EFFECTS OF BORON FERTILIZER AND IRRIGATION FREQUENCY ON GROWTH, YIELD AND NUTRIENT CONTENT OF MUSTARD (BARI sarisha-14)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF BORON FERTILIZER AND IRRIGATION FREQUENCY ON GROWTH, YIELD AND NUTRIENT CONTENT OF MUSTARD (BARI sarisha-14)"** submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bonafide research work carried out by **MST. ISME TARA**, Registration No. **18-09286** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

December, 2020
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Dedicated to

My

Beloved Parents

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The Author

EFFECTS OF BORON FERTILIZER AND IRRIGATION FREQUENCY ON GROWTH, YIELD AND NUTRIENT CONTENT OF MUSTARD (BARI sarisha-14)

ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to determine the effect of boron fertilizer and irrigation frequency on growth, yield and nutrient content of mustard (BARI sarisha-14) during the period from November 2019 to February 2020. The experiment consisted of four levels of boron *viz*. control - 0 kg B ha^{-1} (B_0), 0.5 kg B ha^{-1} (B_1), 1.0 kg B ha^{-1} (B_2) and 1.5 kg B ha^{-1} (B_3) and 3 levels of irrigation *viz*. control - no irrigation (I_0), one irrigation at 25 DAS (I_1) and two irrigations at 25 and 50 DAS (I_2). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Considering the application of boron, B_2 (1.0 kg B ha^{-1}) showed best performance in terms of yield and yield contributing parameters and showed highest number of siliqua $plant^{-1}$ (78.78), length of siliqua (4.49 cm), number of seeds $siliqua^{-1}$ (35.89), 1000 seed weight (4.51 g), seed yield (1437.00 kg ha^{-1}) and harvest index (41.80%) whereas control treatment B_0 (0 kg B ha^{-1}) gave the lowest performance. Treatment B_3 (1.5 kg B ha^{-1}) showed highest N, P, K, B content in straw and B content in seed followed by B_2 (1.0 kg B ha^{-1}). Considering irrigation treatments, I_2 (Two irrigations at 25 and 50 DAS) gave best results on growth, yield and yield contributing parameters. The highest number of siliqua $plant^{-1}$ (77.42), length of siliqua (4.47 cm), number of seeds $siliqua^{-1}$ (36.00), 1000 seed weight (4.41 g), seed yield (1422.00 kg ha^{-1}), stover yield (1989.00 kg ha^{-1}) and harvest index (41.44%) were recorded from I_2 whereas control treatment I_0 gave the lowest results. Treatment I_2 also showed highest N, P, K, B content in straw and B content in seed. Regarding combined effect, B_2I_2 showed highest number of siliqua $plant^{-1}$ (85.67), length of siliqua (4.77 cm), number of seeds $siliqua^{-1}$ (39.33), 1000 seed weight (5.12 g), seed yield (1780.00 kg ha^{-1}), stover yield (2107.00 kg ha^{-1}) and harvest index (45.78%) while the highest amount of N, P, K, B content in straw and B content in seed were found from B_3I_2 treatment followed by B_2I_2. Hence, the results summarized that different boron and/or irrigation levels had significant and positive effect on growth, yield contributing parameters, yield and nutrient uptake of mustard and these can be considered as essential practices for higher mustard production.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Mustard belongs to the family Brassicaceae (Cruciferae), is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Currently it ranks as the world third oil crops in terms of production and area (Adnan *et al*., 2013). *Brassica napus*, *B. campestris* and *B. junceaare* the three species of mustard those produce edible oil which ranks the third most important sources of edible vegetable oil in the world after palm and soybean (Zhang and Zhou, 2006 and Adnan *et al*., 2013). Among the speices, *Brassica napus* and *Brassica campestris* are regarded as "rapeseed" while *Brassica juncea* is regarded as mustard. It is originated from Asia, but now is cultivating as a main commercial oil crop in Canada, China, Australia, and India. Oil seed rape (*Brassica napus* L.) has become one of the most important oil crops (Miri, 2007) and at present it is the third largest source of vegetable oil all over the world (Starner *et al*., 1999).

Among the oilseed crops, mustard is the major oilseed crop, which covers about 60% of the oilseed production in Bangladesh (BBS, 2019). It is an important source of cooking oil in Bangladesh and it meets one third of the edible oil requirement of the country (Ahmed *et al*., 1988). Edible oil is an essential integral part of the daily diet of the people in Bangladesh. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. More energy is supplied by plant products than by animal products (USDA, 2014). For example oil extracted from coconut, groundnut or mustard supplies 900 kilocalories (energy) as against butter and fist which provide 729 and 273 kilocalories respectively. It is evident that vegetable oil which may be obtained from plant sources by cultivation of oil crops is not less important than animal fat for energy. Mustard is rich in minerals like calcium, magnesium, iron, vitamin A, C and proteins. 100 g mustard seed contains 508 kilocalories energy, 28.09 g carbohydrates, 26.08 g proteins, 36.24 g total fat, 12.2 g dietary fiber, 31 I.U. vitamin A, 7.1 mg vitamin C, 266 mg calcium, 9.21 mg iron, 370 mg magnesium and 738 mg potassium (USDA, 2014).

In context of Bangladesh, mustard (*Brassica* spp.) is popular edible oil in rural area and is considered important for improving the taste of a number of food items (Aziz *et al*., 2011). Bangladesh is principally an agricultural country and produces a good number of oil seed crops like mustard, sesame, groundnut, linseed, safflower, sunflower, soybean, castor etc. The first three of these are considered as the major oil seed crops.

Mustard (*Brassica* spp.) is a winter crop in Bangladesh. It is also a thermo sensitive as well as photosensitive (Ghosh and Chatterjee, 1988). It also serves as an important raw material for industrial use such as in soap, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals, etc. Its oil not only plays a vital role as fat substitute in our daily diet but also nourish the economy of the nation. It is widely used as a cooking ingredient, condiment and for its medicinal value. Moreover, mustard oilcake is utilized as cattle and fish feed and small quantities are also used as manure. It accounts about 72% of total oil seed production in the country (Alamin *et al*., 2019). Moreover, mustard oilcake is utilized as cattle feed and small quantities are also used as manure. It accounts about 72% of total oil seed production in the country. Mustard is one of the most important oilseed crops throughout the world after soybean and groundnut (FAO, 2004).

In Bangladesh, it occupies first position of the list in respect of area and production among the oilseed crops (BBS, 2019). Oilseeds are important in the economy of Bangladesh which constitutes the most important group of crop next to cereals occupying 4.22% of the total cropped area (BBS, 2009).

In the year 2017-18, the total oilseed production was 927 thousand metric ton and total area covered by oilseed crops was 975 thousand acre. In the year of 2017-18, mustard covered 760 thousand acres land and the production was 352 thousand metric ton (BBS, 2018).

The average yield of the crop stands at 990 kg/ha (BBS, 2009), which is very low compared to the yield of many mustard growing countries of the world. There are several reasons that can explain this yield variation, which cover abiotic and biotic factors. Among the biotic and abiotic factors, unavailability of high yielding varieties (Akber *et al*., 1994), nutrient deficiency (Varma *et al*., 2002) and lack of cultural practices like irrigation (Hossain *et al*., 2013) are responsible for lower productivity of mustard. The newly released high yielding potential varieties of mustard could not compensate the yield gap possibly due to boron deficiency in soil and lack of irrigation.

Mustard, a *Brassica* crop, is very responsive to boron application (Mengel and Kirkby, 1987). Reproductive growth, especially flowering, fruit and seed set is more sensitive to boron deficiency than vegetative growth (Dear and Lipsett, 1987). Boron requirement for root growth in boron inefficient rapeseed cultivars was higher than that in B efficient cultivars (Hu *et al*., 1994; Xiong *et al*., 1995). Availability of boron to plants is affected by a variety of soil factors including soil solution, pH, texture, moisture, temperature, oxide content, carbonate content, organic matter content, and clay mineralogy (Goldberg *et al*., 2000, Shekhawat *et al*., 2008, Padbhusan and Kumar, 2015). Boron is generally less available in high pH soil. Increasing pH favours its retention by soils or soil constituents (Mezuman and Karen, 1981; Bloesch *et al*., 1987; Goldberg, 1997). Application of boron significantly influenced the yield by improving the yield attributing characters.

Boron application improves the yield by 35-39% over the control (Kumararajaa *et al*., 2015).

The crop is mainly grown during the winter season (October-March). The growth yield attributes and yield of mustard increased significantly with the increase in number irrigation (Verma *et al*., 2014). Applications of three irrigations significantly increased seed yield by 15.5% and 52.8% over two and one irrigations, respectively (Kibbria, 2013).

Similarly, it was reported that two irrigation once at flowering and others at siliqua formation stage increased the seed yield by 28% over rainfed plot. The highest plant height, branches plant^{-1}, filled siliqua plant^{-1}, seeds siliqua^{-1}, 1000 seed weight and stover yield were obtained from two irrigations and consequently it produced the highest seed yield (Ghosh *et al*., 1994 and Hossain *et al*., 2013).

Adequate supply of moisture in soil helps in proper utilization of plant nutrients, resulting in proper growth and high yield (Verma *et al*., 2014). The frequency of irrigation and the amount of water required depend on such factors as cultivar, soil type, season, amount of rainfall and diseases; therefore, it is difficult to give definite recommendation. Over irrigation, as well as under irrigation may lower yields (Sultana, 2007). Efficient water management thus plays a vital role in mustard production. Irrigation had significant effect on all the yield and yield contributing characters (Hossain *et al*., 2013).

Keeping in view of above facts, a field experiment entitled, "effects of boron and irrigation on growth, yield and nutrients content of mustard (BARI sarisha-14)" was conducted during rabi 2019-20 to fulfill the following objectives:

1. To evaluate the effect of irrigation levels and boron fertilization on growth and yield of mustard.
2. To determine the nutrients content of mustard

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oil crop in Bangladesh, which can contribute largely in the national economy. Investigation on the influence of boron application and irrigation on the growth and yield of mustard have been progressed in many countries of the world. The proper fertilizer management and also agronomic practices like irrigation management accelerates its growth and influenced its yield. Therefore, available findings of the effect of irrigation and boron fertilizer and combined effect relevant to the present study have also been briefly reviewed under the following heads:

2.1 Effect of boron

Apart from major plant nutrients, boron plays an important role in the production phenology of mustard and this crop responds to applied boron (Yadav *et al.* 2016). Genotypic variations exist in sensitivity to boron deficiency. The problem of micronutrient deficiency is becoming more serious due to introduction of high yielding varieties, increasing cropping intensity, use of high analysis fertilizers and limited use of organic manures (Anonymous, 2010). These are causes for poor productivity of oilseed crops. Hence, it is necessary to adopt the proper micronutrient management practices especially boron to increase the productivity of oilseed crops.

Masum *et al*. (2019) conducted a study at (AEZ-20) Shiberbazar, Sylhet during November 2016- February 2017, to quantify the effect of boron on yield and yield attributes of mustard, and different doses and form of B application. Five B (boric acid) levels *viz*. T_1 = basal application of B @ 2kg ha^{-1}; T_2 = foliar spray (FS) of B @ 0.5% at vegetative stage (VS); T_3 = FS of B @ 1% at VS; T_4 = FS of B @ 0.5% at VS + pod formation stage (PFS) and T_5 = FS of B @ 1% at VS + PFS and T_6 =

control (no boron) were used. Results indicated that yield and yield attributes of mustard were significantly influenced by boron application. The effects of boron were significant on number of siliquae plant^{-1}, number of seeds siliqua^{-1}, seed yield, stover yield, 1000-seed weight, biological yield and harvest index (%). The highest number of siliquae plant^{-1} (35.93), number of seeds siliqua^{-1} (30.03), stover yield (1946.0 kg ha^{-1}) and 1000-seed weight (3.617 g) were obtained from the treatment T_5. The seed yield (801.17 kg ha^{-1}) was found also in the treatment T_5 which was over double than control (T_0). Therefore, two times foliar application of B @1 % at VS and PFS is a good option to increase yield and yield contributing characters of mustard in AEZ 20.

Recently, Awal *et al*. (2020) conducted an experiment to explore the effect of agronomic biofortification of sulphur and boron nutrients on the growth and yield of mustard crop. 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. Boron fertilizations significantly influence the plant height, production of branches and leaves per plant, dry matter accumulation and yield attributes and yield of mustard crop. The mustard crop fertilized with 40 kg S ha^{-1} in combination with 1 B kg ha^{-1} produced taller plant, higher number of branches and leaves in each plant and higher amount of dry matter per plant while these plant traits were found as minimum when the growing the mustard crops in control plots i.e. the plants received neither sulphur nor boron. Application of boron @ 1 kg ha^{-1} produced the highest seed yield (2.73 t ha^{-1}) whereas the lowest seed yield (1.08 t ha^{-1}) was found where no boron was applied. The result conclude that sulphur and boron @ 40 and 1 kg per hectare, respectively was found to be most effective dose in enhancing growth and yield of mustard crop.

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 consisted of two factors. Factor-A: nitrogen (N) doses: 4 doses, $N_{\mathbf{0}}$= without nitrogen, N_1= 60 kgha^{-1}, N_2=90 kgha^{-1}, N_3=120 kgha^{-1} and factor-B: boron (B) doses: 3 doses, $B_{\mathbf{0}}$= without boron, B_1=1 kg ha^{-1}, B_2 = 2 kg ha^{-1}. Data on different parameters related to seed yield and quality was recorded and statistically significant variation was found for nitrogen and boron. In terms of nitrogen fertilizer, 120 kg N ha^{-1} produced the highest in respect of plant height (67.67 cm), number of branches per plant (6.94), number of siliqua per plant (151.44), number of seeds per siliqua (24.90), 1000 seed weight (3.81 g), seed yield (1466.33 kg ha^{-1}), stover yield (4577.96 kgha^{-1}), harvest index (24.23 %) and the lowest value found at control in most of the parameters. In case of boron fertilizer, plant height (59.75 cm), number of branches per plant (6.67), number of siliqua per plant (124.61), number of seeds per siliqua (22.51), 1000 seed weight (3.71 g), seed yield (1321.08 kgha^{-1}), stover yield (4378.55 kgha^{-1}), harvest index (22.97 %) were highest in boron @ 2 kg B/ha whereas the lowest results were found in control. Due to the interaction effect of nitrogen and boron in mustard, the plant height (72.00 cm) , number of branches per plant (7.39), number of siliqua per plant (157.00), number of seeds per siliqua (26.37), 1000 seed weight (3.86 g), seed yield (1569.00 kgha^{-1}), stover yield (4712.65 kgha^{-1}), harvest index (25.00 %) were highest in nitrogen @ 120 kg Nha^{-1} combined with boron @ 2 kg Bha^{-1} whereas the lowest value was found in nitrogen @ 0 kg Nha^{-1} combined with boron @ 0 kg Bha^{-1} in mustard.

Azam *et al*. (2017) conducted an experiment in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during 2014-2015 to know the combined effect of different levels of sulphur (S) and boron (B) on yield and yield contributing characters, nutrient and oil content of mustard and to find out the suitable combination of sulphur (S) and boron (B) for yield maximization of mustard. There were 16 treatment combinations comprising four levels each of S

(S0= 0, S1=10, S2= 20 and S3= 30 kg S ha^{-1}) and B (B0= 0, B= 1, B2= 2 and B3= 3 kg B ha^{-1}). It was replicated thrice in a randomized complete block design. Results showed that the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) contributed positively for better performance of yield contributing characters of mustard. The combination S2B3 (20 kg S ha^{-1} and 3 kg B ha^{-1}) produced the highest grain yield (2180 kg ha^{-1}) followed by S3B2 and S3B3 treatment combination. The highest protein and oil content of mustard were recorded from S3B3 (30 kg S ha^{-1} and 3 kg B ha^{-1}) treatment followed by S2B3 treatment combination. Therefore, the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) might be suitable dose for cultivation of mustard in tejgaon series soils under agro-ecological zone of 28 (Madhupur Tract) Bangladesh.

Choudhary and Bhogal (2017) conducted a field experiment to study the response of mustard cultivars to boron application at Directorate of Rapeseed Mustard Research, Sewar, Bharatpur (Rajasthan). The experiment was laid out in split plot design with three cultivars of mustard (Aravali, Laxmi and Vardan) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}) with three replications. The results revealed that the mustard cultivar Laxmi produced higher mean seed yield (16.32q ha^{-1}) followed by Aravali (15.30 q ha^{-1}) and Vardan (14.05 q ha^{-1}). The seed yield of mustard was significantly influenced with the increase in the levels of B and the highest yield ((17.59q ha^{-1}) was recorded with 2 kg B ha^{-1}, which was significantly at par with 1.5kg B ha^{-1}. The B uptake by mustard seed increased significantly with its application and maximum value (53.6g ha^{-1}) was recorded with 2kg B ha^{-1}. Among the mustard genotypes, Laxmi utilized the maximum amount of B in its seeds followed by vardan and Aravali genotypes. The contents of protein and oil were maximum in seeds of Laxmi cultivars. The yields of protein oil were also highest in Laxmi cultivar. Boron application also significantly improved the contents and yields of protein and oil over control. Fatty acids except those of oleic and linolenic acid were not affected significantly by mustard cultivars. Oleic acid in oil increased and erucic acid decreased with increasing levels of boron. The SFA, linoleic, linolenic acids were not affected significantly by boron application. In general, the amounts of fatty acids were higher in oil of Aravali genotype than those of Laxmi and Vardan genotypes.

