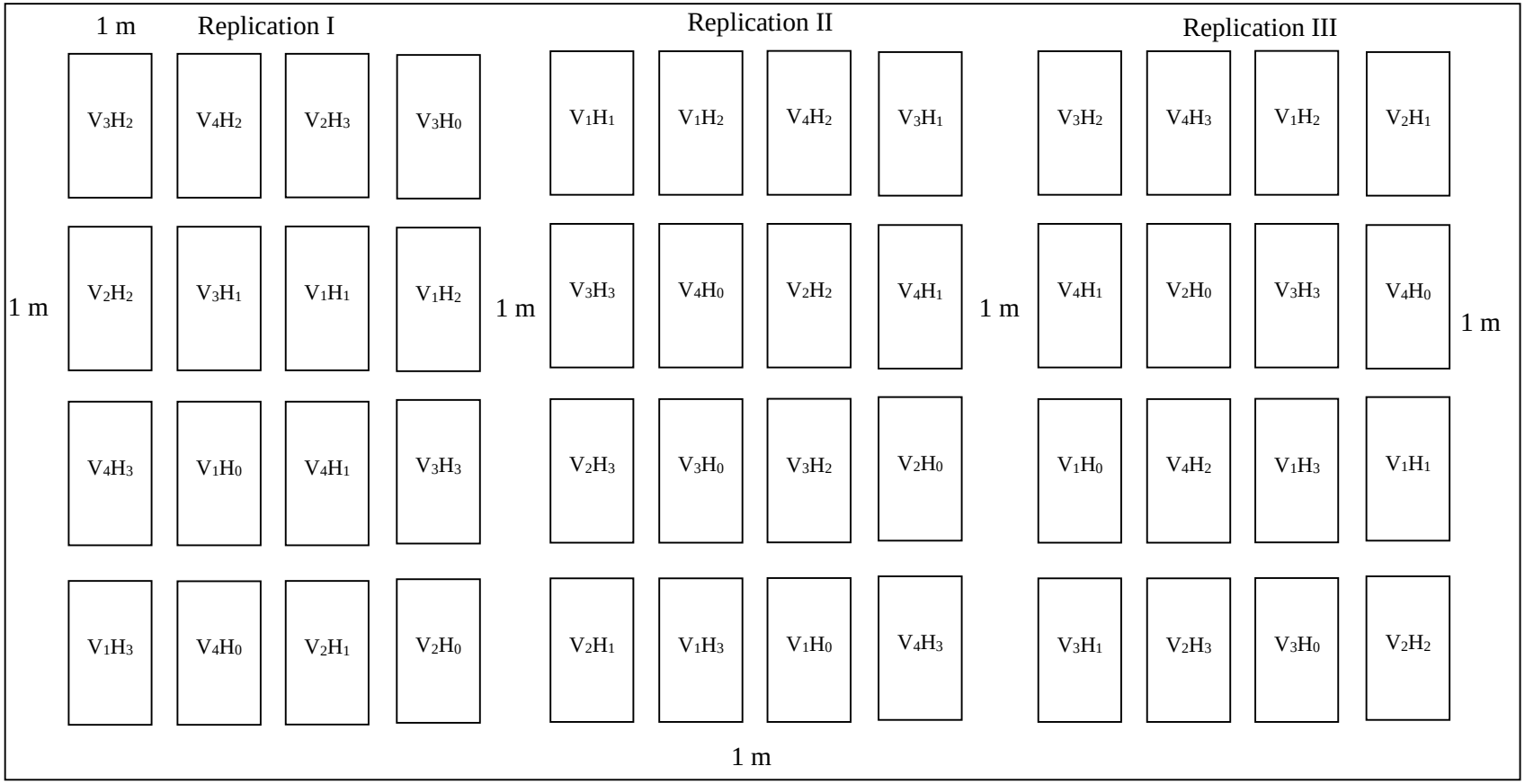


Figure 1. Layout of the experimental plot

3.3.4 Application of manure and fertilizers

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses (BARI, 2014) and as per treatment of the experiment.

Table 1. Dose and method of application of fertilizers in mustard field

Fertilizers and Manures	Dose ha^{-1}	Application (%)			
		Basal	20 DAS	30 DAS	40 DAS
Cowdung	5 tonnes	100	--	--	--
Urea	220 kg	--	33.33	33.33	33.33
TSP (Triple Super Phosphate)	170 kg	100	--	--	--
MoP (Muriate of potash)	85 kg	100	--	--	--
Zinc sulphate	5 kg	100	--	--	--
Gypsum	150 kg		--	--	--
Humic acid (HA)	12 kg	50	--	50	--

DAS: Days after sowing

3.3.5 Seed sowing

The seeds of mustard variety were sown on 4 November, 2017 in rows in the furrows having a depth of 2-3 cm.

3.3.6 Intercultural operations

3.3.6.1 Thinning

Seeds germination started after four 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.

3.3.6.2 Irrigation and weeding

Irrigation was provided for two times after seed sowing and before flowering to all experimental plots equally. The crop field was weeded before providing irrigation.

3.3.6.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plants.

Ripcord 10 EC was sprayed at the rate of 1 ml with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.4 Crop sampling and data collection

Five plants from each treatment and each replication were randomly selected and marked with sample card. Plant height, 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 plant were harvested manually.

3.6 Data collection

The following data were recorded

i. Plant height (cm)
ii. Number of branches plant^{-1}
iii. Number of leaves plant^{-1}
iv. SPAD value
v. Days to 1st flowering
vi. Days to harvest
vii. Number of siliqua plant^{-1}
viii. Length of siliqua (cm)
ix. Number of seeds siliqua^{-1}
x. Weight of 1000 seeds (g)
xi. Seed yield hectare^{-1} (t)
xii. Stover yield hectare^{-1} (t)
xiii. Biological yield hectare^{-1} (t)

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 plant^{-1}

The number of branches plant^{-1} was counted at 30, 40, 50 DAS and at harvest from selected plants. The average number of branches plant^{-1} was determined and recorded.

3.7.3 Number of leaves plant^{-1}

The number of leaves plant^{-1} was counted at 30, 40, 50 DAS and at harvest from selected plants. The average number of leaves plant^{-1} was determined and recorded.

3.7.4 SPAD value

SPAD value was determined from plant samples by using an automatic SPAD meter immediately after removal of leaves from plants to avoid rolling and shrinkage at 30, 40, 50 DAS and at harvest from selected plants.

3.7.5 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.

3.7.6 Days to harvest

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

3.7.7 Number of siliqua plant^{-1}

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

3.7.8 Length of siliqua (cm)

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

3.7.9 Number of seeds siliqua^{-1}

The number of seeds siliqua^{-1} was recorded from randomly selected 10 siliqua at the time of harvest. Data were recorded as the average and express in seeds siliqua^{-1}.

3.7.10 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).

3.7.11 Seed yield hectare^{-1} (t)

The seeds collected from 2.25 (1.8 m × 1.25 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 hectare^{-1} and express in seed yield of t ha^{-1}.

3.7.12 Stover yield hectare^{-1} (t)

The stover collected from 2.25 (1.8 m × 1.25 m) square meter area of each plot was sun dried properly, weighted and data were recorded. The stover yield of each plot were converted into yield hectare^{-1} and express in stover yield of t ha^{-1}.

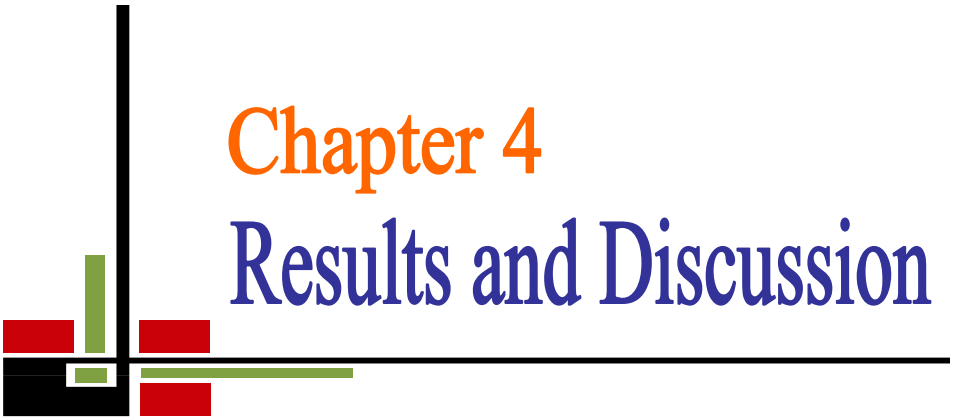
3.7.13 Biological yield

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

Biological yield = Seed yield + Stover yield.

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed the morphology and yield of mustard as influenced by varieties and humic acid. 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 4
Results and Discussion

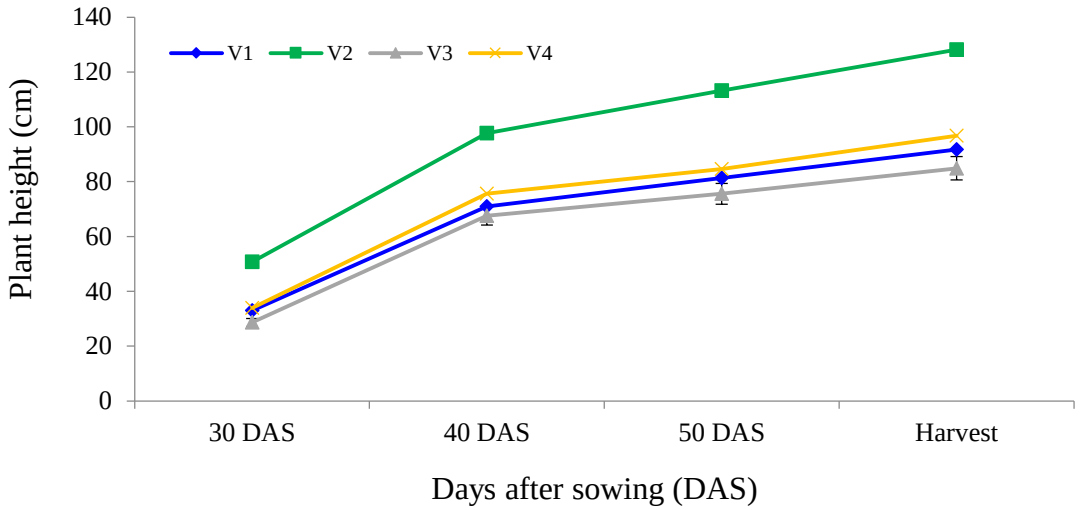
CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprised presentation and discussion of the results obtained from the study the effects of variety and humic acid on morpho-physiological parameters and yield of mustard. The analyses of variance (ANOVA) of the data on different morpho-physiology and yield of mustard are presented in Appendix IV-IX. The results have been presented and discussed in the different tables and graphs and possible interpretations are given under the following headings:

