GROWTH AND YIELD RESPONSES OF RAPESEED AND MUSTARD TO BORON AND SELENIUM

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DECEMBER, 2021

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A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

AGRONOMY

SEMESTER: JULY- DECEMBER, 2021

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CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND YIELD RESPONSES OF RAPESEED AND MUSTARD TO BORON AND SELENIUM"** submitted to the Department of Agronomy, 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 **AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. SHAWKAT ZAMAN**, Registration No. **19-10196** 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.

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Dedicated to

My

Beloved Mother

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percentage Coefficient of Variation
DAS	=	Days After Sowing
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural 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 Celcius
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
LSD	=	Least Significant Difference
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the Almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, ***Dr. Mirza Hasanuzzaman****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, ***Dr. Md. Mahabub Alam****, Assistant Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

The author feels to express his heartfelt thanks to the honorable Chairman, ***Prof. Dr. Md. Abdullahil Baque,*** *Department of Agronomy along with all other teachers and staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

The author feels proud to express his deepest and endless gratitude to all of his course mates, Labmates and friends to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses his heartfelt thanks to his beloved parents, sisters and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

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ABSTRACT

The present study was carried out at the Agronomy experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2020 to February 2021 to study the growth and yield response of different brassica oilseeds species to boron and selenium. Two factors experiment consisted of three varieties *viz*., V_1 (BARI Sarisha-16), V_2 (BARI Sarisha-14) and V_3 (BARI Sarisha-17) with four doses of boron and/or selenium *viz*. control treatment S_0 (no boron or selenium), S_1 (Boron; 1 mM spray), S_2 (Selenium; 25 µM spray) and S_3 (Boron+ Selenium; 1 mM + 25 µM spray) were considered. There were 12 treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. The variety V_1 (BARI Sarisha-16) showed higher plant growth and dry matter accumulation and also gave the maximum seed yield (3008 kg ha^{-1}) compared to V_2 (BARI Sarisha-14) and V_3 (BARI Sarisha-17). Similarly, S_3 (Boron+ Selenium) treatment showed the best performance on growth, yield contributing parameters and also gave the highest seed yield (2323 kg ha^{-1}) compared to other treatments of boron or selenium treatments. Regarding treatment combination of variety and boron + selenium, significant variation was found for most of the parameters. Treatment combination of V_1S_3 showed better performance on different parameters and gave the highest seed yield (3137 kg ha^{-1}) with highest harvest index (35.32%) but V_3S_3 gave the highest stover yield (6587 kg ha^{-1}) whereas, V_2S_0 gave least performance for the most of the parameters. From the above results, it may be concluded that among variety, V_1 (BARI Sarisha-16) is better than V_2 (BARI Sarisha-14) and V_3 (BARI Sarisha-17) regarding yield performance. Again, together application of Boron + Selenium is better than individual application of Boron or Selenium regarding growth and yield performance. As a result, V_1S_3 performed best regarding yield of mustard compared to other treatment combinatio

CHAPTER I

INTRODUCTION

Mustard *(Brassica* sp.) is the main cultivable edible *rabi* oilseed crop of Bangladesh. It is one of the most important oil seed crops of the world after soybean and groundnut (FAO, 2012). It is commonly known as 'Sarisha' in Bangla and is being cultivated throughout the country during the winter season (November to March). It has a remarkable demand for edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country and it covers the major portion of the total edible oil requirement of the country (AIS, 2010). Bangladesh occupies the 5th place in respect of total oil seed production in the world and mustard occupies the first position in respect of area (61.2%) and production (52.6%) among the oil crops grown in Bangladesh (BBS, 2010).

Mustard oil plays an important role as a fat substitute in our daily diet. This oil is widely used in cooking and as medical ingredients. Mustard is not only a rich source of energy (about 9 kcal g^{-1}), but also rich in fat soluble vitamins like A, D, E and K (Alim *et al*., 2020). Seeds of mustard contain 40-45% oil and 20-25% protein. Mustard oilcake contains 40% protein that is used as nutritious animal feed and high quality manure for crop production (Alim *et al*., 2020). With increasing population, the demand of edible oil is increasing day by day. Therefore, it is highly accepted that the production of edible oil should be increased considerably to fulfill the demand.

Among the oil seed crops grown in Bangladesh, mustard tops the list in respect of both production and acreage (BBS, 2015). The present area and production of mustard is 3.25 lac hectare and 3.59 lac metric ton respectively (BBS, 2018). The average yield of mustard in Bangladesh is very low (1080 kg/ha) (BBS, 2018) compared to other mustard growing countries of the world. The major reasons for low yield of rapeseed-mustard in our country are due to lack of high yielding variety and proper management practices e.g. balanced manure and fertilizer application, use of organic matter to maintain soil fertility level etc. There is a great scope of increasing yield of mustard by selecting high yielding varieties and improving management practices (Bhuiyan *et al.,* 2008).

Nutrient management is one of the most important factors that affect the mustard productivity. Mustard is an energy rich crop which requires the major, secondary and micronutrients in adequate quantity for higher production. Mustard is quite responsive to micronutrients boron (B), which plays important role in growth and development of this crop (Yanthan and Singh, 2021).

Availability of boron to plant is affected by variety of soil factor including soil pH, texture, moisture, temperature, oxide content, carbonate content, organic matter content and clay mineralogy (Goldberg *et al*., 2000). Its deficiency has been realized as the second most important micronutrient constraint in crops after that of zinc on global scale (Ahmed *et al*., 2012). Boron (B) plays an important role in the development and differentiation of sugar in plant. It helps in the normal growth of plant and in adsorption of nitrogen (N) in soil and also makes up the calcium (Ca) deficiency to some extent. Boron also helps in root development, flowers and pollen grain formation. Boron application produced the best quality of seeds in respect of protein content of mustard (Sharma *et al*., 1990). Boron deficiency in mustard may cause sterility *i.e*., less pods and less seeds per pod, attributing low seed yield (Islam and Anwar, 1994). On the other hand, optimum B nutrition in mustard resulted maximum plant height, plant dry weight, number of siliquea/plant, number of seeds/siliquea, stover yield and seed yield (Yadav *et al*., 2016; Mosam and Umesha, 2022).

Selenium (Se) is a nonmetal element belonging to the oxygen–sulfur–tellurium group, and is ranked 70th among the 98 elements that form the earth's crust (Edelstein, 2016). One of the possible ways to challenge the widespread Se deficiency affecting world population is a bio-fortification of plants with this element. The essential effects and reciprocal relationships of Se in human organism has already been reported (Drutel *et al*., 2013), whereas Se is considered as beneficial element to plant (Edelstein, 2016). Indeed, the use of NPK-fertilizers enriched with sodium selenate in Finland since 1980 contributed to significant decrease of mortality level caused by cancer and cardiovascular diseases, in the absence of environmental pollution due to this element (Alfthan *et al*., 2015). The latter phenomenon is connected to a large extent with: redox processes in soil; formation of insoluble complexes of Se with aluminum as well as iron oxides and hydroxides; microbial reduction of Se to the non-active elemental form and formation of volatile methylated derivatives (Edelstein, 2016).

Investigations on separate plant fortification with Se showed that plant growth is promoted within narrow concentration ranges (Medrano-Macias *et al*., 2016; Pilon-Smits and Quinn, 2010). Conversely to Se is supposed to be just essential to plants – hyper-accumulators of this element, able to concentrate up to 4 g Se per kg dry weight without evident symptoms of Se toxicity (Terry *et al*., 2000; Cakir *et al*., 2012). Some similarities of Se biological functions among humans, animals, and plants suggest the existence of close interactions between these elements even in plants. In this respect, Se shows strong antioxidant and immune-modulating properties both in mammals and plants, by protecting the organism against different forms of oxidant stress (Golubkina and Papazyan, 2006; Zimmermann and Kohrle, 2002). Moreover, Se reportedly increases plant tolerance to drought, salinity, UV-rays, viral diseases and herbivore, both through antioxidant defense enhancement and acting as an antioxidant directly or indirectly by encouraging the activities of antioxidant enzymes (Medrano-Macias *et al*., 2016; Pilon-Smits and Quinn, 2010; Hasanuzzaman *et al*., 2010); Se display strong protection against heavy metals in biological systems (Smolen and Sady, 2011; Shekari *et al*., 2017). Under high Se absorptions, all living beings including mammals and plants synthesize specific volatile methylated derivatives (Golubkina and Papazyan, 2006; Van-Huysen *et al*., 2003). High Se concentration could enter the food chain and injure humans and animals. In humans, daily intake greater than 900 µg Se may result in toxicity, termed selenosis (Kopsell *et al*., 2009). High Se concentrations were shown to provoke oxidative stress responses such as increased lipid peroxidation in plants (Hartikainen *et al*. 2000).

Brassica (genus of mustard) has three species that produce edible oil, they are *B. napus*, *B. campestris* and *B. juncea*. Of these, *B. napus* and *B. campestris* are of the greatest importance in the world's oil seed trade. Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). A significant yield difference among the varieties of rapes and mustard with the same species (Uddin *et al*., 1987). Oil content variation due to different variety and different method (Singh *et al*., 1999). Yield contributing characters (number of branches plant^{-1}, number of capsules plant^{-1}, capsule length, 1000-seed weight etc.) and yield of different variety varied significantly (BARI, 2001; Mamun *et al*., 2014; Alam *et al*., 2014; Ahmed and Kashem, 2017).

Considering the facts above, there are great scopes of increasing of mustard production by increasing cultivated area with choosing proper variety and optimum nutrition of micronutrients to plants, the present study was undertaken with the following objectives:

1. To observe the combination effect of boron and selenium on growth and yield of different varieties of *Brassica* oilseeds.
2. To find out the maximum growth and yield of mustard variety by the influence of boron and selenium.
3. To study the response of different *Brassica* oilseeds species to boron and selenium

CHAPTER II

REVIEW OF LITERATURE

The response of mustard varieties to different levels of organic boron and selenium for its successful cultivation has been investigated by numerous investigators in various parts of the world. In Bangladesh, there have not enough studies on growth and yield response of different *Brassica* oilseeds species to B and Se. However, the available research findings in this connection over the world have been reviewed in this chapter.

