EFFECTS OF BORON ON GROWTH, YIELD AND YIELD ATTRIBUTES OF MUSTARD

AFSANA MUMU

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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EFFECTS OF BORON ON GROWTH, YIELD AND YIELD ATTRIBUTES OF MUSTARD

By

Afsana Mumu

Reg. No. 14-06117

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Approved by:

Prof. Dr. H. M. M. Tariq Hossain
Supervisor
Department of Agronomy
SAU, Dhaka

Prof. Dr. Md. Jafar Ullah
Co-Supervisor
Department of Agronomy
SAU, Dhaka

Prof. Dr. Tuhin Suvra Roy
Chairman
Examination Committee
Department of Agronomy
SAU, Dhaka

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "**EFFECTS OF BORON ON GROWTH, YIELD AND YIELD ATTRIBUTES OF MUSTARD**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **Afsana Mumu,** Registration no. **14-06117** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:

Place: Dhaka, Bangladesh

Prof. Dr. H. M. M. Tariq Hossain

Department of Agronomy

Sher-e-Bangla Agricultural University,

Dhaka-1207

Dedication

Every challenging work needs self-efforts as well as guidance of elder especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

mother,

whose affection, love, encouragement and prays of day and night make me able to get such success and honour,

along with all hard working

and respected

teachers.

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The Author

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ABSTRACT

A field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from October- 2019 to February 2020 in Rabi season to investigate the effects of boron on growth, yield and yield attributes of mustard. The experiment consisted of two factors, and following split-plot design with three replications. Factor A: mustard varieties (2) *viz.* V_1= BARI Sarisha-14, V_2= BARI Sarisha-15 and Factor B: Different boron level (6) *viz.* B_0 = 0 kg ha^{-1}, B_1 = 1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 = 2.0 kg ha^{-1}. Data on different parameters were collected for assessing results for this experiment and showed significant variation on growth, yield and yield contributing characteristics of mustard due to the effect of different treatments and their combinations. In case of varieties, BARI Sarisha-14 (V_1) recorded the maximum number of silique plant^{-1} (101.87), siliqua length (9.55 cm), seeds siliqua^{-1} (22.51), 1000-seed weight (3.59 g), seed yield (1.63 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.36 t ha^{-1}) and harvest index (30.36 %). Due to boron levels, 2.0 kg boron ha^{-1} (B_5) treated plots recorded the maximum number of silique plant^{-1} (100.50), siliqua length (9.54 cm), seeds siliqua^{-1} (23.67), 1000 seeds weight (3.67 g), seed yield (1.76 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.67 t ha^{-1}) and harvest index (31.08 %). On the other hand BARI Sarisha-14 (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plots recorded the maximum number of silique plant^{-1} (115.00), siliqua length (10.84 cm), seeds siliqua^{-1} (26.34), 1000-seed weight (3.82 g), seed yield (1.87 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.85 t ha^{-1}) and harvest index (31.89 %). However mustard varieties showed linear relationship between different boron levels on seed yield of mustard and correlation ship between seed yield and yield contributing characteristics.

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ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agriculture	Agric.	Milliliter	mL
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
And others	et al.	Triple super phosphate	TSP
Applied	App.	Milligram(s)	mg
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	Cm	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	Cv.	Regulation	Regul.
Degree Celsius	°C	Research and Resource	Res.
Department	Dept.	Review	Rev.
Development	Dev.	Science	Sci.
Dry Flowables	DF	Society	Soc.
East	E	Soil plant analysis development	SPAD
Editors	Eds.	Soil Resource Development Institute	SRDI
Emulsifiable concentrate	EC	Technology	Technol.
Entomology	Entomol.	Tropical	Trop.
Environmment	Environ.	Thailand	Thai.
Food and Agriculture Organization	FAO	United Kingdom	U.K.
Gram	g	University	Univ.
Horticulture	Hort.	United States of America	USA
International	Intl.	Wettable powder	WP
Journal	J.	Serial	Sl.
Kilogram	Kg	Percentage	%
Least Significant Difference	LSD	Number	No.
Liter	L	Microgram	µ

CHAPTER-I

INTRODUCTION

Mustard (*Brassica spp*. L.) is a worldwide cultivated thermo and photosensitive oilseed crop. Asia produces 41.50 % of mustard seed which occupies the first position in terms of percentage share of production followed by the USA (FAO, 2018).

Edible oils play vital roles in human nutrition by providing calories and aiding in digestion of several fat soluble vitamins, for example Vitamin A (National Research Council, 1989). The per capita recommended dietary allowance of oil is 6 gm/day for a diet with 2700 Kcal (BNNC, 1984). Oilseeds were cultivated in less than 2.20 % of total arable land under rice-based cultivation system in Bangladesh, where three fourth of total cultivable land was engaged in rice production in 2015-16 (BBS, 2019). Mustard is the major oilseeds in Bangladesh which exhibits an increase in production from 1994 to 2018 except few fluctuations in the case of total production and area under cultivation (FAO, 2018).

Mustard occupied more than 69.94 % of the total cultivated area of oilseeds followed by sesame, groundnut, and soybean (BBS, 2019).With the increase in population, the demand for edible oil and oilseeds is in increasing trend (Alam, 2020). Bangladesh has to import a noticeable amount of edible oil and oilseeds to meet up the existing accelerating demand. The value of imported oilseed and edible oil has increased dramatically from USD 544 million in 2002-03 to USD2371 million in 2018-19 which were 4.99 and 4.23 % of the total value of imports respectively (Bangladesh Bank, 2020). Yield of mustard has increased from 0.75 tha^{-1} in 2001 to 1.15 tha^{-1} in 2019 (MoA, 2008; BBS, 2019). Bangladesh was not in an advantageous position in the case of mustard production (Miah and Rashid, 2015). The inadequate yield of mustard might be grounded by several factors like, lack of high yielding varieties, improper cultural practices, insufficient nutrient management, soil nutrient depletions and so on.

Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (1987) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. *Brassica* (genus of mustard) has three species that produce edible oil, they are *B. napus, B. campestris* and *B. juncea*. Of these, *B. napus* and *B.*

campestris are of the greatest importance in the world's oil seed trade. In this subcontinent, *B. juncea* is also an important oil seed crop. Until recently, mustard varieties such as Tori-7, Sampad (both *Brassica campestris*) and Doulat (*Brassica juncea*) were mainly grown in this country. Recently several varieties of high yielding potential characteristics has been developed by BARI for improved production of mustard in Bangladesh.

Crop yield reductions are strongly related with soil quality degradation, particularly nutrient depletions which can be attributed to either insufficient fertilizer use or imbalanced fertilization (Roy *et al*., 2003; Haque *et al*., 2014; Tan *et al*., 2005; Chaudhary *et al*., 2007). Fertilizers have effect on yield and yield attributes of crops and justified fertilizers and resource use is crucial to maintain productivity of crops (Sultana *et al.*, 2019; Sultana *et al*., 2015). Intensive cropping coupled with cultivation of high yielding varieties has extensively exhausted soil fertility not only in respect of macronutrients but also micronutrients.

Apart from major plant nutrients, boron plays a significant role in the phenology of mustard production and this crop responds to boron applications (Karthikeyan and Shukla, 2011). Boron deficiency in plants affects pollen germination and pollen tube development as well as nitrogen fixation and flower shedding in chickpea and low boron can result in plants being functionally male sterile like in wheat (Chhipa and Lal, 1989; Woods, 1996; Rerkassam *et al*., 1997). Young leaves become deformed and curled due to deficiency of boron. Growing points perish and axillary shoots emerge, eventually becoming moribund and die. In severe cases, flower buds used to shed prematurely, the flowers that form are likely to be malformed and restricted seed-set was observed (Havlin *et al*., 1999). Boron deficiency in soils is major problem in cultivation of oil seed crops (Islam *et al*., 1999). Reduced yield of mustard has been reported when cultivated on low boron soils or where availability of boron restricted under high soil pH, liming and drought periods during the growth period. For this reason, boron deficiency in mustard is observed on a worldwide basis (Shorrocks, 1997). As a result, boron fertilization is required to increase crop production and nutritional quality. There were numerous reports of mustard response positively to boron fertilization (Islam, 2005 and Saha *et al*., 2003). Dynamic soil characteristics such as organic matter, texture, soil pH, cultivation, drought, and microbial activity all impact the boron availability to plants (Communar and Keren, 2005 and Mengel and Kirkby, 2001). Boron is generally less available in clay soils and availability increases with increasing temperature (Fleming, 1980). Soil pH is regarded as a major factor regulating B availability in soils. Increasing pH favours its retention by soils or soil constituents (Mezuman and Karen, 1981; Bloesch *et al*., 1987; Goldberg. 1997). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Dear and Lipsett. 1987; Noppakoonwong *et al*., 1997). Thus, B fertilization is necessary for improvement of crop yield as well as nutritional quality.

Keeping this in view, the present research was undertaken to investigate the effects of boron on growth, yield and yield attributes of mustard with the following objectives:

Objectives:

i. To evaluate the performance of mustard varieties.
ii. To know the effect of different levels of boron fertilization on growth and yield of mustard.
iii. To determine the combined effect of variety and different levels of boron fertilization on growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to the effects of boron on growth, yield and yield attributes of mustard, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of mustard varieties

Plant height

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up. Tyeb *et al.* (2013) reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars. Rashid *et al.* (2010) conducted a field experiment to find out the effect of the different levels of fertilizers on the growth parameters of mustard varieties of BARI sharisa-9 (V_1), BARI sharisa-12 (V_2) and BARI sharisa-15 (V_3), and to find out the optimum and economically viable fertilizer dose and reported that variety BARI sharisa-15 is of the tall plant type and that others are of intermediate and short stature in plant height. The significant difference in plant height might be associated with the variety characteristics or genetic makeup of the plant. Sana *et al.* (2003) reported that, the final plant height reflected the growth behavior of a crop.

Number of branches

Helal *et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop. Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15. Sana *et al.* (2003) reported that, higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Dry matter weight

Helal *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, dry matter production pattern at different days after sowing showed that different varieties varied their dry matter production pattern. These variations were noticed from one stage to another stage and none of the variety/line followed the same pattern at different days of sampling. It indicated that each variety/line responded independently from one stage to another stage to the environment in respect of growth of plant, branching and leaf number and ultimately differed in dry matter production. Rashid *et al.* (2010) noticed significant variation in dry matter (DM) accumulation for different mustard varieties on all days after sowing. This might be due to the different varieties which produced a different type of siliqua, and thus, the DM varied significantly.

Number of siliqua plant^{-1}

Alam *et al.* (2014) A field experiment was conducted at the Central Research Station of BARI, Gazipur for two consecutive years 2010-11 and 2011-12 with 30 varieties/ genotypes of rapeseed-mustard under three dates of sowing viz., 25 November, 5 December, and 15 December to determine changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Varieties/genotypes of mustard used in the experiment exerted significant influence on yield and yield attributes and among different varieties maximum number of silique/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. This has contributed to higher yield. The lowest number of silique/plant (52.0 and 56.3) were found in BARI Sarisha-14. Mamun *et al.* (2014) found that the number of silique plant^{-1} of mustard was significantly affected by different varieties. Singh *et al.*, (2001) conducted an experiment in Jodhpur and observed that number of silique/plant recorded higher in cultivar Pusa Bold (257) compared to cultivar TS9 (198). Yadav *et al.* (1978) suggested that for ensuring high yields in *B. juncea*, the plant type should have more number of silique/plant (100-125).

Length of siliqua

Hossain *et al.* (1996) reported that the varieties of rapeseed differed significantly in respect of siliqua length. The longer siliqua was found in hybrid BGN-900 (7.75 cm) that was similar to Hyole-101, Sampad, Dhali and Hyola-51.

Number of seed siliqua^{-1}

Rahman *et al*. (2019) carried out an experiment at Sher-e-Bangla Agricultural University Farm, Dhaka- 1207, Bangladesh during Rabi season, November 2017 to February 2018 to find out the effect of different sowing methods and varieties on the yield of (*Brassica campestris*). The experiment comprised of two factors - the treatment consisted of four sowing methods viz. S_0 = Broadcast method, S_1 = Line to line space 20 cm, S_2 = Line to line space 25 cm and S_3= Line to line space 30 cm and three different varieties viz. V_1 = BARI Sarisha 14, V_2 = BARI Sarisha 15 and V_3 = BARI Sarisha 17. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Result revealed that the maximum number of seed per silliqua (23.12) was produced in V_2 (BARI Sarisha 15) treatment and the minimum number of seed per silliqua (18.82) was produced in V_1 (BARI Sarisha 14) treatment. Helal *et al.* (2016) observed significant variations in terms of number of seeds/siliqua among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity.

1000-seed weight

Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 had the highest 1000- seed weight (4.00 g) whereas the lowest (2.82 g) - in SAU Sarisha-3. Mondal and Wahab (2001) described that, weight of 1000 seeds varied from variety to variety and species to species.

Seed yield

Biswas *et al.* (2019) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques. The planting techniques were as conventional sowing and sowing seeds in puddle soil that assigned to the main plot and five varieties *viz*. Improved Tori-7, BARI Sarisha -13, BARI Sarisha -15, BARI Sarisha -16 and SAU SR-3 in the sub-plots. Result revealed that mustard varieties significantly affect seed yield and among different varieties higher seed yield (2.24 t ha^{-1}) was observed in Improved Tori-7 variety which was followed by BARI Sarisha-16 (1.96 t ha^{-1}) and BARI Sarisha-13 (1.57 t ha^{-1}). The lowest seed yield (1.34 t ha^{-1}) was obtained from V_3 (BARI Sarisha-15) which was statistically similar with SAU SR-3 (1.53 t ha^{-1}). Das *et al*. (2019) carried out a field experiment in the CR Farm of Gayeshpur, BCKV, Nadia, and West Bengal, India during *rabi* season of 2015-16 and 2016-17 to find out suitable hybrid variety and optimum spacing for different hybrids. Three hybrid varieties of mustard *viz.* Kesari 5111(V1), Kesari 5222(V2) and Kesari Gold(V3) were taken as treatments in the main plot, whereas, four spacing - 30cm × 10cm (S_1), 30cm × 20cm (S_2), 40cm × 20cm (S_3) and 40cm × 30cm (S4) were imposed as subplot treatment. The experiment was conducted in split plot design with 3 replications and repeated in *rabi* seasons for two consecutive years (2015-16 and 2016-17). The results of the experiment revealed that seed yield significantly differ among varieties and the maximum seed yield was recorded in Kesari Gold (1746 and 2153 kg ha^{-1} respectively in 1st and 2nd year) followed by Kesari 5111. Helal *et al.* (2016) reported that the production of higher yield by different varieties might be due to the contribution of cumulative favorable effects of the crop characteristics viz., number of branches/plant, siliquae/plant and seeds/siliqua. Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Bio-902 remained at par with RGN-13 and significantly superior as compared to RGN-48 and PBR-357. Bio-902 cultivar produced 8.72 and 23.03 per cent higher yield, respectively, over RGN- 48 and PBR-357. However, RGN-13 and RGN-48 were remained at par with each other and significantly superior over PBR-357. Islam and Mahfuza (2011) conducted an experiment at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2010- 2011. BARI Sarisha-11 produced the highest seed yield (1472 kg ha^{-1}) while BARI Sarisha-14 the lowest (1252 kg ha^{-1}). The highest mean seed yield was recorded at maturity stage (1480 kg ha^{-1}) and decreased towards green siliqua stage. Zaman *et al.* (1991) who reported that seed yield of mustards were varied with different varieties.

Stover yield

Sultana *et al.* (2009) studied that stover yield for different varieties of rapeseed under study differed significantly. Kollania produced higher stover yield (2159.0 kg ha^{-1}) which was statistically at par with SAU Sarisha-1 (2156.0 kg ha^{-1}) and higher than Improved Tori -7 (1681.0 kg ha^{-1}).

Biological yield

Tobe *et al.* (2013) also reported variation in biological yield among different cultivars of B. napus and showed that cv. Hyola410 produced the highest seed yield (4759 kg ha^{-1}) as compared to cvs. RDF003 (4280 kg ha^{-1}) and Sarigol (3628 kg ha^{-1}). Rana and Pachauri (2001) quoted that cv. Bio 902 recorded higher biological yield (7250 kg ha^{-1}) as compared to cv. TERI (OE) M 21 (6850 kg ha^{-1}).