4.1 Plant height

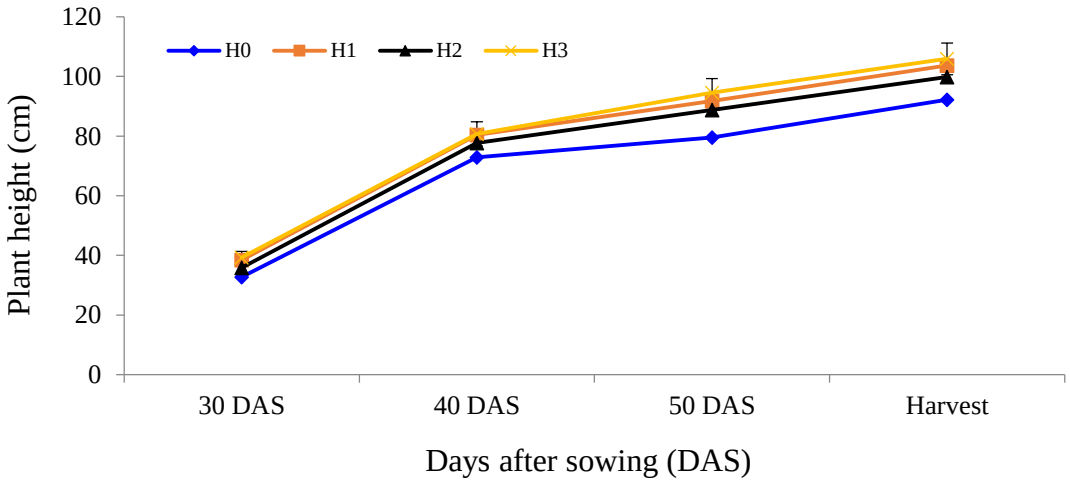
Plant height of mustard at 30, 40, 50 DAS (days after sowing) and at harvest showed statistically significant variation due to different varieties (Figure 2 and Appendix IV). The tallest plant at 30, 40, 50 DAS and at harvest (50.69, 97.65, 113.16 and 128.19 cm, respectively) was recorded from V_2 (BARI Sarisha 11) which was followed (33.92, 75.58, 84.58 and 96.81 cm, respectively) by V_4 (BARI Sarisha 15) and (33.05, 70.95, 81.37 and 91.78 cm, respectively) by V_1 (BARI Sarisha 9) and they were statistically similar, while the shortest plant (28.64, 67.59, 75.58 and 84.87 cm, respectively) was observed from V_3 (BARI Sarisha 14). Generally plant height is a genetical characters and it is controlled by the genetic make up of the specific variety. Variety plays an important role in producing longest plant of mustard because different varieties perform differently for their genotypic characters also vary from genotype to genotype. Laxminarayana and Pooranchand (2000) found no significant variations in terms of plant height among the cultivars that they studied earlier. But in an another experiment Mamun *et al*. (2014) reported that BARI Sarisha-13 performed well in terms of plant height compared to other varieties that they studied. Hakim *et al*. (2014) evaluated two varieties and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted 186.56 cm plant height. Altogether therefore these results indicate that different varieties of mustard produced different size of plant height.



V_1: BARI Sarisha 9 V_2: BARI Sarisha 11

V_3: BARI Sarisha 14 V_4: BARI Sarisha 15

Figure 2. Effect of different varieties on plant height of mustrad. (Vertical bars represent LSD value at 5% level of probability)



H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

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

Different humic acid showed statistically significant variation in terms of plant height of mustard at 30, 40, 50 DAS and at harvest (Figure 3 and Appendix IV). The tallest plant (39.32, 80.72, 94.61 and 105.91 cm, respectively) was found from H_3 (Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}), which was statistically similar (38.39, 80.45, 91.79 and 103.70 cm, respectively) to H_1 (Recommended dose of organic + inorganic fertilizer) and followed (35.90, 77.70, 88.74 and 99.83 cm, respectively) by H_2 (12 kg HA ha^{-1}), whereas the shortest plant (32.70, 72.91, 79.54 and 92.22 cm, respectively) from H_0 (0 kg fertilizer i.e. control condition) at 30, 40, 50 DAS and at harvest, respectively. Rajpar *et al*. (2011) reported that the application of humic acid @ 6.35 kg $acre^{-1}$ positively affected plant height. These results indicate that humic acid along with organic and inorganic fertilizer increases plant height of mustard.

Interaction effect of varieties and humic acid varied significantly on plant height of mustard at 30, 40, 50 DAS and at harvest (Table 2 and Appendix IV). The tallest plant (55.64, 103.32, 122.42 and 139.39 cm, respectively) was recorded from the treatment combination of V_2H_3 (BARI Sarisha 11 and Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}), while the shortest plant (27.40, 67.66, 68.56 and 77.81 cm, respectively) from V_3H_0 (BARI Sarisha 14 and 0 kg fertilizer i.e. control condition) at 30, 40, 50 DAS and at harvest. These results are reported by Mamun *et al*. (2014) and Rajpar *et al*. (2011). Altogether it suggests that interaction with variety and humic acid (HA) showed positive effect to elongate the length of plant height of mustard from early to harvest.

4.2 Number of branches $plant^{-1}$

Different varieties varied significantly in terms of number of branches $plant^{-1}$ of mustard at 30, 40, 50 DAS and at harvest (Figure 4 and Appendix V). The maximum number of branches $plant^{-1}$ at 30, 40, 50 DAS and at harvest (3.23, 5.35, 6.95 and 7.98, respectively) was found from V_3 which was statistically similar (3.20, 5.33, 6.93 and 7.85, respectively) to V_4 and followed (3.05, 4.73, 5.90 and 6.18, respectively) by V_2, whereas the minimum number (2.90, 4.47, 4.82 and 5.00, respectively) was found from V_1. Mamun *et al*. (2014) reported that BARI Sarisha-13 performed well for branches $plant^{-1}$ (6.14).

Table 2. Interaction effect of different varieties and humic acid on plant height at different days after sowing (DAS) and harvest of mustard

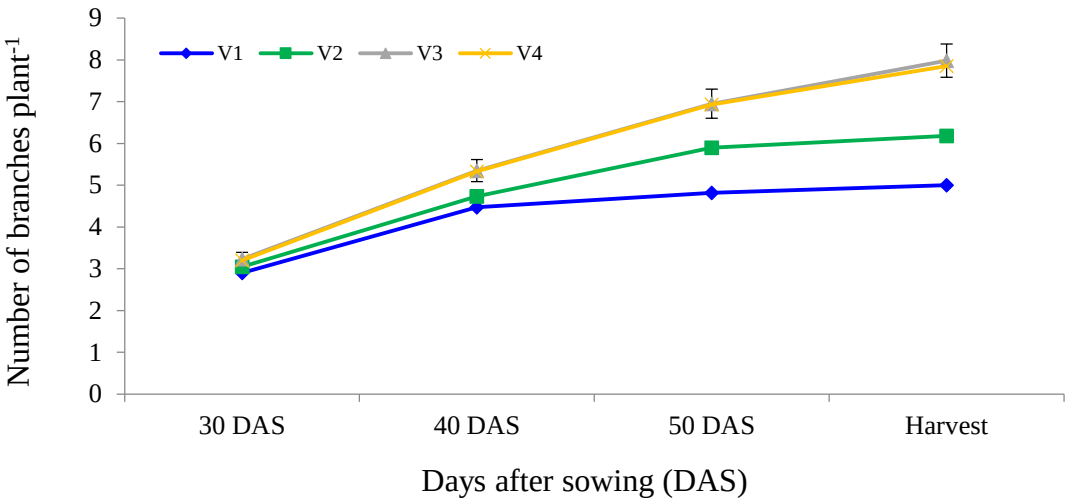
Treatments	Plant height (cm) at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1H_0	30.34 f-i	65.11 g	72.26 ef	91.27 d
V_1H_1	33.63 d-f	73.23 d-f	81.96 cd	91.80 d
V_1H_2	32.41 e-h	70.92 d-g	82.00 cd	91.73 d
V_1H_3	35.82 de	74.56 c-e	89.25 bc	92.33 d
V_2H_0	42.59 c	87.66 b	96.43 b	107.67 c
V_2H_1	53.72 ab	101.01 a	119.00 a	135.37 ab
V_2H_2	50.81 b	98.59 a	114.77 a	130.35 b
V_2H_3	55.64 a	103.32 a	122.42 a	139.39 a
V_3H_0	27.40 i	67.66 fg	68.56 f	77.81 e
V_3H_1	28.54 ghi	67.41 fg	78.00 de	86.93 d
V_3H_2	27.76 hi	66.84 fg	76.92 de	86.10 d
V_3H_3	30.85 f-i	68.45 e-g	78.85 de	88.64 d
V_4H_0	30.46 f-i	71.19 d-g	80.92 c-e	92.13 d
V_4H_1	37.67 d	80.14 c	88.19 bc	100.71 c
V_4H_2	32.60 e-g	74.44 c-e	81.27 cd	91.12 d
V_4H_3	34.97 d-f	76.54 cd	87.92 bc	103.27 c
$LSD_{(0.05)}$	4.206	5.732	7.960	7.674
Level of significance	*	*	*	**
CV(%)	6.90	4.41	5.38	4.58