Yadav *et al*. (2016) conducted a field experiment at Agriculture Research Farm, Banaras Hindu University, Varanasi, during two consecutive rabi season of 2012-2013 and 2013-2014 to study the effect of boron (B) on growth, yield and quality of mustard *(Brassica juncea* L.). The experiment comprised of 11 B levels *i.e.,* 0, 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.50, 2.75 and 3.0 kg B ha^{-1}. The results revealed that the highest number of siliqua $plant^{-1}$ (242 and 245), length of siliqua (5.3 and 5.4 cm), number of seeds $siliqua^{-1}$ (16.3 and 16.2), seed yield (1.89 and 2.02 t ha^{-1}), oil content (35.5 and 36%) were recorded where 1.5 kg B ha^{-1} was applied, while maximum protein content (22.2 and 21.9%) was noticed with application of 1.75 kg B ha^{-1} during 2012-13 and 2013-14, respectively. Application of 1.5 kg B ha^{-1} gave average increase in seed yield of 36% and oil yield of 52%. It also increased the uptake of B by seed and stover significantly over control.

Kumararaja *et al.* (2015) conducted a field experiment to assess the effects of different levels of boron in B- deficient calcareous soil on yield and some yield components of Indian mustard (cv. Varuna). Application of boron significantly influenced the yield by improving the yield attributing characters. Application of 16 kg Borax/ ha resulted in maximum seed yield under both the years. Boron application improves the yield by 35-39% over the control. The dose response curve followed by first order derivative regression showed that optimum B fertilized dose was 1.73 kg B/ha. Boron contents in stem, leaves and seed increased significantly with increase in B application.

Padbhushan and Kumar (2014) conducted a greenhouse experiment with green gram grown on boron (B) deficient calcareous soils was to study the influence of soil and foliar applied boron on green gram. The treatments comprised of four levels of soil applied boron viz. 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1} and two levels of foliar applied boron viz. 0.1 and 0.2 per cent borax solution with common control. It was found that soil applied boron has more influence on mean dry matter yield while foliar applied boron has on mean grain yield. Among all soil applied boron 0.5 mg kg^{-1} is best treatment while 0.1% is best foliar treatment. Soil applied boron was at the par with foliar applied boron.

Hamideldin and Hussein (2014) conducted a field experiment in sesame plants which were sprayed with different concentrations of boron solution at 20, 30 and 40 ppm at different stages of plant growth (1, 2 and 3 months). Treating plants with boron solution at 20 ppm gave the highest results in growth criteria as compared with corresponding control or plants treated with higher boron solutions (30 and 40 ppm). The highest oil viscosity was recorded at a boron concentration of 30 ppm.

Maria and Ladislav (2014) performed an experiment to investigate the effect of increasing doses of boron on oil production of oilseed rape. Doses of nitrogen and sulfur (183 kg N ha^{-1}, 46.5 kg S ha^{-1}) and different doses of boron (200 g B ha^{-1}, 400 g B ha^{-1}, 800 g B ha^{-1}) were applied. The result shows that the boron nutrition positively influences the oil content in seeds of oilseed rape *(Brassica napus L.).*

Stoltz and Wallenhammar (2013) studied the effect of soil and foliar applied boron (B) on flower development, nectar production, seed yield and germination in organic red clover was investigated in B deficient soils. The results showed that there is a greater increase in seed yield when B is applied to the soil compared with foliar application. Among different treatments, soil applied 0.5 kg ha^{-1} dose was reported optimum.

Nandini *et al*. (2012) reported that soil application of boron @ 1.5 kg ha^{-1} recorded significantly higher plant height (57.53 cm) and branches (4.2 $plant^{-1}$) as compared to control (46.87 cm, 2.9 $plant^{-1}$ respectively). Again, application of boron @ 1.5 kg ha^{-1} also recorded significantly higher pods per plant (61), 100 seed weight (13.26 g), seed yield (1831 kg ha^{-1}) and harvest index (46.34 %) of soybean as compared to control 38, 12.66 g, 931 kg ha^{-1} and 44.21 % , respectively). This was mainly due to optimum application of boron helps in improving the productivity of soybean and lower yield in control plot due to boron deficiency in soil.

Hossain *et al*. (2012) conducted an experiment at the Regional Agricultural Research Station (RARS), Jessore (AEZ11, High Ganges River Floodplain) during 2003-2006 to evaluate the response of different varieties of mustard to boron application. Boron application was made at 0 and 1 kg/ha. The mustard varieties responded to B application. The response of the three *Brassica* species followed the order: *B. napus* > *B. campestris* > *B. juncea*. The varieties chosen from *B. campestris* were BARI Sarisha 6, BARI Sarisha 9, and BARI Sarisha 12. The *B. napus* varieties were BARI Sarisha 7, BARI Sarisha 8, and BARI Sarisha 13. Varieties BARI Sarisha 10 and BARI Sarisha 11 were from the *B. juncea* group. The seed yield was positively and significantly correlated with the yield contributing characters viz. pods/plant, seeds/pod, and 1000-seed weight, but not with plant height and pod length. This result showed that boron had positive influence on reproductive development, not on vegetative. The result suggests that BARI Sarisha 10 and BARI Sarisha 11 were the most B in-responsive (B efficient) varieties. So the farmers can grow these varieties in the moderately B deficient soils with a minimum dose (0.5 kg/ha) of B application.

Rashid *et al*. (2012) reported that soil application of boron @ 1.5 kg ha^{-1} has recorded significantly higher pods per plant (100), 100 seed weight (3.59 g), oil content (40.77 %) and seed yield (1.68 t ha^{-1}) of mustard as compared to control (75.7 $plant^{-1}$, 3.49 g, 39.95 % and 0.92 t ha^{-1}, respectively).

Khurana *et al.* (2012) in a field study reported that berseem fodder yield increased significantly in the first and second cuttings with soil application of 0.75 kg B ha^{-1}. However, significant increase in yield was obtained in the third cutting with the application of 1.0 kg B ha^{-1}.

Hossain *et al.* (2011) carried out a research to find out the optimum rate of B application for maximizing nutrient uptake and yield of mustard in calcareous soil, boron was applied at 0, 1, and 2 kg/ha. Effect of B was evaluated in terms of yield and mineral nutrients (N, P, K, S, Zn, and B) uptake. The mustard crop responded significantly to B application. Boron and N concentrations of grain and stover were significantly increased with increased rate of B application indicating that B had positive role on protein synthesis. In case of P, S, and Zn, the concentrations were significantly increased but in case of K, it remained unchanged in stover. The grain B concentration increased from 19.96 pg/g in B control to 45.99 pg/g and 51.29 pg/g due to application of 1 kg and 2 kg B/ha, respectively. Concerning the effect of B on the nutrient uptake, six elements followed the order K> N> S> P> B> Zn and these were significantly influenced by B application.

Aravind Kumar *et al.* (2010) reported that foliar application of boron @ 0.3 % sprayed at 35 and 55 DAS of sunflower has recorded significantly higher head weight (44.70 g), 100 seed weight (5.17 g) and seed yield (983 kg ha^{-1}) as compared to control (38.20 g, 4.83 g and 757 kg ha^{-1}, respectively). This was mainly due to boron helps in seed setting and seed filling resulted in higher productivity. And combined use of any two micronutrient could not shows any significant effect on yield over alone application of boron. Similar result was also observed by Nadian *et al.* (2010) and reported that soil application of boron @ 2.5 kg ha^{-1} has recorded significantly higher grain yield as compared to control.

Lalitha *et al.* (2008) reported that foliar spray of boric acid @ 0.2 % at 60 DAS of niger has recorded significantly higher 100 seed weight (5.87 g), seed yield (983 kg ha^{-1}), oil content (41.10) and oil yield (404 kg ha^{-1}) as compared other treatments.

Hussain *et al*. (2008) conducted an experiment at Farming Systems Research and Development (FSRD) site Jalalpur, Sylhet during the two consecutive rabi seasons of 2005-06 and 2006-07 in Surma-Kushiara flood plain soil (AEZ-20) to show the effect of boron application on yield and yield attributes of different mustard varieties. The experiment involved five boron levels viz. 0, 0.5, 1.0, 1.5 and 2.0 kg B / ha and three mustard varieties viz. BARI sharisha-8, BARI sharisha-9 and BARI sharisha-11. The result from two years experiment revealed that 1-1.5 kg boron/ha should be applied along with recommended fertilizers produced higher seed yield. BARI sharisha-11 and BARI sharisha-8 performed better and highly response to boron than BARI sharisha-9. Highest seed yield (1.57 t/ha) was obtained from the combination of BARI Sharisha - 11 and boron level 1.0 kg/ha.

Harmankaya *et al.*, (2008) observed that the yield loss in common bean *(Phaseolus vulgaris* L.) was due to boron deficiency when the susceptible cultivars were grown in calcareous boron deficient soils. The yield was obtained higher in boron applied genotypes (Sehirali-90, Yunus-90, Karacasehir-90, Onceler-90, Goyniik-98 and Akman-98) than control. Applications of soil and foliar boron increased yield average of 10 and 20 per cent, respectively.

Halder *et al*. (2007) carried out a field experiment during the two consecutive seasons of 2000-2002. The objectives were to evaluate the effect of boron on the yield of mustard and to screen out the suitable variety (s) tested against different boron levels for maximizing yield of mustard in the study area. Four varieties of mustard *viz*., BARI Sharisha-6, 7, 8 and 9 and 4 levels each of boron (0, 1.0, 1.5 and 2.0 kg ha^{-1}) along with a blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5 t ha^{-1} were taken in the study. Results revealed that BARI Sharisha-6 integrated with 1.5 kg B ha^{-1} was found to be superior to all other treatment combinations. The highest mean seed yield of sunflower (1.96 t ha^{-1}) was recorded with the said treatment by 25.64% yield increase. Among the 4 tested varieties of mustard, BARI Sharisha-7 showed a good performance and produced the highest mean yield (1.77 t ha^{-1}) as compared to other varieties used. On the other hand, boron at the rate of 1.5 kg ha^{-1} individually increased the highest seed yield by 58.83%, over boron control (B_0). However, from regression analysis, a positive but quadratic relationship was observed between seed yield and boron levels.

Dixit and Elamathi (2007) reported that foliar application of boron (0.2 per cent) in green gram increased the plant height, number of nodules $plant^{-1}$, dry weight $plant^{-1}$ and number of pods $plant^{-1}$, 1000-seed weight, grain yield and haulm yield over the control.

Halder *et al.* (2007) reported that soil application of boron @ 1.5 kg ha^{-1} has recorded significantly higher yield of sunflower as compared to control. Patil *et al.* (2006) reported that application of boron and zinc through soil as well as foliar application among them foliar application of borax @ 0.1 % at 55 DAS has recorded significantly higher yield parameters of sunflower as compared to soil application.

Malewar *et al.*, (2001) reported that with increasing levels of borax up to 10 kg Borax ha^{-1}, stover yield increased from 9.47 to 14.41 percent and seed yield increased from 6.54 to 10.21 percent in mustard.

2.2 Effect of irrigation

Bangladesh Agricultural Research Institute (BARI) developed a number of Brassica oilseed varieties with high yield potentials and improved management practices, the yield range being between 1.4 and 2.1 t ha^{-1} (BARI, 2016). Therefore, there is a scope to increase the yield level by using High Yielding Variety (HYV) and adopting proper management practices like spacing, weeding, irrigation, seed rate, fertilizer application etc. In Bangladesh, both rapeseed and mustard are grown on the residual soil moisture in winter season. Irrigation is a vital factor for proper growth and development of rapeseed and mustard crops in dry season. Because requires water 60 to 169 mm water throughout its life cycle (Rahman, 1989; Sarkar *et al*., 1989). In fact, Brassica is an irrigated crop since its yields is greatly increased by the presence of adequate soil moisture in different growth stages (Prasad and Eshanullah, 1988). Singh *et al.* (2002) tested four *Brassica* spp. *(Brassica carinata, Brassica napus, Brassica juncea and Brassica campestris)* under 2 moisture regimes, i.e. normal irrigation (3 irrigations at branching, bolting and siliquae filling stages) and limited irrigation (one irrigation at branching stage). Results revealed that growth, development and yield of all *Brassica* spp. were adversely affected under limited irrigation condition.

Rana *et al*. (2020) conducted a field experiment to evaluate the effect of sulfur fertilization and irrigation scheduling on mustard hybrids. Experiment comprised 18 treatment combination involving three irrigation scheduling (0.4, 0.6 and 0.8 IW/CPE) and two hybrids (NRCHB-506 and PAC 432) as main plot treatment and three sulfur (S) levels (0, 30 and 60 kg S ha^{-1}) as sub-plot treatment in split-plot design replicated thrice during rabi season (Oct-March) of 2015-16 and 2016-17. Statistical analysis of the results revealed that individually irrigation scheduling at 0.8 IW (Irrigation water)/CPE (Cumulative pan evaporation), mustard variety 'PAC 432' and sulfur application at 60 kg ha^{-1} reported to have maximum plant height, number of primary and secondary branches, dry matter accumulation, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, siliqua length and seed yield. Similar results were also obtained in relation to dry matter heat use efficiency (DM-HUE) at different stages and seed yield HUE. However, the variation in most of the parameters observed with either 0.6 or 0.8 IW/CPE and application of 30 or 60 kg S ha^{-1} was found non-significant during the course of the trial. In terms of interaction, mustard variety 'PAC 432' irrigated at 0.8 and 0.6 IW/CPE and fertilized with 60 or 30 kg S ha^{-1} proved significantly superior over other treatments and recorded the highest plant height, better yield constituents and maximum yield, while the lowest values for the same were recorded in 'NRCHB-506' irrigated at 0.4 IW/CPE with no sulfur application during both the years of experimentation.

Singh *et al*. (2019) conducted field experiments for two consecutive rabi seasons during 2014-15 and 2015-16 to evaluate growth and yield parameters of yellow *sarson (Brassica rapa* L.) affected by different irrigation levels, planting methods and mulching. Significantly higher numbers of leaves per plant and dry matter accumulation in leaves and stem were reported at 1.2 IW (Irrigation water)/CPE (Cumulative pan evaporation) ratio over 0.6 and 0.3 IW/CPE ratio in both the years of study. Seed yield of yellow *sarson* increased significantly up to 0.9 IW/CPE ratio as compared to remained irrigation levels. In both the years, yellow *sarson* planted on raised bed produced 11.5 and 7.1 per cent higher seed yield with higher number of leaves over flat bed planting method, respectively. Application of rice straw mulch recorded 11.7 and 12.3 percent significantly higher seed yield than no mulch, respectively.

Alamin *et al*. (2019) conducted an experiment to evaluate the effect of sowing time and irrigation frequency on the growth and yield of mustard. The treatment consisted of three different sowing times (*viz*., T_1 = Early sowing, T_2 = Optimum sowing, T_3 = Late sowing), and four irrigation frequency (*viz*., I_0=No irrigation, B= 1 irrigation, I_2 =2 irrigation and I_3= 3 irrigation). There was a significant variation among the treatments in respect of major parameters studied. The tallest plant was recorded with optimum sowing time. The maximum number of leaves, number of branches $plant^{-1}$, and number of siliquae $plant^{-1}$ and length of siliqua was found with optimum sowing time. The maximum yield (1.12 t ha^{-1}) of seed was exhibited from optimum sowing time. The tallest plant was produced with three irrigation. The maximum branches $plant^{-1}$, siliqua $plant^{-1}$ and seed $silliqua^{-1}$

were recorded from three irrigation. The highest (1.05 t ha^{-1}) yield of seed was obtained from three irrigation. The combinations of sowing time and irrigation had significant effects on most of the parameter. The highest yield (1.42 t ha^{-1}) of seed was obtained from the combination of three irrigation and optimum sowing time. The highest stover and biological yield was obtained from the combination of three irrigation and optimum sowing time.

Rathore *et al.* (2019) conducted a field experiment to evaluate the effect of differential irrigation regimes on mustard and found the significant positive effect of irrigation on different parameters of mustard such as plant height, dry matter $plant^{-1}$, number of primary and secondary branches $plant^{-1}$, grain yield, stover yield and harvest index.

Shivran *et al*. (2018) conducted a field experiment during rabi season of 2013-2014 to study the effect of various irrigation schedule and sulphur levels on productivity and water use efficiency of Indian mustard *[Brassica juncea* (L.)]. The pH of soil of experiment field was 7.3 with available N 129.0, P_2O_5 17.1 and K_2O 187 kg ha^{-1}. The treatment consisted of six irrigation stages IR0 (no sown irrigation), IR_1 (30-35 DAS), IR_2 (flowering), IR_3 (30-35 DAS and flowering), IR_4 (30-35 and siliqua development) and IR_5 (30-35, flowering + siliqua development) in main plot. And three levels of Sulphur S0 (no sulphur), S_1 (20 Kg ha^{-1}) and S_2 (30 kg ha^{-1}) in sub plot were tested in split plot design (SPD) with three replications. Results showed that the maximum seed yield was observed with the three irrigation levels IR_5 (30-35 + F + SD) which were higher by 20.47, 25.51, 47.01, 54.65 and 123.90 percent over IR_4, IR_3, IR_2, IR_1 and IR_0 respectively.