Harvest index

Thakur *et al.* (2021) carried out an investigation on the agronomic evaluation of Mustard (*Brassica juncea* L.) hybrids under agroclimatic conditions of Prayagraj (U.P.) was carried out during Rabi 2019-2020. The field experiment was laid out in Randomised Block Design, replicated four having 5 different variety as treatments. The finding of the experiment indicated that harvest index significantly influenced by different varieties and maximum harvest index (36.95) was observed in T^2 [45S35]. However, treatment T_1 [BULLET] found to be statistically at par with T_2 [45S35]. As discussed earlier, the different hybrids have different yield potential, which is the reason for yield variation among different varieties. Lal *et al.* (2020) conducted an experiment was with four mustard varieties (RGN-73, RGN-229, RH-30 and Pusa bold) in two growing environments (open environment and neem shade) to investigate the performance of mustard (*Brassica juncea* L.) varieties under *Azadirachta indica* L. shade and open condition in hot-arid region of Rajasthan and result revealed that The maximum harvest index under RGN-73 (20.8%) was higher but statistical at par with RGN-229 (20.5%), while both varieties were significantly superior than RH-30 (18.9%) and Pusa bold (18.3%). This might be due to genotype characteristics and high yielding potential of the variety. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) reported that variety had a great influence on harvest index.

2.2 Effect of different boron levels

Plant height

Ara *et al*. (2015) conducted a field trial to examine the response of nitrogen and boron on growth of rapeseed cv. BARI Sarisha-14. The experiment consisted of four levels of nitrogen (N_0:0, N_1:60, N_2:120 and N_3:180 kg N ha^{-1}) and three levels of boron (B_0:0, B_1:1 and B_2:2 kg ha^{-1}). The maximum plant height, number of leaves, number of primary branches was found from B_2 and interaction effect from N_2B_2 treatment. Dey and Dipak (2015) reported that the impact of B application on plant height of mustard was positive to some extent but not significant. Mallick and Raj (2015) observed that application of boron @ 1.0 kg B ha^{-1} also resulted into significant increase in different growth parameters like plant height over that of control treatment. Hussain *et al.* (2008) reported that plant height produced significant variations among different B levels recorded highest at 1.0 kg B ha^{-1}. Sharma (2006) observed that boron is directly or indirectly involved in several physiological and biochemical processes during plant growth. B deficiency causes reduction in cell enlargement in growing tissues. Its deficiency is responsible for creating male sterility and inducing floral abnormalities. Rana *et al*. (2005) found that spray of borax @ 0.2% at 50% flowering stage of mustard (*Brassica juncea* L.) resulted into a significant increase in plant height and number of branches than control. Saha *et al*. (2003) reported that plant height was not remarkably influenced by boron application. Stangoulis *et al.* (2001) observed that boron is relatively immobile in plant, and thus its availability is essential at all the stages of growth, especially during fruit/seed development. However, recent physiological studies have revealed the presence of channel-mediated facilitated diffusion and energy-dependent active transport against concentration gradients in B transport systems.

Number of branches

Riaj *et al.* (2018) reported that number of branches per plant for different levels of boron gave significant variation. The highest significant increase in number of branches per plant (6.67) was recorded from B_2 treatment containing 2 kg B/ha. On the other hand the minimum number of branches per plant (5.82) was observed from the B_0 treatment. Naser and Islam (2001) reported that suitable dose of boron fertilizer significantly influenced plant height and branches per plant of mustard. Hu *et al.* (1994) conducted an experiment to know the effect of B application on the agronomic traits, yield and oil content of a double-row rape (*Brassica napus* L.) cultivar and observed that higher number of branches per mustard plant with the application of boron fertilizer.

Dry matter weight

Awal *et al.* (2020) carried out an experiment to investigate the effect of agronomic biofortification of sulphur and boron nutrients on the growth and yield of mustard crop. His experiment was laid out in a randomized complete block design (RCBD) with three replicates. The experiment was carried out in the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh. Three doses of sulphur (S) *viz.* 0, 20 and 40 kg ha^{-1} and three doses of boron (B) *viz.* 0, 0.5 and 1.0 kg ha^{-1} and their possible combinations were used as basal doses. Experiment result revealed that the effect of sulphur and boron on the total dry matter accumulation was significant. The higher TDM production was found from the plants grown with 40 kg S ha^{-1} and 1.0 kg B ha^{-1} as compared to that with lower doses of sulphur and boron application and lower amount of dry matter was accumulated when the crop received neither sulphur nor boron. Pooniya and Shivay (2011) reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.

Number of siliqua plant^{-1}

Rana *et al*. (2005) reported that 0.2 % borax spray at 50 % flowering resulted significant increase in number of silique plant$_{-1}$, number of seeds siliqua$_{-1}$ and 1000-seed weight as compared to control that might be due to role of B in fertility improvement and photosynthetic translocation. They reported that 0.2 % borax spray at 50 % flowering stage significantly increased the seed, biological yield and harvest index as compared to control that might be because of marked increase in yield attributes as compared to control. Chatterjee *et al.* (1985) reported that the number of silique plant^{-1} of mustard found higher in presence of available boron in the soil. Dutta and Uddin (1983) observed increased number of silique/plant of mustard by increasing rate of boron. Gupta (1980) who reported that application of boron increased siliqua formation of mustard.

Length of siliqua

Jana *et al.* (2009) studied the effect of boron on yield of mustard in red and laterite soils of West Bengal and reported that application of B significantly increased length of siliqua. Application of 15 to 20 kg borax ha^{-1} gave higher values of yield attributes, seed and stover yields.

Number of seeds siliqua^{-1}

Kour *et al*. (2017) conducted a field experiments in Jammu area to assess the effects of Zn and B on mustard (*Brassica juncea* L.) yield, nutrient uptake and economics in a mustard - maize (*Zea mays* L.) cropping sequence. RDF + 10 kg Zn + 2 kg B ha^{-1} resulted in a substantial improvement in yield characteristics such as seeds siliquae^{-1} was higher than the required fertiliser dose. Yadav *et al.* (2016) reported that the effect of boron on rape seed formation was good and it significantly increased the seeds siliqua^{-1}. Islam and Sarker (1993) observed that number of seeds siliqua^{-1} increased with the increasing rate of boron application.

1000-seed weight

Riaj *et al.* (2018) reported that different levels of boron exhibited statistically significant variation for 1000 seed weight. It increased significantly with higher levels of boron with the highest (3.71 g) at B_2 treatment comprising of 2 kg boron/ha and (3.52 g) lowest in (B_0) control treatment. Ara *et al.* (2014) studied the effect of nitrogen (N) and boron (B) on seed yield contributing characters of rapeseed (*Brassica campestris* L.). The experiment consisted of four N levels *viz.* 0, 60, 120, 180 kg ha^{-1} and three B levels *viz*. 0, 1, 2 kg ha^{-1}. The results showed a significant increase of seed weight plant^{-1} and 1000-seed weight to both N and B application independently. The highest seed weight plant^{-1}, 1000-seed weight was obtained at 2 kg ha^{-1} B. Hossain *et al*. (2012) investigated the response of different varieties of mustard to boron application @ 0 and 1 kg ha^{-1}. The response of the three *Brassica* species followed the order: *B. napus* > *B. campestris* > *B. juncea*. The seed yield was positively and significantly correlated with the yield contributing characters *viz*. Pods plant^{-1}, seeds pod^{-1} and 1000-seed weight, but not with pod length. This result showed that boron had positive influence on reproductive development not on vegetative. The result suggests that species of *B. napus* variety were the most B in-responsive. Akter *et al*. (2007) studied the response of fertibor on the yield and yield components of mustard in non-calcareous brown floodplain soil of Burirhat, Rangpur and non-calcareous grey floodplain soil of Rajbari, Dinajpur. There were five treatments: T_1= control, T_2=2 kg B ha^{-1} from boric acid, T_3=1 kg B ha^{-1} from fertibor, T_4=2 kg B ha^{-1} from fertibor and T_5=3 kg B ha-1 from fertibor. Application of different levels of B from fertibor significantly influenced the yield and yield components of mustard up to 2 kg ha^{-1} and declined thereafter.

Seed yield

Kumararaja *et al.* (2015) reported that boron application improved the yield by 35-39% over the control. Al-Hilfy *et al*. (2012) analyzed the effects of boron and potassium on white mustard growth and yield response. Due to increases in silique plant^{-1} and seed silique^{-1} for both seasons, greater concentrations of boron were better in seed yield ha^{-1}, rising 42.14 per cent and 56.36 per cent for both seasons compared to control. Singh and Pal (2011) observed that the higher yield may be attributed to application of zinc and boron along with recommended dose of fertilizer as zinc and boron are involved in cell division and enzyme activation. With the increment in supply of essential micronutrients to mustard, their availability, acquisition, mobilization and influx into the plant tissues increased and thus improved yield attributes and finally the yield. Yang *et al.* (2009a) reported that B significantly increased seed yield of rapeseed compared with the low B control, which was attributed to increased number of seeds per silique and siliqua per plant. These results suggested that application of B could produce higher seed yield. Mollah *et al*. (2005) reported that application of 1.0 to 2.0 kg B ha^{-1} significantly influenced seed yield of mustard varieties under the test over control. Dhali x 2 kg B ha^{-1} produced the highest seed yield which was statistically similar to Dhali x 1 B ha^{-1}. The lowest seed yield was obtained from Rai-5 x 0 kg of boron. Chakraborty and Das (2000) observed that the increase in seed yield might be due to role of boron in germination and growth of pollen tubes. Stover yield of mustard increased significantly and was found maximum (3.20 t ha^{-1}) with addition of recommended dose of fertilizer + 40 kg S ha^{-1} + 2 kg B ha^{-1}, however it was statistically at par with recommended dose of fertilizer + 2 kg B ha^{-1}. Lu *et al.* (2000) found that B contributed 48.5% yield advantage of rapeseed.

Stover yield

Malewar *et al.* (2001) observed that stover yield was significantly increased with the increment of boron levels. Sinha *et al.* (1991) reported that the stover yield of mustard increased significantly by boron application. Dear and Lipsett (1987) opined that vegetative growth is less sensitive to B deficiency compered to reproductive growth of plant.

Biological yield

A field experiment was conducted by Choudhary and Bhogal (2013) to study the responses of mustard cultivars to boron application at Directorate of Rapeseed Mustard Research, Sewar, and Bharatpur. Results revealed that mustard cultivar Laxmi recorded higher mean dry matter yield and lowest in Vardan. The biological yield of mustard cultivars increased significantly with increasing levels of boron application upto 20 kg borax ha^{-1} over control. Karthikeyan and Shukla (2008) observed that increase in biological yield of mustard from 26.0 g pot^{-1} to 34.8 g pot^{-1} was obtained with the increasing levels of boron i.e. 2 mg kg^{-1}.

Harvest index

Riaj *et al.* (2018) conducted a field experiment at the Agronomy Research Field of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during the period from November, 2015 to February 2016 to find out the effect of nitrogen and boron on the yield and yield attributes of mustard. The experiment result revealed that, application of boron at different levels showed statistically significant differences for harvest index. The application of B increased harvest index of mustard up to the highest level (2 kg B/ha). The highest harvest index (22.97%) was recorded from B_2 treatment comprising of 2 kg B/ha. On the other hand the lowest harvest index (21.41%) was recorded from the B_0 treatment (control). Hussain *et al.* (2012) reported that the highest and lowest harvest index were due to differences in rate of boron application. Banueles *et al.* (1990) conducted an experiment to study the influence of Selenium, salinity and boron on seleium uptake in wild nustard and observed significant differences for different level of boron application.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the effects of boron on the growth and yield and yield attributes of mustard. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from October-2019 to February 2020 in Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the central laboratory & Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-Ecological Zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.2.4 Climate and weather

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

3.3 Test crop

Mustard variety namely BARI Sarisha-14 and BARI Sarisha-15 were used as test crop for this experiment.. The important characteristics of this variety is mentioned below:

3.3.1 BARI Sarisha-14

BARI Sarisha-14 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. Developed by crossing between Tori and Sonali Sarisha and released, in the year of 2006. Short duration variety, plant height 75-85 cm, leaf light green, smooth, siliqua/plant 80-102, two chambers are present in pod but as like as four chambers. Seed/siliqua 22-26, seed color pink, 1000 seed weight 3.5-3.8 g, crop duration 75-80 days, after harvest aman and before transplant boro. It is easily cultivated because of short duration. It's planting in Rabi season from mid-October to mid-November given yield 1.45-1.60 t/ha having Oil content 44-45%.

3.3.2 BARI Sarisha-15

BARI Sarisha-14 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. Developed by Selection from local germplasm and released, in the year of 2006. Short durated variety, plant height 90-100 cm, siliqua/plant 70-80, two chambers are present in pod, seed/siliqua 20-22, pod is narrow and taller than BARI sarisha-14, seed color yellow, 1000 seed weight 3.25-3.50 g, crop duration 80-85 days, after harvest aman and before transplant boro, it is easily cultivated because of short duration. It's planting in Rabi season from mid-October to mid-November. Yield given 1.45-1.60 t ha^{-1} and oil content 48-52%.

3.4 Seed collection

Seeds of BARI Sarisha-14 and BARI Sarisha-15, were collected respectively from Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

3.5 Experimental treatment

There were two factors in the experiment namely mustard varieties and different level of boron fertilizers as mentioned below:

Factor A: Mustard varieties (2)

i. V_1= BARI Sarisha-14
ii. V_2= BARI Sarisha-15 and

Factor B: Different boron levels (6)

i. B_0 = 0 kg ha^{-1}
ii. B_1 = 1.0 kg ha^{-1}
iii. B_2 = 1.25 kg ha^{-1}
iv. B_3 = 1.50 kg ha^{-1}
v. B_4 = 1.75 kg ha^{-1} and
vi. B_5 = 2.0 kg ha^{-1}

3.6 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot there was variety treatment and in sub plot there was different boron fertilization treatment. There were 12 treatment combinations and 36 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2.0 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was shown in Appendix- IV.

3.7 Land preparation

The experimental land was opened with a power tiller on 1^{th} October, 2019. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 2^{th} October, 2019 and was ready for sowing seeds.

3.8 Fertilizer requirement

Fertilizers	Quantity/requirement (kg ha^{-1})
Urea	250
TSP	170
MoP	85
Gypsum	150
Boric Acid (As Boron source)	10
Cow-dung	8000

Source: (BARI Krishi Projukti hatboi-2019 recommendation)

3.9 Fertilizer application

Urea, triple super phosphate (TSP), muriate of potash (Mop), gypsum, zinc sulphate, boric acid and cow dung were used as sources of nitrogen, phosphorus, potassium, zinc, boron and others nutrient respectively. Total amount of TSP, MoP, gypsum, Zinc sulphate, cow-dung and one and half amount of urea were applied at final land preparation. Different boron level from boric acid source was also applied during final land preparation according with par treatment requirement. The rest amount of urea was applied during flower initiation of mustard (BARI krishi projukti hatboi-2019 recommendation).

3.10 Sowing of seeds

Seeds were sown at the rate of 10 kg ha^{-1} in the furrow on date 2^{nd} October, 2019 and the furrows were covered with the soils soon after seeding. Seeds were being treated with Bavistin before sowing the seeds to control the seed borne disease. The seeds were sown continuously in 25 cm apart rows at about 2-3 cm depth in afternoon and covered with soil and maintaining 25 cm × 25 cm planting configuration by thinning.

3.11 Intercultural operations

i) Weeding

Weeding followed by thinning were done after 15 DAT and 45 days after transplanting

ii) Irrigation

Irrigation was given in the respective plots to ensure puddle soil. First irrigation was given at 15 days after transplanting (DAT) and the second irrigation was given at 40-45 (DAT). A little irrigation was given at 55-60 (DAT).

iii) Application of pesticides

In the experimental field mustard crops were attacked by aphids (*Lipaphis erysimi*. K). Malathion 57 EC at the rate of 2 ml/litre of water was applied for controlling aphids attack in the field. Application of spraying pesticide was done in the afternoon while the pollinating bees were away from the experimental field.

3.12 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant.