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

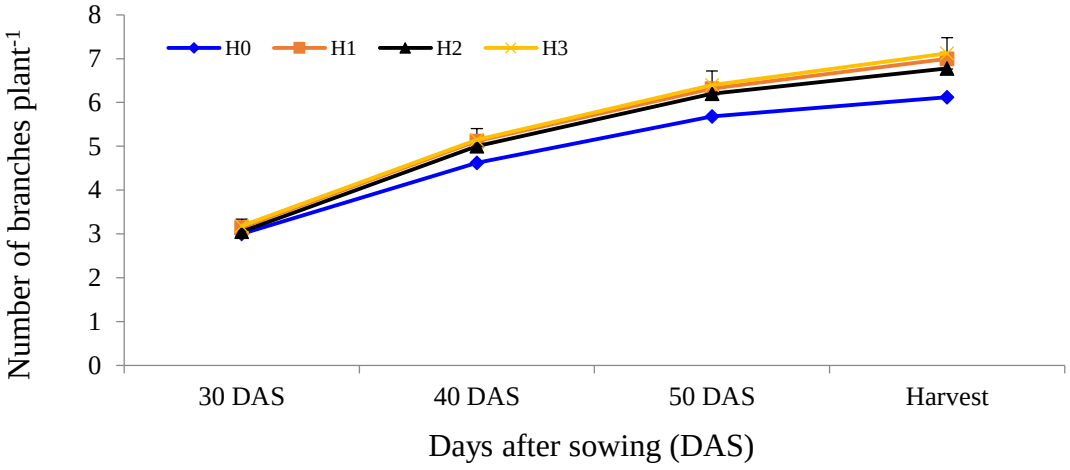
* = Significant at 5% level and ** = Significant at 1% level



V_1: BARI Sarisha 9 V_2: BARI Sarisha 11

V_3: BARI Sarisha 14 V_4: BARI Sarisha 15

Figure 4. Effect of different varieties on number of branches plant^{-1} of mustrad. (Vertical bars represent LSD value at 5% level of probability)



H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

Figure 5. Effect of different levels of humic acid on number of branches plant^{-1} of mustard. (Vertical bars represent LSD value at 5% level of probability)

Number of branches plant^{-1} at 30, 40, 50 DAS and at harvest of mustard showed statistically significant differences due to different humic acid (Figure 5 and Appendix V). The maximum number of branches plant^{-1} (3.18, 5.15, 6.40 and 7.12, respectively) was recorded from H_3, which was statistically similar (3.15, 5.12, 6.32 and 7.00, respectively) to H_1 and followed (3.05, 5.00, 6.20 and 6.78, respectively) by H_2, while the minimum number (3.00, 4.62, 5.68 and 6.12, respectively) was found from H_0 at 30, 40, 50 DAS and at harvest, respectively. These results are consistent with the results of number of branches plant^{-1}.

Number of branches plant^{-1} of mustard at 30, 40, 50 DAS and at harvest showed significant differences due to the interaction effect of varieties and humic acid (Table 3 and Appendix V). The maximum number of branches plant^{-1} (3.33, 5.47, 7.20 and 8.33, respectively) was found from the treatment combination of V_3H_3 and the minimum number (2.73, 3.73, 4.00 and 4.07, respectively) was observed from V_1H_0 at 30, 40, 50 DAS and at harvest.

4.3 Number of leaves plant^{-1}

Number of leaves plant^{-1} of mustard at 30, 40, 50 DAS and at harvest varied significantly due to different varieties (Table 4 and Appendix VI). The maximum number of leaves plant^{-1} at 30, 40, 50 DAS and at harvest (14.24, 26.70, 39.65 and 46.90, respectively) was observed from V_2 which was followed (13.18, 23.35, 37.12 and 43.32, respectively) by V_3 and (12.93, 23.17, 36.85 and 42.34, respectively) by V_4, while the minimum number (10.78, 20.57, 31.88 and 35.80, respectively) was found from V_1. It was observed that different varieties of mustard produced different number of leaves plant^{-1}.

Statistically significant variation was recorded due to different humic acid in terms of number of leaves plant^{-1} of mustard at 30, 40, 50 DAS and at harvest (Table 4 and Appendix VI). The maximum number of leaves plant^{-1} (13.41, 24.28, 38.22 and 44.89, respectively) was recorded from H_3, which was statistically similar (13.10, 24.03, 37.52 and 44.13, respectively) to H_1 and followed (12.63, 23.57, 37.30 and 42.55, respectively) by H_2, whereas the minimum number (12.00, 21.90, 32.47 and 36.78, respectively) was found from H_0 at 30, 40, 50 DAS and at harvest, respectively. Therefore these results indicate that humic acid along with organic and inorganic fertilizer increases number of leaves plant^{-1}.

Table 3. Interaction effect of different varieties and humic acid on number of branches plant^{-1} at different days after sowing (DAS) and harvest of mustard

Treatments	Number of branches plant^{-1} at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1H_0	2.73 f	3.73 f	4.00 g	4.07 g
V_1H_1	3.00 de	4.67 de	5.13 ef	5.40 ef
V_1H_2	2.87 ef	4.60 de	4.93 f	5.13 f
V_1H_3	3.00 de	4.87 cd	5.20 ef	5.47 ef
V_2H_0	3.00 de	4.27 e	5.47 e	5.67 e
V_2H_1	3.07 cd	4.87 cd	6.00 d	6.27 d
V_2H_2	3.00 de	4.87 cd	6.00 d	6.33 d
V_2H_3	3.13 b-d	4.93 b-d	6.13 cd	6.47 d
V_3H_0	3.20 a-c	5.20 a-c	6.47 bc	7.20 c
V_3H_1	3.20 a-c	5.40 ab	7.07 a	8.33 a
V_3H_2	3.20 a-c	5.27 a-c	7.07 a	8.07 ab
V_3H_3	3.33 a	5.47 a	7.20 a	8.33 a
V_4H_0	3.07 cd	5.27 a-c	6.80 ab	7.60 bc
V_4H_1	3.33 a	5.53 a	7.07 a	8.00 ab
V_4H_2	3.13 b-d	5.27 a-c	6.80 ab	7.60 bc
V_4H_3	3.27 ab	5.33 a-c	7.07 a	8.20 a
$LSD_{(0.05)}$	0.149	0.435	0.412	0.463
Level of significance	*	*	*	*
CV(%)	4.85	5.24	4.01	4.10

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Table 4. Effect of different varieties and humic acid on number of leaves plant^{-1} at different days after sowing (DAS) and harvest of mustard

Treatments	Number of leaves plant^{-1} at			
	30 DAS	40 DAS	50 DAS	Harvest
Mustard varieties				
V_1	10.78 c	20.57 c	31.88 c	35.80 c
V_2	14.24 a	26.70 a	39.65 a	46.90 a
V_3	13.18 b	23.35 b	37.12 b	43.32 b
V_4	12.93 b	23.17 b	36.85 b	42.34 b
$LSD_{(0.05)}$	0.440	0.783	1.162	1.471
Level of significance	**	**	**	**
Levels of bio-stimulator				
H_0	12.00 c	21.90 b	32.47 b	36.78 c
H_1	13.10 a	24.03 a	37.52 a	44.13 a
H_2	12.63 b	23.57 a	37.30 a	42.55 b
H_3	13.41 a	24.28 a	38.22 a	44.89 a
$LSD_{(0.05)}$	0.440	0.783	1.162	1.471
Level of significance	**	**	**	**
CV(%)	4.13	4.00	3.83	4.19

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Interaction effect of varieties and humic acid showed significant differences on number of leaves plant^{-1} of mustard at 30, 40, 50 DAS and at harvest (Table 5 and Appendix VI). The maximum number of leaves plant^{-1} (15.37, 28.20, 42.33 and 50.40, respectively) was recorded from the treatment combination of V_2H_3, while the minimum number (10.27, 18.73, 27.40 and 30.60, respectively) was found from V_1H_0 at 30, 40, 50 DAS and at harvest.

4.4 SPAD value

SPAD value of mustard at 30, 40, 50 DAS and at harvest showed statistically significant variation due to different varieties (Table 6 and Appendix VII). The highest SPAD value at 30, 40, 50 DAS and at harvest (33.59, 40.95, 50.14 and 45.07, respectively) was recorded from V_2 which was followed (32.69, 38.31, 47.74 and 42.96, respectively) to V_3 and (32.44, 38.08, 47.72 and 42.35, respectively) by V_4, while the lowest (30.85, 35.47, 42.89 and 37.01, respectively) was observed from V_1. Altogether, the results of this suggest that different varieties of mustard produced different SPAD value.

Statistically significant variation was recorded due to different humic acid in terms of SPAD value of mustard at 30, 40, 50 DAS and at harvest (Table 6 and Appendix VII). The highest SPAD value (33.02, 39.20, 48.59 and 43.72, respectively) was found from H_3, which was statistically similar (32.84, 38.84, 48.11 and 43.05, respectively) to H_1 and followed (32.28, 38.24, 47.48 and 42.01, respectively) by H_2, whereas the lowest (31.43, 36.53, 44.31 and 38.61, respectively) was recorded from H_0 at 30, 40, 50 DAS and at harvest, respectively. These results indicate that humic acid along with organic and inorganic fertilizer increases SPAD value.

Interaction effect of varieties and humic acid varied significantly on SPAD value of mustard at 30, 40, 50 DAS and at harvest (Table 7 and Appendix VII). The highest SPAD value (34.21, 43.00, 52.55 and 47.77, respectively) was recorded from the treatment combination of V_2H_3, while the lowest (30.13, 34.37, 40.22 and 34.56, respectively) from V_1H_0 at 30, 40, 50 DAS and at harvest.