2.1 Effect of genotypes on growth, yield and quality on mustard

A field experiment was conducted, to study the performance of Indian mustard genotype in relation to sulphur fertilization. Singh *et al*. (2002) found that 'Pusa Bahar' gave the highest seed yield (1,456 kg ha^{-1}), and the magnitude of increase was5.0, 20.1 and 13 per cent more yield than 'Varuna', 'PPM-16'and 'Rohini', respectively. Significantly, higher yield attributes and oil content and its production were also noted in 'Pusa Bahar' over all other varieties. They also reported that 'Pusa Bahar' significantly increased yield attributes and oil content and its production were also noted higher in 'Pusa Bahar'over all other varieties. They also reported that 'Pusa Bahar' significantly increased yield attributes such as siliquae $plant^{-1}$, siliquae length, seeds $siliqua^{-1}$, seed yield $plant^{-1}$and 1000-seed weight over 'Rohini' and 'PBM-16' but at par with 'Varuna' genotype.

A field experiment was conducted during 1996-97 and 1997-98 at crop research center, Pantnagar Singh *et al*. (2002) studies the effect of different fertility levels on yield attributes, seed yield, harvest index, oil content and oil yield of promising *Brassica* varieties. Branches $plant^{-1}$ (31.86), seed weight $plant^{-1}$ (4.75), 1000-seed weight (4.4 g), seeds $siliqua^{-1}$ (9.7) and seed yield (1,350 kg ha^{-1}) were highest in 'PCB-9221' (Kiran) of *Brassica carinata*. Oil content of 'Kranti' of *Brassica juncea* was higher but oil yield was more in

‘BC-9221’. Both the varieties of *Brassica carinata* had significantly increased seed yield than of Indian mustard varieties.

Haider *et al*. (2007) carried out a field experiment during the two consecutive seasons of 2000-2002 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 Sharis ha-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. Among the 4 tested varieties of mustard, BARI Sharis ha-7 showed a good performance and produced the highest mean yield (1.77 t ha^{-1}) as compared to other varieties used.

Hussain *et al*. (2008) conducted an experiment 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. Among three mustard varieties of BARI sharisha-8, BARI sharisha-9 and BARI sharisha-11; BARI sharisha-11 and BARI sharisha-8 performed better and highly response to boron than BARI sharisha-9. Highest seed yield (1570 kg/ha) was obtained from the combination of BARI Sharisha-11 and boron level 1.0 kg/ha.

Thuan *et al*. (2010) evaluated to genotypes of Indian mustard (*B. Juncea*) viz., ‘Pusa Mahak’ and ‘Pusa Krishna’ under organic and inorganic sulphur (S) levels and observed that ‘Pusa Mahak’ recorded higher number of siliquae $plant^{-1}$ and test weight, number of seed $siliqua^{-1}$ than ‘Pusa Krishna’. They also reported that application of sulpur @ 40 kg ha^{-1} produced 19.3% higher seed yield than the control.

Singh *et al*. (2010) conducted an experiment in sandy loam soils of Varanasi and reported that ‘NRCHB-101’ being at par to Ashirwad produced significantly higher seed yield and stover yield over Varuna, Kranti and Vardan in both the years (1811 kg ha^{-1} and 1827 kg ha^{-1}). On pooled basis, NRCHB-

101 recorded seed yield of 1819 kg ha^{-1}, which in turn recorded 3.72, 6.33, 7.23 and 7.92 percent higher seed yield than Ashirwad, Varuna, Kranti and Vardan, respectively.

Pachauri *et al*. (2012) was conducted field experiment during winter season of 2008-09 and 2009-10 on sandy loam soil at agricultural research farm of Raja Balwantsingh college, Bichpuri, Agra to find out the effect of sulphur levels on growth, yield and quality of Indian mustardon genotypes. The treatments consisted of four genotypes (‘Pusa Bold’, ‘Rohni’, ‘Varuna’ and ‘Kranti’) of mustard and four levels of sulphur (0, 30, 60 and 90 kg ha^{-1}) applied through elemental sulphur in factorial randomize block design replicated thrice. ‘Pusa Bold’ genotype recorded the highest seed yield of 2.05 and 2.09 tha^{-1} during 2008-09 and 2009-10, respectively followed by ‘Varuna’, ‘Rohini’ and ‘Kranti’ genotypes.

Three Indian mustard Cultivars (‘Kranti’, ‘Bio-902’ and ‘Rohini’) were by Singh *et al*. (2012) tested with 4 levels of sulphur (0, 20, 40, 60 kg ha^{-1}) during the winter season of 2006-2007. The variety ‘Rohini’gave higher plant height, number of branches plant^{-1}, siliquae plant^{-1}, seeds siliqua^{-1}, 1000-grain weight, harvest index and resulted significantly higher seed and stover yield, oil and protein content than ‘Bio-902’ and ‘Kranti’. The application of 60 kg sulphur ha^{-1} gave significantly higher grain yield and quality (protein and oil content in seed) over all other levels of sulphur application and the control.

Alam *et al*. (2014) conducted a field experiment with 30 varieties/genotypes of rapeseed-mustard under three dates of sowing *viz*., 25 November, 5 December, and 15 December to determine changes in crop phenology, growth and yield of mustard genotypes under late sown condition. Yield and yield attributes of different varieties varied significantly. Among the varieties, BARI Sarisha-16 of *Brassica juncea* gave significantly the highest seed yield (1495 and 1415 kg/ha), which was statistically identical to BJDH-11, BJDH-12, BJDH-05, BJDH-20, and BARI Sarisha-6 and significantly different from all other varieties. The highest seed yield (1758 and 1825 kg/ha) were recorded from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25 November planting and BJDH-11 produced the highest yield at 15 December in both the years.

Kumar *et al*. (2015) conducted an experiment in sandy loam soil of West Bengal on two varieties of rapeseed (NC-1, B-9) and four varieties of mustard (SEJ-2, NPJ-112, JD-6 and NRCHB 101) and reported that mustard variety JD-6 recorded significantly higher plant height (180.32 cm) and was on par with NRCHB 101 (178.03 cm). NRCHB-101 achieved maximum number of siliqua per plant (146.10) and seed yield (1.54 t ha^{-1}).

Ahmed and Kashem (2017) conducted a varietal trial of mustard in haor areas of south Sunamganj district, Bangladesh to find out the suitable mustard variety/varieties. A total of five varieties *viz*. BADC 1, SAU Sarisha-3, BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-15 were tested in the farmer's field. Significant differences were found among the mustard varieties for number of branches $plant^{-1}$, number of capsules $plant^{-1}$, capsule length, 1000-seed weight and seed yield. The mustard var. BARI Sarisha-11 produced the highest number of branches $plant^{-1}$, number of capsules $plant^{-1}$, 1000-seed weight resulting the highest seed yield (1.64 t ha^{-1}), followed by BARI Sarisha-15 (1470 kg ha^{-1}). The seed yield of BARI Sarisha-11 and BARI Sarisha-15 was not differed significantly, but the growth duration of BARI Sarisha-15 was shorter than the others.

Beenish *et al*. (2018) conducted a field experiment to study the organic manures and biofertilizers: Effect on the growth and yield of Indian mustard varieties. The treatments consisted of five mustard varieties (Rudra 99D, Shikhar, Rani, Varuna and Yellow Goldey) with 10 fertilizer treatments. The result of the study revealed that the variety Rani recorded significantly tallest plant, highest number of primary branches, number of siliquae/plant, seeds per siliqua, seed and straw yields, whereas secondary branches were significantly highest with variety yellow Goldey.

Ahamed *et al*. (2019) carried out an experiment to find out the effect of different sowing methods and varieties on the yield of (*Brassica campestris*). The experiment comprised of four sowing methods *viz*. S_0 = Broadcast method, S_1 = Line to line space 20 cm, S_2 = Line to line space 25 cm and S_3= Line to line space 30 cm and three different varieties *viz*. V_1 = BARI Sarisha-14, V_2 = BARI Sarisha-15 and V_3 = BARI Sarisha-17. The highest plant population (77.25) was observed in case of BARI Sarisha-14. The tallest plant of mustard was found in case of with BARI Sarisha-15. The maximum branches plant^{-1}, dry matter weight plant^{-1}, siliqua plant^{-1}, seed silliqua^{-1}, and length of silliqua were obtained from BARI Sarisha-15. The highest yield of seed (950 kg/ha) was obtained from BARI Sarisha-15. The combinations of different sowing methods and different varieties had significant effect on almost all the parameters. The highest biological yield per hectare (5.08 tones) was obtained from broadcast method with BARI Sarisha-15 treatment combination.

Alim *et al*. (2020) conducted an experiment using two mustard varieties BARI Sarisha-14 (V_1) and BARI Sarisha-16 (V_2) in combination with six integrated nutrient managements (INM). The highest seed yield (1820 kg ha^{-1}) was obtained from BARI Sarisha-16 and the lower seed yield (1.51 t ha^{-1}) was observed in BARI Sarisha-14.

Sarker *et al*. (2021) conducted a research to investigate the growth and yield performance of mustard varieties. The experiment was arranged in a randomized complete block design consisting of eight mustard varieties (*viz*. BARI Sarisha-8, BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16, Rai and Tori-7) as treatment and replicated thrice. All the growth, yield attributes and yield were substantially influence among the mustard varieties except the phenological parameters. Results of the experiment showed that the highest plant height (131.33 cm), seed yield

(1813.33 kg ha^{-1}) and stover yield (3876.67 kg ha^{-1}) were found in BARI Sarisha-16. BARI Sarisha-11 was found better in respect of maximum siliqua $plant^{-1}$, weight of seeds $plant^{-1}$, 1000-seed weight and harvest index. Besides this, BARI Sarisha-14 showed the maximum number of seeds $siliqua^{-1}$.