3.13 Harvesting and processing

From the experimental field mustard crop was harvested at maturity when about 80% of the siliquae turned into straw yellowish in color. Harvesting was done in the morning to avoid shattering. Boarder lines plants were excluded. Crops were harvested from the pre demarcated area of 1 m^2 at the centre of each plot at ground level with the help of a sickle for grain and stover yield. Prior to harvesting, five plants were sampled randomly from each plot, were bundled separately, tagged them and brought to a clean cemented threshing floor from which different yield parameters were recorded. The crop was sun dried properly by spreading them over floor and seeds were separated from the siliquae by beating the bundles with the help of bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were also dried in the sun. Seed and stover yield were recorded. The biological yield was calculated as the sum of the seed yield and stover yield.

3.14 Data collection

The data were recorded on the following parameters

a) Growth parameters

i. Plant height (cm)
ii. Branches plant^{-1} (no.)
iii. Total dry matter weight plant^{-1} (g)

b) Yield contributing characters

i. Siliqua plant^{-1} (no.)
ii. Length of siliqua (cm)
iii. Seeds siliqua^{-1} (no.)
iv. 1000-seed weight (g)

c) Yield characters

i. Seed yield (t ha^{-1})
ii. Stover yield (t ha^{-1})
iii. Biological yield (t ha^{-1})
iv. Harvest index (%)

3.15 Relationship

i. Relationship between boron levels and seed yield of mustard varieties.

ii. Correlation of seed yield plant^{-1} with siliqua plant^{-1} and 1000-seed weight of mustard varieties along with different boron levels.

3.16 Procedure of recording data

i) Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 15, 30, 45 DAS and harvest respectively. Mean plant height of mustard plant were calculated and expressed in cm.

ii) No. of branches plant^{-1}

The branches plant^{-1} was counted from five randomly sampled plants and recorded data at 30, 45 DAS and harvest respectively. It was done by counting total number of branches of all sampled plants then the average data were recorded. Data were recorded at harvest respectively.

iii) Total dry matter weight plant^{-1} (g)

Five plants were collected randomly from each plot at 30, 45 DAS and harvest respectively. The sample plants were oven dried for 72 hours at 70°C and then dry matter content plant^{-1} was determined. Mean dry matter plant^{-1} of mustard plant were calculated and expressed in gram (g) for recording data.

iv) No. siliqua plant^{-1} (no.)

Siliqua plant^{-1} was counted from the 5 selected plant sample and then the average siliqua number was calculated.

v) Length of siliqua plant^{-1} (cm)

Length of 5 siliquae collected randomly from the sampled plants and the mean length was recorded.

vi) Seeds siliqua^{-1} (no.)

Seeds siliqua^{-1} was counted from splitting five siliquae which were sampled from sample plants and then mean value was determined.

vii) 1000-seed weight (g)

1000-seeds were counted which were taken from the seed sample of each plot, then weighed it in an electrical balance and data were recorded.

viii) Seed yield (t ha^{-1})

The mean seed weight was taken by threshing the plants of each sample area and then converted to t ha^{-1} in dry weight basis.

ix) Stover yield (t ha^{-1})

The stover weights of mustards were calculated after threshing and separation of the grains from the plant of sample area and then expressed in t ha^{-1} on dry weight basis.

x) Biological yield (t ha^{-1})

The summation of seed yield and above ground stover yield was the biological yield. Biological yield =Grain yield + Stover yield.

xi) Harvest index (%)

Harvest index was calculated on dry weight basis with the help of following formula.

Harvest index (HI %) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100$

Here, Biological yield = Grain yield + stover yield

3.17 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

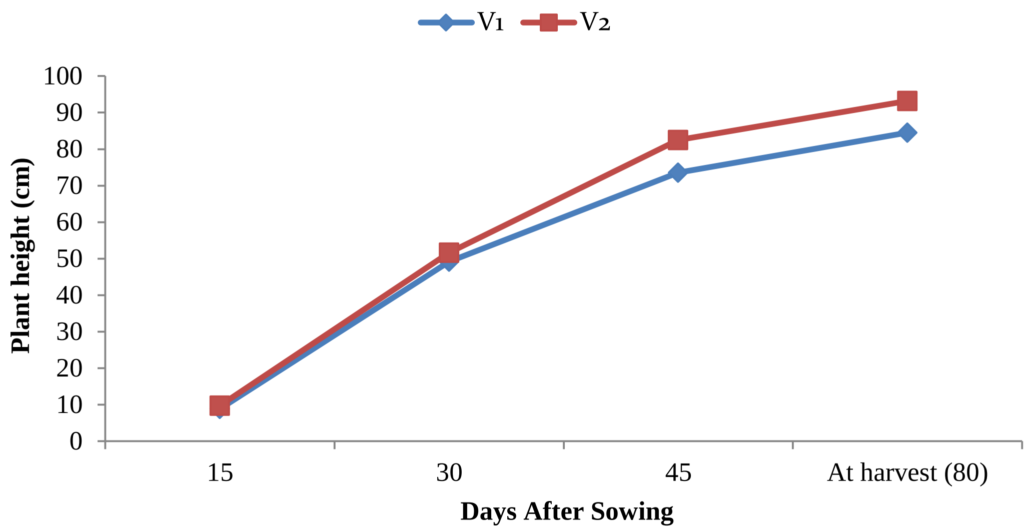
Results obtained from the present study have been presented and discussed in this chapter with a view to study the effects of boron on growth, yield and yield attributes of mustard. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of variety

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Different mustard variety significantly differ plant height at different days after sowing (Fig. 1). Experiment result revealed that BARI Sarisha-15 mustard variety (V_2) recorded the maximum plant height (9.75, 51.61, 82.53 and 93.20 cm) at 15, 30, 45 DAS and at harvest respectively. Whereas BARI Sarisha-14 mustard variety (V_1) recorded the minimum plant height (8.86, 49.19, 73.53 and 84.50 cm) at 15, 30, 45 DAS and at harvest respectively. The variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the variety. Das *et al.* (2019) and Tyeb *et al.* (2013) also found similar result with the present study and reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up. Sana *et al.* (2003) reported that, the final plant height reflected the growth behavior of a crop.



Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

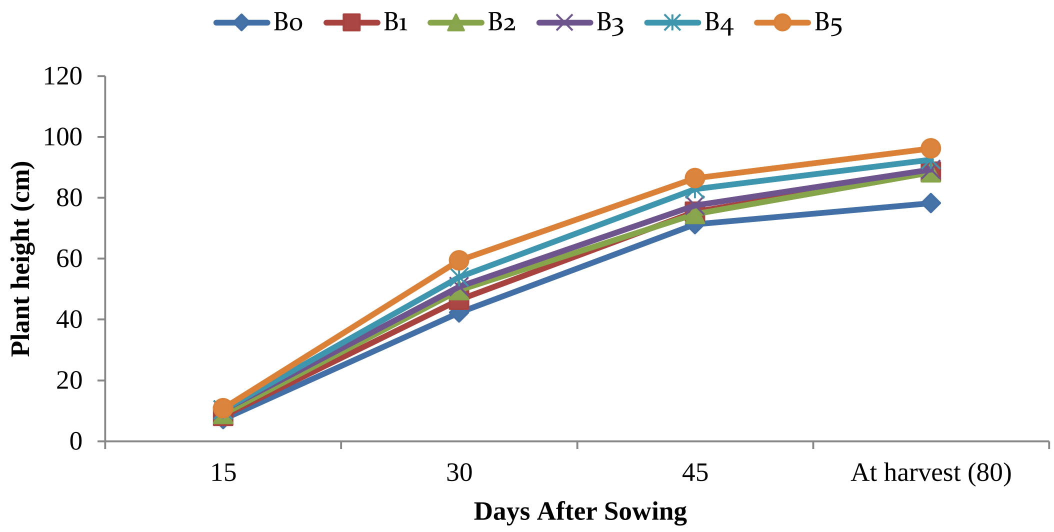
Fig. 1. Effect of variety on plant height of mustard at different DAS

($LSD_{(0.05)}$= 0.42, 0.83 , 5.06 and 1.43 at 15, 30, 45 DAS and at harvest respectively).

Effect of different boron levels

Different boron levels significantly effect on plant height of mustard at different days after sowing. Experiment result revealed, that increasing boron levels gradually increasing plant height. (Fig. 2). Due to variation of boron levels, application of 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum plant height (10.84, 59.40, 86.44 and 96.21 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with 1.75 kg boron ha^{-1} (B_4) treated plot recorded plant height (10.33 and 53.91 cm) at 15 DAS and 45 DAS. Whereas control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum plant height (7.24, 42.25, 71.32 and 78.19 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with 1.0 kg boron ha^{-1} ($B_{1)}$ and 1.25 kg boron ha^{-1} ($B_{2)}$ treated plot recorded plant height (75.43 and 74.67 cm) at 45 DAS. Boron is a micronutrient necessary for plant growth. Without adequate boron in the soil, plants may appear healthy but will not flower or fruit. Boron helps control the transport of sugars in plants. It is important to cell division and seed development. Application of Boron play a major role in cell elongation, photosynthesis and translocation of photosynthates. Hussain *et al.* (2008) reported that plant height produced significant variations among different B levelss.

Sharma (2006) also found similar result which supported the present finding and observed that boron is directly or indirectly involved in several physiological and biochemical processes during plant growth. B deficiency causes reduction in cell enlargement in growing tissues. Its deficiency is responsible for creating male sterility and inducing floral abnormalities.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 2. Effect of different boron levels on plant height of mustard at different DAS ($LSD_{(0.05)}$= 0.67, 1.87, 4.16 and 2.71at 15, 30, 45 DAS and at harvest respectively).

Combined effect of variety and different boron levels

Different mustard variety along with different boron levels significantly effect on plant height of mustard at different days after sowing. Experiment result showed that, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum plant height (11.33, 62.20, 95.49 and 102.01 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.75 kg boron ha^{-1} (B_4) treated plot and cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.50 kg boron ha^{-1} (B_3) treated plot recorded plant height (11.25 and 11.25 cm) at 15 DAS. Whereas cultivation of BARI Sarisha-14 mustard variety along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum plant height (6.71, 41.01, 61.90 and 70.37

cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with control or 0 kg boron ha^{-1} (B_0) treated plot recorded the plant height (43.48 cm) at 30 DAS.

Table. 1. Combined effect of variety and different boron levels on plant height of mustard at different DAS

Treatment Combinations	Plant height (cm)			
	15 DAS	30 DAS	45 DAS	At harvest
V_1B_0	6.71 f	41.01 g	61.90 f	70.37 h
V_1B_1	8.50 c-e	47.87 e	73.12 e	83.83 g
V_1B_2	9.14 c	49.75 de	75.79 c-e	86.88 e-g
V_1B_3	9.07 c	48.18 e	75.86 c-e	87.56 d-f
V_1B_4	9.40 c	51.77 cd	77.12 c-e	87.97 d-f
V_1B_5	10.36 b	56.60 b	77.40 c-e	90.41 c-e
V_2B_0	7.77 e	43.48 fg	80.74 c	86.01 fg
V_2B_1	8.09 de	44.99 f	77.73 c-e	93.28 c
V_2B_2	8.78 cd	49.50 de	73.55 de	89.72 c-f
V_2B_3	11.25 ab	53.45 c	79.03 cd	91.02 cd
V_2B_4	11.25 ab	56.04 b	88.67 b	97.18 b
V_2B_5	11.33 a	62.20 a	95.49 a	102.01 a
$LSD_{(0.05)}$	0.94	2.52	5.88	3.71
CV(%)	5.99	3.09	4.43	2.53

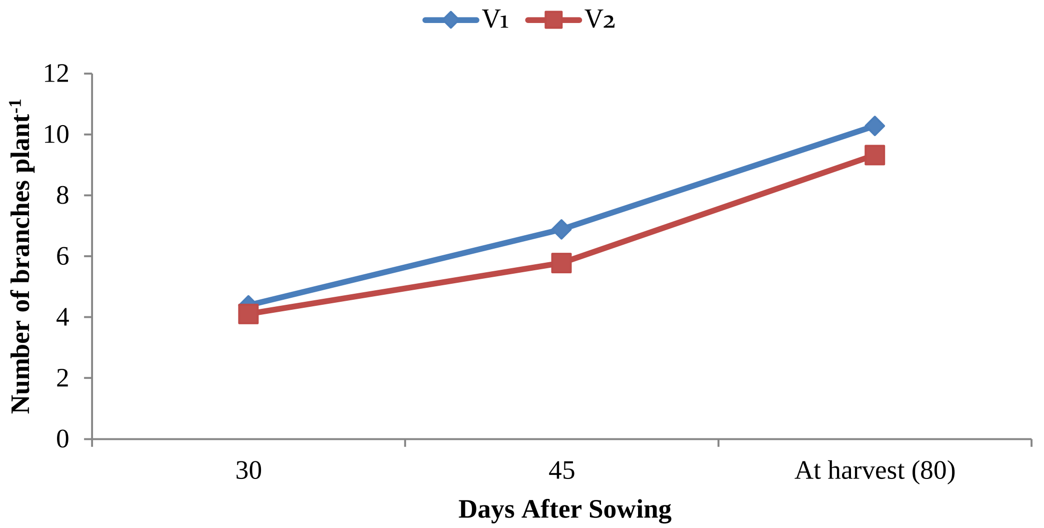
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

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

Effect of variety

Different variety significantly effect on number of branches $plant^{-1}$ of mustard (Fig. 3). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of branches $plant^{-1}$ (4.39, 6.88 and 10.28) at 30, 45 DAS and at harvest respectively while BARI Sarisha-15 mustard (V_2)

variety cultivation recorded the minimum number of branches plant^{-1} (4.11, 5.78 and 9.33) at 30, 45 DAS and at harvest respectively. The reason of difference in number of branches plant^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity. Helal *et al.* (2016) also found similar result which supported the present finding and reported that that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop. Mamun *et al.* (2014) reported that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15.



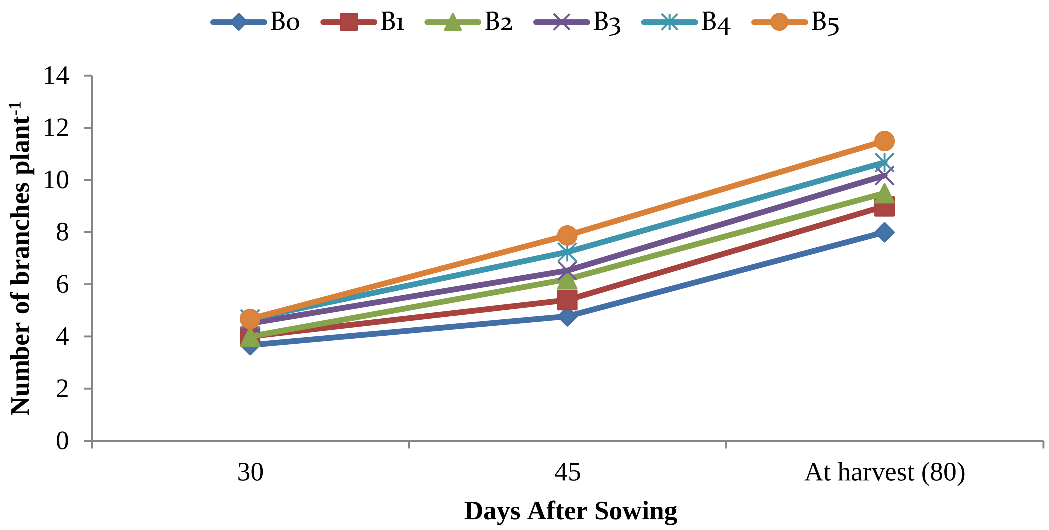
Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 3. Effect of variety on number of branches plant^{-1} of mustard at different DAS (LSD$_{(0.05)}$= 0.11, 0.43 and 0.63 at 30, 45 DAS and at harvest respectively).

Effect of different boron levels

Boron is an important micro nutrient which influences the growth and development of the plant. In this experiment different levels of boron application significantly impact on number of branches palnt^{-1} of mustard at different days after sowing (Fig. 4). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of branches palnt^{-1} (4.67, 7.88 and 11.50) at 30, 45 DAS and at harvest respectively with was statistically similar with 1.75 kg boron ha^{-1} (B_4) treated plot recorded number of branches palnt^{-1} (4.67) at 30 DAS. Whereas 0 kg boron ha^{-1}

(B_0) treated plot recorded the minimum number of branches palnt^{-1} (3.67, 4.77 and 8.00) at 30, 45 DAS and at harvest respectively. The increase in number of branches palnt^{-1} of mustard might be due to the involvement of sufficient levels of boron present in soil, influence different physiological process of plant like cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants, and pollination and seed set etc which ultimately increase the number of branches palnt^{-1} of mustard. The result obtained from the present study was similar with the findings of Riaj *et al.* (2018) and reported that number of branches per plant for different levels of boron gave significant variation. The highest significant increase in number of branches per plant (6.67) was recorded from B_2 treatment containing 2 kg B/ha. On the other hand the minimum number of branches per plant (5.82) was observed from the B_0 treatment. Naser and Islam (2001) reported that suitable dose of boron fertilizer significantly influenced plant height and branches per plant of mustard.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 4. Effect of different boron levels on number of branches plant^{-1} of mustard at different DAS (LSD$_{(0.05)}$= 0.10, 0.36 and 0.46 at 30, 45 DAS and at harvest respectively).