Table 5. Interaction effect of different varieties and humic acid on number of leaves plant^{-1} at different days after sowing (DAS) and harvest of mustard

Treatments	Number of leaves plant^{-1} at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1H_0	10.27 i	18.73 e	27.40 e	30.60 g
V_1H_1	10.80 hi	21.07 d	32.93 d	37.00 f
V_1H_2	10.73 hi	20.80 d	33.27 d	37.40 f
V_1H_3	11.33 gh	21.67 cd	33.93 d	38.20 ef
V_2H_0	12.60 ef	23.67 b	33.40 d	39.20 ef
V_2H_1	14.73 ab	27.67 a	41.40 a	50.00 a
V_2H_2	14.27 bc	27.27 a	41.47 a	48.00 ab
V_2H_3	15.37 a	28.20 a	42.33 a	50.40 a
V_3H_0	12.93 d-f	22.40 b-d	33.73 d	37.80 ef
V_3H_1	13.13 d-f	23.27 bc	37.80 bc	46.13 bc
V_3H_2	13.00 d-f	23.13 bc	37.27 bc	43.80 cd
V_3H_3	13.67 cd	23.87 b	38.60 b	45.53 bc
V_4H_0	12.20 fg	22.80 bc	35.33 cd	39.53 ef
V_4H_1	13.73 cd	24.13 b	37.93 b	43.40 cd
V_4H_2	12.53 ef	23.07 bc	37.20 bc	41.00 de
V_4H_3	13.27 de	23.40 bc	38.00 b	45.41 bc
$LSD_{(0.05)}$	0.881	1.565	2.325	2.942
Level of significance	*	*	*	*
CV(%)	4.13	4.00	3.83	4.19

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Table 6. Effect of different varieties and humic acid on SPAD value at different days after sowing (DAS) and harvest of mustard

Treatments	SPAD value at			
	30 DAS	40 DAS	50 DAS	Harvest
Mustard varieties				
V_1	30.85 c	35.47 c	42.89 c	37.01 c
V_2	33.59 a	40.95 a	50.14 a	45.07 a
V_3	32.69 b	38.31 b	47.74 b	42.96 b
V_4	32.44 b	38.08 b	47.72 b	42.35 b
$LSD_{(0.05)}$	0.552	0.647	0.956	0.979
Level of significance	**	**	**	**
Levels of bio-stimulator				
H_0	31.43 c	36.53 c	44.31 c	38.61 c
H_1	32.84 a	38.84 ab	48.11 ab	43.05 a
H_2	32.28 b	38.24 b	47.48 b	42.01 b
H_3	33.02 a	39.20 a	48.59 a	43.72 a
$LSD_{(0.05)}$	0.552	0.647	0.956	0.979
Level of significance	**	**	**	**
CV(%)	5.34	4.26	4.23	5.37

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Table 7. Interaction effect of different varieties and humic acid on SPAD value at different days after sowing (DAS) and harvest of mustard

Treatments	SPAD value at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1H_0	30.13 h	34.37 h	40.22 e	34.56 j
V_1H_1	30.96 f-h	35.60 gh	43.59 d	37.43 i
V_1H_2	30.77 gh	35.44 gh	43.48 d	37.76 i
V_1H_3	31.56 e-g	36.46 fg	44.26 d	38.31 hi
V_2H_0	31.78 d-g	37.10 ef	45.09 cd	39.96 f-h
V_2H_1	34.50 a	42.08 ab	51.84 a	46.99 ab
V_2H_2	33.87 ab	41.61 b	51.07 a	45.56 bc
V_2H_3	34.21 a	43.00 a	52.55 a	47.77 a
V_3H_0	32.27 c-e	37.08 ef	45.10 cd	39.11 g-i
V_3H_1	32.55 c-e	38.31 c-e	48.52 b	44.64 cd
V_3H_2	32.46 c-e	37.97 c-e	48.31 b	43.44 cd
V_3H_3	33.46 a-c	38.98 cd	48.95 b	44.65 cd
V_4H_0	31.54 e-g	37.56 d-f	46.81 bc	40.82 fg
V_4H_1	33.35 a-c	39.38 c	48.49 b	43.13 de
V_4H_2	32.02 d-f	37.95 c-e	47.04 bc	41.26 ef
V_4H_3	32.85 b-d	38.38 c-e	28.61 b	44.17 cd
$LSD_{(0.05)}$	1.104	1.294	1.912	1.957
Level of significance	*	**	**	**
CV(%)	5.34	4.26	4.23	5.37

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

4.5 Days to 1st flowering

Days to 1st flowering of mustard showed statistically significant variation for different varieties (Table 8 and Appendix VIII). The highest days to 1st flowering (37.00) was found from V_2, while the lowest days (31.00) was observed from V_3 which was statistically similar (32.25 and 33.25) to V_4 and V_1. BARI (2001) reported the highest days to flowering (32 days) was found in Jamalpur-1 variety and lowest in BARI Sarisha-10. These results indicate that different varieties of mustard required different days to 1st flowering.

Statistically significant variation was recorded due to different humic acid in terms of days to 1st flowering (Table 8 and Appendix VIII). The highest days to 1st flowering (36.08) was observed from H_0, which was statistically similar (34.42) to H_2, whereas the lowest days (31.25) was recorded from H_3 which was statistically similar (31.75) to H_1. These results indicate that humic acid along with organic and inorganic fertilizer minimize days to flowering of mustard.

Interaction effect of varieties and humic acid showed significant differences on days to 1st flowering (Table 9 and Appendix VIII). The highest days to 1st flowering (39.00) was found from the treatment combination of V_2H_3, while the lowest days (26.00) was observed from V_3H_1.

4.6 Days to harvest

Days to harvest flowering of mustard showed statistically significant variation due to different varieties (Table 8 and Appendix VIII). The highest days to harvest (108.67) was recorded from V_2 which was followed (85.50 and 83.92) by V_1 and V_4, while the lowest days (80.33) was observed from V_3. It was observed that different varieties of mustard required different days to harvest.

Statistically significant variation was recorded due to different humic acid in terms of days to harvest (Table 8 and Appendix VIII). The highest days to harvest (93.17) was found from H_1, which was statistically similar (90.25) by H_2, whereas the lowest days (86.58) was observed from H_0 which was followed (88.42) by H_3. These results consistent with the results of days to harvest of mustard.

Table 8. Effect of different varieties and humic acid on different yield contributing characters of mustard

Treatments	Days to 1st flowering	Days to harvest	Number of siliqua plant^{-1}	Length of siliqua (cm)
Mustard varieties				
V_1	33.25 b	85.50 b	94.23 b	4.91 b
V_2	37.00 a	108.67 a	149.22 a	6.84 a
V_3	31.00 b	80.33 c	97.53 b	5.29 b
V_4	32.25 b	83.92 b	78.47 c	5.39 b
$LSD_{(0.05)}$	2.521	3.304	4.557	0.467
Level of significance	**	**	**	**
Levels of bio-stimulator				
H_0	36.08 a	86.58 c	93.55 c	4.46 b
H_1	31.75 b	93.17 a	109.17 ab	6.09 a
H_2	34.42 a	90.25 ab	104.73 b	5.77 a
H_3	31.25 b	88.42 bc	112.00 a	6.11 a
$LSD_{(0.05)}$	2.521	3.304	4.557	0.467
Level of significance	**	**	**	**
CV(%)	9.06	4.42	5.21	9.98

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Table 9. Interaction effect of different varieties and humic acid on different yield contributing characters of mustard

Treatments	Days to 1st flowering	Days to harvest	Number of siliqua plant^{-1}	Length of siliqua (cm)
V_1H_0	35.00 a-c	89.00 c	79.53 ef	3.52 d
V_1H_1	30.67 c-e	82.67 c-e	98.13 d	5.47 b
V_1H_2	36.67 ab	89.33 c	96.13 d	5.23 b
V_1H_3	30.67 c-e	81.00 d-f	103.13 d	5.44 b
V_2H_0	36.67 ab	101.00 b	122.40 c	4.87 bc
V_2H_1	39.00 a	113.00 a	157.93 ab	7.48 a
V_2H_2	33.33 a-d	114.67 a	153.27 b	7.33 a
V_2H_3	39.00 a	106.00 b	163.27 a	7.69 a
V_3H_0	36.67 ab	81.67 d-f	100.00 d	4.11 cd
V_3H_1	26.00 e	75.67 ef	96.60 d	5.92 b
V_3H_2	34.33 a-c	80.67 d-f	94.67 d	5.57 b
V_3H_3	27.00 e	83.33 cd	98.87 d	5.56 b
V_4H_0	36.00 a-c	74.67 f	72.27 f	5.34 b
V_4H_1	31.33 b-e	101.33 b	84.00 e	5.29 b
V_4H_2	33.33 a-d	76.33 d-f	74.87 ef	4.95 bc
V_4H_3	28.33 de	83.33 cd	82.73 e	5.96 b
$LSD_{(0.05)}$	5.041	6.607	9.113	0.933
Level of significance	**	**	**	**
CV(%)	9.06	4.42	5.21	9.98

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Interaction effect of varieties and humic acid showed significant differences on days to harvest (Table 9 and Appendix VIII). The highest days to harvest (114.67) was recorded from the treatment combination of V_2H_2, while the lowest days (74.67) from V_4H_0.

4.7 Number of siliqua plant^{-1}

Number of siliqua plant^{-1} of mustard showed statistically significant variation due to different varieties (Table 8 and Appendix VIII). The highest number of siliqua plant^{-1} (149.22) was found from V_2 which was followed (97.53 and 94.23) by V_3 and V_1 and they were statistically similar, while the lowest number (78.47) was observed from V_4. Hakim *et al*. (2014) reported that S-9 ranked 1st with 581.11 pods plant^{-1}, while variety Early Mustard resulted 484.67 pods plant^{-1}. These results are consistent with the results of number of siliqua plant^{-1}.

Statistically significant variation was recorded due to different humic acid in terms of number of siliqua plant^{-1} (Table 8 and Appendix VIII). The highest number of siliqua plant^{-1} (112.00) was recorded from H_3, which was statistically similar (109.17) to H_1 and followed (104.73) by H_2, whereas the lowest (93.55) was found from H_0. These results indicate that humic acid along with organic and inorganic fertilizer increases the number of siliqua plant^{-1} of mustard.

Interaction effect of varieties and humic acid showed significant differences on number of siliqua plant^{-1} (Table 9 and Appendix VIII). The highest number of siliqua plant^{-1} (163.27) was recorded from the treatment combination of V_2H_3, while the lowest (72.27) was found from V_4H_0.

4.8 Length of siliqua

Length of siliqua of mustard showed statistically significant variation due to different varieties (Table 8 and Appendix VIII). The highest length of siliqua (6.84 cm) was recorded from V_2, while the lowest length (4.91 cm) was observed from V_1 which was followed (5.29 cm and 5.39 cm) by V_3 and V_4 and they were statistically similar. Hussain *et al*. (2008) reported that BARI sharisha-8

performed better in terms of siliqua length. The results indicate that different varieties of mustard produced different length of siliqua.

Statistically significant variation was recorded due to different humic acid in terms of length of siliqua (Table 8 and Appendix VIII). The highest length of siliqua (6.11 cm) was found from H_3, which was statistically similar (6.09 and 5.77 cm) to H_1 and H_2, whereas the lowest length (4.46 cm) was recorded from H_0. These results indicate that humic acid along with organic and inorganic fertilizer produced longest length of siliqua of mustard.