2.2 Effect of boron and/or selenium

2.2.1 Effect of boron

Recent advances in B research have greatly improved an understanding for B uptake and transport processes (Brown *et al*., 2002; Takano *et al*., 2002), and roles of B in cell wall formation (Matoh, 1997; O'Neill *et al*., 2004), cellular membrane functions (Goldbach *et al*., 2001) and anti-oxidative defense systems (Cakmak and Romheld, 1997). Boron deficiency is a worldwide problem for field crop production where significant crop losses occur both in yield and quality (Nyomora *et al*., 1997; Wei *et al*., 1998). Availability of B to plants is affected by a variety of soil factors including soil pH, texture, moisture, temperature, oxide content, carbonate content, organic matter content and clay mineralogy (Goldberg *et al*., 2000). Boron is generally less available in clay soils and availability increases with increasing temperature (Fleming, 1980). Soil pH is regarded as a major factor regulating B availability in soils. Increasing pH favours its retention by soils or soil constituents (Goldberg, 1997). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Noppakoonwong *et al*., 1997). Thus, B fertilization is necessary for improvement of crop yield as well as nutritional quality. Mustard as a *Brassica* crop is very responsive to B application (Mengel and Kirkby, 1987). There are numerous reports on the positive response of mustard to B fertilization (Islam, 2005; Hossain *et al*., 1995 and Saha *et al*., 2003).

Boron (B) fertilization is required for increasing crop yield and nutritional quality. There have been numerous reports on mustard's positive response to B fertilization (Mounika *et al*. 2021). Brassicas have a greater B need, and a severe deficit can lead to floral abortion and a reduction in seed yield (Hossain *et al*., 2011). Apart from essential plant nutrients, B is vital in the phenology of mustard production, and this crop responds to boron application (Yadav *et al*., 2016).

Haider *et al*. (2007) carried out a field experiment during the two consecutive seasons of 2000-2002 to evaluate the effect of B on the yield of mustard and to screen out the suitable variety(s) tested against different B levels for maximizing yield of mustard in the study area. Results revealed that B at the rate of 1.5 kg ha^{-1} individually increased the highest seed yield by 58.83%, over B_0, 1.0 and 2.0 kg ha^{-1}). However, from regression analysis, a positive but quadratic relationship was observed between seed yield and B levels.

Hussain *et al*. (2008) conducted an experiment 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 B application on yield and yield attributes of different mustard varieties. The experiment involved five B 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 B/ha should be applied along with recommended fertilizers produced higher seed yield. Highest seed yield (1.57 t/ha) was obtained from the combination of BARI Sharisha-11 and B level 1.0 kg/ha.

Hossain *et al*. (2011) conducted an experiment was conducted for three years from 2003-04 to 2005-06 to find out the optimum rate of B application for maximizing nutrient uptake and yield of mustard in calcareous soil of Jessore, Bangladesh. B was applied at 0, 1, and 2 kg ha^{-1}. The mustard variety BARI Sarisha-8, (*B. napus* group) was selected for the experiment. 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. The optimum rate of B was found to be 1 kg/ha There was no significant difference between 1 and 2 kg B ha^{-1}in all the years. B 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.

Ara *et al*. (2015) conducted an experiment to examine the response of nitrogen and B on growth, yield attributes and yield of rapeseed cv. BARI Sarisha- 14. The experiment consisted four levels of nitrogen (N_0: 0, N_1: 60, N_2: 120 and N_3: 180 kg N ha^{-1}) and three levels of B (B_0: 0, B_1: 1 and B_2: 2 kg ha^{-1}). The maximum plant height, number of leaves, number of primary branches, length of inflorescence, number of siliquae, seed weight of 100 siliquae, seed yield $plant^{-1}$, seed yield ha^{-1} was found from B_2 (83.7 cm, 22.7 4 $plant^{-1}$, 6.0 $plant^{-1}$, 33.4 cm, 25.4 $plant^{-1}$, 10.4 g, 5.2 g, and 1.5 t, respectively) for B levels.

Yadav *et al*. (2016) conducted a field experiment 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 (*B. 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 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%.

Riaj *et al*. (2018) conducted a field experiment 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_0= without nitrogen, N_1= 60 $kgha^{-1}$, N_2=90 $kgha^{-1}$, N_3=120 $kgha^{-1}$ and Factor-B: B doses: 3 doses, B_0= without B, B_1=1 $kgha^{-1}$, B_2= 2 $kgha^{-1}$. The highest 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 kg ha^{-1}), stover yield (4378.55 kg ha^{-1}), harvest index (22.97%) were recorded in B @ 2 kg B/ha whereas the lowest results were found in control. Due to the interaction effect of nitrogen and B 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 kg ha^{-1}), stover yield (4712.65 kg ha^{-1}), harvest index (25.00 %) were highest in nitrogen @ 120 kg N ha^{-1} combined with B @ 2 kg B ha^{-1} in mustard.

Nadaf and Chandranath (2019) conducted a field experiment to study the effect of Zn and B levels on yield, quality and nutrient uptake in mustard during rabi, 2017 with 10 treatments. The treatment comprised of two levels of zinc (10 kg ha^{-1} and 20 kg ha^{-1}) and two levels of B (1 kg ha^{-1} and 2 kg ha^{-1}) and their combinations. These treatments were compared with RDF + FYM @ 5 t ha^{-1} and RDF (60:50:40 N: P_2O_5: K_2O) alone. Application of $ZnSO_4$ @ 20 kg ha^{-1} along with borax @ 2 kg ha^{-1} recorded higher seed yield (1973 kg ha^{-1}), oil content (37.08 %), oil yield (731 kg ha^{-1}), uptake of zinc (242 g ha^{-1}) and B (76 g ha^{-1}) were noticed over RDF + FYM alone. However, which was on par with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 1 kg ha^{-1} and RDF + ZnSO4 @ 10 kg ha^{-1} + borax @ 2 kg ha^{-1}.

Yanthan and Singh (2021) carried out a field experiment entitled the effect of B and Zn levels on growth and yield of yellow mustard (*Brassica campestris* L.). The experiment was laid out in Randomized Block Design with nine treatments and replicated thrice. The plot consisted of two levels of B (1 and 2 kg/ha) and zinc (5 and 10 kg/ha) along with RDF as NPKS each at 80:40:40:40 kg/ha respectively. The results revealed that the maximum no. of siliqua plant^{-1} (86.07), no. of seeds siliqua^{-1} (40.27), test weight (3.85 g), seed yield (1.95 t ha^{-1}), stover yield (2.96), harvest index (39.70%) and benefit cost ratio (2.6) was obtained in the treatment RDF + 1 kg B/ha (T_2).

Mosam *et al*. (2022) conducted a field experiment to evaluate the effect of B levels and row spacing on growth and yield of mustard (*Brassica juncea* L.). The experiment was laid out in a randomized block design with nine treatments with three replications. The treatments comprising of different levels of B and row spacing whose effect was observed in mustard. The results obtained that the application of B @ 3 kg/ha plus row spacing of 30cm recorded significantly maximum plant height (192.53 cm), plant dry weight (36.95 g/plant), number of siliquea/plant (314.47), test weight (5.14g), number of seeds/siliquea (15.33), stover yield (4610 kg/ha), seed yield (2480 kg/ha). Therefore, treatment with application of B @ 3 kg/ha long with row spacing of 30cm was more productive and can be recommended to farmers after further trails.

2.2.2 Effect of selenium

The Se concentration in plants depends on the chemical form of Se, its concentration and bioavailability in soils and the accumulation capacity of the plant. In higher plants metabolism of Se is closely related to that of sulfur due to their chemical similarity. The non-specific incorporation of the selenoamino acids (selenomethionine and selenocysteine) into proteins is thought to be the major cause of Se toxicity in non-accumulator plants supplied with a high Se dose (Brown and Shrift, 1982).

Lyons *et al*. (2005) suggested that one explanation for higher toxicity of selenite compared to selenate is that after uptake selenite is incorporated faster than selenate into selenoamino acids in roots. High Se concentrations were shown to provoke oxidative stress responses such as increased lipid peroxidation in plants (Hartikainen *et al*. 2000).

The ability to accumulate and tolerate high Se levels is related to differences in Se metabolisms between accumulator and non-accumulator plant species. Se accumulators and some secondary accumulators limit the integration of selenoamino acids into proteins by converting Se into soluble non-protein seleno-amino acids like Se-methyl-seleno-cysteine, U-glutamyl-Semethylseleno-cysteine, and seleno-cystathionine (Brown and Schift,1982; Terry *et al*. 2000; Whanger, 2002).

The Se-methyl-seleno-cysteine is the most predominant selenoamino acid in the Se-accumulators such as garlic (*Allium sativum* L.), onion (*Allium cepa* L.), broccoli (*Brassica oleracea* L.) and wild leek (*Allium tricoccum* L.) (Neuhriel *et al*., 1999; Whanger, 2002). Se has been shown to act as a cancer-preventing agent (Clark *et al*., 1996; Whanger, 2002; Ellis and Salt, 2003) and Se-methylselenocysteine in particular has been shown to have chemoprotective effects against cancer (Finley *et al*., 2001). In non-accumulator plants, selenomethione has been found to be the main Se species in seeds of cereals (Stadlober *et al*., 2001) and in seed and leaves of pea (*Pisum sativum* L.) plants (Smrkolj *et al*., 2006).

The uptake of selenate into roots and its distribution in plants is much faster than that of selenite (Asher *et al*., 1977; Arvy, 1993; Pilon-Smits *et al*., 1998; Cartes *et al*., 2005). De Souza *et al*. (1998) reported that total Se accumulation in a plant was about 10-fold higher from selenate than from selenite. It was proposed that selenate, chemically analogous to the sulphate ion, is actively transported into roots via sulphate transporters and subsequently quickly transported into shoots (Asher *et al*., 1977; Arvy, 1993; Terry *et al*., 2000). In addition, plants can actively take up organic forms of Se such as selenomethionine (Zayed *et al*., 1998; Terry *et al*., 2000). The transport of Se from roots to shoots is thought to occur via xylem (Asher *et al*., 1977; Arvy, 1993).

The positive effect of Se on plant growth was reported by Singh *et al*. (1980), who showed that the application of 0.5 mg kg^{-1} Se as selenite stimulated growth and dry-matter yield of Indian mustard (*Brassica juncea* L.). More recently, it was revealed that Se, applied at low concentrations, enhanced growth and antioxidative capacity of both mono and dicotyledonous plants. The growth-promoting response to Se was demonstrated in lettuce and ryegrass

(*Lolium perenne* L.) (Hartikainen *et al*., 1997; Hartikainen and Xue, 1999) and in soybean (*Glycine max* L.) (Djanaguiraman *et al*., 2005).