Combined effect of variety and different boron levels

Combined effect of variety and different boron levels significantly effect on number of branches plant^{-1} (Table 2). Experiment result revealed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of branches plant^{-1} (4.67, 8.87 and 13.00) at 30, 45 DAS and at harvest respectively, which was statistically similar with, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded number of branches plant^{-1} (4.67), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.50 kg boron ha^{-1} (B_3) treated plot recorded number of branches plant^{-1} (4.67), with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the number of branches plant^{-1} (4.67) and with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.75 kg boron ha^{-1} (B_5) treated plot recorded the number of branches plant^{-1} (4.66) at 30 DAS. Whereas, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of branches plant^{-1} (3.67, 4.29 and 7.67) at 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.0 kg boron ha^{-1} (B_1) treated plot recorded number of branches plant^{-1} (3.67), with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.25 kg boron ha^{-1} (B_2) treated plot recorded number of branches plant^{-1} (3.67), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 0 kg boron ha^{-1} (B_0) treated plot recorded number of branches plant^{-1} (3.67) at 30 DAS; with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 0 kg boron ha^{-1} (B_0) treated plot recorded number of branches plant^{-1} (8.33) at harvest respectively.

Table. 2. Combined effect of variety and different boron levels on number of branches plant^{-1} of mustard at different DAS

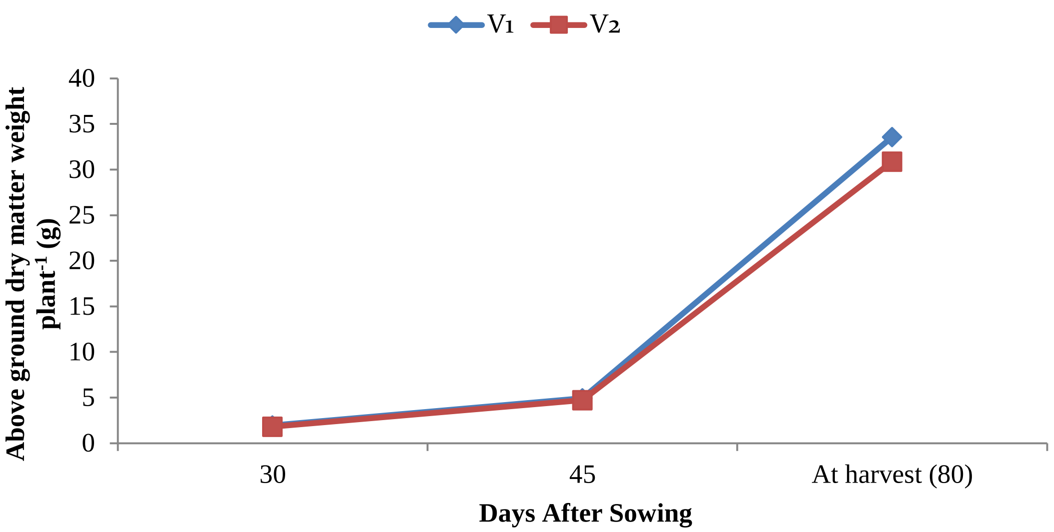
Treatment Combinations	Number of branches plant^{-1}		
	30 DAS	45 DAS	At harvest
V_1B_0	3.67 c	5.25 e	8.33 gh
V_1B_1	4.33 b	5.37 e	9.33 ef
V_1B_2	4.33 b	6.71 d	9.33 ef
V_1B_3	4.67 a	7.52 bc	10.67 bc
V_1B_4	4.67 a	7.55 b	11.00 b
V_1B_5	4.67 a	8.87 a	13.00 a
V_2B_0	3.67 c	4.29 f	7.67 h
V_2B_1	3.67 c	5.40 e	8.66 fg
V_2B_2	3.67 c	5.67 e	9.67 de
V_2B_3	4.33 b	5.51 e	9.67 de
V_2B_4	4.66 a	6.93 cd	10.33 b-d
V_2B_5	4.67 a	6.89 d	10.00 c-e
$LSD_{(0.05)}$	0.14	0.61	0.82
CV(%)	2.05	4.85	3.96

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. Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

4.1.3 Above ground dry matter weight plant^{-1} (g)

Effect of variety

The above ground dry matter weight (g plant^{-1}) differ among different varieties due to reason that individual variety have individual growth stage, and resources utilization its surrounded which influences the above ground dry matter weight (g plant^{-1}). In this experiment result showed that different mustard varieties significantly effect on above ground dry matter weight (g plant^{-1}) of mustard at different DAS (Fig. 5). Among different mustard varieties BARI Sarisha-14 mustard variety recorded the maximum above ground dry matter weight plant^{-1} (1.96, 4.93 and 33.57 g) at 30, 45 DAS and at harvest respectively. Whereas cultivation of BARI Sarisha-15 mustard variety recorded the minimum above ground dry matter weight plant^{-1} (1.82, 4.72 and 30.86) at 30, 45 DAS and at harvest respectively. Resources utilization ability had greater in high yielding varieties which influences the dry matter accumulation. The result obtained from the present study was similar with the findings of Helal *et al.* (2016) who reported that each variety/line responded independently from one stage to another stage to the environment in respect of growth of plant, branching and leaf number and ultimately differed in dry matter production. Rashid *et al.* (2010) also reported that the different varieties which produced a different type of siliqua, and thus, the DM (Dry matter) varied significantly.

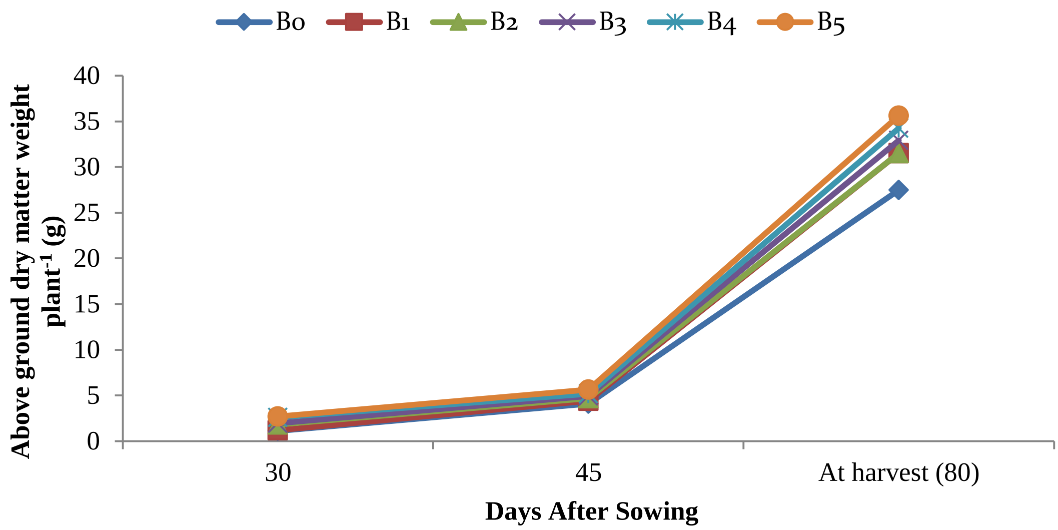


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 5. Effect of variety on above ground dry matter weight plant^{-1} of mustard at different DAS ($LSD_{(0.05)}$= 0.10, 0.20 and 1.11 at 30, 45 DAS and at harvest respectively).

Effect of different boron levels

Different boron levels significantly effect on above ground dry matter weight plant^{-1} (g) of mustard at different DAS (Fig. 6). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum above ground dry matter weight plant^{-1} (2.70, 5.64 and 35.61 g) at 30, 45 and at harvest respectively, whereas 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum above ground dry matter weight plant^{-1} (11.10, 4.09 and 27.49 g) at 30, 45 and at harvest respectively which was statistically similar with 1.0 kg boron ha^{-1} (B_1) treated plot recorded above ground dry matter weight plant^{-1} (1.20) at 30 DAS. The variation of dry matter weight due to reason that B fertilizer significantly enhanced photosynthetic activity of leaves, which consequently resulted in more accumulation of dry matter in mustard. Awal *et al.* (2020) reported that lower amount of dry matter was accumulated when the crop received neither sulphur nor boron. Pooniya and Shivay (2011) reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 6. Effect of different boron levels on above ground dry matter weight plant^{-1} of mustard at different DAS ($LSD_{(0.05)}$= 0.11, 0.18 and 1.27 at 30, 45 DAS and at harvest respectively).

Combined effect of variety and different boron levels

Different mustard variety along with different boron levels significantly effect on above ground dry matter weight plant^{-1} (g) of mustard at different DAS (Table 3). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum above ground dry matter weight plant^{-1} (2.84, 5.65 and 36.88 g) at 30, 45 DAS and at harvest respectively, which was statistically similar with, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded above ground dry matter weight plant^{-1} (5.62 g) at 45 DAS and with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded above ground dry matter weight plant^{-1} (35.65 g) at harvest respectively. Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum above ground dry matter weight plant^{-1} (1.00, 3.77 and 24.39 g) at 30 , 45 DAS and at harvest respectively.

Table. 3. Combined effect of variety and different boron levels on above ground dry matter weight plant^{-1} of mustard at different DAS

Treatment Combinations	Above ground dry matter weight plant^{-1} (g)		
	30 DAS	45 DAS	At harvest
V_1B_0	1.19 e	4.40 d	30.58 e
V_1B_1	1.20 e	4.49 d	31.71 de
V_1B_2	2.00 c	5.04 bc	32.27 de
V_1B_3	1.99 c	4.81 c	34.33 bc
V_1B_4	2.56 b	5.20 b	35.65 ab
V_1B_5	2.84 a	5.65 a	36.88 a
V_2B_0	1.00 f	3.77 e	24.39 f
V_2B_1	1.20 e	4.35 d	31.33 de
V_2B_2	1.63 d	4.32 d	30.77 e
V_2B_3	1.94 c	5.07 bc	31.52 de
V_2B_4	2.60 b	5.16 b	32.83 cd
V_2B_5	2.56 b	5.62 a	34.33 bc
$LSD_{(0.05)}$	0.15	0.26	1.91
CV(%)	4.65	3.17	3.29

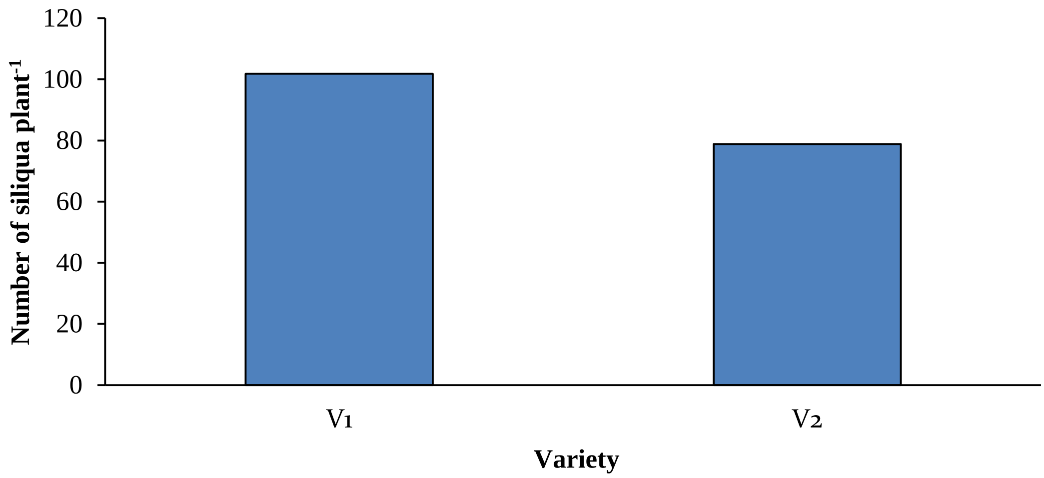
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

4.2 Yield contributing characters

4.2.1 Number of silique plant^{-1}

Effect of variety

Different variety significantly effect on number of silique plant^{-1}of mustard (Fig. 7). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of silique plant^{-1} (101.87) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of silique plant^{-1} (78.85). Different mustard varieties have different number of silique plant^{-1} was due to the genetic makeup of the variety and higher number of silique plant^{-1} is obtained from high yielding varieties comparable to low yielding mustard varieties. The result obtained from the present study was similar with the findings of Alam *et al.* (2014) who reported that varieties of mustard significantly influence on yield and yield attributes and among different varieties maximum number of silique/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. Mamun *et al.* (2014) also found similar result with the present study and reported that the number of silique plant^{-1} of mustard was significantly affected by different varieties.

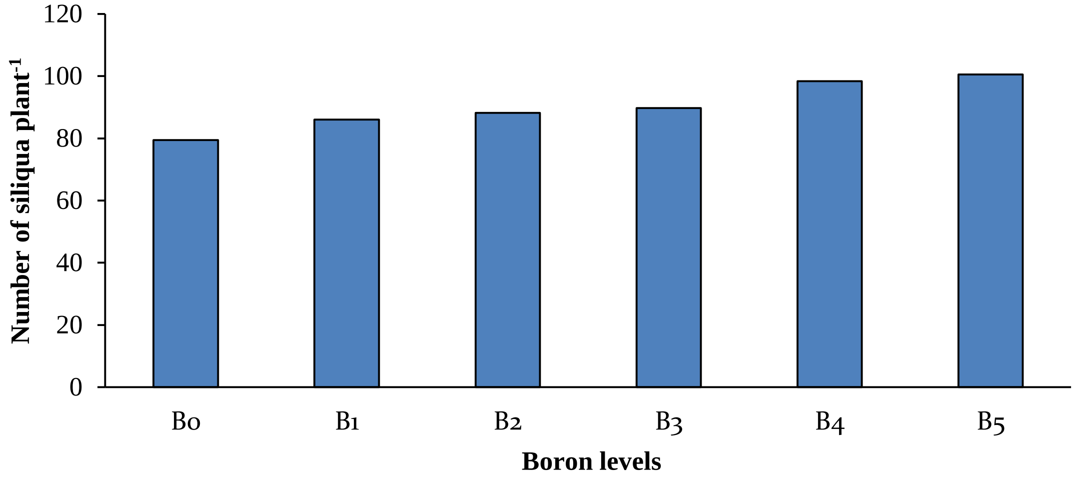


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 7. Effect of variety on number of siliqua plant^{-1} of mustard (LSD$_{(0.05)}$= 1.49)

Effect of different boron levels

Application of different levels of boron significantly effect on number of silique plant^{-1} of mustard (Fig. 8). Experiment result showed that, Application of 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of silique plant^{-1} (100.50) which was statistically similar with 1.75 kg boron ha^{-1} (B_4) treated plot recorded the number of silique plant^{-1} (98.35), while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of silique plant^{-1} (79.44). Boron enhance the primary and secondary branches which are silique bearing organs as flowers are borne at the terminals of the branches. Therefore with increased number of branches, there was increase in the number of silique per plant. Chatterjee *et al.* (1985) reported that the number of silique plant^{-1} of mustard found higher in presence of available boron in the soil. Dutta and Uddin (1983) observed increased number of silique/plant of mustard by increasing rate of boron. Gupta (1980) also reported that application of boron increased siliqua formation of mustard.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 8. Effect of different boron levels on number of silique plant^{-1} of mustard ($LSD_{(0.05)}$= 2.26).