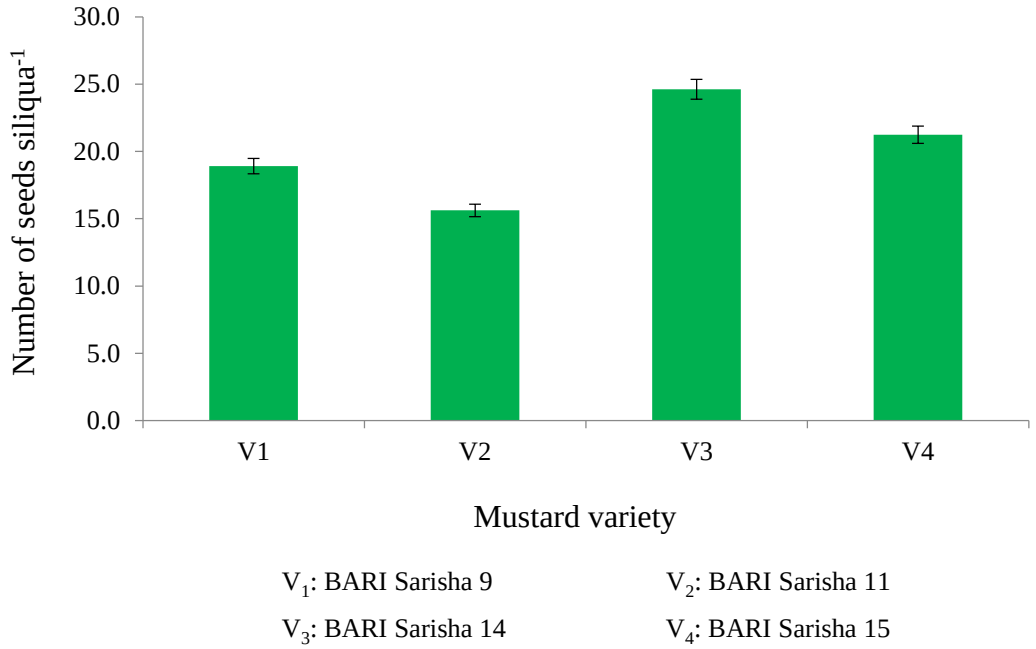
Interaction effect of varieties and humic acid showed significant differences on length of siliqua (Table 9 and Appendix VIII). The highest length of siliqua (7.69 cm) was recorded from the treatment combination of V_2H_3, while the lowest length (4.11 cm) was found from V_3H_0.

4.9 Number of seeds siliqua^{-1}

Number of seeds siliqua^{-1} of mustard showed statistically significant variation due to different varieties (Figure 6 and Appendix VIII). The highest number of seeds siliqua^{-1} (24.63) was found from V_3 which was followed (21.25) by V_4, while the lowest number (15.62) was recorded from V_2 which was statistically similar (18.92) to V_1. Therefore the results indicate that different varieties of mustard produced different number of seeds siliqua^{-1}.

Statistically significant variation was recorded due to different humic acid in terms of number of seeds siliqua^{-1} (Figure 7 and Appendix VIII). The highest number of seeds siliqua^{-1} (21.73) was found from H_3, which was statistically similar (21.15) to H_1 and followed (20.07) by H_2, whereas the lowest number (17.47) from H_0. These results inconsistent with the results of number of seeds siliqua^{-1}.

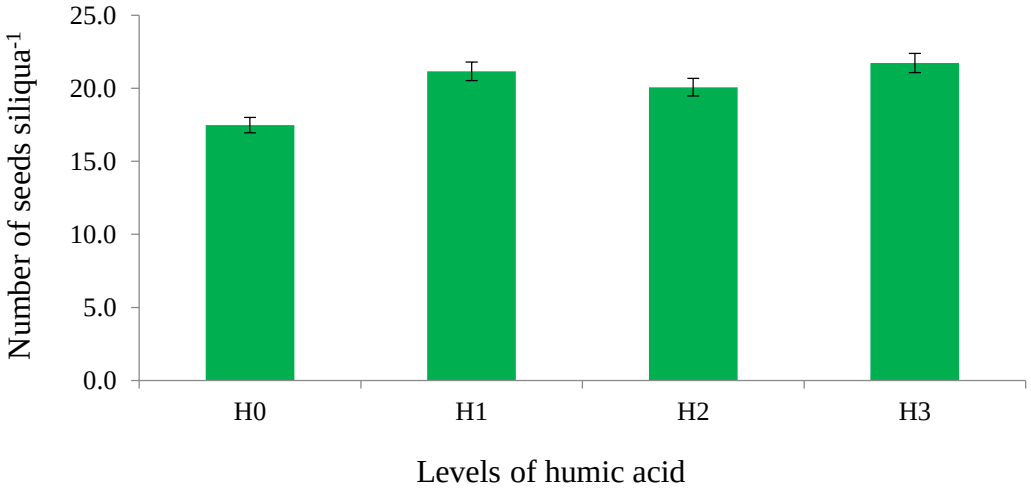
Interaction effect of varieties and humic acid showed significant differences on number of seeds siliqua^{-1} (Figure 8 and Appendix VIII). The highest number of seeds siliqua^{-1} (27.00) was recorded from the treatment combination of V_3H_3, while the lowest number (13.67) was found from V_2H_0.



V_1: BARI Sarisha 9 V_2: BARI Sarisha 11

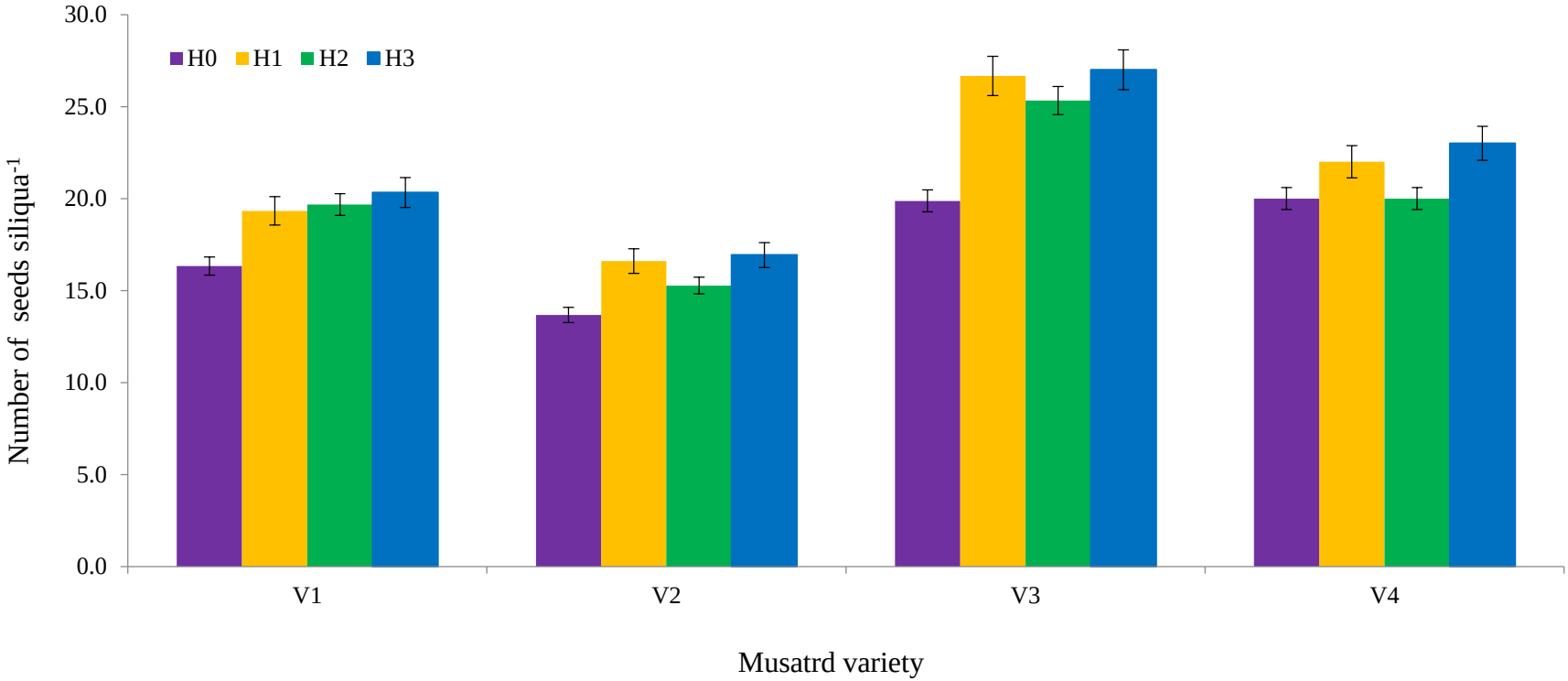
V_3: BARI Sarisha 14 V_4: BARI Sarisha 15

Figure 6. Effect of different mustard variety on number of seeds siliqua^{-1} of mustard. (Vertical bars represent LSD value at 5% level of probability)



H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

Figure 7. Effect of different levels of humic acid on number of seeds siliqua^{-1} of mustard. (Vertical bars represent LSD value at 5% level of probability)



V_1: BARI Sarisha 9 V_2: BARI Sarisha 11

V_3: BARI Sarisha 14 V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

Figure 8. Interaction effect of different mustard variety and levels of humic acid on number of seeds $siliqua^{-1}$ of mustard. (Vertical bars represent LSD value at 5% level of probability

4.10 Weight of 1000 seeds

Weight of 1000 seeds of mustard showed statistically significant variation due to different varieties (Table 10 and Appendix IX). The highest weight of 1000 seeds (3.98 g) was recorded from V_2 which was followed (3.77 g) by V_3, while the lowest weight (2.96 g) was observed from V_1 which was followed (3.43 g) by V_4. Karim *et al.* (2000) stated that the higher weight of 1000-seed in J-3023 (3.43 g) J-3018 (3.42 g) and J-4008 (3.50 g). It was observed that different varieties of mustard produced different weight of 1000 seeds.

Statistically significant variation was recorded due to different humic acid in terms of weight of 1000 seeds (Table 10 and Appendix IX). The highest weight of 1000 seeds (3.70 g) was found from H_3, which was statistically similar (3.68 g) to H_1 and followed (3.54 g) by H_2, whereas the lowest 1000 seeds weight (3.22 g) was observed from H_0. These results indicate that humic acid along with organic and inorganic fertilizer increases weight of 1000 seeds of mustard.

Interaction effect of varieties and humic acid showed significant differences on weight of 1000 seeds (Table 11 and Appendix IX). The highest weight of 1000 seeds (4.27 g) was recorded from the treatment combination of V_2H_1, while the lowest weight (2.61 g) was found from V_1H_0.