Jat *et al.* (2018) conducted a field experiment and evaluated the effect of differential irrigation regimes and confirmed about the significant positive impact of irrigation on agronomic traits such as plant height, dry matter $plant^{-1}$, number of primary and secondary branches $plant^{-1}$.

Roy *et al*. (2017) conducted an experiment during October 2013 to February 2014 to evaluate the effect of irrigation and sulphur (S) application on the growth, yield and oil content of rapeseed *(Brassica napus).* There were three levels of irrigation *viz*. no irrigation, one irrigation at 25 days after sowing and two irrigation at 25 days after sowing and 53 days after sowing, and three levels of S viz. 15, 30 and 45 kg S ha^{-1} as gypsum .The experiment was laid out in a split plot design with three replications assigning irrigation in the main plots and S levels in the subplots. Irrigation and added S significantly influenced plant height, number of primary and secondary branches per plant, number of siliquae per plant, siliqua length, seeds per siliqua, seed yield and seed oil content. Seed yield was mainly influenced by number of siliquae per plant and seeds per siliqua. Two irrigations had better performances on all parameters under study. The highest seed yield (1527 kg ha^{-1}) was obtained with two irrigations coupled with application of 45 kg S ha^{-1} which was statistically similar to two irrigations with 30 kg S ha^{-1}. Sulphur application greatly influenced seed oil content showing the highest oil content due at 45 kg S ha^{-1}.

Parmar *et al.* (2016) studied the yield attributing traits such as number of siliquae plant^{-1}, number of seeds siliquae^{-1}and 1000-seed weight as affected by irrigation regimes and found considerable increase in them with increase in IW: CPE ratio from 0.60 to 1.0.

Hossain *et al*. (2013) carried out an experiment to study the effect of irrigation and sowing method on yield and yield attributes of mustard. The experiment consists of two factors i) irrigation *viz*. no irrigation (I_0), one irrigation (I1)and two irrigations (I2) ii) sowing method *viz*. line sowing method (M_1) and broadcasting method (M_2). Irrigation had significant effect on all the yield and yield contributing characters. The highest plant height, number of branches plant^{-1}, filled siliqua plant^{-1}, sliqua length, number of seed siliqua^{-1}, 1000-seed weight and stover yield were obtained from I_2 (two irrigations) and consequently it produced the highest seed yield. Sowing method also had significant influence on almost all the yield and yield contributing characters. All the yield contributing characters except number of unfilled siliqua plant^{-1}were found best at line sowing method (M_1) and consequently it produced the highest seed yield. However it could be noted from the study that the combination of two irrigations with line sowing method is better to get higher yield of mustard.

Kibbria (2013) conducted an experiment with no irrigation, one irrigation at pre-flowering and two irrigation (one at pre-flowering and siliquae formation) and three irrigation (one at pre-flowering, siliquae formation stage and seed maturation). Three irrigations applied at 20, 40 and 60 DAS produced more plant height (101.00 cm) than under no irrigation. Significant increase in dry matter was found up to three irrigations. The maximum number of primary branches (7.70) per plant with two irrigations compared to without irrigation. The highest siliquae plant^{-1} (138.8) increased by two irrigation than no irrigation (111.9). Maximum number of seeds (20.06) siliqua^{-1} was found when two irrigations were applied (one at pre-flowering stage and one at siliquae formation). Length of siliqua (5.23 cm) was highest with two irrigation compared to one irrigation or without irrigation (control). Maximum weight of 1000 seeds (3.16 g) siliquae^{-1} was found when two irrigations were applied. The highest seed yield (1.98 ton ha^{-1}), stover yield was (1.98 ton ha^{-1}) and biological yield (3.97) was by two irrigations (before flowering and siliquae formation stage) whereas the lowest was from control (no irrigation). The maximum harvest index (51.16 %) was obtained from two irrigations and the minimum harvest index (48.72%) was obtained from no irrigation.

Piri *et al.* (2011) showed that application of two irrigations at 45 and 90 DAS significantly increased plant height. The maximum number of branches per plant of mustard with one irrigation at 45 DAS than two irrigations at 45 and 90 DAS followed by no irrigation. Application of two irrigations at 45 and 90 DAS significantly increased 1000 seeds weight, seed yield, stover yield than one irrigation and no irrigation. The increase in stover yield also may be attributed to higher plant height than more number of total branches.

Meena (2011) noted improvement in total number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1}, test weight and seed yield with increasing IW/CPE ratio and maximum values of these parameters were recorded under 0.8 IW (Irrigation water)/CPE (Cumulative pan evaporation) ratio.

Meena (2010) observed that with application of three irrigations at branch initiation, 50% flowering and 50% pod development stages of mustard, significantly higher values of nitrogen, phosphorus and potassium content in seed and stover as well as nitrogen uptake by respective parts were noticed.

Sultana *et al*. (2009) carried out a study during November 2006 to March 2007 to evaluate the effect of irrigation and variety on growth, yield attributes and yield of rapeseed. The treatment comprised of three levels of irrigation viz. no irrigation, one irrigation at 20 DAS, one irrigation at 35 DAS, two irrigations at 20 and 35 DAS and three irrigations at 20, 35 50 DAS and three varieties *viz*. SAU Saris ha^{-1}, Kollania and Improved Tori-7. Three irrigations (at 20, 35 and 50 DAS) increased economic yield with higher values of harvest index as the yield attributes like branches plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1} and 1000 seed weigh were higher. The seed yield with three irrigations was 111.93% and 10.73% higher than no irrigation and two irrigations, respectively. The variety SAU Sarisha-1 showed its superiority by producing 1.4 % and 45.94 % higher yield than Kollania and Improved Tori-7, respectively. This variety (SAU Sarisha-1) also showed higher branches plant^{-1}, seeds siliqua^{-1}, 1000 seed weight, biological yield and harvest index. In most of the cases interaction of three irrigations with SAU Sarisha-1 performed best in respect of grain yield as well as other studied parameters. The highest seed yield (1827.0 kg ha^{-1}) was obtained with the interaction of three irrigation with SAU Sarisha-1. This was achieved due to the maximum number of branches plant^{1}, seeds siliquae^{-1} and 1000 seed weight in this interaction.

Nagdive *et al.* (2007) conducted a study at three irrigations given to mustard crop at branching, flowering and siliquae development stages and recorded marked improvement in yield and quality of seed and showed higher content of oil and protein.

Sultuna (2007) carried out an experiment on rapeseed in Sher-e - Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. The maximum plant height was found at three irrigation (20, 35, 50 DAS) compared to other treatments including control (no irrigation). The highest plant dry matter, maximum number of branches per plant, number of siliquae per plant and number of seeds siliqua^{-1} were found at three irrigation (20, 35, 50 DAS) compared to other treatments including control (no irrigation). It was also found that the 1000 seeds weight, seed yield (1827.0 kg ha^{-1}), biological yield and harvest index were higher at three irrigation (20, 35, 50 DAS) than control treatment (no irrigation).

Ghanbahadur and Lanjewar (2006) observed higher number of siliquae plant^{-1}, pod length, number of seeds pod^{-1} and test weight with irrigation at 0.6 IW: CPE than at 0.4 IW: CPE resulting in increment of seed, stover and biological yield over 0.4 IW: CPE ratio.

Piri and Sharma (2006) when made an assessment of effect of different irrigation regimes in north western plains vouched for the fact that increasing the frequency of irrigation from 0 to 2 and applying them at 30 and 60 DAS culminated in significantly better performance of mustard with respect to plant height, dry matter accumulation, secondary branches plant^{-1} and relative growth rate.

Latif (2006) conducted an experiment to observed the effect of irrigation on the growth and yield of rapeseed *(Brassica campertries).* He tested four irrigation treatments *viz.,* no irrigation, one irrigation (at pre-flowering stage), two irrigation (one at pre-flowering stage and siliquae formation) and three irrigation (one at pre-flowering stage, siliquae formation and seed maturation stage). Plant height was maximum (104.46 cm) with three irrigations compared to no irrigation (control). Maximum number of seeds per siliquae (27.20), siliquae length (7.65 cm) and number of siliquae (136.24) were found when three irrigations were applied compared to no irrigation (control).

Yadav (2005) conducted a study in arid area of Bikaner, irrigation was observed to improve growth characters and application of irrigation at three stages of crop growth *viz*., branching, flowering and pod filling recorded higher plant height, dry matter accumulation Plant^{-1}, chlorophyll content, number of primary and secondary branches plant^{-1}.

Kumawat (2004) conducted a field study with the application of three irrigations at branching, flowering and siliqua development stages significantly increased N, P and K concentrations in seed and stover as well as their uptake in comparison to less frequent irrigation. Similar effect of irrigation regimes was also noticed by Ghanbahadur and Lanjewar (2006) who observed significantly higher uptake of both N and P in 0.6 IW: CPE ratio as compared to 0.4 IW: CPE.

Giri (2001) conducted two experiments to find out the effect of irrigation on growth and yield of mustard. Dry matter production was 107.1 g plant^{-1} with two irrigations at flowering and siliquae development stage, which was higher than the dry matter produced with one irrigation at flowering stage but one irrigation, produced higher dry matter than two irrigation. In case of two irrigation, siliquae number (277) was found in irrigation at flowering and siliquae formation stage followed by siliquae per plant (324) with one irrigation at flowering stage. But the difference was not significant.

Raut *et al.* (1999) studied the effects of irrigation (at pre-Flowering and siliquae setting stages, pre-flowering + 50% flowering + siliquae setting stages, pre flowering + 50% flowering + seed filling stages, and pre-flowering + 50% flowering + siliquae setting + seed filling stages) on the dry matter production and yield of Indian mustard cv. Pusa Bold. Irrigations once at pre-flowering + 50% flowering + siliquae setting + seed filling stages gave the highest dry matter production at 30 DAS (1.2 g per plant). Pre-flowering + 50% flowering + seed filling stages gave the highest dry matter production at 90 DAS (74.0 g per plant) and at harvest (112.25 g per plant) as well as the highest grain yield (15.99 q ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to study the effect of boron fertilizer and irrigation frequency on growth, yield and nutrient content of mustard (BARI sarisha-14). The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter 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). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix II.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix III.

3.4 Test crop

Seeds of BARI sarisha-14 as plant material were used for the present study.

3.5 Experimental details

3.5.1 Treatments of the experiment

Factor A: Boron application– Four levels

1. B_0 = Control (0 kg B ha^{-1})
2. B_1 = 0.5 kg B ha^{-1}
3. B_2 = 1.0 kg B ha^{-1}
4. B_3 = 1.5 kg B ha^{-1}

Factor B: Irrigation levels – Three irrigations

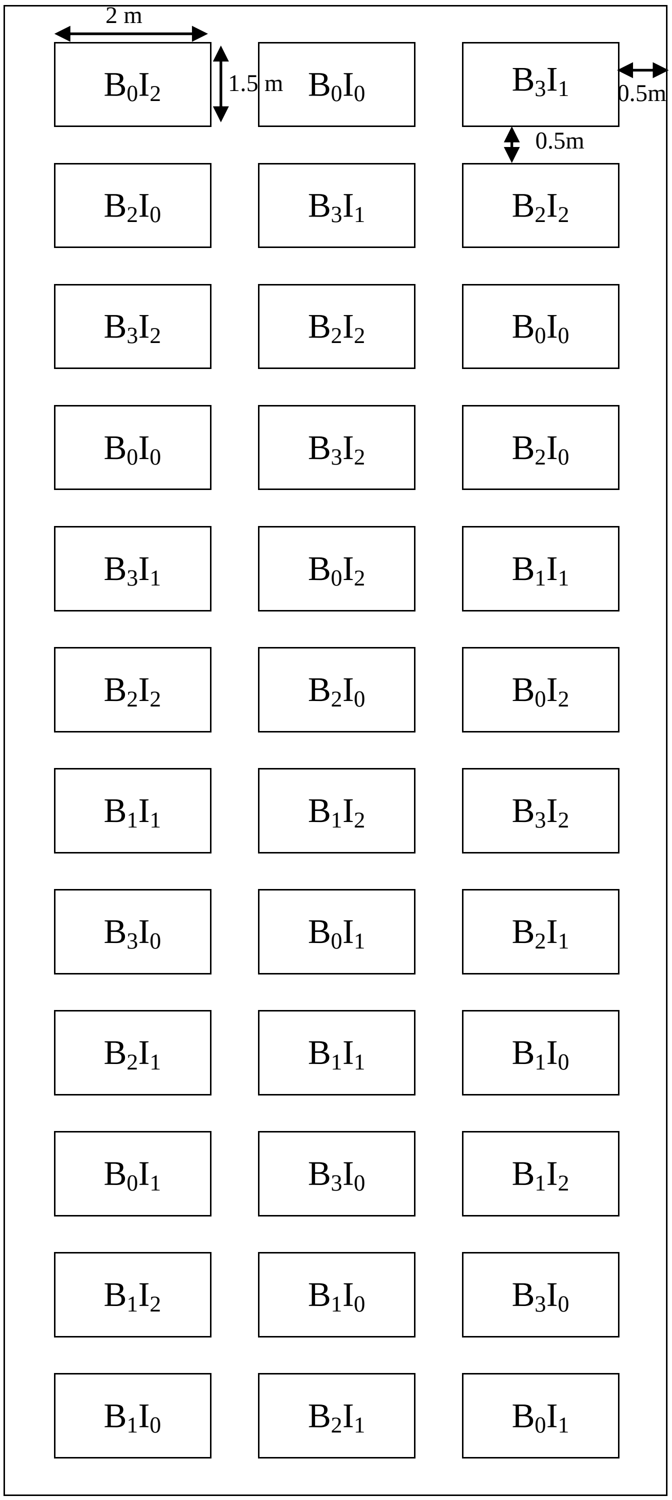
1. I_0 = Control (No irrigation)
2. I_1 = One irrigation at 25 DAS
3. I_2 = Two irrigations at 25 and 50 DAS

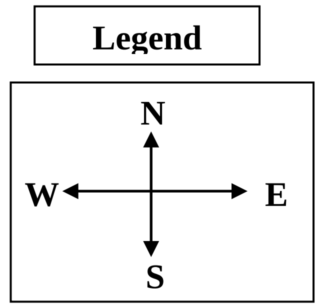
Treatment combinations – Twelve (12) treatment combinations

B_0I_0, B_0I_1, B_0I_2, B_1I_0, B_1I_1, B_1I_2, B_2I_0, B_2I_1, B_2I_2, B_3I_0, B_3I_1 and B_3I_2.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of different levels of boron (B) and irrigations. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot was 1.50 m × 2 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The layout of the experiment field is presented in Figure 1.





Treatments

Factor A: Boron– Four levels

1. B_0 = Control (0 kg B ha^{-1})
2. B_1 = 0.5 kg B ha^{-1}
3. B_2 = 1.0 kg B ha^{-1}
4. B_3 = 1.5 kg B ha^{-1}

Factor B: Irrigation– Three irrigations

1. I_0 = Control (No irrigation)
2. I_1 = One irrigation at 25 DAS
3. I_2 = Two irrigations at 25 and 50 DAS

Fig. 1. Layout of the experimental plot

3.5.3 Collection of seeds

BARI sarisha-14, a high yielding variety of mustard developed by Bangladesh Agricultural Research Institute (BARI), Gazipur was used as test crop. Seeds were collected from BARI, Joydebpur, Gazipur.

3.6 Preparation of the main field

The plot selected for the experiment was opened in the last week of October, 2019 with a power tiller, and was exposed to the sun for a few days, after that the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing seeds. The land operation was completed on 4 November 2019. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Fertilizers and manure application

The N, P, K, S, Zn and B nutrients were applied through urea, Triple super phosphate (TSP), Muriate of potash (MoP) Gypsum, $ZnSO_4$ and Boric acid, respectively. Boron (B) was applied in the plot as per treatment where rest of the nutrients was applied according to Krishi Projukti Hat Boi, BARI, 2016. Name and doses of nutrients were as follows:

Plant nutrients	Manure and fertilizer	Doses ha^{-1}
--	Cowdung	10 t
N	Urea	220 kg
P	TSP	160 kg
K	MoP	80 kg
S	Gypsum	130 kg
Zn	$ZnSO_4$	4 kg
B	Boric acid	As per treatment

One third (1/3) of whole amount of Urea and full amount of TSP, MoP, $ZnSO_4$ and Gypsum were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 20 days after transplanting (DAT) and 50 DAT respectively.

3.8 Sowing of seeds

Seeds were sown continuously @ 7 kg ha^{-1} on 5 November 2019 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept about 120 per plot. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mustard.

3.9.1 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 29 November 2019. The final weeding and thinning were done after 24 days of sowing, on 29 November 2019. Care was taken to maintain constant plant population per plot**.**

3.9.2 Irrigation

Irrigation was done as per treatments. Three irrigation treatments including control were used under the present study. Maximum two irrigations were applied according to treatments followed by one irrigation.