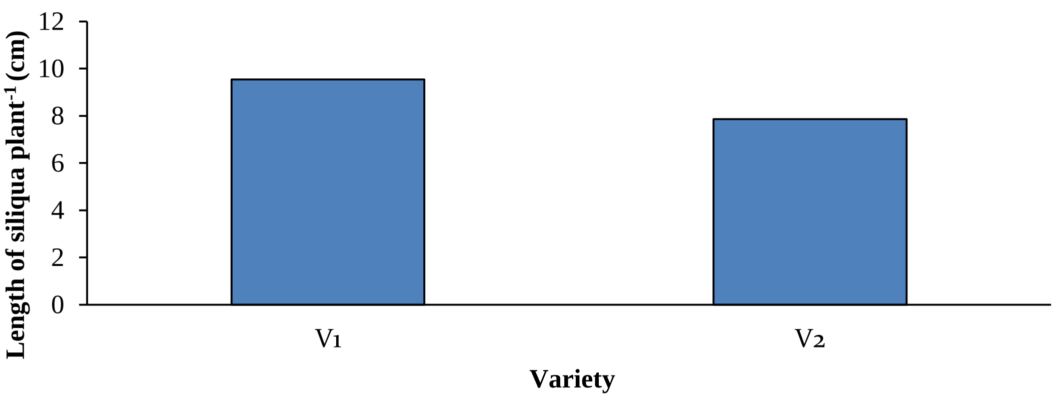
Combined effect of variety and boron levels

Different mustard variety along with different boron levels significantly effect on number of silique plant^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of silique plant^{-1} of mustard (115.00) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of silique plant^{-1} of mustard (68.74).

4.2.2 Length of siliqua plant^{-1} (cm)

Effect of variety

Different variety significantly effect on siliqua length plant^{-1} (cm) of mustard (Fig. 9). Experiment result showed that cultivation of BARI Sarisha-14 mustard variety (V_1) recorded the maximum siliqua length plant^{-1} (9.55 cm) while cultivation of BARI Sarisha-15 mustard variety (V_2) recorded the minimum siliqua length plant^{-1} (7.87 cm). Different mustard varieties have different siliqua length plant^{-1} was due to the genetic makeup of the variety. The result obtained from the present study was similar with the findings of Hossain *et al.* (1996) and they reported that the varieties of rapeseed differed significantly in respect of siliqua length. The longer siliqua was found in hybrid BGN-900 (7.75 cm) that was similar to Hyole-101, Sampad, Dhali and Hyola-51.

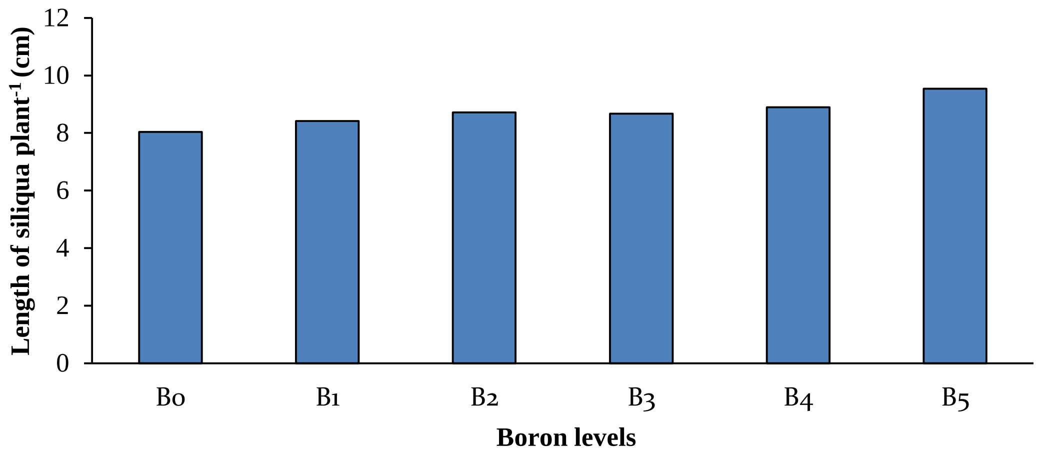


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 9. Effect of variety on length of siliqua plant^{-1} of mustard ($LSD_{(0.05)}$= 0.45)

Effect of different boron levels

Different levels of boron applied in the experiment field showed significant effect on siliqua length plant^{-1} of mustard (Fig. 10). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum siliqua length plant^{-1} of mustard (9.54 cm), while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum siliqua length plant^{-1} of mustard (8.04 cm). Adequate supply of nutrients facilitated better growth and development of crop plant, enhanced nutrient uptake which resulted significant increase in length of silique. Boron deficiency reduces chlorophyll and soluble protein contents in the leaves, and the resultant loss in photosynthetic enzyme activity obstructs the photosynthetic reaction and decreases net photosynthesis as a result its effects on growth and yield of plant. Jana *et al.* (2009) also found similar result which supported the present finding and reported that application of B significantly increased length of siliqua. Application of 15 to 20 kg borax ha^{-1} gave higher values of yield attributes, seed and stover yields.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 8. Effect of different boron levels on length of siliqua plant^{-1} of mustard (LSD$_{(0.05)}$= 0.35).

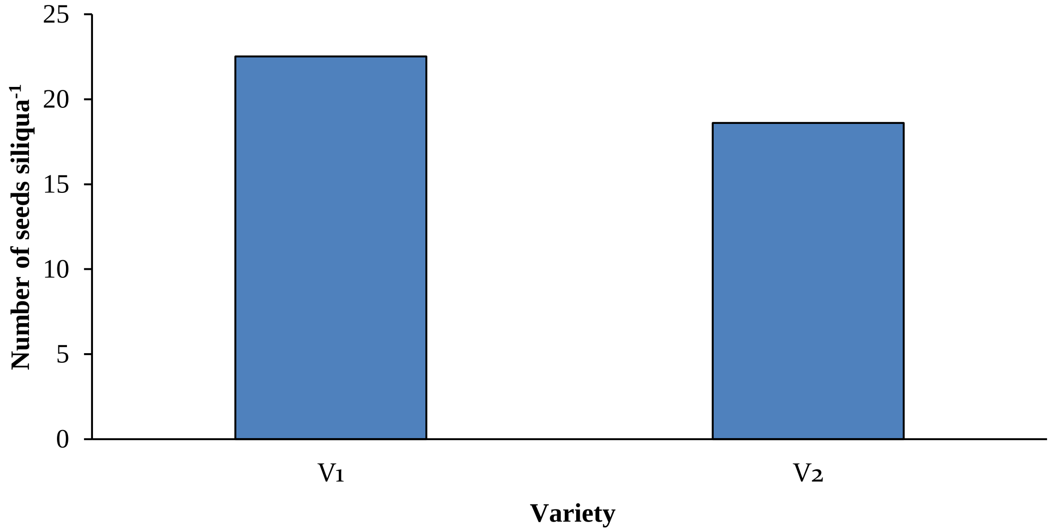
Combined effect of variety and different boron levels

Different mustard variety along with different boron levels significantly effect on siliqua length plant^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum siliqua length plant^{-1} (10.84 cm) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum siliqua length plant^{-1} (7.24 cm).

4.2.3 Number of seeds siliqua^{-1}

Effect of variety

Mustard varieties significantly effect on number of seeds siliqua^{-1} (Fig. 11). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of seeds siliqua^{-1} (22.51) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of seeds siliqua^{-1} (18.61). The differences of number of seeds siliqua^{-1} was due to the genetic makeup of the varieties. Similar result observed by Helal *et al.* (2016) and reported that, variations in terms of number of seeds/siliqua among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity.

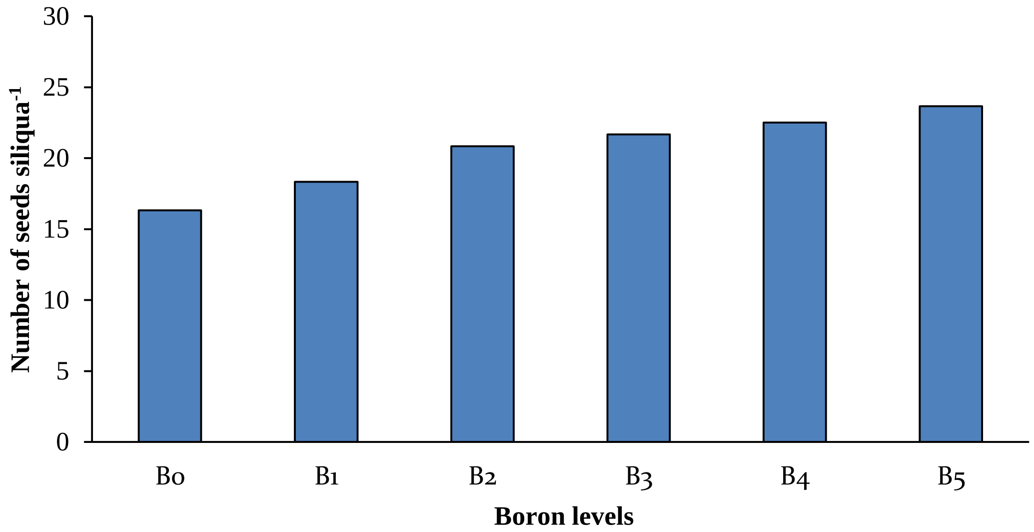


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 11. Effect of variety on number of seeds siliqua^{-1} of mustard ($LSD_{(0.05)}$= 1.89).

Effect of different boron levels

Application of different levels of boron significantly effect on number of seeds silique^{-1} of mustard (Fig. 12). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of seeds siliqua^{-1} of mustard (23.67) which was statistically similar with 1.75 kg boron ha^{-1} (B_4) treated plot recorded the number of seeds siliqua^{-1} of mustard (22.51), while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of number of seeds siliqua^{-1} of mustard (16.34). The result obtained from the present study was similar with the findings Kour *et al*. (2017) reported that RDF + 10 kg Zn + 2 kg B ha^{-1} resulted in a substantial improvement in yield characteristics such as seeds siliquae^{-1} was higher than the required fertilizer dose. Yadav *et al.* (2016) reported that the effect of boron on rape seed formation was good and it significantly increased the seeds siliqua^{-1}.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 12. Effect of different boron levels on number of seeds siliqua^{-1} of mustard (LSD$_{(0.05)}$= 1.23).

Combined effect of variety and different boron levels

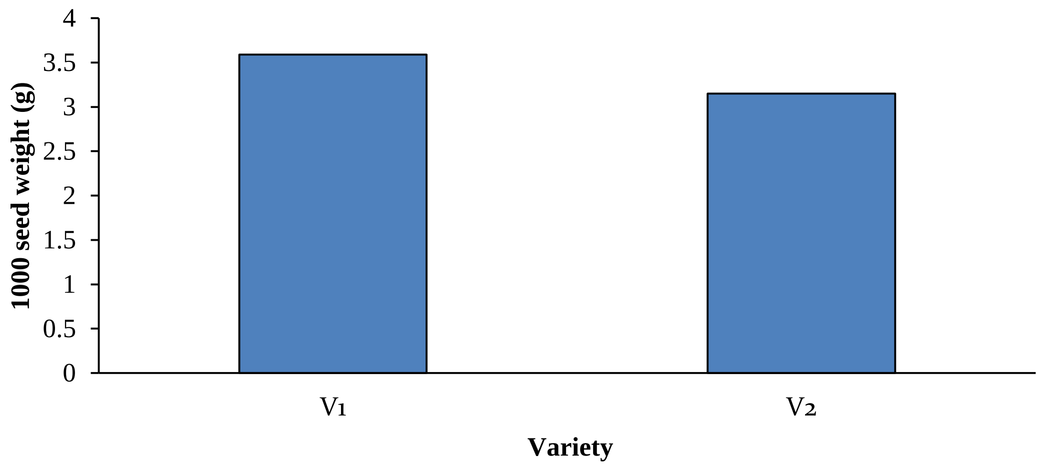
Different mustard variety along with different boron levels significantly effect on number of seeds siliqua^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5)

treated plot recorded the maximum number of seeds siliqua^{-1} (26.34) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of seeds siliqua^{-1} (15.34) which was statistically similar with, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.0 kg boron ha^{-1} (B_1) treated plot recorded number of seeds siliqua^{-1} (16.00).

4.2.4 1000 seed weight (g)

Effect of variety

Different varieties significantly effect on 1000 seed weight of mustard. (Fig. 13). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum 1000 seed weight (3.59 g) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum 1000 seed weight (3.15 g). The differences of the 1000 seed weight among different mustard varieties may be attributes to the varietal performance and genetic makeup of the varieties. Similar result observed by Mamun *et al.* (2014) who reported that among different varieties BARI Sarisha-13 had the highest 1000- seed weight (4.00 g) whereas the lowest (2.82 g) - in SAU Sarisha-3. Mondal and Wahab (2001) described that, weight of 1000 seeds varied from variety to variety and species to species.

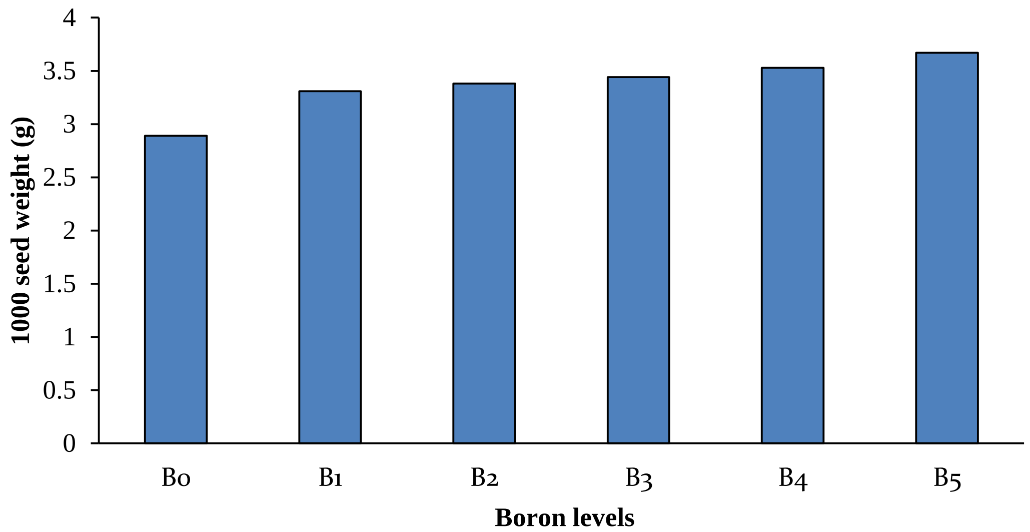


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 13. Effect of variety on 1000-seed weight of mustard ($LSD_{(0.05)}$= 0.07)

Effect of different boron levels

Application of different levels of boron significantly effect on 1000-seed weight of mustard (Fig. 14). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum 1000-seed weight (3.67 g) while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum 1000-seed weight (2.89 g). Boron was more pronounced on most of the yield attributes of mustard, because it plays a positive role in improving the vegetative structure for nutrient absorption and supply strong sink through evolution of reproductive structure as well as production of assimilates to fill important economical site i.e. siliqua and seed. Riaj *et al.* (2018) also found similar result which supported the present finding and reported that different levels of boron exhibited statistically significant variation for 1000-seed weight. It increased significantly with higher levels of boron with the highest (3.71 g) at B_2 treatment comprising of 2 kg boron/ha and (3.52 g) lowest in (B_0) control treatment. Akter *et al.* (2007) also reported that application of different levels of B from fertibor significantly influenced the yield and yield components of mustard up to 2 kg ha^{-1} and declined thereafter.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 14. Effect of different boron levels on 1000-seed weight of mustard ($LSD_{(0.05)}$= 0.14).

Combined effect of variety and different boron levels

Different mustard variety along with different boron levels significantly effect on 1000 seed weight of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum 1000-seed weight (3.82 g) which was statistically similar with, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded 1000-seed weight (3.69 g) and with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.50 kg boron ha^{-1} (B_3) treated plot recorded 1000-seed weight (3.65 g). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum 1000-seed weight (2.43 g).