4.11 Seed yield hectare^{-1}

Seed yield hectare^{-1} of mustard varied significantly due to different varieties (Table 10 and Appendix IX). Data revealed that the highest seed yield (2.45 t ha^{-1}) was found from V_2 which was followed (1.64 t ha^{-1}) by V_4, while the lowest seed yield (1.36 t ha^{-1}) was found from V_1 which was followed (1.54 t ha^{-1}) by V_3. Afroz *et al*. (2011) was obtained higher seed yield from variety BARI Sarisha-9. Mamun *et al*. (2014) reported that maximum seed yield (1.60 t ha^{-1}) for BARI Sarisha-13. These data are consistent with morpho-physiological and yield contributing characters of this study. Therefore variety BARI Sharisha 11 gave higher seed yield of mustard by improving morpho-physiological and yield character under edaphic and climatic condition of SAU.

Table 10. Effect of different varieties and humic acid on weight of 1000 seeds, seed and stover yield of mustard

Treatments	Weight of 1000 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Mustard varieties			
V_1	2.96 d	1.36 d	2.10 c
V_2	3.98 a	2.45 a	3.18 a
V_3	3.77 b	1.54 c	2.58 b
V_4	3.43 c	1.64 b	2.58 b
$LSD_{(0.05)}$	0.140	0.087	0.112
Level of significance	**	**	**
Levels of bio-stimulator			
H_0	3.22 c	1.32 d	2.10 c
H_1	3.68 a	1.93 b	2.86 a
H_2	3.54 b	1.69 c	2.50 b
H_3	3.70 a	2.04 a	2.97 a
$LSD_{(0.05)}$	0.140	0.087	0.112
Level of significance	**	**	**
CV(%)	4.76	6.07	5.15

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Table 11. Interaction effect of different varieties and humic acid on weight of 1000 seeds, seed and stover yield of mustard

Treatments	Weight of 1000 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
V_1H_0	2.61 h	1.03 j	1.50 h
V_1H_1	3.04 fg	1.52 e-g	2.39 de
V_1H_2	2.92 g	1.27 hi	2.02 g
V_1H_3	3.28 ef	1.62 d-f	2.47 de
V_2H_0	3.44 e	1.62 d-f	2.38 de
V_2H_1	4.27 a	2.81 a	3.59 a
V_2H_2	4.04 a-c	2.52 b	3.16 b
V_2H_3	4.18 ab	2.85 a	3.58 a
V_3H_0	3.53 de	1.24 i	2.12 fg
V_3H_1	3.90 bc	1.73 d	2.85 c
V_3H_2	3.79 cd	1.44 f-h	2.48 de
V_3H_3	3.84 c	1.74 d	2.87 c
V_4H_0	3.32 ef	1.39 g-i	2.40 de
V_4H_1	3.52 de	1.68 de	2.60 d
V_4H_2	3.39 e	1.53 e-g	2.34 ef
V_4H_3	3.51 de	1.95 c	2.97 bc
$LSD_{(0.05)}$	0.279	0.175	0.224
Level of significance	*	**	**
CV(%)	4.76	6.07	5.15

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

V_1: BARI Sarisha 9; V_2: BARI Sarisha 11; V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition), H_1: Recommended dose of organic and inorganic fertilizer, H_2: 12 kg HA ha^{-1} and H_3: Recommended dose of organic and inorganic fertilizer also used 12 kg HA ha^{-1}

* = Significant at 5% level and ** = Significant at 1% level

Statistically significant variation was recorded due to different humic acid in terms of seed yield hectare^{-1} (Table 10 and Appendix IX). The highest seed yield (2.04 t ha^{-1}) was observed from H_3, which was followed (1.93 t ha^{-1}) to H_1, whereas the lowest seed yield (1.32 t ha^{-1}) was observed from H_0 which was followed (1.69 t ha^{-1}) by H_2. 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. These results of this study consistent that humic acid along with organic and inorganic fertilizer increases seed yield hectare^{-1} of mustard.

Interaction effect of varieties and humic acid showed significant differences on seed yield hectare^{-1} (Table 11 and Appendix IX). The highest seed yield (2.85 t ha^{-1}) was recorded from the treatment combination of V_2H_3 and the lowest seed yield (1.03 t ha^{-1}) was observed from V_1H_0.

4.12 Stover yield hectare^{-1}

Stover yield hectare^{-1} of mustard showed statistically significant variation due to different varieties (Table 10 and Appendix IX). The highest stover yield (3.18 t ha^{-1}) was recorded from V_2 which was followed by (2.58 t ha^{-1}) by V_2 and V_3, while the lowest stover yield (2.10 t ha^{-1}) was observed from V_1. BARI (2001) reported the highest straw yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg was obtained from variety Tori-7. Therefore, the results indicate that different varieties of mustard produced different stover yield.

Statistically significant variation was recorded due to different humic acid in terms of stover yield hectare^{-1} (Table 10 and Appendix IX). The highest stover yield (2.97 t ha^{-1}) was found from H_3 which was statistically similar (2.86 t ha^{-1}) to H_1 and followed (2.50 t ha^{-1}) by H_2, whereas the lowest stover yield (2.10 t ha^{-1}) was observed from H_0. These results indicate that humic acid along with organic and inorganic fertilizer produced the highest stover yield of mustard.

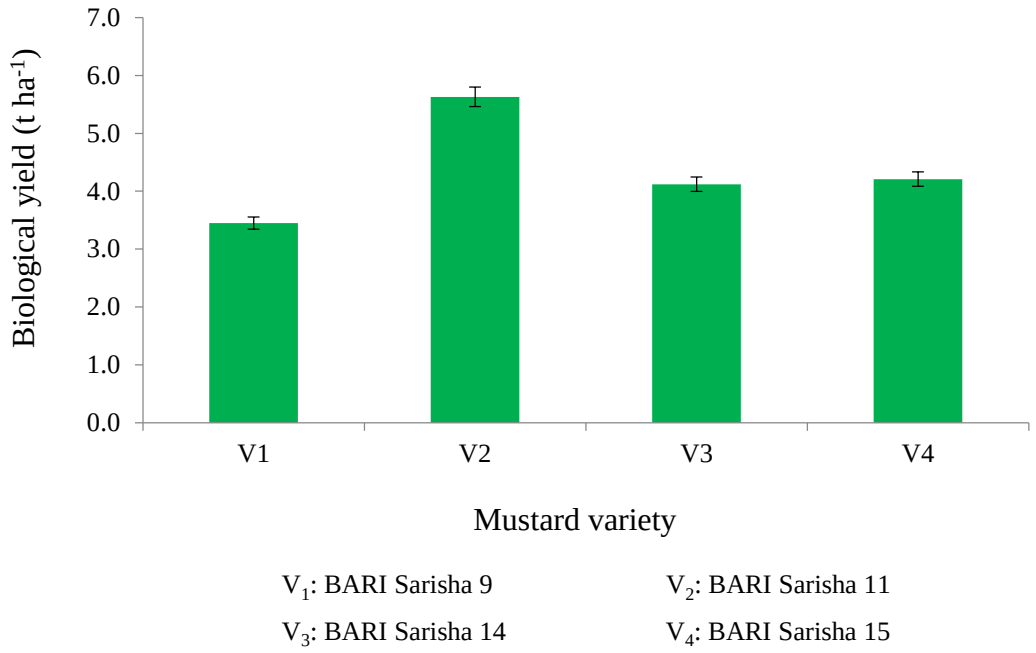
Interaction effect of varieties and humic acid showed significant differences on stover yield hectare^{-1} (Table 11 and Appendix IX). The highest stover yield (3.59 t ha^{-1}) was recorded from the treatment combination of V_2H_1, while the lowest stover yield (1.50 t ha^{-1}) was found from V_1H_0.

4.13 Biological yield hectare^{-1}

Biological yield hectare^{-1} of mustard showed statistically significant variation due to different varieties (Figure 9 and Appendix IX). The highest biological yield (5.63 t ha^{-1}) was recorded from V_2 which was followed by (4.21 and 4.12 t ha^{-1}) by V_4 and V_3, while the lowest biological yield (3.45 t ha^{-1}) was observed from V_1. These results are consistent with the results of biological yield hectare^{-1}.

Statistically significant variation was recorded due to different humic acid in terms of biological yield hectare^{-1} (Figure 10 and Appendix IX). The highest biological yield (5.01 t ha^{-1}) was found from H_3 which was followed (4.79 t ha^{-1}) by H_1, whereas the lowest biological yield (3.42 t ha^{-1}) was observed from H_0 which was followed (4.19 t ha^{-1}) by H_2. Therefore these results of this study indicate that humic acid along with organic and inorganic fertilizer increases biological yield of mustard.

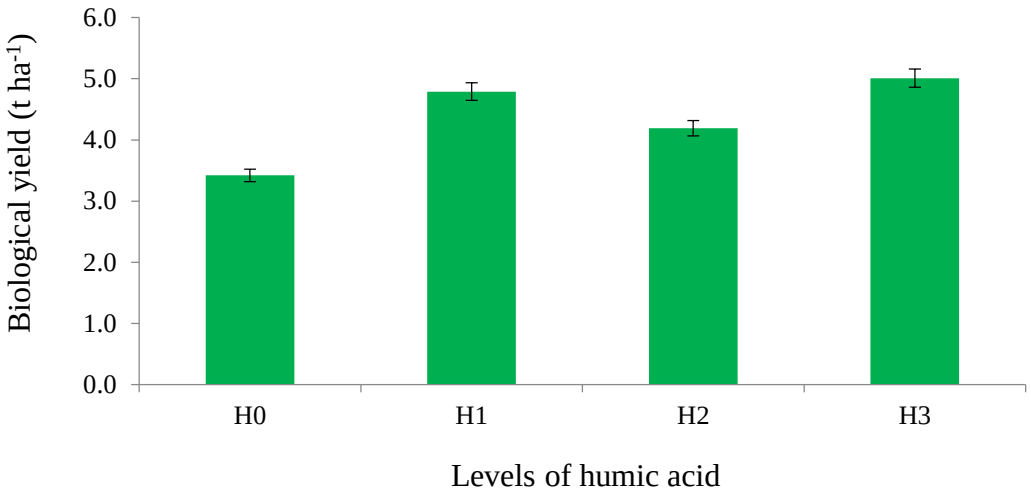
Interaction effect of varieties and humic acid showed significant differences on biological yield hectare^{-1} (Figure 11 and Appendix IX). The highest biological yield (6.43 t ha^{-1}) was recorded from the treatment combination of V_2H_3, while the lowest biological yield (2.53 t ha^{-1}) was found from V_1H_0.