3.9.3 Plant protection

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2ml L^{-1}

water. The insecticide was sprayed twice, the first on 25 November 2019 and the last on 10 January, 2020. The crop was kept under constant observations from sowing to harvesting.

3.10 Harvesting

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 10 February 2020. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds and stover were put in desiccators for chemical analysis.

3.11 Data collection

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise. The following parameters were recorded during the study:

3.11.1 Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

3.11.2 Yield contributing parameters

1. No. of siliqua plant^{-1}
2. Length of siliqua (cm)
3. No. of seeds siliqua^{-1}
4. Weight of 1000 seeds (g)

3.11.3 Yield parameters

1. Grain yield (kg ha^{-1})
2. Stover yield (kg ha^{-1})
3. Harvest index (%)

3.11.4 Nutrients content

1. Nitrogen (N) content in straw (%)
2. Potassium (K) content in straw (%)
3. Phosphorus (P) content in straw (%)
4. Boron (B) content in seed and straw (ppm)

3.12 Procedure of recording data

3.12.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of 10 plants of each plot. The height was measured from the ground level to the tip of the leaves and average was recorded.

3.12.2 Number of leaves plant^{-1}

Number of leaves were calculated from randomly selected 10 sample plants and the mean data was recorded.

3.12.3 Number of branches plant^{-1}

The total number of branches was counted from randomly selected 10 plants of each plot. The average branches number was calculated which is termed as number of branches plant^{-1}.

3.12.4 Number of siliquae plant^{-1}

Number of total siliquae of ten plants from each unit plot was noted and the mean number was expressed as per plant basis.

3.12.5 Length of siliqua

The length of 10 siliquae from each samples were collected randomly and the mean length was expressed as per siliqua basis (cm).

3.12.6 Number of seeds siliqua^{-1}

Number of total seeds of ten randomly selected samples of siliquae from each plot was noted and the mean number was expressed as per siliqua basis.

3.12.7 Weight of 1000 seeds

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance and the mean weight were expressed in gram.

3.12.8 Seed yield

Dry weight of seed (at 10% moisture level) from harvested area of each plot was taken and then converted to ton per hectare.

3.12.9 Stover yield

Dry weight of straw (sun dried) from harvested area of each plot was taken and then converted to ton per hectare.

3.12.10 Harvest index

The harvest index was calculated on the ratio of grain yield to biological yield and expressed into percentage. It was calculated by using the following formula:

$$\text{Harvest Index} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

Where, Biological yield = Grain yield + Stover yield

3.12.11 Analysis of different chemical constituents of tomato fruits

Chemical analysis was done in the laboratory following the procedure of nutrient content measurement in fruit regarding nitrogen (N), phosphorus (P), potassium (K) and boron (B).

3.12.11.1 Determination of nitrogen (%)

Oven dried of plant samples were grined in a Mill passed through 40 mesh screen, mixed well and stored in plastic vials.

For the determination of N an amount of 1 g oven dry grined sample were taken in a micro Kjeldahl flask. One gram catalyst mixture (K_2SO_4; $CuSO_4.5H_2O$ in the ratio of 100:10:1) and 10 ml conc. H_2SO_4 were added. The flasks were heated at 160°C and added 2 ml H_2O_2 than heating was continued at 360°C until digests become clear and colorless.

After cooling the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner.

Nitrogen in the digest was estimated by distilling with 10N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

The amount of nitrogen was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight (g)

3.12.11.2 Determination of phosphorus and potassium (%)

Oven dried of plant samples were grined in a Mill passed through 40 mesh screen, mixed well and stored in plastic vials.

Exactly 1 g of grined fruit sample was taken in a 250 ml conical flask. 20 ml Di-acid mixture was added (previously prepared by adding 60% HNO_3 and $HClO_4$ in 2:1 ration through wet oxidation method) to the fruit sample.

Flask was stirred to moisten the entire mass of tissue and was placed on an electric hot plate. The content was heated at 180-200°C until white fume was evolved. 5 ml Di-acid mixture was added to the flask if the contents become dry before the end of the digestion. The flask was removed from the hot plant and was allowed to cool. Than 20-30 ml distilled water was added and shaken and after that the solution was filtered with Whatman Filter Paper No.1 in 100 ml volumetric flask. The conical flask was washed several times to ensure that all the minerals are transferred to the volumetric flask. The volume was made upto the mark with distilled water.

The contents of phosphorus (P) was measured by Spectophotometer HALO DB-20S at 660 nm and potassium (K) was measured by flame photometer JENWAY PFP7.

3.12.11.3 Determination of boron (ppm)

Oven dried of plant samples were grined in a Mill passed through 40 mesh screen, mixed well and stored in plastic vials.

Exactly 0.5 g of grined fruit sample was taken in a 250 ml conical flask. 5 ml Di-acid mixture was added (previously prepared by adding HNO_3 and $HClO_4$ in 5:1 ration through wet oxidation method) to the fruit sample. Flask was stirred to moisten the entire mass of tissue and was placed on an electric hot plate.

The content was heated at 150-200° for 2-2.5 hours and was cooled. The solution was filtered with Whatman Filter Paper No.1 in 25 ml volumetric flask for stock solution. 2 ml of stock solution was taken and added 4 ml buffer solution (250 g Ammonium acetate + 15 g Na EDTA + 400 ml distilled water + 400 ml acetic acid and final volume is 1000 ml) and 4 ml Azomethen-H (0.20 g Azomethen-H + 0.50 g ascorbic acid and final volume 100 ml) and wait till 30 minutes.

The contents of boron (B) was measured by Spectophotometer at 420 nm.

3.13 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

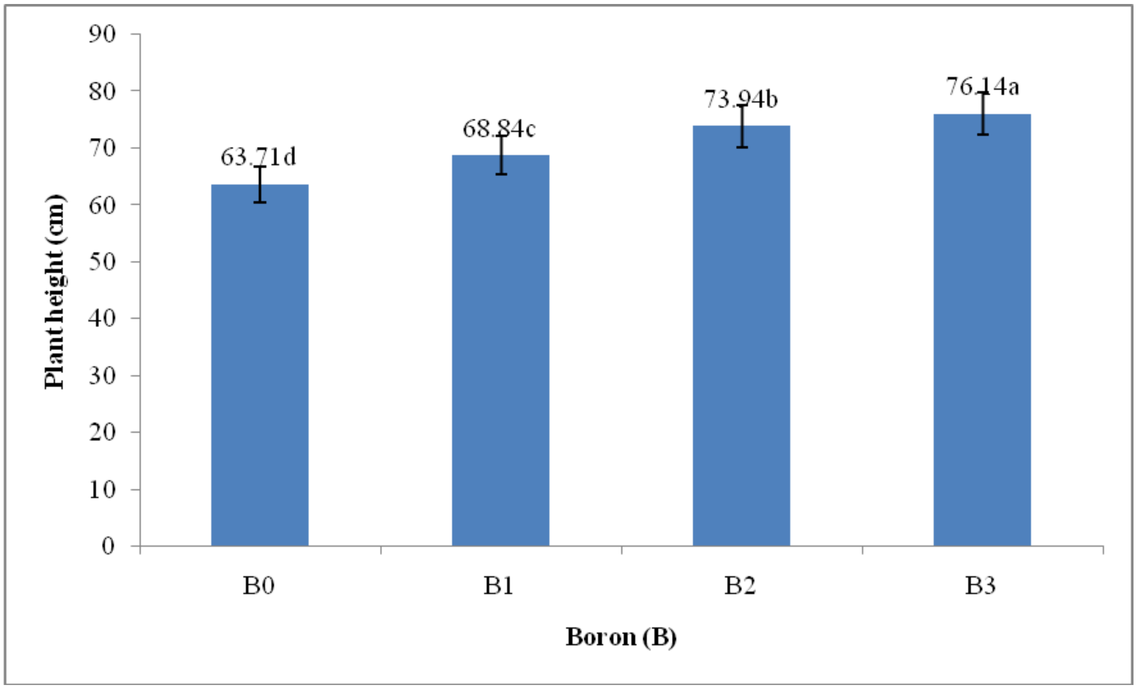
The study was conducted to find out the effect of boron fertilizer and irrigation frequency on growth, yield and nutrient content of mustard (BARI sarisha-14). The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

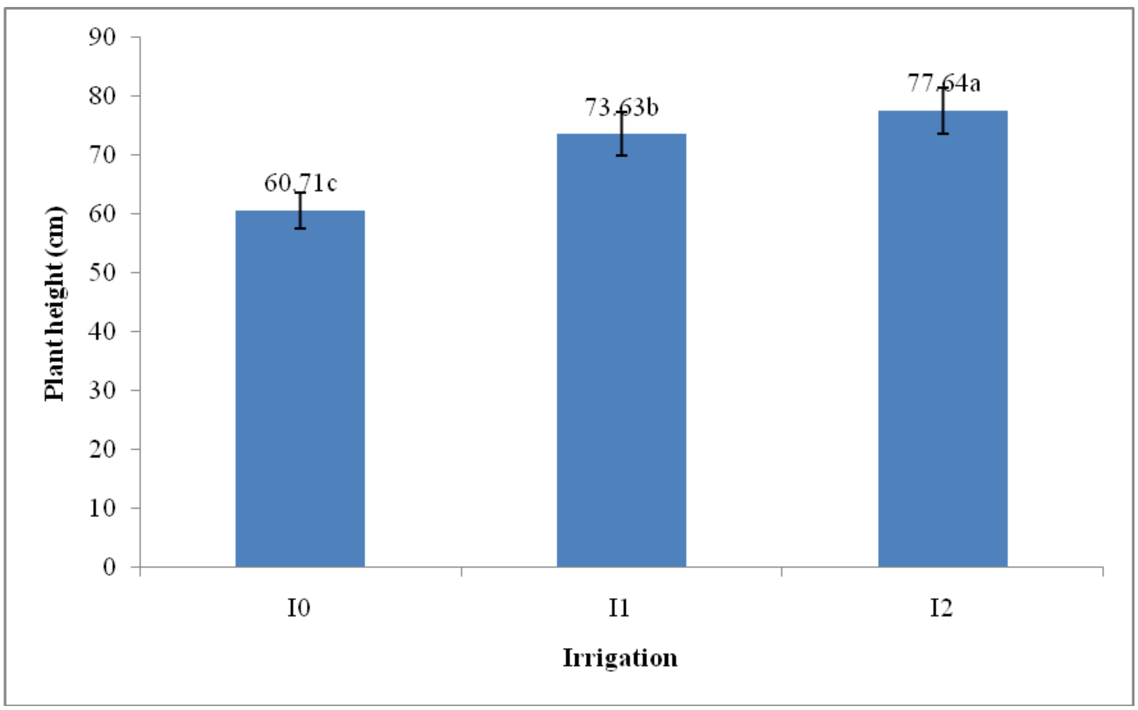
Different boron treatment showed a statistically significant variation for plant height of mustard under different irrigations (Figure 2 and Appendix IV). Results showed that the treatment B_3 (1.5 kg B ha^{-1}) gave highest plant height (76.14 cm) was recorded from which was significantly different from other treatments followed by B_2 (1.0 kg B ha^{-1}). The lowest plant height (63.71 cm) was recorded from the control treatment B_0 (0 kg B ha^{-1}). This finding was agreed with the result of Awal *et al*. (2020) and Riaj *et al.* (2018). Results showed that plant height was increased with the increasing of boron. Riaj *et al*. (2018) achieved highest plant height of mustard at 2 kg B/ha compared to control and 1 kg B/ha.

Different level of irrigation exhibited statistically significant differences for plant height of mustard (Figure 3 and Appendix IV). It was found that I_2 (Two irrigations at 25 and 50 DAS) treatment showed highest plant height (77.64 cm) which was significantly different from other treatments followed by I_1 (One irrigation at 25 DAS) whereas the lowest plant height (60.71 cm) was recorded from the control treatment I_0 (No irrigation).



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

Figure 2. Plant height of mustard as influenced by different levels of boron



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

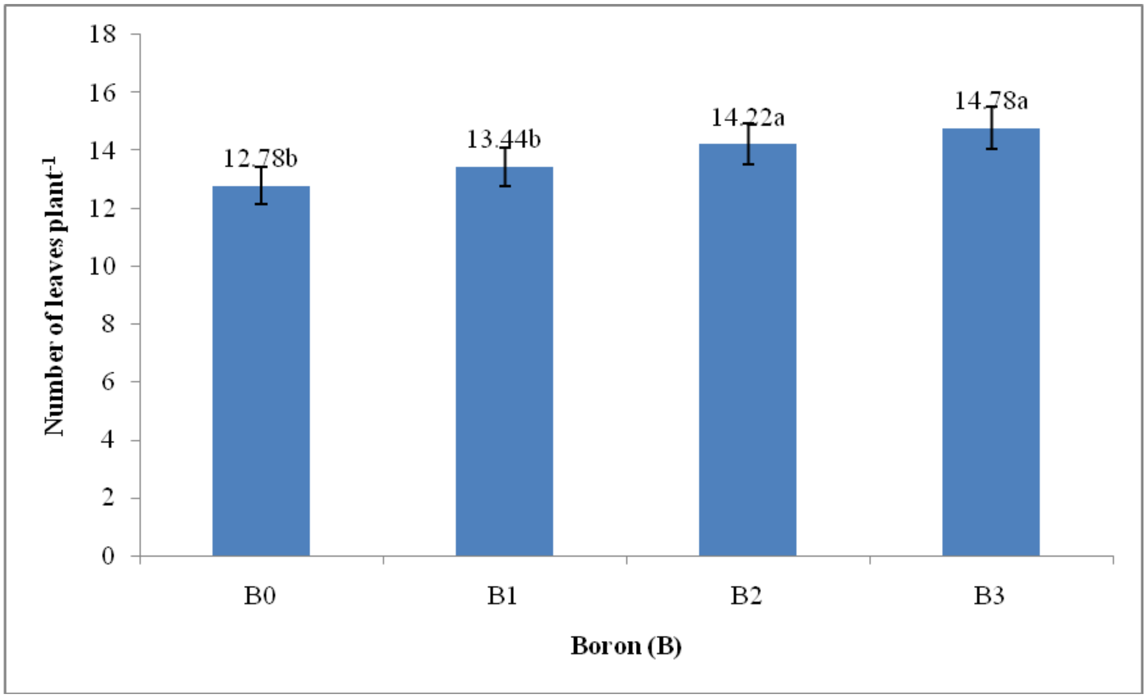
Figure 3. Plant height of mustard as influenced by different levels of irrigation

Results also showed that plant height increased with the increase of irrigation frequencies. It might be due to the soil moisture availability for the plant was sufficient. Similar result was reported by Rathore *et al.* (2019), Rathore *et al.* (2019), Latif (2006), Sultana (2007) and Kibbria (2013). Piri *et al*. (2011) and Hossain *et al*. (2013) reported maximum plant height when two irrigations were applied during branching and siliquae development stage.

Significant interaction effect was also recorded between boron and irrigation levels in consideration of plant height of mustard under the present experiment (Table 1). Results revealed that the highest plant height (84.68 cm) was recorded from the treatment combination of B_3I_2 which was statistically similar with the treatment combination of B_2I_2. The lowest plant height (58.03 cm) was recorded from the treatment combination of B_0I_0 which was statistically identical with the treatment combination of B_1I_0.

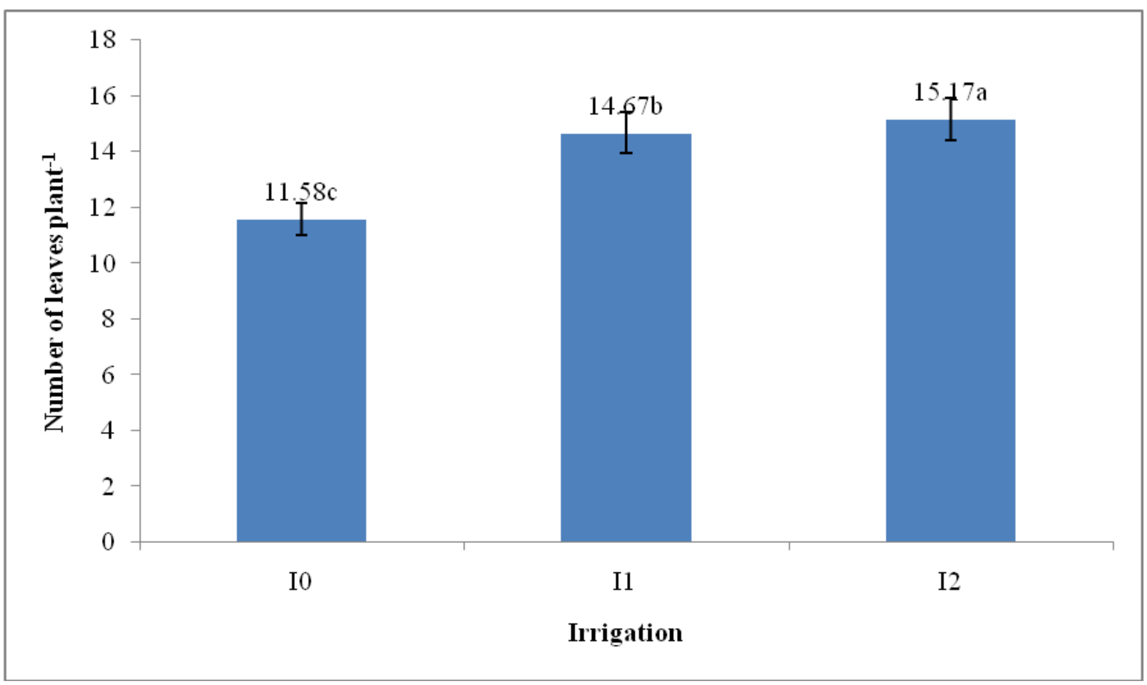
4.1.2 Number of leaves plant^{-1}

A statistically significant variation for number of leaves plant^{-1} of mustard was recorded for the effect of boron (Figure 4 and Appendix IV). The highest number of leaves plant^{-1} (14.78) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) which was statistically identical with B_2 (1.0 kg B ha^{-1}). On the other hand, the lowest number of leaves plant^{-1} (12.78) was recorded from the control treatment B_0 (0 kg B ha^{-1}) which was statistically identical with B_1 (0.5 kg B ha^{-1}). This result from the present study might be due to cause of boron which helps in cell division, translocation of photosynthates that leads to increase number of leaves and dry matter production. Supported result was also observed by Awal *et al*. (2020).