Table. 4. Combined effect of variety and different boron levels siliqua plant^{-1}, length of siliqua plant^{-1}, seeds siliqua^{-1} and 1000 seeds weight of mustard

Treatment Combinations	Number of silique plant^{-1}	Length of siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000 seeds weight (g)
V_1B_0	90.14 d	8.84 c	17.34 fg	3.35 de
V_1B_1	98.00 c	9.10 bc	20.67 ce	3.48 cd
V_1B_2	99.34 c	9.50 b	22.00 c	3.55 b-d
V_1B_3	99.07 c	9.50 b	24.34 b	3.65 a-c
V_1B_4	109.70 b	9.54 b	24.34 b	3.69 ab
V_1B_5	115.00 a	10.84 a	26.34 a	3.82 a
V_2B_0	68.74 h	7.24 f	15.34 h	2.43 g
V_2B_1	74.00 g	7.74 e	16.00 gh	3.13 f
V_2B_2	77.00 g	7.94 de	19.67 de	3.20 ef
V_2B_3	80.34 f	7.84 de	19.00 ef	3.23 ef
V_2B_4	87.00 de	8.24 d	20.67 ce	3.36 de
V_2B_5	86.00 e	8.24 d	21.00 cd	3.53 b-d
$LSD_{(0.05)}$	3.19	0.49	1.74	0.20
CV(%)	2.08	3.34	4.98	3.62

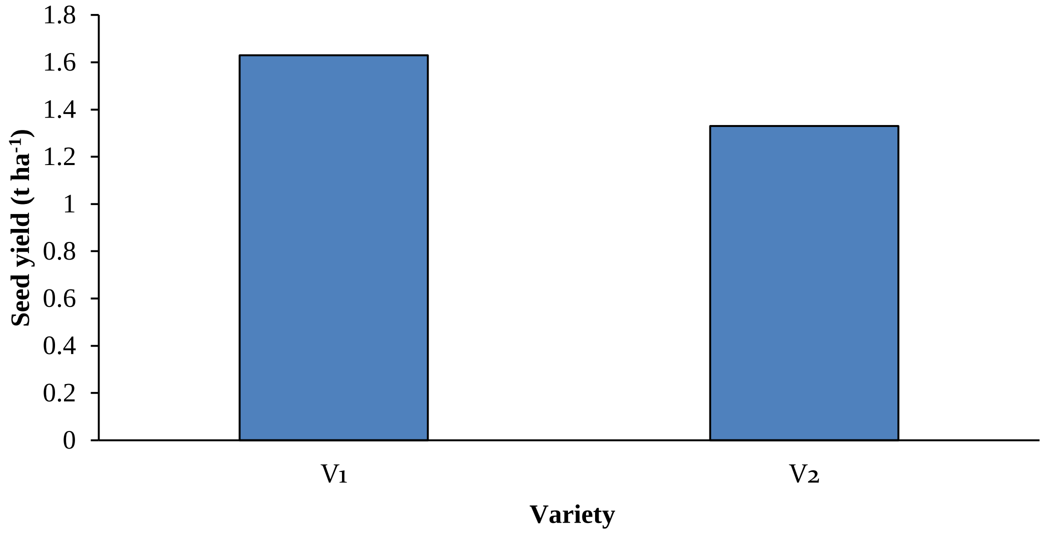
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

4.3 Yield characters

4.3.1 Seed yield (t ha^{-1})

Effect of variety

Mustard varieties significantly effect on seed yield plant^{-1} (Fig. 15). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum seed yield (1.63 t ha^{-1}) while BARI Sarisha-15 mustard variety cultivation recorded the minimum seed yield (1.33 t ha^{-1}). Different mustard variety have individual genetic makeup which influenced the growth and yield among different varieties. Biswas *et al.* (2019) also found similar result which supported the present finding and reported that seed yield differed among different varieties of mustard. Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Zaman *et al.* (1991) who reported that seed yield of mustards were varied with different varieties.

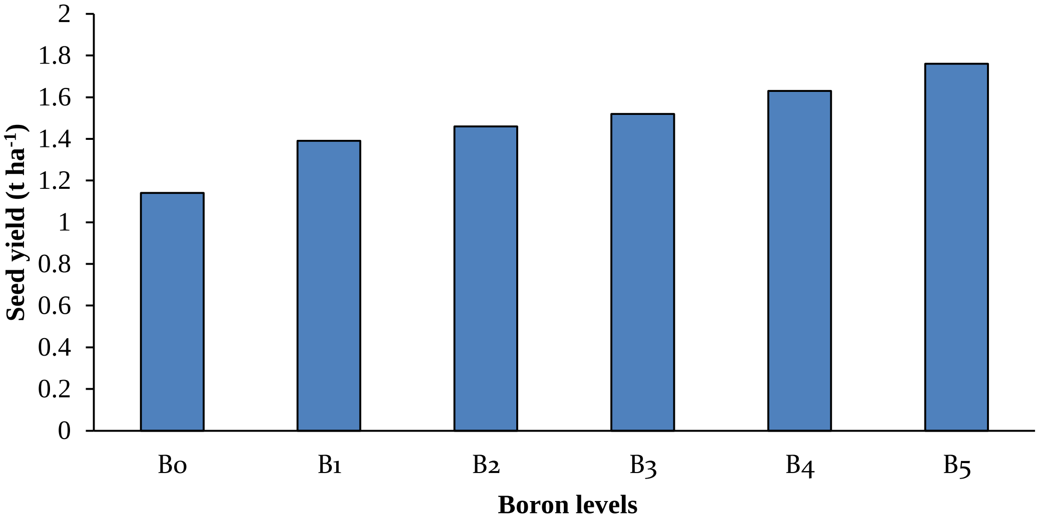


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 15. Effect of variety on seed yield of mustard ($LSD_{(0.05)}$= 0.06).

Effect of different boron levels

Different boron levels significantly effect on seed yield (t ha^{-1}) of mustard (Fig. 16). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum seed yield (1.76 t ha^{-1}) while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum seed yield (1.14 t ha^{-1}). Application of boron enhanced more uptakes of major nutrients resulting greater photosynthetic activities and led to greater vegetative growth of plants. Ultimately this accelerated growth due to proper metabolic activities produced higher seed yield in mustard. Singh and Pal (2011) reported that with the increment in supply of essential micronutrients to mustard, their availability, acquisition, mobilization and influx into the plant tissues increased and thus improved yield attributes and finally the yield. Yang *et al.* (2009a) reported that B significantly increased seed yield of rapeseed compared with the low B control, which was attributed to increased number of seeds per silique and siliqua per plant. These results suggested that application of B could produce higher seed yield. Mollah *et al*. (2005) reported that application of 1.0 to 2.0 kg B ha^{-1} significantly influenced seed yield of mustard varieties under the test over control. Dhali x 2 kg B ha^{-1} produced the highest seed yield which was statistically similar to Dhali x 1 B ha^{-1}. The lowest seed yield was obtained from Rai-5 x 0 kg of boron.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 16. Effect of different boron levels on seed yield of mustard ($LSD_{(0.05)}$= 0.07).

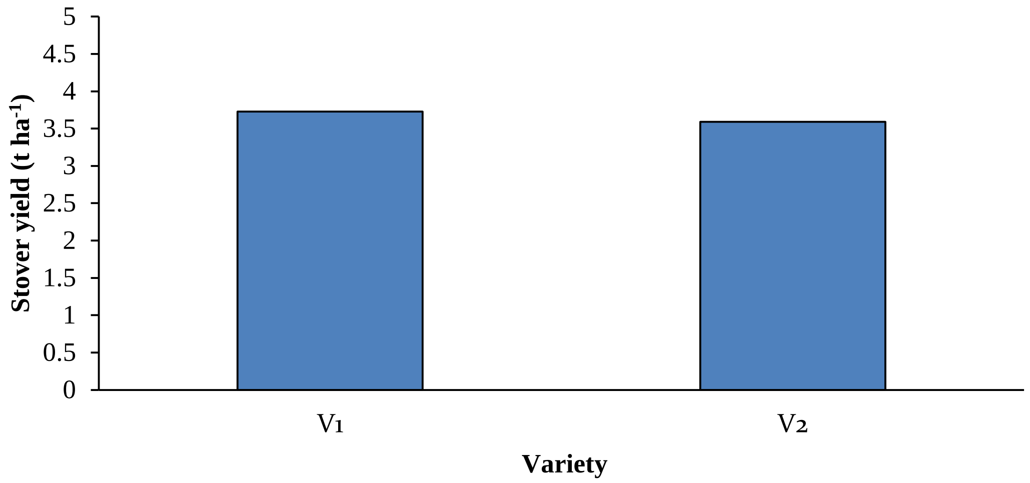
Combined effect of variety and boron levels

Different mustard variety along with different boron levels significantly effect on seed yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum seed yield (1.87 t ha^{-1}). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum seed yield (0.89 t ha^{-1}).

4.3.2 Stover yield (t ha^{-1})

Effect of variety

Different varieties significantly effect on stover yield (t ha^{-1}) of mustard (Fig. 17). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum stover yield (3.73 t ha^{-1}) while BARI Sarisha-15 mustard variety cultivation recorded the minimum stover yield (3.59 t ha^{-1}). Sultana *et al.* (2009) also found similar result with present study and reported that stover yield of mustards were varied with different varieties.

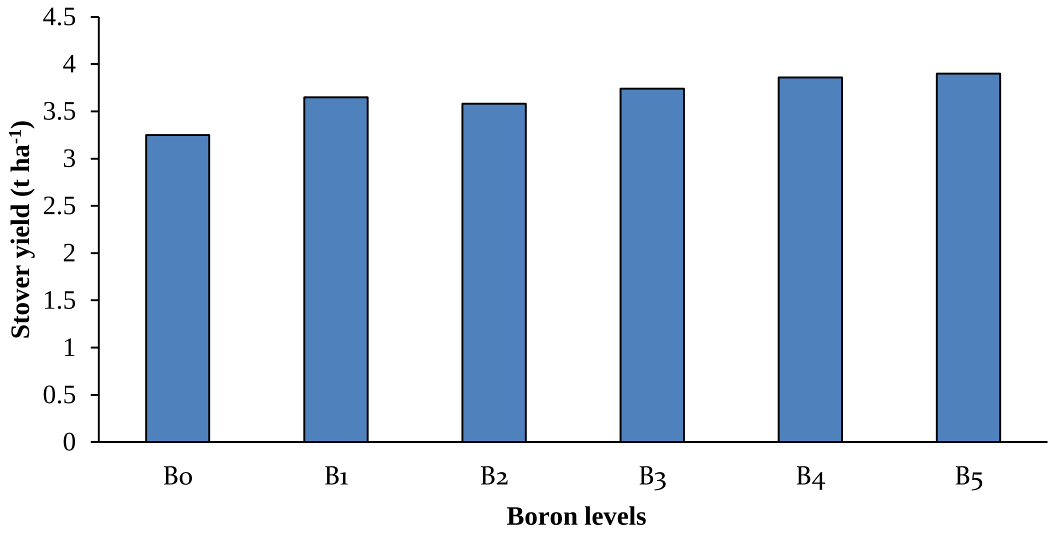


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 17. Effect of variety on stover yield of mustard ($LSD_{(0.05)}$= 0.14).

Effect of different boron levels

Application of different levels of boron significantly effect on stover yield (t ha^{-1}) of mustard (Fig. 18). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum stover yield (3.90 t ha^{-1}) which was statistically similar with 1.75 kg boron ha^{-1} (B_4) treated plot recorded stover yield (3.86 t ha^{-1}) while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum stover yield (3.25 t ha^{-1}). The result obtained from the present study was similar with the findings of Malewar *et al.* (2001) and they observed that stover yield was significantly increased with the increment of boron levels.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 18. Effect of different boron levels on stover yield of mustard ($LSD_{(0.05)}$= 0.13).

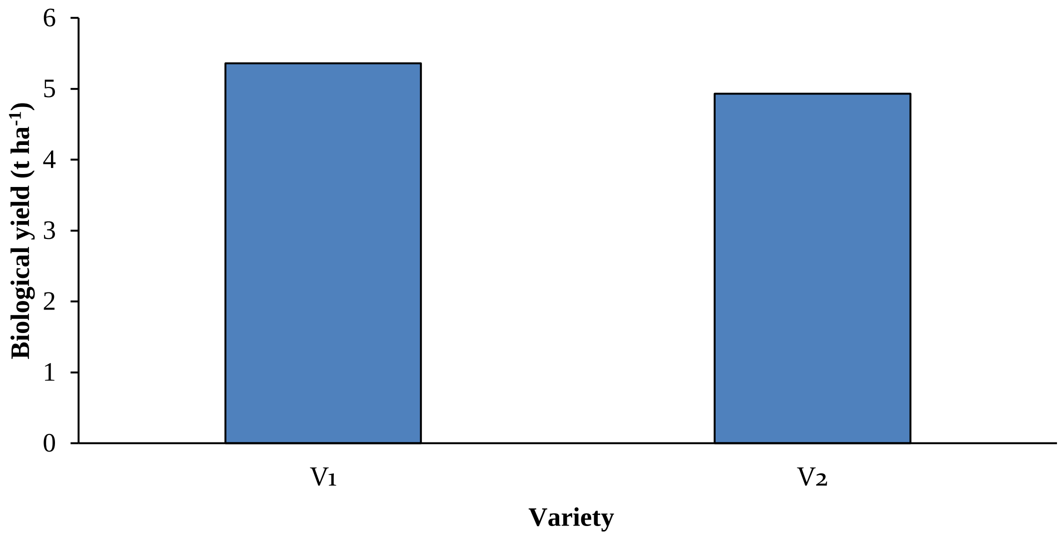
Combined effect of variety and boron levels

Combined effect of variety and boron levels significantly effect on stover yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum stover yield (3.99 t ha^{-1}) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded stover yield (3.97 t ha^{-1}) and with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2 kg boron ha^{-1} (B_5) treated plot recorded stover yield (3.82 t ha^{-1}). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum stover yield (3.0 t ha^{-1}).

4.3.3 Biological yield (t ha^{-1})

Effect of variety

Different variety cultivation significantly effect on biological yield (t ha^{-1}) of mustard (Fig. 19). Experiment result showed that cultivation of BARI Sarisha-14 mustard variety recorded the maximum biological yield (5.36 t ha^{-1}) while cultivation of BARI Sarisha-15 mustard variety recorded the minimum biological yield (4.93 t ha^{-1}). The variation of biological yield by different varieties might be due to the contribution of cumulative favourable effects of the crop characteristics viz., seed and stover yield of the crop. Tobe *et al.* (2013) also found similar result which supported the present finding and reported that variation in biological yield differ among cultivars of *B. napus*. Rana and Pachauri (2001) also quoted that cv. Bio 902 recorded higher biological yield (7250 kg ha^{-1}) as compared to cv. TERI (OE) M 21 (6850 kg ha^{-1}).

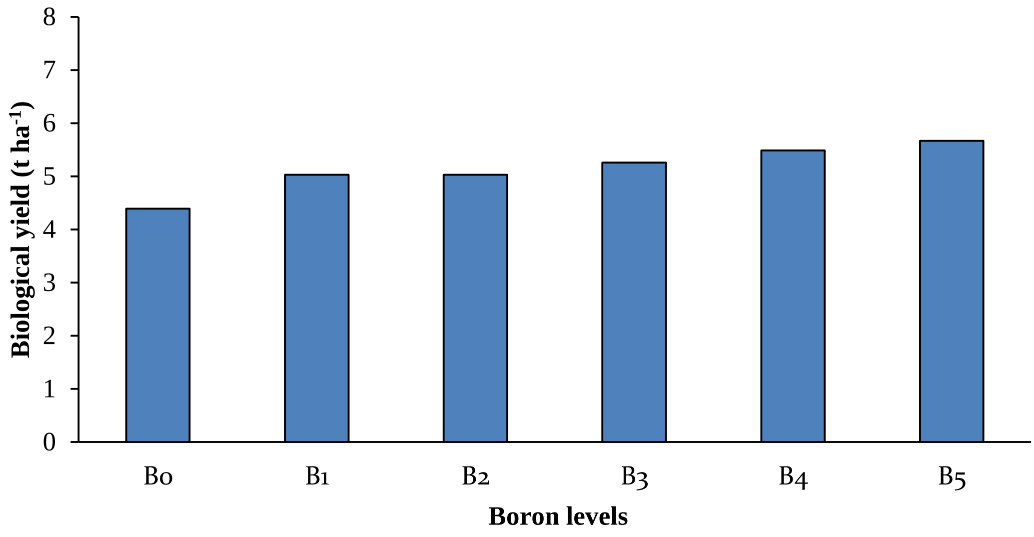


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 19. Effect of variety on biological yield of mustard ($LSD_{(0.05)}$= 0.19).