V_1: BARI Sarisha 9 V_2: BARI Sarisha 11

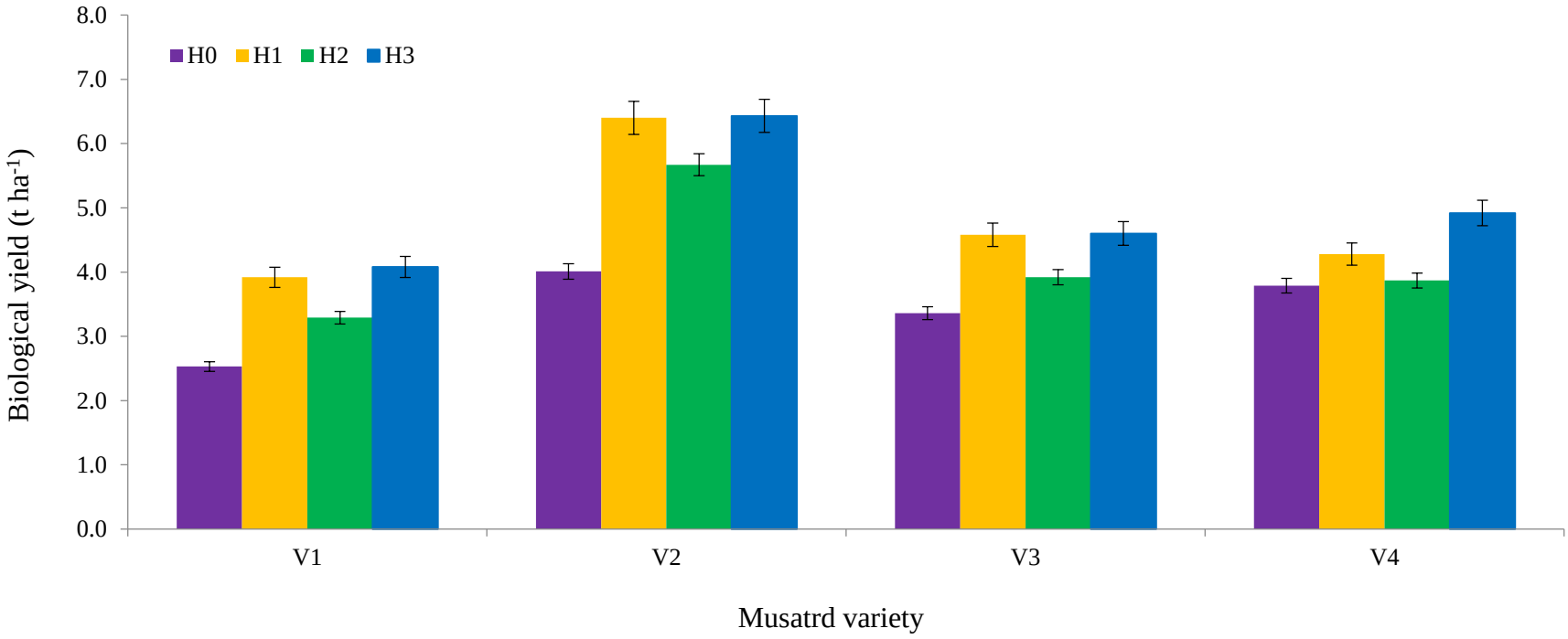
V_3: BARI Sarisha 14 V_4: BARI Sarisha 15

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



H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

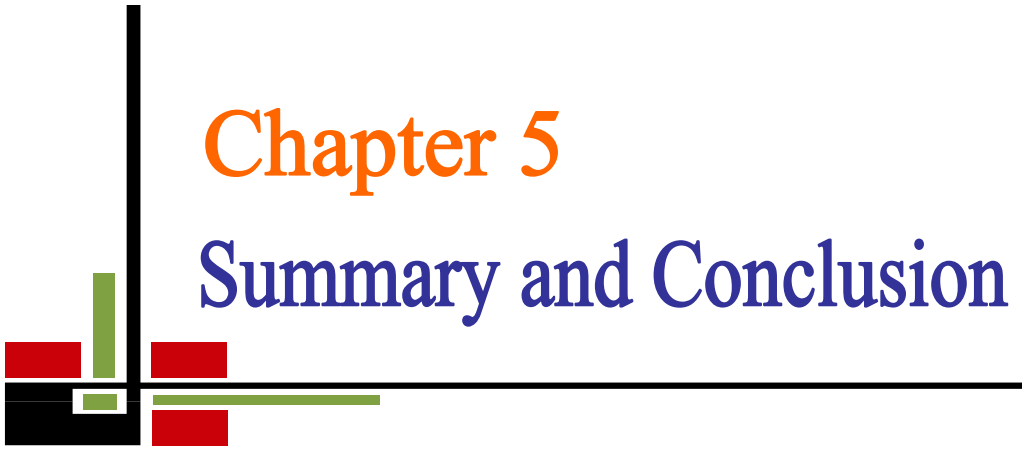
Figure 10. Effect of different levels of humic acid on biological yield of mustard. (Vertical bars represent LSD value at 5% level of probability)



V_1: BARI Sarisha 9
V_2: BARI Sarisha 11
V_3: BARI Sarisha 14
V_4: BARI Sarisha 15

H_0: 0 kg fertilizer (control condition)
H_1: Recommended dose of organic + inorganic fertilizer
H_2: 12 kg HA ha^{-1}
H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}

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



Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period of October 2017 to February 2018 to study the effects of variety and humic acid on morpho-physiological parameters and yield of mustard. BARI Sarisha 9, BARI Sarisha 11, BARI Sarisha 14 and BARI Sarisha 15 were used as planting materials in this experiment. The experiment comprised of two factors; Factor A: Different mustard varieties (4 varieties)- i) V_1: BARI Sarisha 9, ii) V_2: BARI Sarisha 11, iii) V_3: BARI Sarisha 14, iv) V_4: BARI Sarisha 15; and Factors B: Different levels of humic acid (B) as humic acid (4 levels)- i) H_0: 0 kg fertilizer (control condition), ii) H_1: Recommended dose of organic + inorganic fertilizer, iii) H_2: 12 kg HA ha^{-1}, iv) H_3: Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different growth parameters, yield attributes and yield of mustard and observed statistically significant differences for different treatments.

In case of different varieties, the tallest plant at 30, 40, 50 DAS and at harvest (50.69, 97.65, 113.16 and 128.19 cm, respectively) was recorded from V_2, while the shortest plant (28.64, 67.59, 75.58 and 84.87 cm, respectively) was observed from V_3. The maximum number of branches $plant^{-1}$ at 30, 40, 50 DAS and at harvest (3.23, 5.35, 6.95 and 7.98, respectively) was found from V_3, whereas the minimum number (2.90, 4.47, 4.82 and 5.00, respectively) from V_1. The maximum number of leaves $plant^{-1}$ at 30, 40, 50 DAS and at harvest (14.24, 26.70, 39.65 and 46.90, respectively) was observed from V_2, while the minimum number (10.78, 20.57, 31.88 and 35.80, respectively) was found from V_1 at 30, 40, 50 DAS and at harvest. The highest SPAD value at 30, 40, 50 DAS and at harvest (33.59, 40.95, 50.14 and 45.07, respectively) was recorded from V_2, while the lowest (30.85, 35.47, 42.89 and 37.01, respectively) was observed from V_1 at 30, 40, 50

DAS and at harvest. The highest days to 1st flowering (37.00) was found from V_2, while the lowest days (31.00) was observed from V_3. The highest days to harvest (108.67) was recorded from V_2, while the lowest days (80.33) was observed from V_3. The highest number of siliqua plant^{-1} (149.22) was found from V_2, while the lowest number (78.47) was observed from V_4. The highest length of siliqua (6.84 cm) was recorded from V_2, while the lowest length (4.91 cm) was observed from V_1. The highest number of seeds siliqua^{-1} (24.63) was found from V_3, while the lowest number (15.62) was recorded from V_2. The highest weight of 1000 seeds (3.98 g) was recorded from V_2, while the lowest weight (2.96 g) was observed from V_1. The highest seed yield (2.45 t ha^{-1}) was found from V_2, while the lowest seed yield (1.36 t ha^{-1}) was found from V_1. The highest stover yield (3.18 t ha^{-1}) was recorded from V_2, while the lowest stover yield (2.10 t ha^{-1}) was observed from V_1. The highest biological yield (5.63 t ha^{-1}) was recorded from V_2, while the lowest biological yield (3.45 t ha^{-1}) was observed from V_1.

The tallest plant (39.32, 80.72, 94.61 and 105.91 cm, respectively) was found from H_3, whereas the shortest plant (32.70, 72.91, 79.54 and 92.22 cm, respectively) from H_0 at 30, 40, 50 DAS and at harvest. The maximum number of branches plant^{-1} (3.18, 5.15, 6.40 and 7.12, respectively) was recorded from H_3, while the minimum number (3.00, 4.62, 5.68 and 6.12, respectively) was found from H_0 at 30, 40, 50 DAS and at harvest, respectively. The maximum number of leaves plant^{-1} (13.41, 24.28, 38.22 and 44.89, respectively) was recorded from H_3 whereas the minimum number (12.00, 21.90, 32.47 and 36.78, respectively) was found from H_0 at 30, 40, 50 DAS and at harvest, respectively. The highest SPAD value (33.02, 39.20, 48.59 and 43.72, respectively) was found from H_3, whereas the lowest (31.43, 36.53, 44.31 and 38.61, respectively) was recorded from H_0 at 30, 40, 50 DAS and at harvest, respectively. The highest days to 1st flowering (36.08) was observed from H_0, whereas the lowest days (31.25) was recorded from H_3. The highest days to harvest (93.17) was found from H_1, whereas the lowest days (86.58) was observed from H_0. The highest number of siliqua plant^{-1} (112.00) was recorded from H_3, whereas the lowest (93.55) was found from H_0. The highest

length of siliqua (6.11 cm) was found from H_3, whereas the lowest length (4.46 cm) was recorded from H_0. The highest number of seeds siliqua^{-1} (21.73) was found from H_3, whereas the lowest number (17.47) from H_0. The highest weight of 1000 seeds (3.70 g) was found from H_3, whereas the lowest 1000 seeds weight (3.22 g) was observed from H_0. The highest seed yield (2.04 t ha^{-1}) was observed from H_3, whereas the lowest (1.32 t ha^{-1}) was observed from H_0. The highest stover yield (2.97 t ha^{-1}) was found from H_3, whereas the lowest stover yield (2.10 t/ha) was observed from H_0. The highest biological yield (5.01 t ha^{-1}) was found from H_3, whereas the lowest biological yield (3.42 t ha^{-1}) was observed from H_0.