Pennanen *et al*. (2002) also observed that Se induced starch accumulation in chloroplasts of young leaves. Addition of Se at low concentrations alleviated the oxidative stress caused by UV-irradiation in lettuce and ryegrass (Hartikainen and Xue, 1999; Hartikainen *et al*., 2000) and in strawberry (*Fragaria ananassa*) (Valkama *et al*., 2003). Furthermore, at an optimal level Se was able to increase the antioxidative capacity of senescing plants and delay senescence in lettuce, ryegrass (Xue *et al*., 2001) and soybean (Djanaguiraman *et al*., 2005), to improved the recovery of potato plant from light and chilling stress (Seppänen *et al*., 2003), and to enhance salt-resistance in sorrel (*Rumex patientia*) seedlings (Kong *et al*., 2005). Furthermore, Pennanen *et al*. (2002) reported that in addition to Se increasing the growth of plants, it was also able to delay the death of plants.

Selenium (Se) was demonstrated to have an effect in leaf mesophyll and roots tip cells by affecting membrane integrity of chloroplasts and mitochondria (Kong *et al*., 2005). Se has also had a demonstrated effect on germination. Carvalho *et al*. (2003) reported that at higher supplementation level than 29 mg kg^{-1} soil, Se inhibited the growth and germination of tomato, lettuce and radish (*Raphanus sativus* L.) seeds. In contrast, priming of seeds with selenite promoted germination of bitter gourd (*Momordica charantia* L.) seeds at sub-optimal temperatures (Chen and Sung, 2001).

Hanson *et al*. (2004) showed that Se protected Indian mustard plants against feeding by green peach aphids (*Myzus persicae*). In addition, Se protected Indian mustard plants from white cabbage caterpillars (*Pieris rapae* L.). (Hanson *et al*., 2003). Moreover, Se-enriched Indian mustard plants were more tolerant than controls to a root and stem fungal pathogen (*Fusarium* sp.) and a leaf pathogen (*Alternaria brassicicola*) infection (Hanson *et al*. 2003).

Turakainen (2007) reported that Se addition at 0.075 and 0.3 mg kg^{-1} did not promote the growth of potato shoots, roots or stolons as assessed by the dry matter production. Selenate did, however, increase shoot and root biomass production in lettuce (Xue *et al*., 2001, Simojoki *et al*., 2003) and ryegrass fertilized with 0.1 mg Se kg^{-1} (Hartikainen *et al*., 2000). It also increased the shoot dry matter production of soybean sprayed with 50 mg Se L^{-1} (Djanaguiraman *et al*., 2005).

Selenium applications of 0.01 and 0.075 mg kg^{-1} had no effect on the yield of immature tubers of cultivars Satu or Sini, however, the highest yields of cv. Satu were harvested from the mature plants treated with Se at 0.075 and 0.3 mg kg^{-1} (Turakainen, 2007). At an optimal level Se appears to promote tuber growth; potato tubers and rapidly expanding leaves in lettuce and ryegrass leaves are strong sinks for carbohydrates (Xue *et al*., 2001, Hartikainen *et al*., 2000, Pennanen *et al*., 2002). The starch concentration in the upper leaves of young plants increased with increasing Se application levels. Also, the concentration of soluble sugars at the Se application rate of 0.3 mg Se kg^{-1} was elevated (Turakainen, 2007).

Pennanen *et al*. (2002) reported that Se enhanced production and accumulation of starch in granules in young lettuce plants. In Se-treated plants the build-up of energy reserves in leaves became evident as increased shoot yields. The authors concluded that Se-induced increase in growth was related to the inducible role of Se in chloroplast enzymes and carbohydrate metabolism.

Mazzafera (1998) showed that in coffee plants (*Coffea arabica* L.) selenite applied to the soil caused increased soluble sugar concentration in the first pair of leaves. Similarly, foliar application lead to increase in soluble sugar concentration in the beans.

Edelstein (2016) carried out a study with selected tomato 'Abigail' (*Solanum lycopersicum* L.) and basil 'Perry' (*Ocimum basilicum* L.) as model plants for Se supplementation to evaluate (a) effects of Se concentration in nutrient solution on Se content in different organs under fertigation, (b) Se phytotoxicity threshold values, and (c) mechanisms. Plants grown in a glasshouse were irrigated with 0, 1, 2, 5, and 10 mg Se L^{-1} in the first experiment, while with 0, 0.25, 0.5, 0.75, 1.0, and 1.5 mg Se L^{-1} in the second. Plants supplemented with 1.5 mg Se L^{-1} in the irrigation water accumulated 0.23 and 0.88 mg Se/g dry weight (DW) in tomato fruits and basil shoots, respectively. However, tomato roots, shoots and fruits DW were 56%, 36%, and 66% lower than in controls, respectively, and basil roots and shoots DW were 92% and 88% lower than in control, respectively. Calculated toxicity-threshold values were 1.27 mg Se L^{-1} for tomato and 0.44 mg Se L^{-1} for basil. The results indicate that Se supplementation through drip irrigation may efficiently fortify tomato and basil.

Golubkina *et al*. (2018) reported that peculiarities of Se and I assimilation by a natural Se accumulator, such as *Brassica juncea* L., cultivar Volnushka, were assessed upon joint and separate plant foliar supply with sodium selenate (50 mg Se L^{-1}) and potassium iodide (100 mg I L^{-1}), in two crop seasons (spring, summer). The individual application of Se and I, their joint supply did not stimulate plant growth. Separate use of sodium selenate enhanced I accumulation by 2.64 times, while biofortification with I increased the Se content in plant leaves by 4.3 times; this phenomenon was also associated with significant increase of total soluble solids and ascorbic acid content in leaves. The joint supply of Se and I did not affect the mentioned parameters. Both joint and separate application of Se and I led to synergism between these elements in: inhibiting nitrate accumulation; stimulating flavonoids biosynthesis (2–2.3 times compared to control plants) as well as Al and B accumulation; decreasing Cd and Sr concentrations. The consumption of 100 g *Brassica juncea* leaves provided 100% of the adequate human requirement of Se and 15.5% of I.

Sultan *et al*. (2020) carried out a study to evaluate the productivity and quality of white mustard by exogenous application of Se under an arid climate in

Pakistan, during the year 2016. This experiment was conducted using the RCBD with split plot arrangements. The results revealed that the plant height, stem diameter, 1000-seed weight, seed and biological yield were significantly improved by Se.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2020 to February 2021 to study the growth and yield response of different brassica oilseeds species to B and Se. The materials and methods that were used for conducting the experiment are presented under the following headings:

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 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 II.

3.3 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 III.

3.4 Experimental details

3.4.1 Treatments

Factor A: Variety – 3 varieties of mustard

1. V_1 = BARI Sarisha-16
2. V_2 = BARI Sarisha-14
3. V_3 = BARI Sarisha-17

Factor B: Boron + selenium – 4 treatments

1. S_0 = Control (no boron or selenium)
2. S_1 = Boron (1 mM spray)
3. S_2 = Selenium (25 µM spray)
4. S_3 = Boron (1 mM) + Selenium (25 µM)

Treatment combinations – Twelve (12) treatment combinations

V_1S_0, V_1S_1, V_1S_2, V_1S_3, V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_3S_0, V_3S_1, V_3S_2 and V_3S_3.

3.4.2 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 mustard varieties and boron (B) + selenium (Se). The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot was 3.25 m × 1.2 m. The distance between blocks and plots were 0.75 m and 0.50 m, respectively.

3.4.3 Collection of seeds

BARI Sarisha-16, BARI sarisha-14 and BARI Sarisha-17; high yielding varieties of mustard developed by Bangladesh Agricultural Research Institute (BARI), Gazipur were used as test crops. Seeds were collected from BARI, Joydebpur, Gazipur.

3.5 Preparation of the main field

The plot selected for the experiment was opened in the first week of November, 2020 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 15 November 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.6 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 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	250 kg
P	TSP	170 kg
K	MoP	80 kg
S	Gypsum	150 kg
Zn	$ZnSO_4$	5 kg
B	Boric acid	As per treatment (foliar spray)
Se	Selenium	As per treatment (foliar spray)

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. Boric acid and

Selenium were applied as foliar spray according to the treatments. The remaining urea was top dressed in two equal installments at 20 days after sowing (DAS) and 30 DAS, respectively.

3.7 Preparation of stock solution for boron and selenium for foliar spray

1 mM B solution: 0.062 g boron dissolved in 1 L of water

25 µM Se solution: 25 ml Se dissolved in 1 L of water

3.8 Application of boron and selenium

Six foliar spray of boron, selenium and boron + selenium were applied according to the treatments started at 20 days after sowing (DAS) and continued to 55 DAS at 7 days intervals.

3.9 Sowing of seeds

Seeds were sown continuously @ 7 kg ha^{-1} on 15 November 2020 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. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.10 Intercultural Operation

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

3.10.1 Weeding and thinning

First weeding and thinning was done on 5 December 2020. Again, 2nd weeding and thinning was done on 15 December 2020. Care was taken to maintain uniform plant population per plot.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 6 December 2020 at 20 days after sowing (DAS) through irrigation channel.

The second irrigation was given at the stage of maximum flowering (35 DAS). The final irrigation was given at the stage of seed formation (50 DAS).

3.10.3 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliquae filling stage. The insects were controlled successfully by spraying Malathion 57 EC @ 2 ml L^{-1} water. The insecticide was sprayed on 6 January 2021. The crop was kept under constant observations from sowing to harvesting.

3.11 General observations of experimental field

The plots under experiment were frequently observed to notice any change in plant growth and other characters were noted down immediately to make necessary measures.

3.12 Harvesting and post harvest operation

The crop was harvested plot wise when 90% siliqua were matured. After collecting sample plants, harvesting was done from 7 February to 22 February 2021 according to varieties assigned. The variety, BARI Sarisha-14 was harvested on 7 February 2021 whereas BARI Sarisha-17 and BARI Sarisha-16 were harvested on 9 February and 22 February 2021, respectively. 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. Seed and straw yield per plot were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise.