Effect of different boron levels

Application of different levels of boron significantly effect on biological yield (t ha^{-1}) of mustard (Fig. 20). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum biological yield (5.67 t ha^{-1}) while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum biological yield (4.39 t ha^{-1}). Boron plays an important role in regulating plants' hormone levels and promoting proper growth. Boron increases flower production and retention, pollen tube elongation and germination, and seed and fruit development. Application of boron improved yield attributes of mustard resulted in increase in seed, stover and biological yield Choudhary and Bhogal (2013) reported that the biological yield of mustard cultivars increased significantly with increasing levels of boron application upto 20 kg borax ha^{-1} over control.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 20. Effect of different boron levels on biological yield of mustard (LSD$_{(0.05)}$= 0.14).

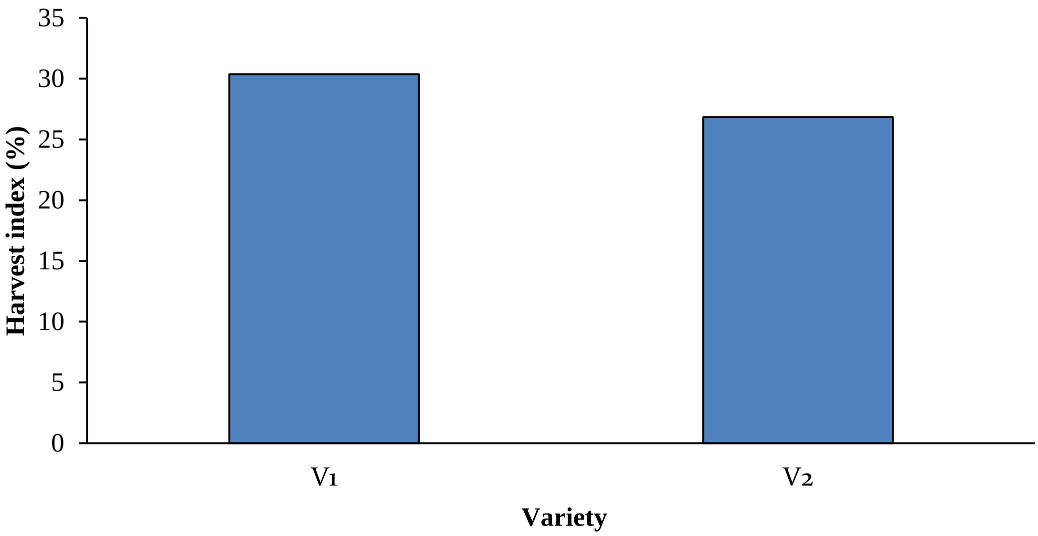
Combined effect of variety and different boron levels

Combined effect of variety and different boron levels significantly effect on biological yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum biological yield (5.85 t ha^{-1}) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded biological yield (5.74 t ha^{-1}). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum biological yield (3.89 t ha^{-1}).

4.3.4 Harvest index (%)

Effect of variety

Mustard varieties significantly effect on harvest index (Fig. 21). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum harvest index (30.36 %) while BARI Sarisha-15 mustard variety cultivation recorded the minimum harvest index (26.83 %). The harvest index differed significantly among the varieties due to its genetic variability. Thakur *et al.* (2021) also found similar result which supported the present finding and reported that the different varieties have different yield potential, which is the reason for yield variation among different varieties which ultimately impact on harvest index. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) also reported that variety had a great influence on harvest index.

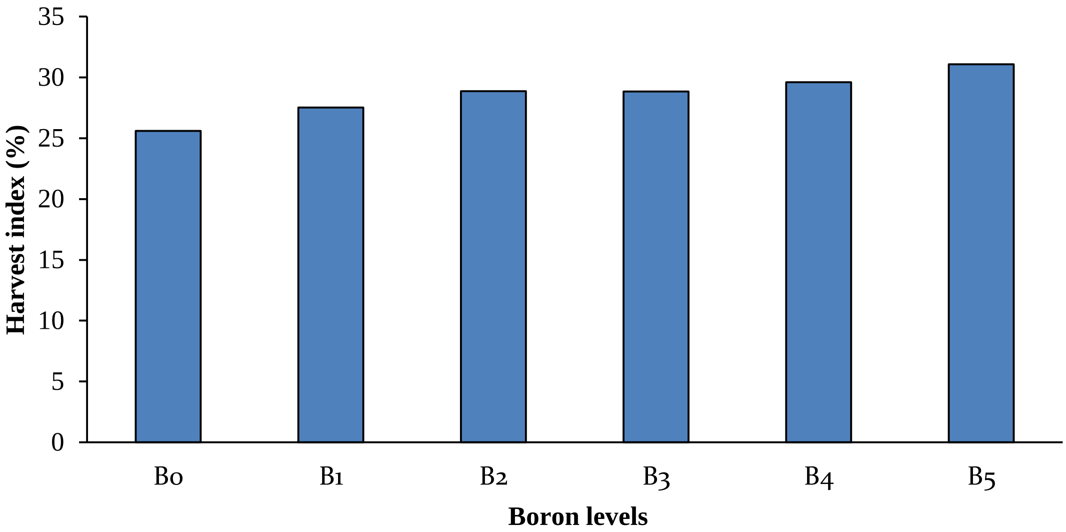


Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Fig. 21. Effect of variety on harvest index of mustard (LSD$_{(0.05)}$= 0.53).

Effect of different boron levels

Application of different levels of boron significantly effect on harvest index (%) of mustard (Fig. 22). Experiment result showed that, 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum harvest index (31.08 %) while control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum harvest index (25.61 %). Boron application might be attributed to sum total effect of increased growth and yield attributing characters. Due to increased supply of boron results in better translocation of photosynthetic to seeds and thus increased to value of harvest index. Riaj *et al*. (2018) also found similar result which supported the present finding and reported that the application of B increased harvest index of mustard up to the highest level. The highest harvest index (22.97%) was recorded from B_2 treatment comprising of 2 kg B/ha. On the other hand the lowest harvest index (21.41%) was recorded from the B_0 treatment (control). Hussain *et al.* (2012) reported that the highest and lowest harvest index were due to differences in rate of boron application.



Here, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

Fig. 22. Effect of different boron levels on harvest index of mustard ($LSD_{(0.05)}$= 1.22).

Combined effect of variety and different boron levels

Different mustard variety along with different boron levels significantly effect on harvest index (%) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum harvest index (31.89 %) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.75 kg boron ha^{-1} (B_4) treated plot recorded harvest index (30.79 %), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.50 kg boron ha^{-1} (B_3) treated plot recorded harvest index (30.66 %), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 1.25 kg boron ha^{-1} (B_2) treated plot recorded harvest index (30.68 %) and with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded harvest index (30.27 %). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum harvest index (22.95 %).

Table. 5. Combined effect of variety and different boron levels on seed, stover, biological yield and harvest index of mustard

Treatment Combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1B_0	1.38 e	3.50 e	4.88 e	28.28 cd
V_1B_1	1.51 d	3.55 e	5.06 c-e	29.84 bc
V_1B_2	1.58 cd	3.57 de	5.15 cd	30.68 ab
V_1B_3	1.68 bc	3.80 bc	5.48 b	30.66 ab
V_1B_4	1.77 ab	3.97 ab	5.74 a	30.79 ab
V_1B_5	1.87 a	3.99 a	5.85 a	31.89 a
V_2B_0	0.89 g	3.00 f	3.89 f	22.95 f
V_2B_1	1.26 f	3.74 cd	5.00 de	25.20 e
V_2B_2	1.33 ef	3.58 de	4.91 e	27.09 d
V_2B_3	1.36 ef	3.67 c-e	5.03 de	27.04 d
V_2B_4	1.49 d	3.75 cd	5.24 c	28.44 cd
V_2B_5	1.66 c	3.82 a-c	5.48 b	30.27 ab
$LSD_{(0.05)}$	0.10	0.18	0.20	1.64
CV(%)	4.06	2.98	2.32	3.57

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg ha^{-1}, B_1 =1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 =2 kg ha^{-1}.

4.4 Relationship between boron levels and seed yield of mustard varieties

A positive linear relationship was observed between different boron levels and seed yield of mustard (Fig. 23). It was evident from the Fig that the regression equation y = 0.297x + 1.112 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.973), indicating that 97.3 % of the variation in the data is determined by the regression line. From this regression analysis, it was evident that there was a strongly positive relationship between different boron levels and seed yield t ha^{-1} of mustard. Seed yield of mustard dependent on various yield contributing characters such as number of silique $plant^{-1}$, siliqua length, seed $siliqua^{-1}$, 1000-seed weight etc. In this present experiment the yield contributing character were significantly varied due to the influence of different boron fertilization levels which ultimately impact on seed yield of mustard and revealed a positive relationship between different boron fertilization levels and seed yield of mustard. In this experiment due to variation of different boron levels, 2 kg boron ha^{-1} treated plot recoded the maximum seed yield (1.76 t ha^{-1}) of mustard comparable to others treatment.

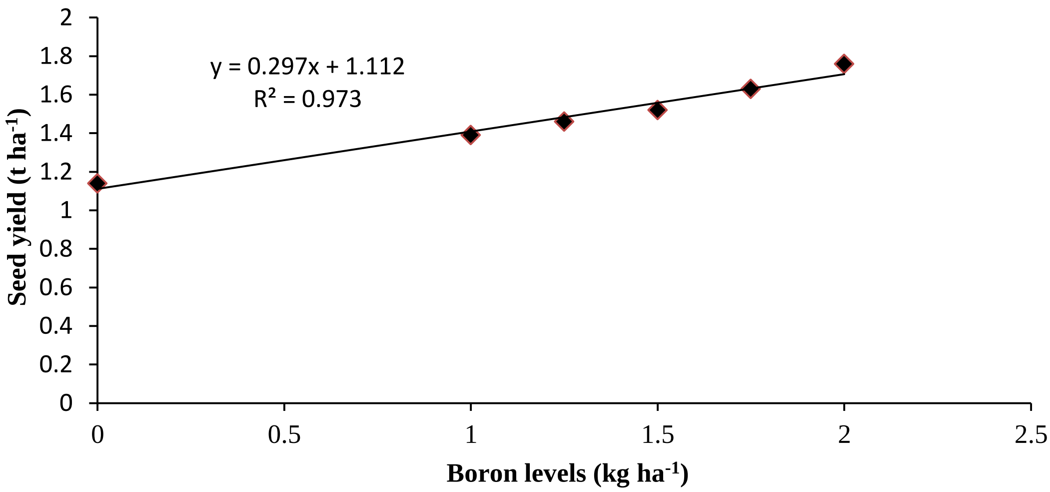


Fig. 23. Relationship between different boron fertilization levels and seed yield of mustard

4. 5. Correlation of seed yield (t ha^{-1}) with siliqua plant^{-1}, seed siliqua^{-1} and 1000-seed weight (g) of mustard varieties along with different boron levels

From the (Fig. 24, 25 and 26) it was noticed that seed yield of mustard varieties was positively correlated with number of silique plant^{-1} (R^2=0.794), number of seed siliqua^{-1} (R^2=0.854) and 1000-seeds weight (R^2=0.955). From the correlation study, it appears that seed yield increase with increasing siliqua plant^{-1}, seed siliqua^{-1} and 1000-seed weight. In this experiment BARI Sarisha-14 mustard variety cultivation along with increasing boron fertilization level @ 2 kg boron ha^{-1} treated plot recorded the maximum seed yield (1.87 t ha^{-1}) which was due to reason that BARI Sarisha-14 mustard variety along with increasing boron level (2 kg boron ha^{-1} treated plot) produce higher number of silique plant^{-1} (115), seed siliqua^{-1} (26.34) and maximum 1000-seeds weight (3.82 g) in comparable to other variety along with different levels of boron fertilization.

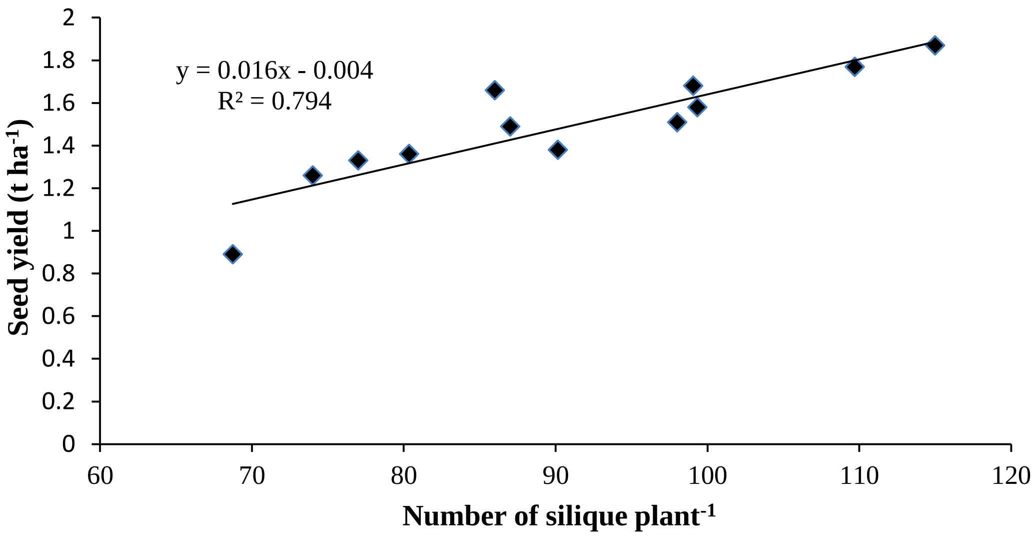


Fig. 24. Relationship between number of silique plant^{-1} and seed yield (t ha^{-1}) of mustard varieties along with different boron levels

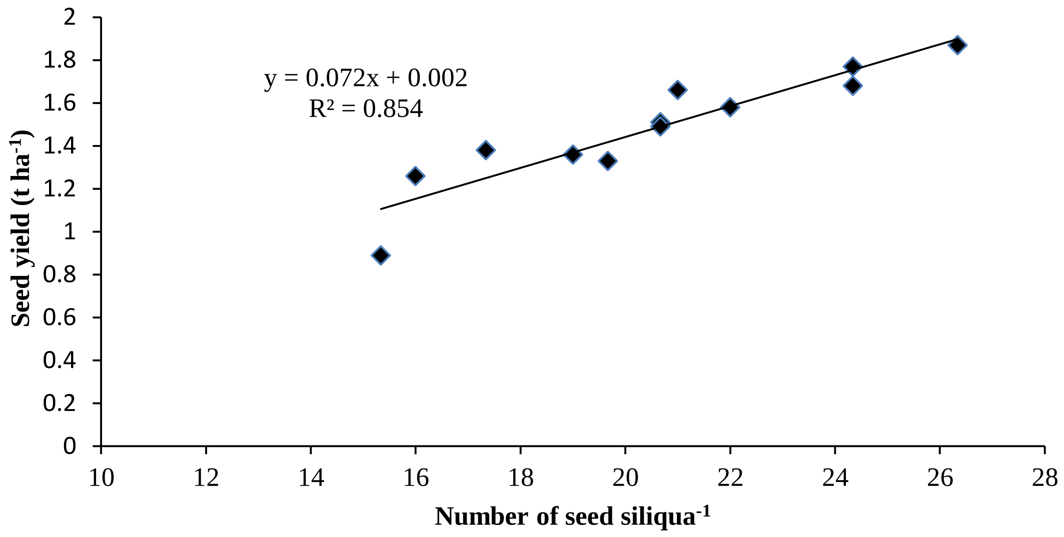


Fig. 25. Relationship between number of seed silique^{-1} and seed yield (t ha^{-1}) of mustard varieties along with different boron levels

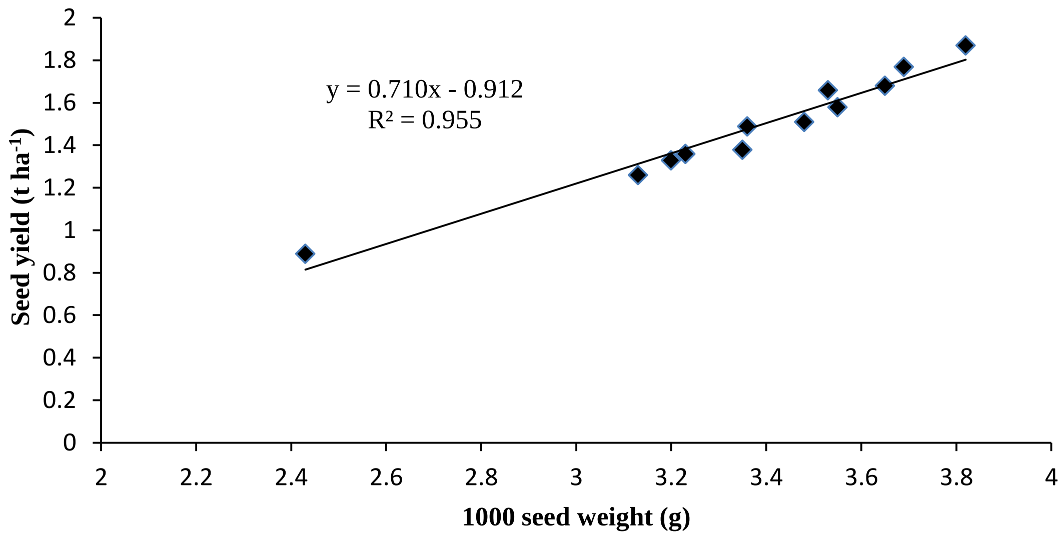


Fig. 26. Relationship between 1000-seed weight and seed yield (t ha^{-1}) of mustard varieties along with different boron levels

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from October-2019 to February 2020 in Rabi season to investigate the effects of boron on growth, yield and yield attributes of mustard. The experiment consisted of two factors, and followed split-plot design with three replications. Factor A: Mustard varieties (2) *viz,* V_1= BARI Sarisha-14, V_2= BARI Sarisha-15 and Factor B: Different boron levels (6) *viz,* B_0 = 0 kg ha^{-1}, B_1 = 1.00 kg ha^{-1}, B_2 = 1.25 kg ha^{-1}, B_3 = 1.50 kg ha^{-1}, B_4 = 1.75 kg ha^{-1} and B_5 = 2.0 kg ha^{-1}. Data on different parameters were collected for assessing results for this experiment and showed significant variation in respect of growth, yield and yield contributing characteristics of mustard due to the effect of different mustard varieties, boron levels and their combinations.