The tallest plant (55.64, 103.32, 122.42 and 139.39 cm, respectively) was recorded from the treatment combination of V_2H_3, while the shortest plant (27.40, 67.66, 68.56 and 77.81 cm, respectively) from V_3H_0 at 30, 40, 50 DAS and at harvest. The maximum number of branches plant^{-1} (3.33, 5.47, 7.20 and 8.33, respectively) was found from the treatment combination of V_3H_3 and the minimum number (2.73, 3.73, 4.00 and 4.07, respectively) was observed from V_1H_0 at 30, 40, 50 DAS and at harvest. The maximum number of leaves plant^{-1} (15.37, 28.20, 42.33 and 50.40, respectively) was recorded from the treatment combination of V_2H_3, while the minimum number (10.27, 18.73, 27.40 and 30.60, respectively) was found from V_1H_0 at 30, 40, 50 DAS and at harvest. The highest SPAD value (34.21, 43.00, 52.55 and 47.77, respectively) was recorded from the treatment combination of V_2H_3, while the lowest (30.13, 34.37, 40.22 and 34.56, respectively) from V_1H_0 at 30, 40, 50 DAS and at harvest. The highest days to 1st flowering (39.00) was found from the treatment combination of V_2H_3, while the lowest days (26.00) was observed from V_3H_1. The highest days to harvest (114.67) was recorded from the treatment combination of V_2H_2, while the lowest days (74.67) from V_4H_0. The highest number of siliqua plant^{-1} (163.27) was recorded from the treatment combination of V_2H_3, while the lowest (72.27) was found from V_4H_0. The highest length of siliqua (7.69 cm) was recorded from the treatment combination of V_2H_3, while the lowest length (4.11 cm) was found from V_3H_0. The highest number of seeds siliqua^{-1} (27.00) was recorded from the treatment

combination of V_3H_3, while the lowest number (13.67) was found from V_2H_0. The highest weight of 1000 seeds (4.27 g) was recorded from the treatment combination of V_2H_1, while the lowest weight (2.61 g) was found from V_1H_0. The highest seed yield (2.85 t ha^{-1}) was recorded from the treatment combination of V_2H_3 and the lowest seed yield (1.03 t ha^{-1}) was observed from V_1H_0. The highest stover yield (3.59 t ha^{-1}) was recorded from the treatment combination of V_2H_1, while the lowest stover yield (1.50 t ha^{-1}) was found from V_1H_0. The highest biological yield (6.43 t ha^{-1}) was recorded from the treatment combination of V_2H_3, while the lowest biological yield (2.53 t ha^{-1}) was found from V_1H_0.

Conclusion:

Recorded information revealed that BARI Sarisha 11 and Recommended dose of organic + inorganic fertilizer + 12 kg HA ha^{-1} was the superior among the other treatments in consideration of yield attributes and yield of mustard.

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

1. Different doses of organic manures and chemicals fertilizer may be used for further study to specify the specific combination,
2. Such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability, and
3. Other management practices may be used for further study.

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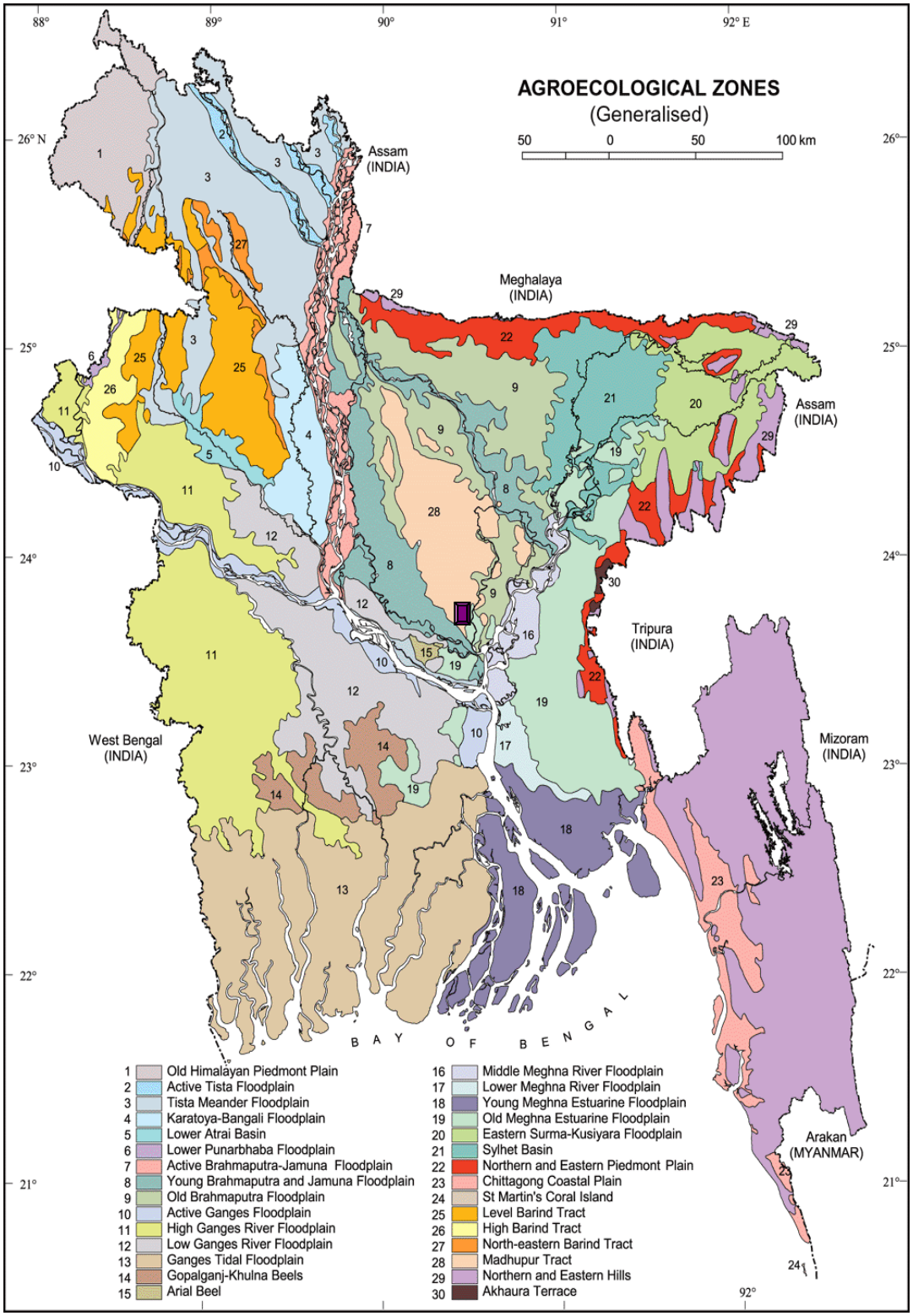
Appendices

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 field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly level

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 $soil^{-1}$
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me 100 g $soil^{-1}$)	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) and harvest of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	2.523	3.536	22.720	0.651
Mustard varieties (A)	3	1126.480**	2199.289**	3363.982**	4403.190**
Levels of humic acid (B)	3	105.347**	157.599**	513.204**	433.970**
Interaction (A×B)	9	15.280*	27.482*	50.336*	116.818**
Error	30	6.362	11.816	22.789	21.179

**: 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^{-1} at different days after sowing (DAS) and harvest of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square			
		Number of branches plant^{-1} at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.003	0.036	0.048	0.011
Mustard varieties (A)	3	0.281**	2.343**	12.376**	24.459**
Levels of humic acid (B)	3	0.088**	0.719**	1.242**	2.396**
Interaction (A×B)	9	0.044*	0.141*	0.114*	0.170*
Error	30	0.008	0.068	0.061	0.077

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

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} at different days after sowing (DAS) and harvest of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square			
		Number of leaves plant^{-1} at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.028	0.011	0.158	1.145
Mustard varieties (A)	3	25.237**	75.865**	126.704**	257.064**
Levels of humic acid (B)	3	4.508**	13.803**	83.301**	161.484**
Interaction (A×B)	9	0.683*	1.956*	5.043*	7.147*
Error	30	0.279	0.881	1.944	3.112

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

Appendix VII. Analysis of variance of the data on SPAD value at different days after sowing (DAS) and harvest of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square			
		SPAD value at			
		30 DAS	40 DAS	50 DAS	Harvest
Replication	2	0.311	0.399	0.027	0.026
Mustard varieties (A)	3	15.569**	60.167**	110.998**	141.002**
Levels of humic acid (B)	3	6.109**	16.892**	44.800**	61.813**
Interaction (A×B)	9	1.875*	3.263**	4.043**	4.046**
Error	30	0.438	0.602	1.315	1.378

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

Appendix VIII. Analysis of variance of the data on different yield contributing characters of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square				
		Days to 1st flowering	Days to harvest	Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}
Replication	2	5.250	2.146	15.914	0.198	0.093
Mustard varieties (A)	3	80.250**	1994.076**	11322.930**	8.623**	173.496**
Levels of humic acid (B)	3	62.306**	94.576**	789.819**	7.339**	42.823**
Interaction (A×B)	9	34.324**	186.910**	216.797**	1.013**	3.816*
Error	30	9.139	15.701	29.867	0.313	1.558

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

Appendix IX. Analysis of variance of the data on weight of 1000 seeds, seed and stover yield and harvest index of mustard of mustard as influenced by different varieties and bio-stimulator

Source of variation	Degrees of freedom	Mean square			
		Weight of 1000 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-})
Replication	2	0.004	0.0001	0.001	0.003
Mustard varieties (A)	3	2.352**	2.810**	2.351**	10.025**
Levels of humic acid (B)	3	0.588**	1.228**	1.857**	6.098**
Interaction (A×B)	9	0.060*	0.104**	0.104**	0.381**
Error	30	0.028	0.011	0.018	0.036

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