3.13 Data Collection and Recording

Experimental data were recorded from 30 DAS and continued until harvest. The followings data were recorded during the experiment:

3.13.1 Morphological parameters

1. Plant height
2. Number of leaves plant^{-1}
3. Fresh weight of stem plant^{-1}
4. Stem dry weight plant^{-1}
5. SPAD value of leaf

3.13.2 Yield contributing parameters

1. Fresh weight of siliqua at 50 DAS
2. Dry weight of siliqua at 50 DAS
3. Siliqua length
4. Number of siliqua plant^{-1}
5. Number of seeds siliqua^{-1}
6. 1000-seed weight

3.13.3 Yield parameters

1. Seed yield ha^{-1}
2. Stover yield ha^{-1}
3. Harvest index

3.14 Procedure of recording data

3.14.1 Morphological parameters

3.14.1.1 Plant height

Plant height was measured using a meter scale from the ground level to the apex of the plants in randomly selected 10 plants from specific rows of each plot at 30, 40, 50 DAS and at harvest and the mean plant height (cm) was recorded.

3.14.1.2 Number of leaves plant^{-1}

Ten plants were selected randomly from the inner rows of each plot. Leaves plant^{-1} was counted from each plant sample at 30, 40 and 50 DAS and then averaged.

3.14.1.3 Fresh weight of stem plant^{-1}

Stem fresh weight plant^{-1} was measured from ten randomly selected plants. It was done by measuring of 10 plants from each plot at 30, 40 and 50 DAS then the average data were recorded.

3.14.1.4 Stem dry weight plant^{-1}

Stem dry weight plant^{-1} was measured from ten randomly selected fresh plants of each plot. Sample plants were dried in an oven at 70°C for 72 hours. The sample plants were transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample plants was taken and the average weight of 10 plants was termed as dry weight plant^{-1} and was expressed in gram (g).

3.14.1.5 SPAD value of leaf

Randomly chosen the plant taken five leaves in each plot. The bottom, middle and top portion of the plant leaves carefully measured at the leaf value. Leaf greenness was measured from randomly selected 5 leaves of each replication with the help of SPAD meter (Model: FT Green LLC, Wilmington, DE, USA) and it was measured in the morning at 30, 40 and 50 DAS.

3.14.2 Yield contributing parameters

3.14.2.1 Fresh weight of siliqua plant^{-1} at 50 DAS

At first total siliqua was collected from pre-selected ten plants of each plot at 50 DAS and after that it was weighed. Average weight was recorded in gram (g).

3.14.2.2 Dry weight of siliqua plant^{-1} at 50 DAS

Collected total siliqua from pre-selected ten plants of each plot at 50 DAS were dried in an oven at 70°C for 72 hours. Then it was transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and the average weight of siliqua of 10 plants was termed as dry weight of siliqua plant^{-1} and was expressed in gram (g).

3.14.2.3 Siliqua length

The length of the siliquae was measured from the base to the tip of the 10 randomly selected siliquae after harvest and then average data was recorded. It was done using meter scale and expressed in centimeter (cm).

3.14.2.4 Number of siliqua plant^{-1}

Number of total siliqua was counted from randomly pre-selected ten plants at harvest from each unit plot and the mean number was recorded. The number of siliqua plant^{-1} was recorded by the following formula.

$$\text{No. of siliqua plant}^{-1} = \frac{\text{Total number of siliqua}}{\text{Total number of plants for collected siliqua}}$$

3.14.2.5 Number of seeds siliqua^{-1}

The number of seeds was counted from randomly taking 10 siliqua per treatment. The average value is calculated as the number of seeds siliqua^{-1}.

3.14.2.6 Weight of 1000 seeds

From the seed stock of each plot, 1000-seed were randomly collected and weighed by an electric balance. The 1000-seed weight was recorded in gram (g).

3.14.4 Yield parameters

3.14.4.1 Seed yield ha^{-1}

Seed yield was calculated from well dried grains (at 10% moisture level) collected from the central 1 m^2 area of inner rows of each plot (leaving boarder rows) and seed yield from 1 m^2 area was converted to kg ha^{-1}.

3.14.4.2 Stover yield ha^{-1}

Stover yield of central 1 m^2 area of inner rows of each plot (leaving boarder rows) was measured from well dried condition and recorded stover yield from 1 m^2 area was converted to kg ha^{-1}.

3.14.4.3 Harvest Index

It denotes the ratio of economic yield to biological yield and was calculated with following formula:

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

Here, biological yield = grain yield + stover yield

3.15 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect of B fertilizer and selenium 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

Effect of variety

Different varieties showed a statistically significant variation for plant height of mustard at different growth stages except at 30 DAS (Figure 1 and Appendix IV). At 40 DAS, the tallest plant (40.68 cm) was recorded from the variety V_2 (BARI Sarisha-14) that was statistically same to V_3 (BARI Sarisha-17) whereas V_1 (BARI Sarisha-16) gave smallest plant (38.19 cm). At 50 DAS and at harvest, the tallest plant (85.76 and 164.10 cm, respectively) was found from the variety V_1 (BARI Sarisha-16) followed by V_3 (BARI Sarisha-17) whereas the smallest plant (75.73 and 86.75 cm, respectively) was achieved by V_2 (BARI Sarisha-14). This finding was agreed with the result of Singh *et al.* (2012), Kumar *et al.* (2015) and Sarker *et al.* (2021). Results showed that plant height was varied significantly due to varietal difference.

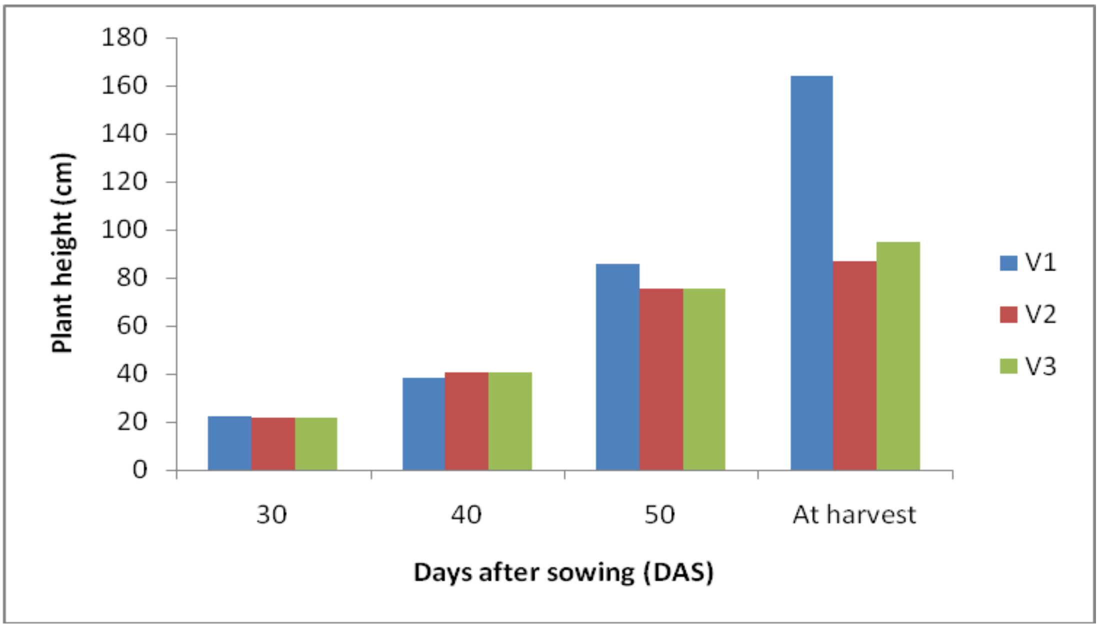

Figure 1. Plant height of different mustard varieties as influenced by B application

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

Effect of B and Se

Different treatments of B and Se exhibited statistically significant differences for plant height of mustard at different growth stages except at 30 DAS (Figure 2 and Appendix IV). At 40 and 50 DAS and at harvest, the treatment S_3 (B + Se; 1 mM + 25 µM spray) showed the tallest plant (42.28, 82.17 and 119.10 cm, respectively) which was significantly different from other treatments followed by S_2 (Se; 25 µM spray) whereas the smallest plant (38.15, 73.77 and 111.00 cm, respectively) was recorded from the control treatment S_0 (no B or Se). Results also showed that plant height increased with the combined application of B and Se compared to individual application of B or Se. It might be due to the soil nutrient availability for the plant due to the role of B or Se to plants. Similar result was reported by Mosam *et al*. (2022) and Sultan *et al*. (2020). Mosam *et al*. (2022) reported higher plant height higher doses of B. Again, Sultan *et al*. (2020) reported that plant height were significantly improved by Se.