In case of mustard varieties, BARI Sarisha-15 mustard variety (V_2) recorded the maximum plant height (9.75, 51.61, 82.53 and 93.20 cm) at 15, 30, 45 DAS and at harvest respectively. BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of branches $plant^{-1}$ (4.39, 6.88 and 10.28) and above ground dry matter weight $plant^{-1}$ (1.96, 4.93 and 33.57 g) at 30, 45 DAS and at harvest respectively. BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of silique $plant^{-1}$ (101.87), siliqua length $plant^{-1}$ (9.55 cm), seeds $siliqua^{-1}$ (22.51), 1000 seed weight (3.59 g), seed yield (1.63 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.36 t ha^{-1}) and harvest index (30.36 %). Whereas BARI Sarisha-14 mustard variety (V_1) recorded the minimum plant height (8.86, 49.19, 73.53 and 84.50 cm) at 15, 30, 45 DAS and at harvest respectively. BARI Sarisha-15 mustard (V_2) variety cultivation recorded the minimum number of branches $plant^{-1}$ (4.11, 5.78 and 9.33) and above ground dry matter weight $plant^{-1}$ (1.82, 4.72 and 30.86) at 30, 45 DAS and at harvest respectively. BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of silique $plant^{-1}$ (78.85), siliqua length $plant^{-1}$ (7.87 cm), seeds $siliqua^{-1}$ (18.61), 1000 seed weight (3.15 g), seed yield (1.33 t ha^{-1}), stover yield (3.59 t ha^{-1}), biological yield (4.93 t ha^{-1}) and harvest index (26.83 %).

In case of different boron levels, application of 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum plant height (10.84, 59.40, 86.44 and 96.21 cm) at 15, 30, 45 DAS and at harvest respectively .Application of 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of branches $palnt^{-1}$ (4.67, 7.88 and 11.50) and above ground dry matter weight $plant^{-1}$ (2.70, 5.64 and 35.61 g) at 30, 45 DAS and at harvest respectively. Application of 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of silique $plant^{-1}$ (100.50), siliqua length $plant^{-1}$ (9.54 cm), seeds $siliqua^{-1}$ (23.67), 1000 seed weight (3.67 g), seed yield (1.76 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.67 t ha^{-1}) and harvest index (31.08 %). Whereas control or 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum plant height (7.24, 42.25, 71.32 and 78.19 cm) at 15, 30, 45 DAS and at harvest respectively. Application of 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of branches $palnt^{-1}$ (3.67, 4.77 and 8.00) and above ground dry matter weight $plant^{-1}$ (11.10, 4.09 and 27.49 g) at 30, 45 and at harvest respectively. Control or application of 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of silique $plant^{-1}$ (79.44), siliqua length $plant^{-1}$ (8.04 cm), seeds $siliqua^{-1}$ (16.34), 1000 seed weight (2.89 g), seed yield (1.14 t ha^{-1}), stover yield (3.25 t ha^{-1}), biological yield (4.39 t ha^{-1}) and harvest index (25.61 %).

In case of combined effect, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum plant height (11.33, 62.20, 95.49 and 102.01 cm) at 15, 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of branches $plant^{-1}$ (4.67, 8.87 and 13.00) and above ground dry matter weight $plant^{-1}$ (2.84, 5.65 and 36.88 g) at 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot recorded the maximum number of silique $plant^{-1}$ (115.00), siliqua length $plant^{-1}$ (10.84 cm), seeds $siliqua^{-1}$ (26.34), 1000 seed weight (3.82 g), seed yield (1.87 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.85 t ha^{-1}) and harvest index (31.89 %). Whereas cultivation of BARI Sarisha-14 mustard variety along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum plant height (6.71, 41.01, 61.90 and 70.37 cm) at 15, 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of branches $plant^{-1}$ (3.67, 4.29 and 7.67) and above ground dry matter weight plant^{-1} (1.00, 3.77 and 24.39 g) at 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg boron ha^{-1} (B_0) treated plot recorded the minimum number of silique plant^{-1} (68.74), siliqua length plant^{-1} (7.24 cm), seeds siliqua^{-1} (15.34), 1000-seed weight (2.43 g), seed yield (0.89 t ha^{-1}), stover yield (3.59 t ha^{-1}), biological yield (3.89 t ha^{-1}) and harvest index (22.95 %).

In case of relationship between boron levels and seed yield a positive linear relationship was observed between different boron levels and seed yield of mustard.

In case of correlation study, seed yield of mustard was positively correlated with number of silique plant^{-1} (R^2=0.794), number of seed siliqua^{-1} (R^2=0.854) and 1000-seeds weight (R^2=0.955). From the correlation study, it appears that seed yield increase with increasing siliqua plant^{-1}, seed siliqua^{-1} and 1000-seed weight. In this experiment BARI Sarisha-14 mustard variety cultivation along with increasing boron fertilization level @ 2 kg boron ha^{-1} treated plot recorded the maximum seed yield (1.87 t ha^{-1}) which was due to reason that BARI Sarisha-14 mustard variety along with increasing boron level (2 kg boron ha^{-1} treated plot) produce higher number of silique plant^{-1} (115), seed siliqua^{-1} (26.34) and maximum 1000-seeds weight (3.82 g) in comparable to other variety along with different levels of boron fertilization.

Conclusion

Based on the above results of the present study, the following conclusions may be drawn

i. BARI Sarisha-14 (V_1) recorded the maximum number of silique plant^{-1} (101.87), siliqua length plant^{-1} (9.55 cm), seeds siliqua^{-1} (22.51), 1000-seed weight (3.59 g), seed yield (1.63 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.36 t ha^{-1}) and harvest index (30.36 %).
ii. In the case of different boron levels, 2.0 kg boron ha^{-1} (B_5) treated plot were recorded the maximum number of silique plant^{-1} (100.50), siliqua length plant^{-1} (9.54 cm), seeds siliqua^{-1} (23.67), 1000-seed weight (3.67 g), seed yield (1.76 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.67 t ha^{-1}) and harvest index (31.08 %).

iii. In the case of combined effect, BARI Sarisha-14 (V_1) along with 2.0 kg boron ha^{-1} (B_5) treated plot were recorded the maximum number of silique $plant^{-1}$ (115.00), siliqua length $plant^{-1}$ (10.84 cm), seeds $siliqua^{-1}$ (26.34), 1000-seed weight (3.82 g), seed yield (1.87 t ha^{-1}), stover yield (3.73 t ha^{-1}), biological yield (5.85 t ha^{-1}) and harvest index (31.89 %). Showed positive linear relationship between different boron levels on seed yield of mustard and correlation between seed yield and yield contributing characters of mustard comparable to other treatments.

iv. It could be concluded that higher seed yield of mustard could be obtained by using BARI Sarisha-14 with application of 2.0 kg boron ha^{-1} under the agroclimatic conditions of Modhupur Tract", AEZ-28.

Recommendation for further work

Before making final conclusion, further trials with the same treatment combinations on different locations of Bangladesh would be useful. Moreover, further investigation is necessary for the other soil types under different AEZ in Bangladesh.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

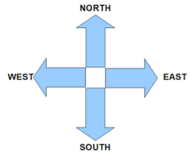
Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

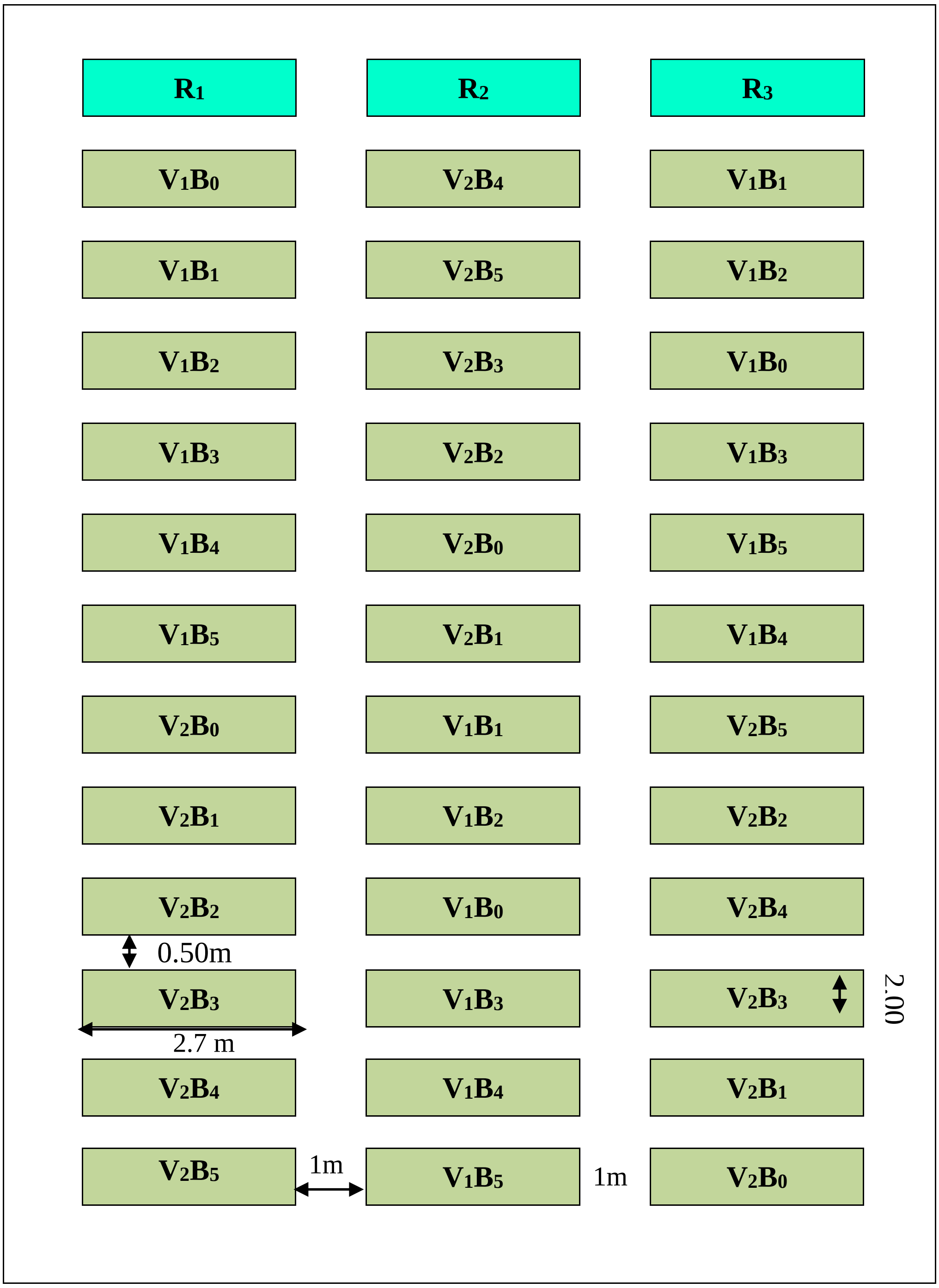
Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from October, 2019 to February 2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7

(Source: Metrological Centre, Agargaon, Dhaka (Climate Division)





Appendix IV. Layout of the experimental field

Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, B_0 = 0 kg boron ha^{-1}, B_1 =1.00 kg boron ha^{-1}, B_2 = 1.25 kg boron ha^{-1}, B_3 = 1.50 kg boron ha^{-1}, B_4 = 1.75 kg boron ha^{-1}and B_5 = 2.00 kg boron ha^{-1}

Appendix V. Analysis of variance of the data of plant height of mustard at different DAS

Mean square of plant height at					
Source	**Df**	**15 DAS**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.62	5.33	11.44	8.33
Variety (V)	1	7.00*	52.42**	729.45*	681.21**
Error (R×V)	2	0.08	0.33	12.44	1.00
Boron level (B)	5	11.45**	211.59**	189.47**	218.72**
V×B	5	1.76**	17.06**	109.65**	35.76**
Error (R×V×B)	20	0.31	2.43	11.94	5.07
Total	35				

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

Appendix VI. Analysis of variance of the data of number of branches plant^{-1} of mustard at different DAS

Mean square of number of branches plant^{-1}				
Source	**Df**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.00907	0.2558	0.28436
Variety (V)	1	0.69722**	10.8241**	8.00890*
Error (R×V)	2	0.00607	0.0925	0.19306
Boron level (B)	5	1.04702**	7.9333**	9.30360**
V×B	5	0.15663**	0.9399**	1.83292**
Error (R×V×B)	20	0.00757	0.0942	0.15093
Total	35			

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

Appendix VII. Analysis of variance of the data of above ground dry matter weight of mustard at different DAT

Mean square of above ground dry matter weight at				
Source	**Df**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.01116	0.02583	4.5216
Variety (V)	1	0.18063*	0.42250*	65.9073**
Error (R×V)	2	0.00466	0.02083	0.6087
Boron level (B)	5	2.70185**	1.83358**	47.2851**
V×B	5	0.04052**	0.21700**	5.7020**
Error (R×V×B)	20	0.00776	0.02333	1.1219
Total	35			

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

Appendix VIII. Analysis of variance of the data of number of silique plant-^{1}, length of siliqua (cm), number of seeds siliqua^{-1} and 1000-seed weight (g) of mustard

Source	Df	Mean square of			
		Number of silique plant^{-1}	**Length of siliqua (cm)**	**Number of seeds siliqua^{-1}**	**1000-seed weight (g)**
Replication (R)	2	11.58	0.2044	1.750	0.02721
Variety (V)	1	4772.74**	25.4016**	136.306*	1.76447**
Error (R×V)	2	1.08	0.1002	1.750	0.00254
Boron level (B)	5	372.17**	1.5071**	45.026**	0.42668**
V×B	5	17.49**	0.3343*	3.260*	0.08477**
Error (R×V×B)	20	3.53	0.0849	1.050	0.01488
Total	35				

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

Appendix IX. Analysis of variance of the data of seed yield, stover yield, biological yield (t ha^{-1}) and harvest index (%) of mustard

Source	Df	Mean square of			
		Seed yield (t ha^{-1})	**Stover yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Replication (R)	2	0.01281	0.00239	0.02618	1.387
Variety (V)	1	0.80401**	0.16674*	1.70303**	111.87**
Error (R×V)	2	0.00154	0.00887	0.01672	0.138
Boron level (B)	5	0.27906**	0.33645**	1.20735**	20.86**
V×B	5	0.01522**	0.08044**	0.14835**	2.86**
Error (R×V×B)	20	0.00361	0.01193	0.01418	1.039
Total	35				

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

PLATES

Plate 1: Photograph showing vegetative stage of mustard

Plate 2: Photograph showing flowering and siliqua formation stage of mustard

Plate 3: Photograph showing field inspection during experimental period