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

Figure 4. Number of leaves $plant^{-1}$ of mustard as influenced by different levels of boron



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

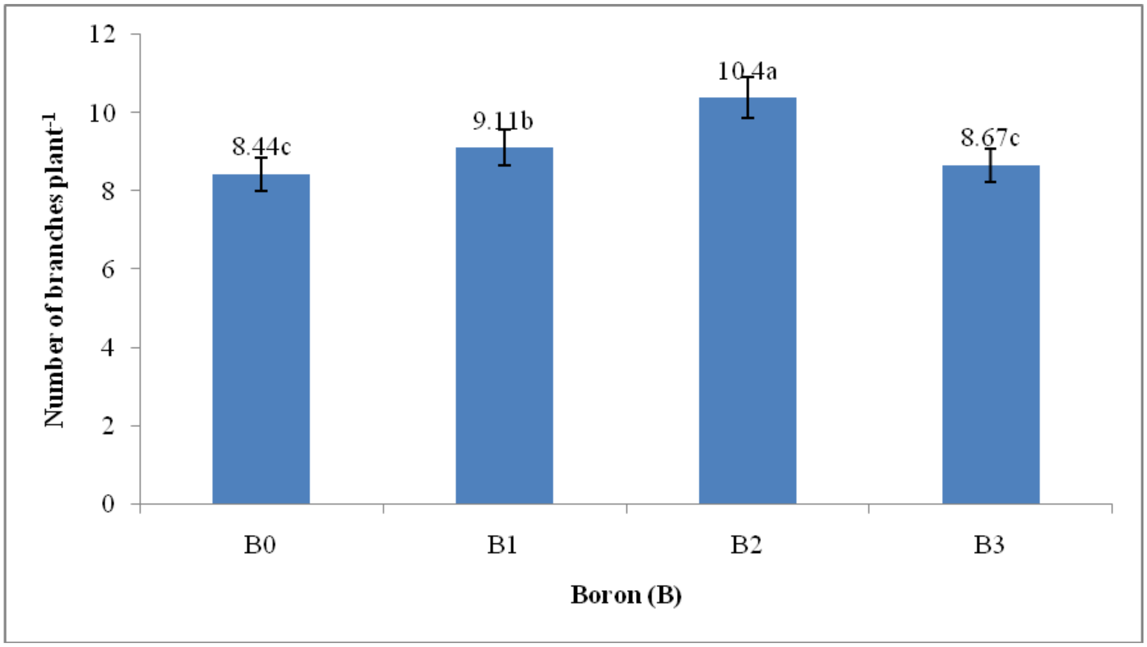
Figure 5. Number of leaves $plant^{-1}$ of mustard as influenced by different levels of irrigation

Number of leaves plant^{-1} for different levels of irrigation showed statistically significant variation (Figure 5 and Appendix IV). The highest number of leaves plant^{-1} (15.17) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was significantly different from other treatments followed by I_1 (One irrigation at 25 DAS) whereas the lowest number of leaves plant^{-1} (11.58) was recorded from the control treatment I_0 (No irrigation). Similar result was also observed by Singh *et al*. (2019) and Alamin *et al*. (2019) who observed increased number of leaves plant^{-1} with increased the increase of irrigation frequencies.

Interactive effect between boron and irrigation levels showed a significant difference for the number of leaves plant^{-1} under the present experiment (Table 1). Results indicated the highest number of leaves plant^{-1} (16.33) was recorded from the treatment combination of B_3I_2 which was statistically similar with the treatment combination of B_3I_1 and B_2I_2. The lowest number of leaves plant^{-1} (11.00) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0 and B_2I_0.

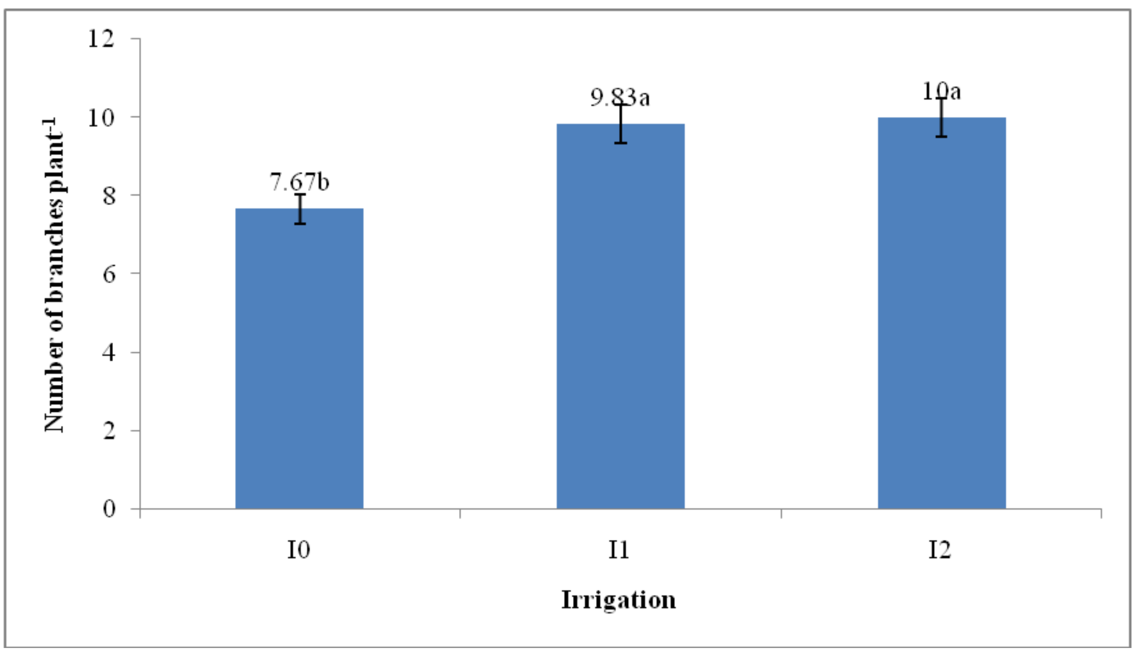
4.1.3 Number of branches plant^{-1}

Remarkable variation was identified on number of branches plant^{-1} due to the effect of different levels of boron application (Figure 6 and Appendix IV). It was observed that the treatment B_2 (1.0 kg B ha^{-1}) showed highest number of branches plant^{-1} (10.40) which was significantly different from other treatments followed by B_1 (0.5 kg B ha^{-1}) whereas the lowest number of branches plant^{-1} (8.44) was recorded from the control treatment B_0 (0 kg B ha^{-1}) which was statistically same with B_3 (1.5 kg B ha^{-1}). Riaj *et al*. (2018) also found similar result with the present study who observed higher number of branches plant^{-1} with higher B application and achieved highest branch number from 2 kg B ha^{-1}. This finding was also at par with the findings of Nandini *et al.* (2012) and Kaisher *et al.,* (2010).



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

Figure 6. Number of branches $plant^{-1}$ of mustard as influenced by different levels of boron



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 7. Number of branches $plant^{-1}$ of mustard as influenced by different levels of irrigation

Table 1. Growth parameters of mustard as influenced by different levels of boron and irrigation

Treatments		Growth parameters		
Boron (B)	Irrigation	Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}
B_0	I_0	58.03 g	11.00 f	6.67 f
	I_1	64.73 f	13.67 d	9.33 d
	I_2	68.37 e	13.67 d	9.33 d
B_1	I_0	59.05 g	11.33 f	7.33 ef
	I_1	72.40 d	14.33 cd	10.33 bc
	I_2	75.08 cd	14.67 c	9.67 cd
B_2	I_0	62.39 f	11.67 ef	9.00 d
	I_1	77.03 c	15.00 bc	11.00 ab
	I_2	82.41 ab	16.00 a	11.33 a
B_3	I_0	63.37 f	12.33 e	7.67 e
	I_1	80.37 b	15.67 ab	9.33 d
	I_2	84.68 a	16.33 a	9.00 d
$LSD_{0.05}$		2.793	0.824	0.944
Significant level		*	**	**
CV(%)		7.96	9.31	9.85

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Variation on number of branches plant^{-1} was found influenced by different irrigation levels (Figure 7 and Appendix IV). Results showed that the treatment I_2 (Two irrigations at 25 and 50 DAS) gave the highest number of branches plant^{-1} (10.00) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of branches plant^{-1} (7.67) was recorded from the control treatment I_0 (No irrigation). Singh *et al.* (2002) found that growth and development of *brassica* were adversely affected under limited irrigation condition. Rana *et al*. (2020), Singh *et al*. (2019) and Alamin *et al*. (2019) also found similar result with the present study. Rathore *et al.* (2019) found significant positive effect of irrigation on number of primary and secondary branches plant^{-1} of mustard.

The recorded data on number of branches plant^{-1} was significantly influence by the combined effect of boron and irrigation (Table 1). Results exhibited that the highest number of branches plant^{-1} (11.33) was recorded from the treatment combination of B_2I_2 which was statistically similar with the treatment combination of B_2I_1. The lowest number of branches plant^{-1} (6.67) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0.

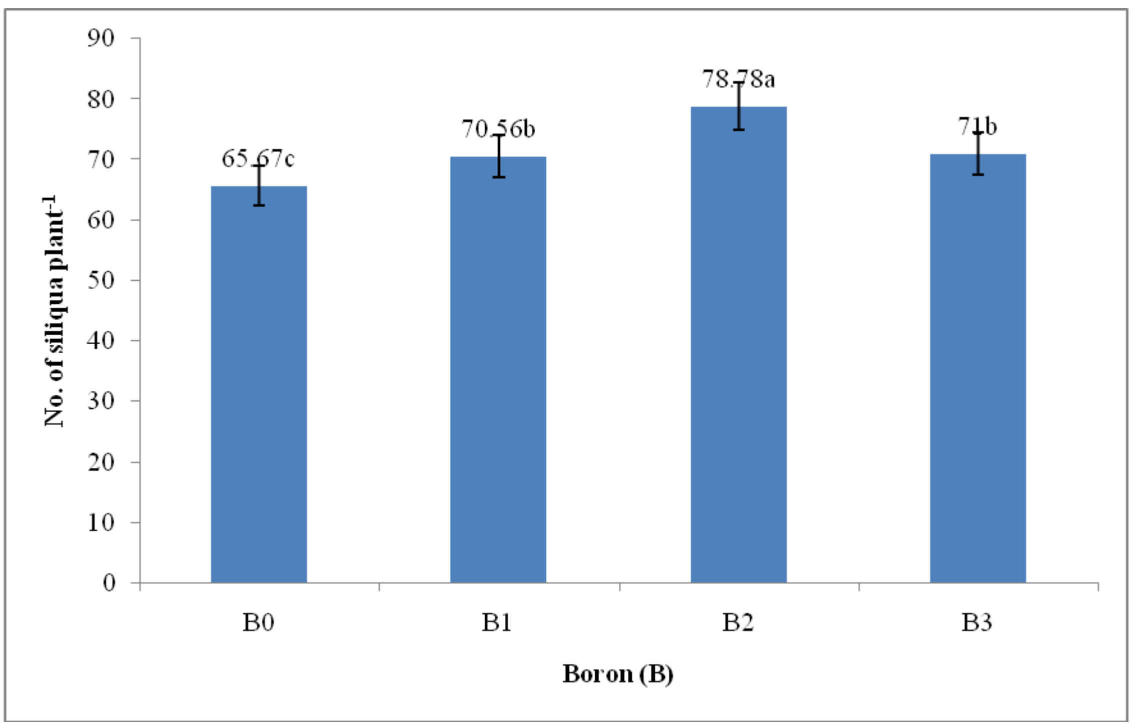
4.2 Yield contributing parameters

4.2.1 Number of siliqua plant^{-1}

Statistically significant variation for number of siliqua plant^{-1} of mustard was recorded for due to the effect of boron (Figure 8 and Appendix V). The treatment B_2 (1.0 kg B ha^{-1}) gave the highest number of siliqua plant^{-1} (78.78) which was significantly different from other treatments followed by B_1 (0.5 kg B ha^{-1}) and B_3 (1.5 kg B ha^{-1}) whereas the lowest number of siliqua plant^{-1} (65.67) was recorded from the control treatment B_0 (0 kg B ha^{-1}). The result obtained from the present study on number of siliqua plant^{-1} was similar with the findings of Masum *et al*. (2020), Yadav *et al*. (2016) and Riaj *et al*. (2018) who observed higher number of siliqua plant^{-1} with boron application compared to control (no B application).

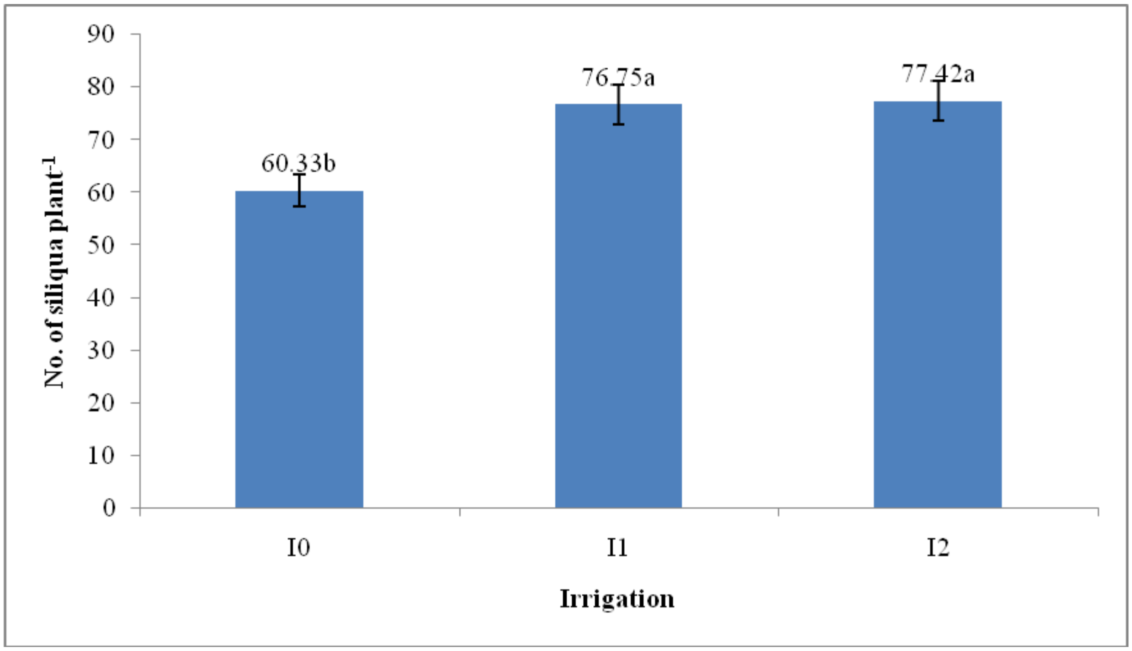
Number of siliqua plant^{-1} for different levels of irrigation also showed statistically significant variation (Figure 9 and Appendix V). The highest number of siliqua plant^{-1} (77.42) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of siliqua plant^{-1} (60.33) was recorded from the control treatment I_0 (No irrigation). The results obtained from the study were supported by Latif (2006), Sultana (2007) and Kibbria (2013) who concluded that number of siliquaeplant^{-1} was significantly increased higher irrigation frequencies. Supported result was also observed by Alamin *et al*. (2019) and Roy *et al*. (2017).

Combined effect of boron and nitrogen showed a significant difference for number of siliqua plant^{-1} under the present study (Figure 10 and Appendix V). Results indicated that the treatment combination of B_2I_2 gave the highest number of siliqua plant^{-1} (85.67) which was statistically same with the treatment combination of B_2I_1. The lowest number of siliqua plant^{-1} (55.67) was recorded from the treatment combination of B_0I_0 which was statistically identical with the treatment combination of B_1I_0.