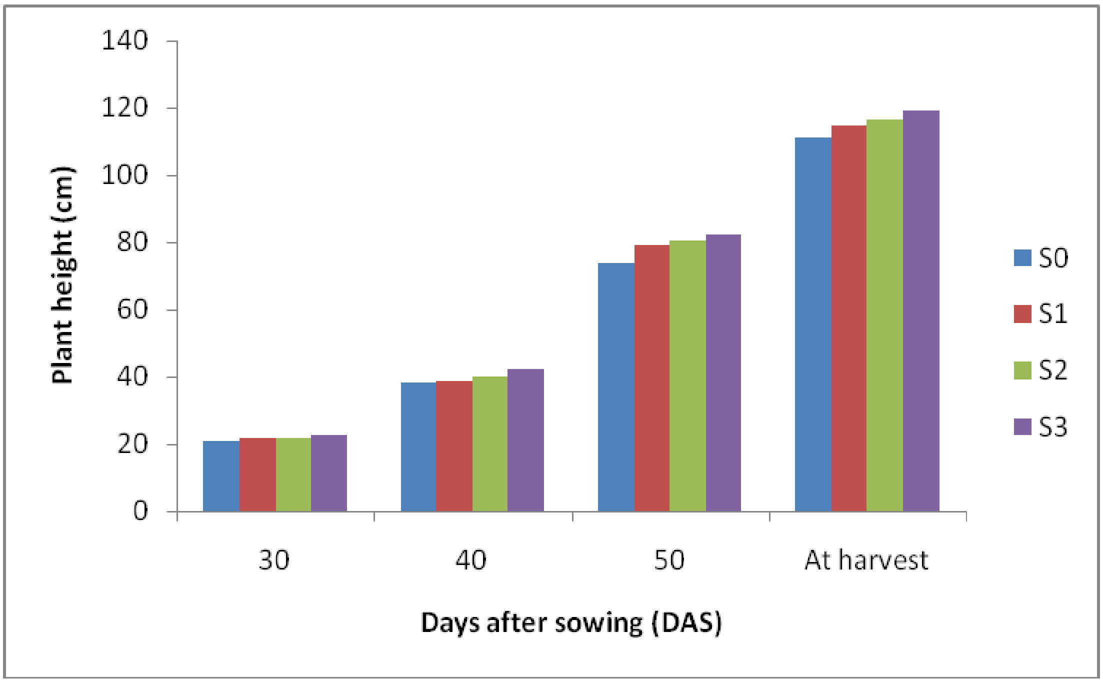

Figure 2. Plant height of different mustard varieties as influenced by Se application

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Combined effect of variety and B and Se

Significant interaction effect was also recorded between variety and B + Se in consideration of plant height of mustard at different growth stages except at 30 DAS (Table 1 and Appendix IV). At 40 DAS, the tallest plant (44.56 cm) was recorded from the treatment combination of V_2S_3 which was significantly different to other treatments followed by V_1S_3 whereas the smallest plant (36.24 cm) was recorded from the treatment combination of V_1S_3 which was significantly same to the treatment combination of V_1S_1. At 50 DAS and at harvest, the tallest plant (89.99 and 169.10 cm, respectively) was recorded from the treatment combination of V_1S_3 that was statistically similar to the treatment combination of V_1S_2. At 50 DAS, the smallest plant (71.23 cm) was recorded from V_3S_0 but at harvest it was recorded from V_2S_0 (82.32 cm).

Table 1. Plant height of different mustard varieties as influenced by B and Se application

Treatment	Plant height (cm) at			
	30 DAS	40 DAS	50 DAS	Harvest
V_1S_0	21.89	36.24 c	76.85 bcd	158.10 c
V_1S_1	22.04	36.55 c	87.48 a	163.50 b
V_1S_2	22.37	38.82 bc	88.73 a	165.70 ab
V_1S_3	23.28	41.16 b	89.99 a	169.10 a
V_2S_0	20.55	38.63 bc	73.23 ef	82.32 h
V_2S_1	21.25	38.91 bc	74.63 de	85.86 gh
V_2S_2	21.69	40.60 b	74.46 de	87.71 fg
V_2S_3	23.09	44.56 a	79.15 b	91.11 ef
V_3S_0	20.65	39.58 b	71.23 f	92.70 de
V_3S_1	21.59	40.31 b	75.83 cde	93.98 de
V_3S_2	21.64	40.71 b	78.11 bc	95.98 d
V_3S_3	21.97	41.11 b	77.38 bc	97.04 d
$LSD_{0.05}$	3.186^{NS}	2.684	2.673	4.409
CV(%)	7.30	8.90	13.91	4.89

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

4.1.2 Number of leaves plant^{-1}

Effect of variety

A statistically significant variation for number of leaves plant^{-1} of mustard was recorded due to varietal difference at different growth stages (Figure 3 and Appendix V). At 30 DAS, the maximum number of leaves plant^{-1} (7.61) was achieved from the variety V_3 (BARI Sarisha-17) which was statistically same to V_2 (BARI Sarisha-14). On the other hand, the minimum number of leaves plant^{-1} at 30 DAS (5.90) was recorded from the variety V_1 (BARI Sarisha-16). At 40 and 50 DAS, the maximum number of leaves plant^{-1} (14.59 and 19.94, respectively) was achieved from the variety V_2 (BARI Sarisha-14) whereas the minimum number of leaves plant^{-1} at 30 DAS (8.47 and 17.69, respectively) was recorded from the variety V_1 (BARI Sarisha-16). This result from the present study might be due to cause of genetical characters.

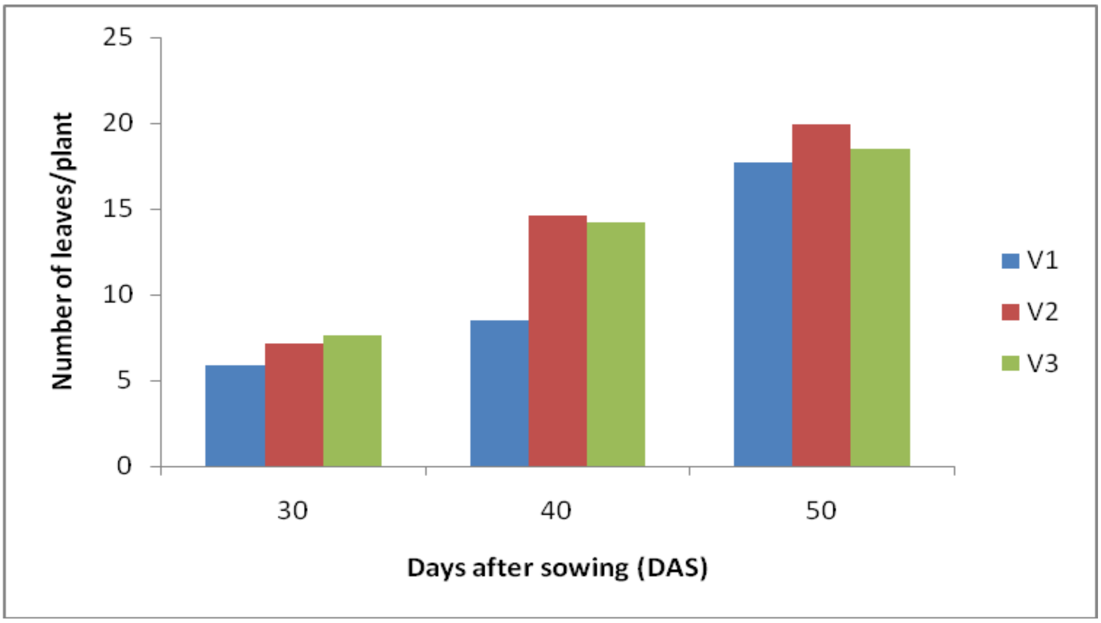

Figure 3. Number of leaves plant^{-1} of different mustard varieties as influenced by B application

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

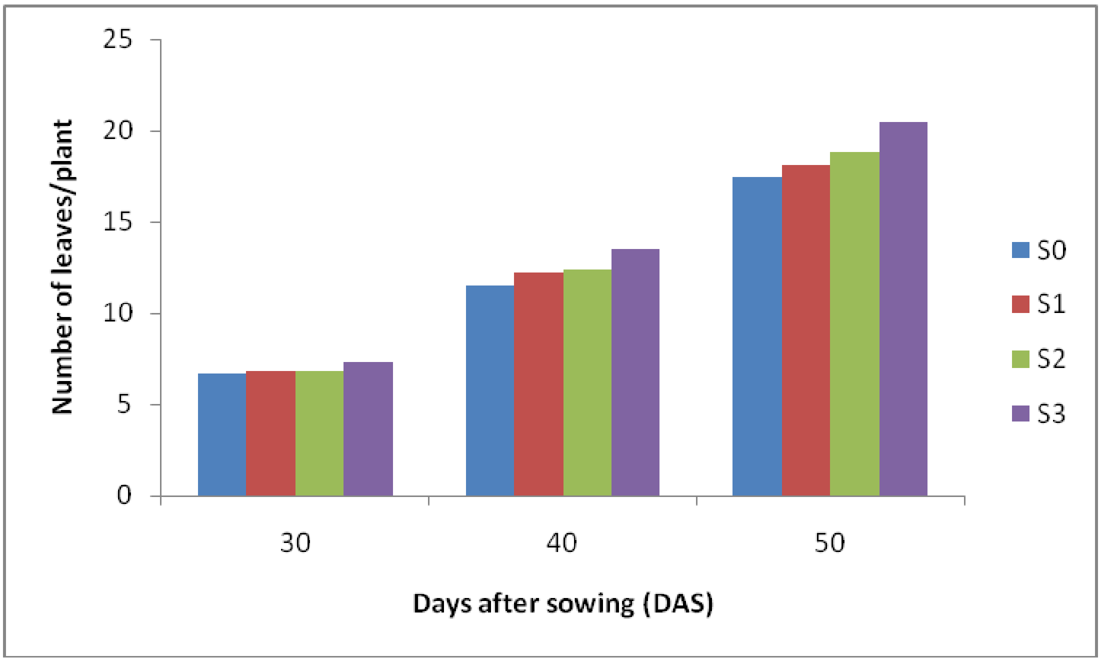

Figure 4. Number of leaves plant^{-1}of different mustard varieties as influenced by Se application

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Effect of B and Se

Number of leaves plant^{-1} for different treatments of B and Se showed statistically significant variation at different growth stages except at 30 DAS (Figure 4 and Appendix V). At 40 and 50 DAS, the highest number of leaves plant^{-1} (13.49 and 20.49, respectively) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment followed by S_2 (Se; 25 µM spray) whereas the lowest number of leaves plant^{-1} (11.35 and 17.43, respectively) was recorded from the control treatment S_0 (no B or Se).