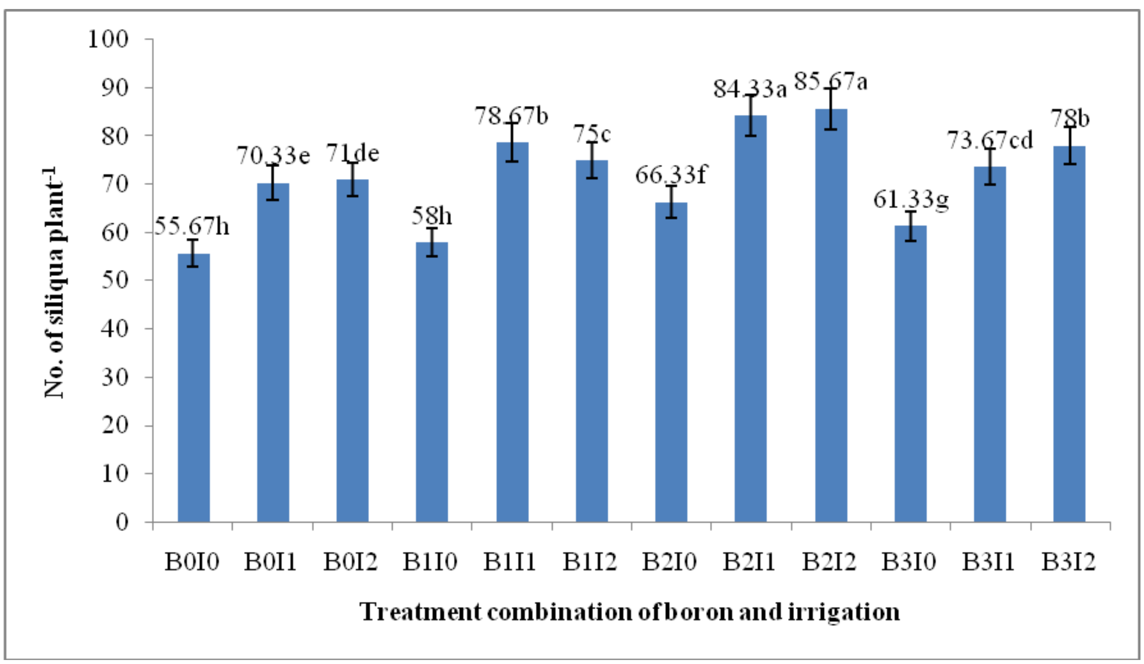
B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

Figure 8. Number of siliqua plant^{-1} of mustard as influenced by different levels of boron



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 9. Number of siliqua plant^{-1} of mustard as influenced by different levels of irrigation



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}
I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 10. Number of siliqua plant^{-1} of mustard as influenced by treatment combination of different levels of boron and irrigation

4.2.2 Length of siliqua (cm)

Length of siliqua was varied significantly due to different levels of boron application (Table 2). It was observed that the highest length of siliqua (4.49 cm) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) followed by B_1 (0.5 kg B ha^{-1}) and B_3 (1.5 kg B ha^{-1}) whereas the lowest length of siliqua (3.99 cm) was recorded from the control treatment B_0 (0 kg B ha^{-1}) which supported by Yadav *et al*. (2016) and Hossain *et al*. (2012), they found varied siliqua length with B application compared to control.

Different irrigation levels had significant influence on length of siliqua (Table 2). The highest length of siliqua (4.47 cm) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was statistically same with I_1 (One irrigation at 25 DAS) whereas the lowest length of siliqua (3.87 cm) was recorded from the control treatment I_0 (No irrigation). Kibbria (2013) and Latif (2006) concluded that length of siliqua was significantly increased up to three irrigations at pre-flowering, siliqua formation stage and seed maturation stage. Similar result was also observed by Alamin *et al*. (2019), Roy *et al*. (2017) and Hossain *et al*. (2013).

Length of siliqua was significantly influenced by combined effect of boron and irrigation levels (Table 2). The highest length of siliqua (4.77 cm) was recorded from the treatment combination of B_2I_2 which was statistically similar with the treatment combination of B_2I_1 and B_1I_1. The lowest length of siliqua (3.67 cm) was recorded from the treatment combination of B_0I_0 which was statistically identical with the treatment combination of B_1I_0.

4.2.3 Number of seeds $siliqua^{-1}$

Remarkable variation was identified on number of seeds $siliqua^{-1}$ due to the effect of different boron levels (Table 2). The highest number of seeds $siliqua^{-1}$ (35.89) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) which was significantly different from other treatments followed by B_1 (0.5 kg B ha^{-1}) and B_3 (1.5 kg B ha^{-1}) whereas the lowest number of seeds $siliqua^{-1}$ (30.33) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Similar result was also observed by Masum *et al*. (2020), Yadav *et al*. (2016) and Riaj *et al*. (2018) which supported the present study.

The recorded data on number of seeds $siliqua^{-1}$ was significantly influence by different irrigation levels (Table 2). The treatment I_2 (Two irrigations at 25 and 50 DAS) gave the highest number of seeds $siliqua^{-1}$ (36.00) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of seeds $siliqua^{-1}$ (28.58) was recorded from the control treatment I_0 (No irrigation). Seed $siliquae^{-1}$ increased with the increasing levels of irrigation due to the supply of adequate soil moisture which helped to elongate the siliqua length and have more number of seeds. Latif (2006), Sultana (2007) and Kibbria (2013) concluded that number of seeds $siliqua^{-1}$ was significantly increased up to three irrigations at pre-flowering, siliquae formation stage and seed maturation stage. Hossain et al. (2013) found a significant increase of seeds per siliquae with two irrigations one at pre-flowering stage and another at fruiting stage. Similar result was also observed by Alamin *et al*. (2019), Roy *et al*. (2017) and Parmar *et al.* (2016) which supported the present study.

Variation on number of seeds $siliqua^{-1}$ was found as significant as influenced by combined effect of boron and irrigation levels (Table 2). The highest number of seeds $siliqua^{-1}$ (39.33) was recorded from the treatment combination of B_2I_2 which was statistically similar with the treatment combination of B_1I_1 and B_2I_1. The lowest number of seeds $siliqua^{-1}$ (27.33) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0 and B_3I_0.

Table 2. Yield contributing parameters of mustard as influenced by different levels of boron and irrigation

Treatments		Yield contributing parameters	
		Length of siliqua (cm)	No. of seeds $siliqua^{-1}$
Effect of boron			
B_0		3.99 c	30.33 c
B_1		4.30 b	33.78 b
B_2		4.49 a	35.89 a
B_3		4.24 b	33.89 b
$LSD_{0.05}$		0.107	0.5023
Significant level		**	*
CV(%)		8.44	7.07
Effect of irrigation			
I_0		3.87 b	28.58 b
I_1		4.43 a	35.83 a
I_2		4.47 a	36.00 a
$LSD_{0.05}$		0.101	1.228
Significant level		**	*
CV(%)		8.44	7.07
Combined effect of boron and irrigation			
B_0	I_0	3.67 h	27.33 e
	I_1	4.07 ef	31.67 c
	I_2	4.23 de	32.00 c
B_1	I_0	3.87 g	27.67 e
	I_1	4.63 ab	37.67 ab
	I_2	4.40 cd	36.00 b
B_2	I_0	4.03 fg	30.33 cd
	I_1	4.67 a	38.00 ab
	I_2	4.77 a	39.33 a
B_3	I_0	3.90 fg	29.00 de
	I_1	4.37 cd	36.00 b
	I_2	4.47 bc	36.67 b
$LSD_{0.05}$		0.178	2.491
Significant level		**	*
CV(%)		8.44	7.07

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

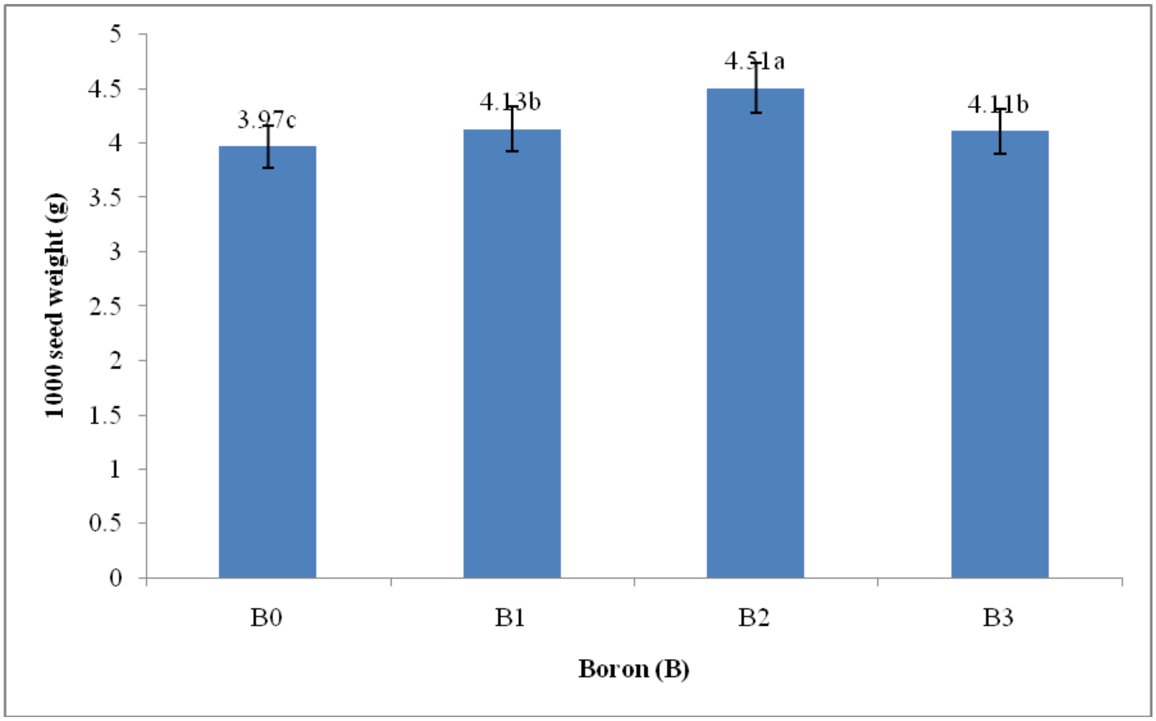
NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

4.2.4 Weight of 1000 seeds (g)

Different levels of boron showed statistically significant differences for 1000 seed weight of mustard under the present study (Figure 11 and Appendix V). The highest 1000 seed weight (4.51 g) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) followed by B_1 (0.5 kg B ha^{-1}) and B_3 (1.5 kg B ha^{-1}) whereas the lowest 1000 seed weight (3.97 g) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Supported result was also observed by Masum *et al*. (2020), Riaj *et al*. (2018), Hossain *et al*. (2012) and Kaisher *et al.,* (2010) who found higher 1000 seed weight with various levels of B application compared to control.

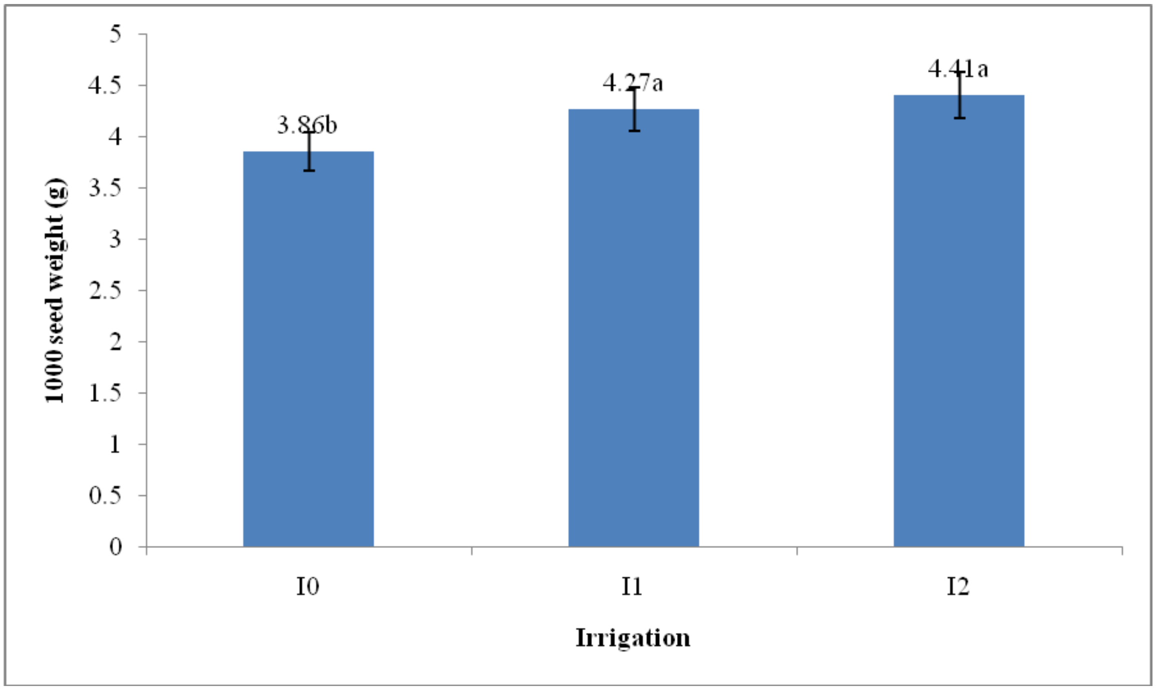
Different irrigation levels exhibited statistically significant variation for 1000 seed weight of mustard (Figure 12 and Appendix V). The highest 1000 seed weight (4.41 g) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest 1000 seed weight (3.86 g) was recorded from the control treatment I_0 (No irrigation). The results obtained in the study were supported by Parmar *et al.* (2016), Hossain *et al*. (2013), Kibbria (2013), Sultana (2007) and Latif (2006) who reported that increasing the frequency of irrigation increased 1000 seed weight. Hossain *et al*. (2013) found a significant increase 1000-seed weight with two irrigations; one at pre-flowering stage and another at fruiting stage.

Combined effect of boron and irrigation levels showed a significant variation for 1000 seed weight of mustard under the present experiment (Figure 13 and Appendix V). The highest 1000 seed weight (5.12 g) was recorded from the treatment combination of B_2I_2 which was significantly different from other treatment combinations followed by B_2I_1. The lowest 1000 seed weight (3.83 g) was recorded from the treatment combination of B_0I_0 which was statistically identical with the treatment combination of B_1I_0, B_2I_0 and B_3I_0.



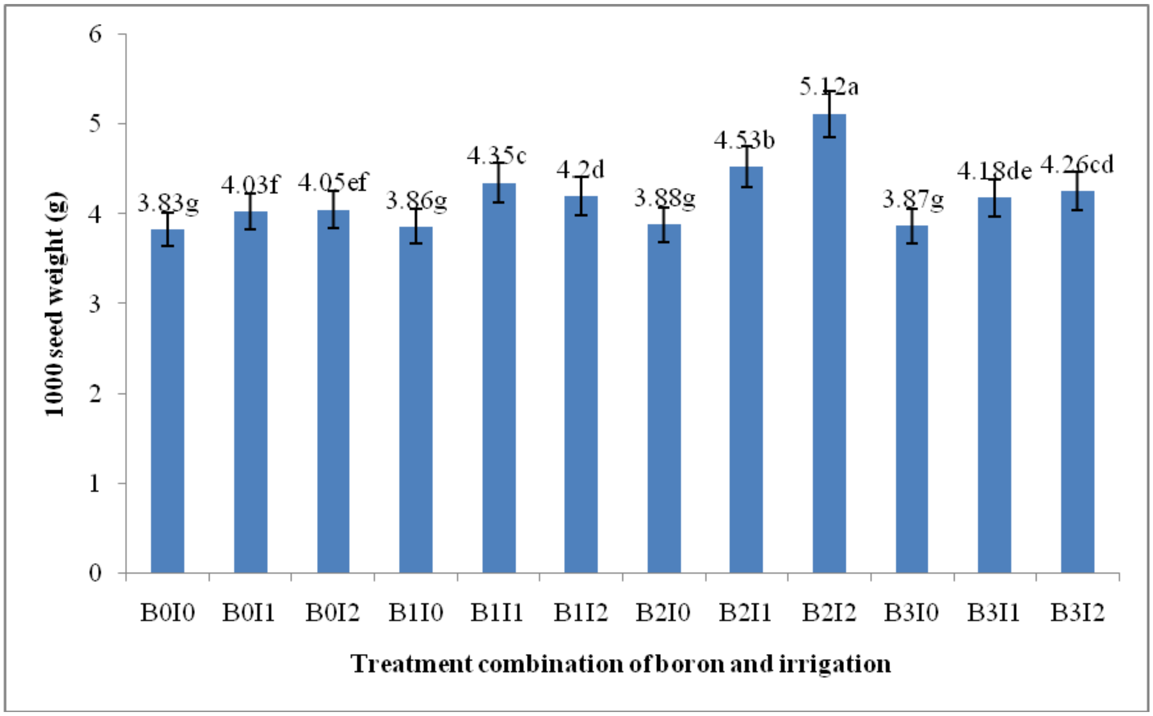
B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

Figure 11. 1000 seed weight of mustard as influenced by different levels of boron



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 12. 1000 seed weight of mustard influenced by different irrigation levels



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 13. Weight of 1000 seeds of mustard as influenced by treatment combination of different levels of boron and irrigation

4.3 Yield parameters

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

Statistically significant variation for seed yield of mustard was recorded for the effect of boron (Table 3). The highest seed yield (1437.00 kg ha^{-1}) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) followed by B_1 (0.5 kg B ha^{-1}) and B_3 (1.5 kg B ha^{-1}) whereas the lowest seed yield (1046.00 kg ha^{-1}) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*, 1981). Moreover, boron stimulates pollen germination, particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants (Jackson and Champman, 1975). Thus it affects the seed formation and development and consequently the yield of crops. The results obtained in the study on seed yield were conformity with the findings of Masum *et al*. (2020), Yadav *et al*. (2016) and Awal *et al*. (2020). Yadav *et al*. (2016) found that application of 1.5 kg B ha^{-1} gave average increase in seed yield of 36%.