Table 2. Number of leaves plant^{-1}of different mustard varieties as influenced by B and Se application

Treatment	Number of leaves plant^{-1} at		
	30 DAS	40 DAS	50 DAS
V_1S_0	5.73 d	7.867 c	16.07 e
V_1S_1	5.83 d	8.433 c	16.50 de
V_1S_2	5.90 d	8.500 c	18.67 bc
V_1S_3	6.13 cd	9.067 c	19.53 b
V_2S_0	6.90 bc	13.90 ab	18.67 bc
V_2S_1	7.00 bc	14.07 ab	19.60 b
V_2S_2	7.00 bc	14.33 ab	19.43 b
V_2S_3	7.70 ab	16.07 a	22.07 a
V_3S_0	7.30 ab	12.83 b	17.57 cde
V_3S_1	7.53 ab	14.23 ab	18.23 bcd
V_3S_2	7.63 ab	14.37 ab	18.20 bcd
V_3S_3	7.97 a	15.33 a	19.87 b
$LSD_{0.05}$	0.947	2.237	1.828
CV(%)	6.70	13.34	9.26

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Combined effect of variety and B and Se

Interactive effect of variety and B + Se levels showed a significant difference for the number of leaves plant^{-1} at different growth stages (Table 2 and Appendix V). At 30 DAS, the highest number of leaves plant^{-1} (7.97) was recorded from V_3S_3 that was statistically similar to V_2S_3, V_3S_0, V_3S_1 and V_3S_2

whereas the lowest number of leaves plant^{-1} (5.73) was recorded from V_1S_0 that was statistically same to V_1S_1 and V_1S_2. Similarly, at 40 and 50 DAS, the highest number of leaves plant^{-1} (16.07 and 22.07, respectively) was recorded from V_2S_3 followed by V_2S_2 whereas the lowest number of leaves plant^{-1} (7.87 and 16.07, respectively) was recorded from V_1S_0 that was statistically similar to V_1S_1 at 50 DAS.

4.1.3 Fresh weight of stem plant^{-1}

Effect of variety

Remarkable variation was identified on fresh weight of stem plant^{-1} due to the effect of variety at different growth stages (Figure 5 and Appendix VI). At 30 DAS, the highest fresh weight of stem plant^{-1} (44.47 g) was recorded from V_1 (BARI Sarisha-16) that was statistically same to V_3 (BARI Sarisha-17) whereas V_2 (BARI Sarisha-14) showed the lowest fresh weight of stem plant^{-1} (41.52 g). Similarly, at 40 and 50 DAS, V_1 (BARI Sarisha-16) showed highest fresh weight of stem plant^{-1} (175.90 and 271.60 g, respectively). At 40 DAS, the lowest fresh weight of stem plant^{-1} (121.40 g) was found from V_2 (BARI Sarisha-14) but at 50 DAS, the lowest (143.40 g) was recorded from V_3 (BARI Sarisha-17).

Effect of B and Se

Variation on fresh weight of stem plant^{-1} was found by different treatments of B and Se at different growth stages (Figure 6 and Appendix VI). Results showed that at 30 DAS, the treatment S_2 (Se; 25 µM spray) gave the highest fresh weight of stem plant^{-1} (46.21 g) which was statistically similar to S_3 (B+ Se; 1 mM + 25 µM spray) whereas the lowest fresh weight of stem plant^{-1} (39.58 g) was recorded from the control treatment S_0 (no B or Se). Again, at 40 and 50 DAS, S_3 (B+ Se; 1 mM + 25 µM spray) treatment gave the maximum fresh weight of stem plant^{-1} (168.10 and 240.10 g, respectively) followed by S_2 (Se; 25 µM spray) whereas the lowest fresh weight of stem plant^{-1} (123.20 and

165.70 g, respectively) was recorded from the control treatment S_0 (no B or Se).

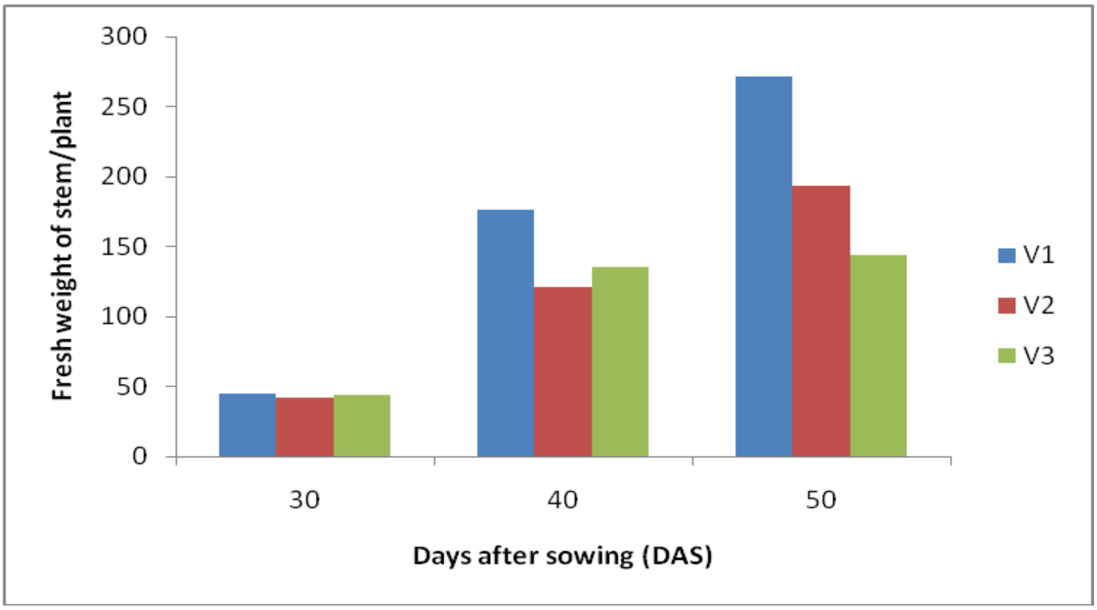

Figure 5. Fresh weight of stem plant^{-1} of different mustard varieties as influenced by B application

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

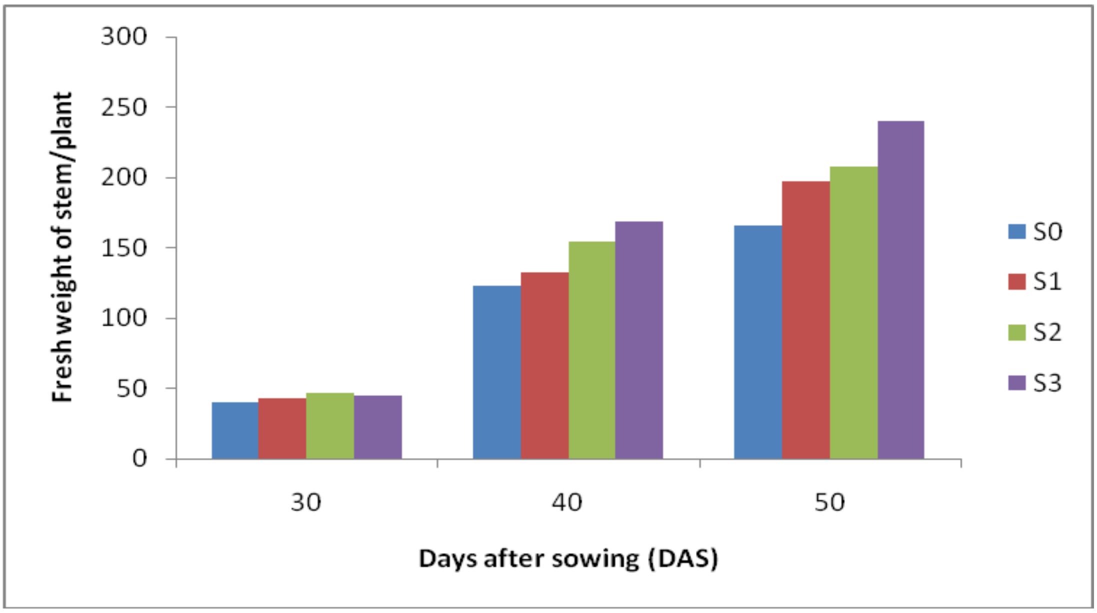

Figure 6. Fresh weight of stem plant^{-1} of different mustard varieties as influenced by Se application

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Table 3. Fresh weight of stem plant^{-1} of different mustard varieties as influenced by B and Se application

Treatment	Fresh weight of stem plant^{-1} at		
	30 DAS	40 DAS	50 DAS
V_1S_0	41.39 cd	145.20 c	222.20 e
V_1S_1	44.87 b	149.10 c	266.00 c
V_1S_2	50.24 a	194.10 b	288.40 b
V_1S_3	41.39 cd	215.40 a	309.90 a
V_2S_0	36.86 e	106.50 g	145.00 h
V_2S_1	39.97 de	110.20 g	186.20 f
V_2S_2	44.24 bc	125.50 e	193.80 f
V_2S_3	45.03 b	143.50 cd	247.00 d
V_3S_0	40.48 d	117.90 f	130.00 i
V_3S_1	44.82 b	136.70 d	138.90 h
V_3S_2	44.15 bc	142.50 cd	141.30 h
V_3S_3	47.48 ab	145.60 c	163.40 g
$LSD_{0.05}$	3.403	6.844	8.137
CV(%)	10.93	11.54	14.37

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Combined effect of variety and B and Se

The recorded data on fresh weight of stem plant^{-1} was significantly influence by the combined effect of variety and B + Se at different growth stages (Table 3 and Appendix VI). At 30 DAS, the highest fresh weight of stem plant^{-1} (50.24 g) was recorded from the treatment combination of V_1S_2 which was statistically similar with the treatment combination of V_3S_3 whereas the lowest fresh weight of stem plant^{-1} (36.86 g) was recorded from V_2S_0. At 40 and 50 DAS, the highest fresh weight of stem plant^{-1} (215.40 and 309.90 g, respectively) was recorded from the treatment combination of V_1S_3 that was significantly different to other treatment combinations followed by V_1S_2. At 40 DAS, the minimum fresh weight of stem plant^{-1} (106.50 g) was recorded from V_2S_0 that was statistically same to V_2S_1 but at 50 DAS, the minimum fresh weight of stem plant^{-1} (130.00 g) was recorded from V_3S_0 that was significantly different to other treatments.

4.1.4 Stem dry weight plant^{-1}

Effect of variety

Significant variation for stem dry weight plant^{-1} of mustard was recorded due to varietal difference at different growth stages (Figure 7 and Appendix VII). At 30, 40 and 50 DAS, the maximum stem dry weight plant^{-1} (4.83, 18.44 and 33.19 g, respectively) was achieved from the variety V_1 (BARI Sarisha-16) which was significantly different other varieties. On the other hand, the minimum stem dry weight plant^{-1} at 30 and 40 DAS (4.18 and 10.78 g, respectively) was recorded from the variety V_2 (BARI Sarisha-14) that was statistically same to V_3 (BARI Sarisha-17). At 50 DAS, the minimum stem dry weight plant^{-1} (19.12 g) was achieved from the variety V_3 (BARI Sarisha-17) that was statistically same to V_2 (BARI Sarisha-14). Ahamed *et al*. (2019) reported that dry matter varied significantly due varietal difference which supported the present study.