Seed yield for different levels of irrigation showed statistically significant variation (Table 3). The highest seed yield (1422.00 kg ha^{-1}) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was significantly different from other treatments followed by I_1 (One irrigation at 25 DAS) whereas the lowest seed yield (919.00 kg ha^{-1}) was recorded from the control treatment I_0 (No irrigation). Alamin *et al*. (2019) and Shivran *et al*. (2018) observed that seed yield was increased with increasing the frequency of irrigation. Rathore *et al.* (2019) found significant positive effect of irrigation on seed yield of mustard. Roy *et al*. (2017) reported that highest seed yield was produced by two irrigations. The lowest yield was produced by no irrigation and this was statistically inferior to one irrigation. Under non-irrigated condition internal moisture deficit led to lower plant height, failed to increase the growth parameters, which adversely affected the yield components, *viz*., dry matter accumulation, siliquae per plant, seeds per siliquae, and 1000-seed weight (Roy *et al*., 2017, Rathore *et al.*, 2019, Hossain *et al*., 2013). These results corroborated with Latif (2006), Sultana (2007), Kibbria (2013), Piri *et al.* (2011) and Singh *et al*. (2019).

Interaction effect between boron and irrigation levels showed a significant difference for the seed yield under the present study (Table 3). The highest seed yield (1780.00 kg ha^{-1}) was recorded from the treatment combination of B_2I_2 which was significantly different from other treatment combinations followed by B_2I_1. The lowest seed yield (745.60 kg ha^{-1}) was recorded from the treatment combination of B_0I_0 which was close to the treatment combination of B_1I_0.

Table 3. Yield parameters of mustard as influenced by different levels of boron and irrigation

Treatments		Yield parameters	
		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Effect of boron			
B_0		1046.00 c	1945.00 c
B_1		1208.00 b	1856.00 d
B_2		1437.00 a	1954.00 b
B_3		1211.00 b	1975.00 a
$LSD_{0.05}$		7.579	8.258
Significant level		*	*
CV(%)		8.00	9.22
Effect of irrigation			
I_0		919.40 c	1868.00 c
I_1		1335.00 b	1940.00 b
I_2		1422.00 a	1989.00 a
$LSD_{0.05}$		6.566	7.091
Significant level		*	*
CV(%)		8.00	9.22
Combined effect of boron and irrigation			
B_0	I_0	745.60 k	1641.00 i
	I_1	1142.00 g	2105.00 a
	I_2	1250.00 e	2087.00 b
B_1	I_0	947.80 j	1943.00 e
	I_1	1443.00 c	1847.00 g
	I_2	1232.00 f	1777.00 h
B_2	I_0	998.90 h	1910.00 f
	I_1	1532.00 b	1847.00 g
	I_2	1780.00 a	2107.00 a
B_3	I_0	985.60 i	1978.00 c
	I_1	1223.00 f	1958.00 d
	I_2	1424.00 d	1987.00 c
$LSD_{0.05}$		13.21	14.30
Significant level		*	*
CV(%)		8.00	9.22

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

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

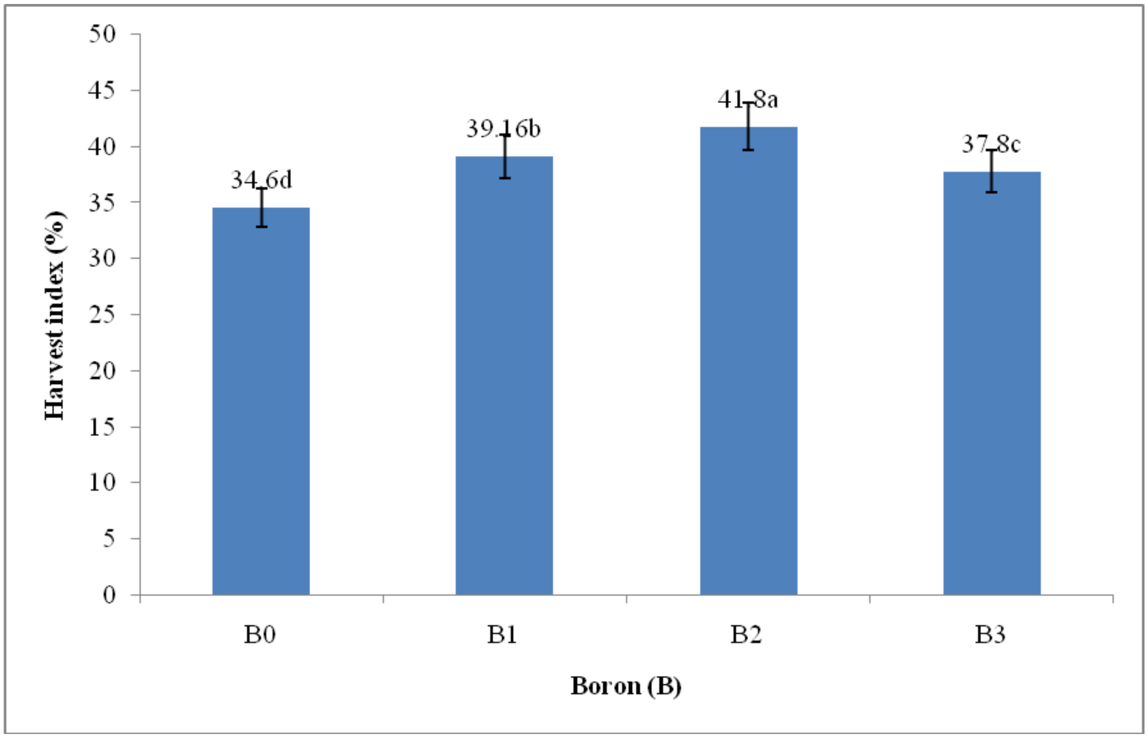
Statistically significant variation for stover yield of mustard was recorded due to the effect of boron (Table 3). The highest stover yield (1975.00 kg ha^{-1}) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) followed by B_2 (1.0 kg B ha^{-1}) whereas the lowest stover yield (1945.00 kg ha^{-1}) was recorded from the control treatment B_0 (0 kg B ha^{-1}). The results obtained from the study were supported by Masum *et al*. (2020), Yadav *et al*. (2016) and Riaj *et al*. (2018). Malewar *et al.*, (2001) reported that with increasing levels of borax up to 10 kg Borax ha^{-1}, stover yield increased from 9.47 to 14.41 percent in mustard.

Stover yield for different levels of irrigation also showed statistically significant variation (Table 3). The highest stover yield (1989.00 kg ha^{-1}) was recorded from I_2 (Two irrigations at 25 and 50 DAS) followed by I_1 (One irrigation at 25 DAS) whereas the lowest stover yield (1868.00 kg ha^{-1}) was recorded from the control treatment I_0 (No irrigation). Similar result was also observed by Alamin *et al*. (2019), Rathore *et al.* (2019), Hossain *et al*. (2013), Kibbria (2013) and Piri *et al.* (2011).

Combined effect of boron and nitrogen showed a significant difference for stover yield under the present study (Table 3). The highest stover yield (2107.00 kg ha^{-1}) was recorded from the treatment combination of B_2I_2 which was statistically identical with the treatment combination of B_0I_1 whereas the lowest stover yield (1641.00 kg ha^{-1}) was recorded from the treatment combination of B_0I_0.

4.3.3 Harvest index (%)

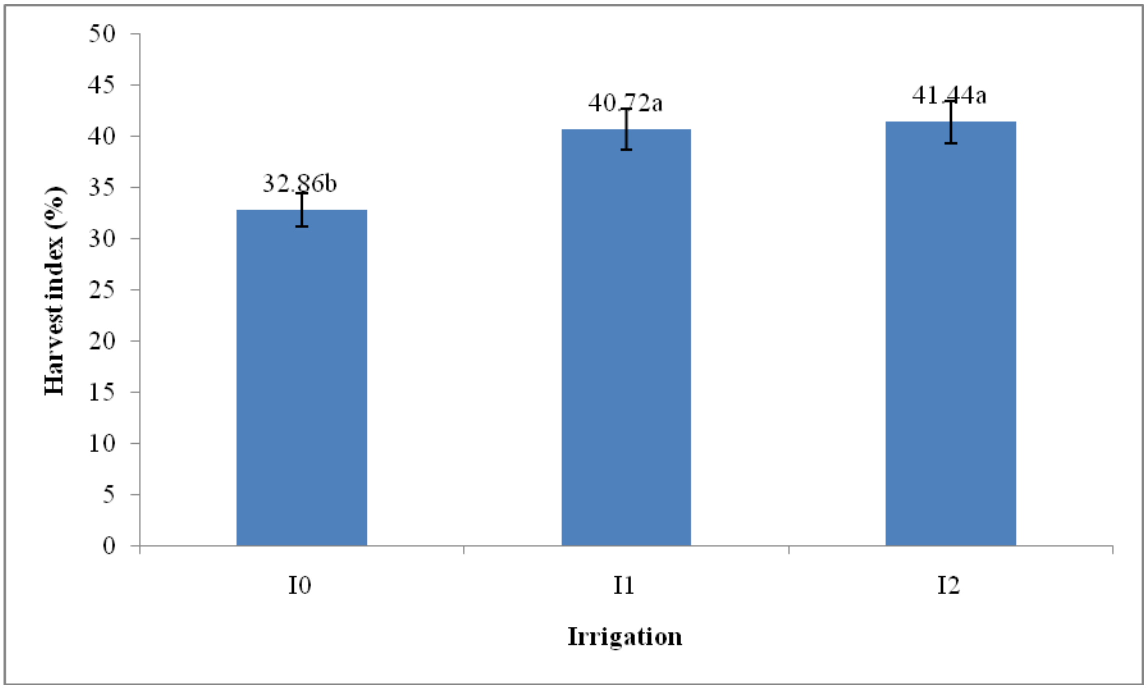
Remarkable variation was identified on harvest index due to the effect of different boron levels (Figure 14 and Appendix VI). The highest harvest index (41.80%) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) followed by B_1 (0.5 kg B ha^{-1}) whereas the lowest harvest index (34.60%) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Supported result was also observed by Masum *et al*. (2020), Riaj *et al*. (2018) and Nandini *et al.* (2012).



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

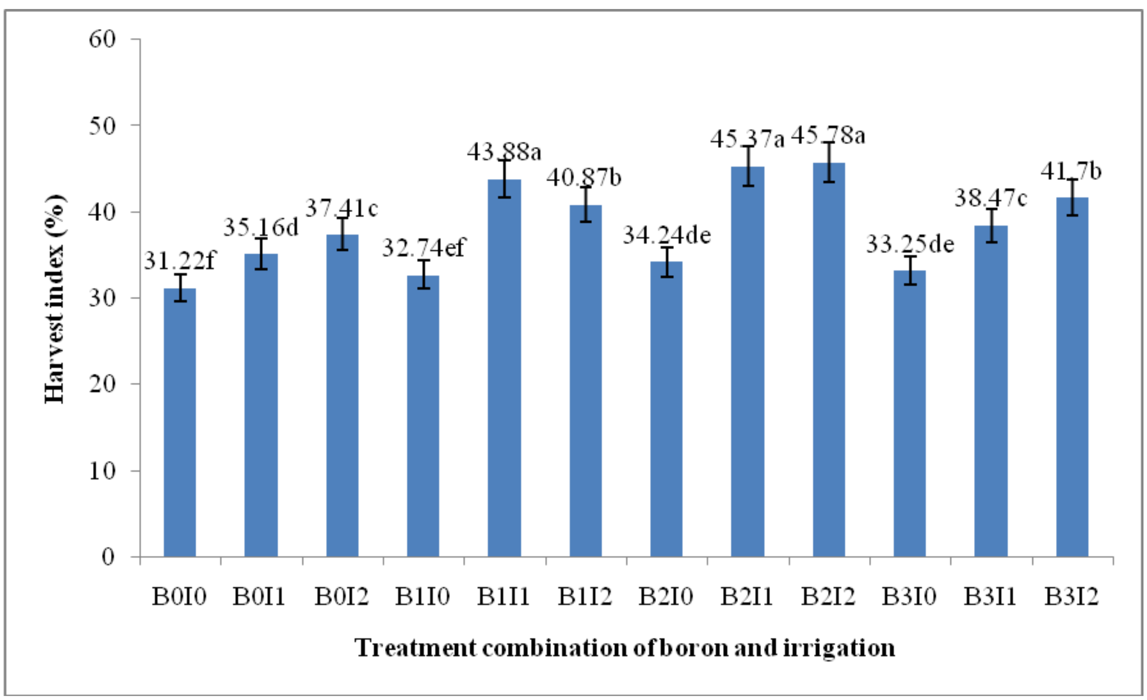
Figure 14. Harvest index of mustard as influenced by different levels of boron

The recorded data on harvest index was significantly influence by different irrigation levels (Figure 14 and Appendix VI). The highest harvest index (41.44%) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest harvest index (32.86%) was recorded from the control treatment I_0 (No irrigation). The result obtained from the present study on harvest index was similar with the findings of Rathore *et al.* (2019), Kibbria (2013) and Sultana *et al.* (2009).



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 15. Harvest index of mustard as influenced by different levels of irrigation



B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 16. Harvest index of mustard as influenced by treatment combination of different levels of boron and irrigation

Variation on harvest index was found as significant as influenced by combined effect of boron and irrigation levels (Figure 16 and Appendix VI). The highest harvest index (45.78%) was recorded from the treatment combination of B_2I_2 which was statistically identical with the treatment combination of B_1I_1 and B_2I_1. The lowest harvest index (31.22%) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0.

4.4 Nutrient contents

4.4.1 Nitrogen (N) content in straw

Different boron treatment showed statistically non-significant variation for nitrogen content in straw of mustard (Table 4). However, the highest nitrogen content in straw (2.59%) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) whereas the lowest nitrogen content in straw (2.40%) was recorded from the control treatment B_0 (0 kg B ha^{-1}). The results obtained from the study were supported by Hossain *et al.* (2011).

Different level of irrigation exhibited non-significant differences for nitrogen content in straw of mustard (Table 4). However, the highest nitrogen content in straw (2.58%) was recorded from I_2 (Two irrigations at 25 and 50 DAS) followed by I_1 (One irrigation at 25 DAS) whereas the lowest nitrogen content in straw (2.36%) was recorded from the control treatment I_0 (No irrigation). Supported result was also observed by Meena (2010).

Significant interaction effect was not recorded between boron and irrigation levels in consideration of nitrogen content in straw of mustard (Table 4). However, the highest nitrogen content in straw (2.72%) was recorded from the treatment combination of B_3I_2 whereas the lowest nitrogen content in straw (2.30%) was recorded from the treatment combination of B_0I_0.

4.4.2 Potassium (K) content in straw (%)

Non-significant variation for potassium content in straw of mustard was found due to the effect of boron (Table 4). However, the highest potassium content in straw (0.408%) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) whereas the lowest potassium content in straw (0.251%) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Similar result was also observed by Hossain *et al.* (2011).

Potassium content in straw for different levels of irrigation also showed non-significant variation (Table 4). However, the highest potassium content in straw (0.402%) was recorded from I_2 (Two irrigations at 25 and 50 DAS) whereas the lowest potassium content in straw (0.222%) was recorded from the control treatment I_0 (No irrigation). Supported result was also observed by Meena (2010).

Combined effect of boron and nitrogen showed non-significant difference for potassium content in straw under the present study (Table 4). However, the highest potassium content in straw (0.523%) was recorded from the treatment combination of B_3I_2 whereas the lowest potassium content in straw (0.203%) was recorded from the treatment combination of B_0I_0.

4.4.3 Phosphorus (P) content in straw (%)

Phosphorus content in straw was not varied significantly due to different levels of boron application (Table 4). However, the highest phosphorus content in straw (0.083%) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) and the lowest phosphorus content in straw (0.063%) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Similar result was also observed by Hossain *et al.,* (2011).

Different irrigation levels had no significant influence on phosphorus content in straw (Table 4). However, the highest phosphorus content in straw (0.082%) was recorded from I_2 (Two irrigations at 25 and 50 DAS) and the lowest phosphorus content in straw (0.061%) was recorded from the control treatment I_0 (No irrigation). Supported result was also observed by Meena (2010).

Phosphorus content in straw was not significantly influenced by combined effect of boron and irrigation levels (Table 4). However, the highest phosphorus content in straw (0.093%) was recorded from the treatment combination of B_3I_2 whereas the lowest phosphorus content in straw (0.050%) was recorded from the treatment combination of B_0I_0.

4.4.4 Boron (B) content in seed (ppm)

Different boron treatment showed a statistically significant variation for boron content in seed mustard under the present study (Table 4). The highest boron content in seed (16.11 ppm) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) which was significantly different from other treatments followed by B_1 (0.5 kg B ha^{-1}) whereas the lowest boron content in seed (12.56 ppm) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Yadav *et al*. (2016) and Hossain *et al.* (2011) also found supported result who reported that application of boron increased the uptake of B by seed significantly over control.

Different level of irrigation exhibited statistically significant differences for boron content in seed of mustard (Table 4). The highest boron content in seed (16.83 ppm) was recorded from I_2 (Two irrigations at 25 and 50 DAS) followed by I_1 (One irrigation at 25 DAS) whereas the lowest boron content in seed (11.50 ppm) was recorded from the control treatment I_0 (No irrigation).

Significant interaction effect was also recorded between boron and irrigation levels in consideration of boron content in seed of mustard (Table 4). The highest boron content in seed (20.00 ppm) was recorded from the treatment combination of B_3I_2 which was statistically identical with the treatment combination of B_2I_2. The lowest boron content in seed (10.67 ppm) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0 and B_2I_0.

4.4.5 Boron (B) content in straw (ppm)

Statistically significant variation for boron content in straw of mustard was recorded for due to the effect of boron (Table 4). The highest boron content in straw (30.89 ppm) was recorded from the treatment B_3 (1.5 kg B ha^{-1}) which was statistically identical with B_2 (1.0 kg B ha^{-1}) whereas the lowest boron content in straw (23.44 ppm) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Yadav *et al*. (2016) and Hossain *et al.* (2011) also found similar result who observed that application of boron increased the uptake of B by stover significantly over control.

Boron content in straw for different levels of irrigation also showed statistically significant variation (Table 4). The highest boron content in straw (32.08 ppm) was recorded from I_2 (Two irrigations at 25 and 50 DAS) followed by I_1 (One irrigation at 25 DAS) whereas the lowest boron content in straw (21.92 ppm) was recorded from the control treatment I_0 (No irrigation).

Combined effect of boron and nitrogen showed a significant difference for boron content in straw under the present study (Table 4). The highest boron content in straw (39.00 ppm) was recorded from the treatment combination of B_3I_2 which was significantly different from other treatment combinations followed by B_2I_2. The lowest boron content in straw (20.33 ppm) was recorded from the treatment combination of B_0I_0 which was statistically similar with the treatment combination of B_1I_0.

Table 4. Nutrient contents of mustard as influenced by different levels of boron and irrigation

Treatments		Nutrient contents				
		Nitrogen (N) content in straw (%)	Potassium (K) content in straw (%)	Phosphorus (P) content in straw (%)	Boron (B) content in seed (ppm)	Boron (B) content in straw (ppm)
Effect of boron						
B_0		2.40	0.251	0.063	12.56 c	23.44 c
B_1		2.45	0.276	0.071	13.11 c	25.22 b
B_2		2.53	0.368	0.080	15.22 b	29.33 a
B_3		2.59	0.408	0.083	16.11 a	30.89 a
$LSD_{0.05}$		0.47	0.330	0.062	0.6968	1.638
Significant level		NS	NS	NS	*	*
CV(%)		5.84	4.37	3.99	5.29	6.56
Effect of irrigation						
I_0		2.35	0.222	0.061	11.50 c	21.92 c
I_1		2.54	0.353	0.078	14.42 b	27.67 b
I_2		2.58	0.402	0.082	16.83 a	32.08 a
$LSD_{0.05}$		0.41	0.270	0.054	0.6094	1.169
Significant level		NS	NS	NS	*	*
CV(%)		9.84	4.37	3.99	5.29	6.56
Combined effect of boron and irrigation						
B_0	I_0	2.30	0.203	0.050	10.67 g	20.33 i
	I_1	2.44	0.267	0.070	13.33 de	24.67 ef
	I_2	2.45	0.283	0.070	13.67 cde	25.33 e
B_1	I_0	2.32	0.213	0.063	11.00 g	21.67 hi
	I_1	2.50	0.297	0.073	14.00 cd	26.00 e
	I_2	2.52	0.317	0.077	14.33 cd	28.00 d
B_2	I_0	2.36	0.217	0.070	11.67 fg	22.33 gh
	I_1	2.58	0.403	0.080	14.67 bc	29.67 c
	I_2	2.66	0.483	0.090	19.33 a	36.00 b
B_3	I_0	2.40	0.253	0.070	12.67 ef	23.33 fg
	I_1	2.63	0.447	0.090	15.67 b	30.33 c
	I_2	2.73	0.523	0.093	20.00 a	39.00 a
$LSD_{0.05}$		0.39	1.30	0.107	1.027	1.639
Significant level		NS	NS	NS	**	*
CV(%)		9.84	4.37	3.99	5.29	6.56

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to determine the effect of boron fertilizer and irrigation frequency on growth, yield and nutrient content of mustard (BARI sarisha-14). The experiment consisted of two factors *viz*. Factor A: Boron (4 levels) i.e. control - 0 kg B ha^{-1}(B_0), 0.5 kg B ha^{-1} (B_1), 1.0 kg B ha^{-1} (B_2) and 1.5 kg B ha^{-1} (B_3) and Factor B: Irrigation (3 levels) i.e. control - no irrigation (I_0), one irrigation at 25 DAS (I_1) and two irrigations at 25 and 50 DAS (I_2). There were 12 treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications.

Most of the parameters affected significantly due to boron doses. Results indicated that, 1.5 kg B ha^{-1} (B_3) showed the highest plant height (76.14 cm), number of leaves plant^{-1} (14.78) and stover yield (1975.00 kg ha^{-1}) but B_2 (1.0 kg B ha^{-1}) showed highest number of branches plant^{-1} (10.40), number of siliqua plant^{-1} (78.78), length of siliqua (4.49 cm), number of seeds siliqua^{-1} (35.89), 1000 seed weight (4.51 g), seed yield (1437.00 kg ha^{-1}) and harvest index (41.80%) whereas control treatment B_0 (0 kg B ha^{-1}) showed the lowest plant height (63.71 cm), number of leaves plant^{-1} (12.78), number of branches plant^{-1} (8.44), siliqua plant^{-1} (65.67), length of siliqua (3.99 cm), number of seeds siliqua^{-1} (30.33), 1000 seed weight (3.97 g), seed yield (1046.00 kg ha^{-1}), stover yield (1945.00 kg ha^{-1}) and harvest index (34.60%). Again, treatment B_3 (1.5 kg B ha^{-1}) showed the highest N (2.59%), K (0.408%), P (0.083%) and B (30.89 ppm) content in straw and B content in seed (16.11 ppm) whereas control treatment B_0 (0 kg B ha^{-1}) showed the lowest N (2.40%), K (0.251%), P (0.063%) and B (23.44 ppm) content in straw and also B content in seed (12.56 ppm).

Likewise, different irrigation treatments showed significant variation on different studied parameters. The highest plant height (77.64 cm), number of leaves plant^{-1} (15.17), number of branches plant^{-1} (10.00), number of siliqua plant^{-1} (77.42), length of siliqua (4.47 cm), number of seeds siliqua^{-1} (36.00), 1000 seed weight (4.41 g), seed yield (1422.00 kg ha^{-1}), stover yield (1989.00 kg ha^{-1}) and harvest index (41.44%) were recorded from I_2 (Two irrigations at 25 and 50 DAS) whereas control treatment I_0 (No irrigation) showed the lowest plant height (60.71 cm), number of leaves plant^{-1} (11.58), number of branches plant^{-1} (7.67), number of siliqua plant^{-1} (60.33), length of siliqua (3.87 cm), number of seeds siliqua^{-1} (28.58), 1000 seed weight (3.86 g), seed yield (919.00 kg ha^{-1}), stover yield (1868.00 kg ha^{-1}) and harvest index (32.86%). Treatment I_2 also showed the highest N (2.58%), K (0.402%), P (0.082%) and B (32.08 ppm) content in straw and B content in seed (16.83 ppm) whereas the lowest N (2.35%), K (0.222%), P (0.061%) and B (21.92 ppm) content in straw and B content in seed (11.50 ppm) were recorded from control treatment I_0.

Treatment combination of boron and irrigation levels showed significant variation for maximum parameters of the study. Treatment combination of B_3I_2 showed the highest plant height (84.68 cm) and number of leaves plant^{-1} (16.33) but the highest number of branches plant^{-1} (11.33), number of siliqua plant^{-1} (85.67), length of siliqua (4.77 cm), number of seeds siliqua^{-1} (39.33), 1000 seed weight (5.12 g), seed yield (1780.00 kg ha^{-1}), stover yield (2107.00 kg ha^{-1}) and harvest index (45.78%) were recorded from B_2I_2. On the other hand, the lowest plant height (58.03 cm), number of leaves plant^{-1} (11.00), number of branches plant^{-1} (6.67), number of siliqua plant^{-1} (55.67), length of siliqua (3.67 cm), number of seeds siliqua^{-1} (27.33), 1000 seed weight (3.83 g), seed yield (745.60 kg ha^{-1}), stover yield (1641.00 kg ha^{-1}) and harvest index (31.22%) were recorded from B_0I_0. Considering nutrient content (in straw or seed), the highest N (2.73%), K (0.523%), P (0.093%) and B (39.00 ppm) content in straw and also B content in seed (20.00 ppm) were recorded from B_3I_2 whereas the lowest N (2.30%), K (0.203%), P (0.050%) and B (20.33 ppm) content in straw and also B content in seed (10.67 ppm) were recorded from B_0I_0.

From the above results, it may be concluded that among the B treatments, B_2 (1.0 kg B ha^{-1}) gave better results in terms of yield and yield contributing parameters. Similarly, regarding irrigation treatments, I_2 (Two irrigations at 25 and 50 DAS) showed best results on yield and yield contributing parameters. In terms of combined effect, B_2I_2 gave best performance So, the treatment combination of B_2I_2 (1.0 kg B ha^{-1} with two irrigations at 25 and 50 DAS) can be considered as best as compared to other treatment combinations.

Recommendation

The present research work was carried out at the Sher-e-Bangla Agricultural University and one season only. Further trial of this work may be conducted in different AEZ of Bangladesh before the final recommendation.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

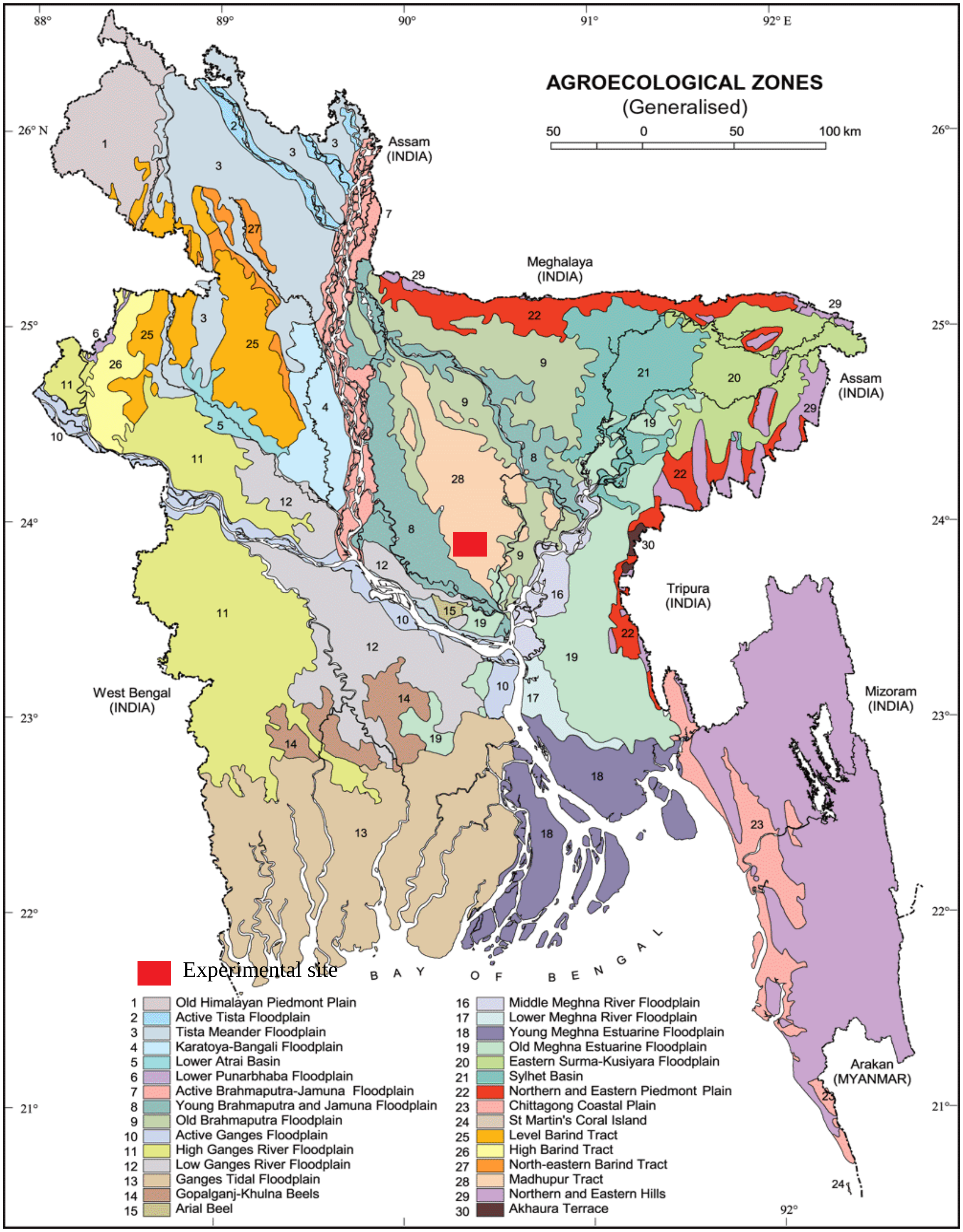

Fig. 17. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2019 to February 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Growth parameters of mustard as influenced by different levels of boron and irrigation

Treatments	Growth parameters		
	Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}
Effect of boron			
B_0	63.71 d	12.78 b	8.44 c
B_1	68.84 c	13.44 b	9.11b
B_2	73.94 b	14.22 a	10.40 a
B_3	76.14 a	14.78 a	8.67 c
$LSD_{0.05}$	1.411	0.768	0.326
Significant level	*	*	*
CV(%)	7.96	9.31	9.85
Effect of irrigation			
I_0	60.71 c	11.58 c	7.67 b
I_1	73.63 b	14.67 b	9.83 a
I_2	77.64 a	15.17 a	10.00 a
$LSD_{0.05}$	1.633	0.469	0.851
Significant level	*	*	*
CV(%)	7.96	9.31	9.85

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}
I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Yield contributing parameters of mustard regarding number of siliqua plant^{-1} and weight of 1000 seeds as influenced by different levels of boron and irrigation

Treatments		Yield contributing parameters	
		No. of siliqua plant^{-1}	Weight of 1000 seeds (g)
Effect of boron			
B_0		65.67 c	3.97 c
B_1		70.56 b	4.13 b
B_2		78.78 a	4.51 a
B_3		71.00 b	4.11 b
$LSD_{0.05}$		1.517	0.093
Significant level		*	**
CV(%)		9.07	10.70
Effect of irrigation			
I_0		60.33 b	3.86 b
I_1		76.75 a	4.27 a
I_2		77.42 a	4.41 a
$LSD_{0.05}$		1.704	0.162
Significant level		*	**
CV(%)		9.07	10.70
Combined effect of boron and irrigation			
B_0	I_0	55.67 h	3.83 g
	I_1	70.33 e	4.03 f
	I_2	71.00 de	4.05 ef
B_1	I_0	58.00 h	3.86 g
	I_1	78.67 b	4.35 c
	I_2	75.00 c	4.20 d
B_2	I_0	66.33 f	3.88 g
	I_1	84.33 a	4.53 b
	I_2	85.67 a	5.12 a
B_3	I_0	61.33 g	3.87 g
	I_1	73.67 cd	4.18 de
	I_2	78.00 b	4.26 cd
$LSD_{0.05}$		2.959	0.142
Significant level		*	**
CV(%)		9.07	10.70

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Harvest index of mustard as influenced by different levels of boron and irrigation

Treatments		Harvest index (%)
Effect of boron		
B_0		34.60 d
B_1		39.16 b
B_2		41.80 a
B_3		37.80 c
$LSD_{0.05}$		1.007
Significant level		*
CV(%)		10.56
Effect of irrigation		
I_0		32.86 b
I_1		40.72 a
I_2		41.44 a
$LSD_{0.05}$		0.8521
Significant level		*
CV(%)		10.56
Combined effect of boron and irrigation		
B_0	I_0	31.22 f
	I_1	35.16 d
	I_2	37.41 c
B_1	I_0	32.74 ef
	I_1	43.88 a
	I_2	40.87 b
B_2	I_0	34.24 de
	I_1	45.37 a
	I_2	45.78 a
B_3	I_0	33.25 de
	I_1	38.47 c
	I_2	41.70 b
$LSD_{0.05}$		1.975
Significant level		**
CV(%)		10.56

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}, B_3 = 1.5 kg B ha^{-1}

I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level