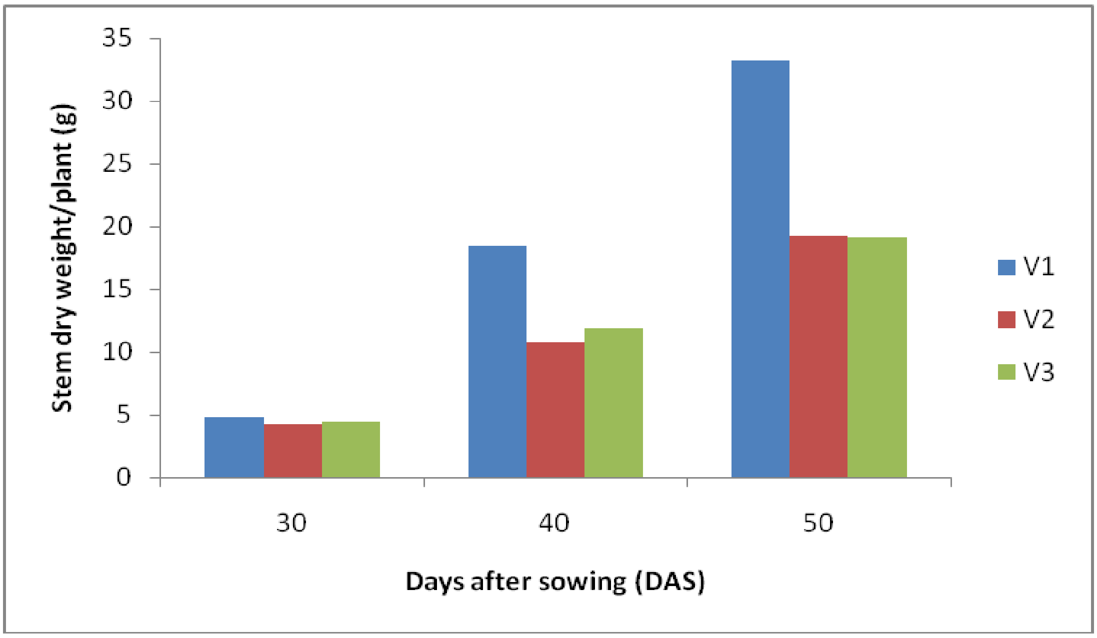

Figure 7. Stem dry weight plant^{-1} of different mustard varieties as influenced by B application

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

Effect of B and Se

Stem dry weight plant^{-1} for different treatments of B and Se showed statistically significant variation at different growth stages (Figure 8 and Appendix VII). At 30, 40 and 50 DAS, the highest stem dry weight plant^{-1} (5.03, 15.12 and 27.99 g, respectively) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment followed by S_2 (Se; 25 µM spray) whereas the lowest stem dry weight plant^{-1} (4.00, 11.61 and 19.50 g, respectively) was recorded from the control treatment S_0 (no B or Se).

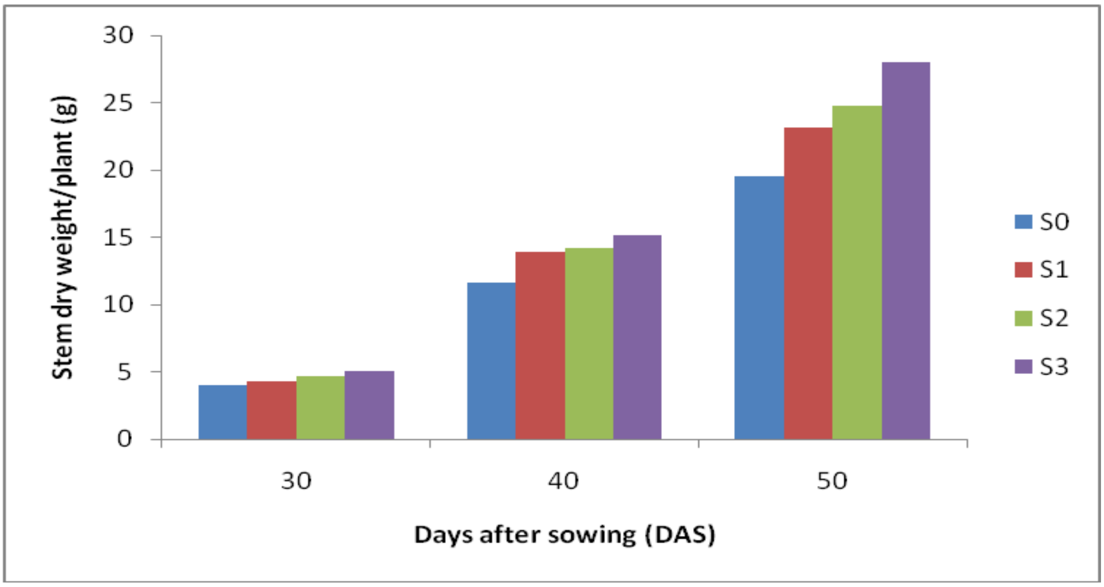

Figure 8. Stem dry weight plant^{-1} of different mustard varieties as influenced by Se application

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Combined effect of variety and B and Se

Combined effect of variety and B + Se levels showed a significant difference for the stem dry weight plant^{-1} at different growth stages (Table 4 and Appendix VII). At 30, 40 and 50 DAS, the highest stem dry weight plant^{-1} (5.61, 20.88 and 37.89 g, respectively) was recorded from V_1S_3 that was statistically similar to V_1S_2 at 50 DAS. On the other hand, at 30 and 40 DAS, the lowest stem dry weight plant^{-1} (3.53 and 8.95 g, respectively) was recorded from V_2S_0 that was statistically similar to V_3S_0 at 40 DAS. Similarly, at 50 DAS, the lowest stem dry weight plant^{-1} (14.45 g) was recorded from V_3S_0 that was significantly different to other treatment combinations.

Table 4. Stem dry weight plant^{-1} of different mustard varieties as influenced by B and Se application

Treatment	Stem dry weight plant^{-1} (g) at		
	30 DAS	40 DAS	50 DAS
V_1S_0	4.38 bc	15.69 c	27.28 c
V_1S_1	4.45 bc	18.56 b	31.29 b
V_1S_2	4.89 b	18.62 b	36.30 a
V_1S_3	5.61 a	20.88 a	37.89 a
V_2S_0	3.53 d	8.95 g	16.78 g
V_2S_1	3.99 cd	11.15 ef	19.60 ef
V_2S_2	4.53 bc	11.45 ef	18.08 fg
V_2S_3	4.67 bc	11.54 e	22.52 d
V_3S_0	4.09 cd	10.20 fg	14.45 h
V_3S_1	4.53 bc	11.88 de	18.45 efg
V_3S_2	4.43 bc	12.47 de	20.03 e
V_3S_3	4.82 b	12.93 d	23.57 d
$LSD_{0.05}$	0.712	1.338	1.886
CV(%)	8.31	12.65	12.28

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

4.1.5 SPAD value of leaf

Effect of variety

Different varieties showed a statistically significant variation for SPAD value of leaf of mustard at different growth stages except at 40 DAS (Figure 9 and Appendix VIII). At 30 and 50 DAS, the highest SPAD value (50.96 and 64.32, respectively) was recorded from the variety V_2 (BARI Sarisha-14) that was statistically same to V_3 (BARI Sarisha-17) whereas V_1 (BARI Sarisha-16) gave lowest SPAD value (48.38 and 58.65, respectively). At 40 DAS, non-significant variation of observed on SPAD value, however, the highest SPAD value (54.74) was recorded from V_2 (BARI Sarisha-14) and the lowest (53.79) was recorded from V_1 (BARI Sarisha-16).

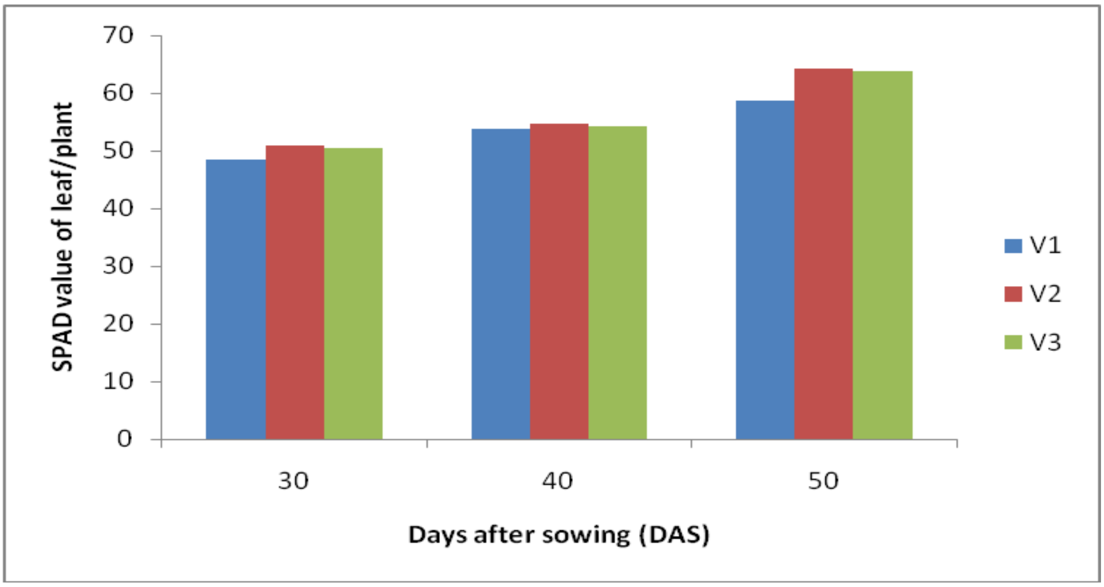

Figure 9. SPAD value of leaf of different mustard varieties as influenced by B application

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

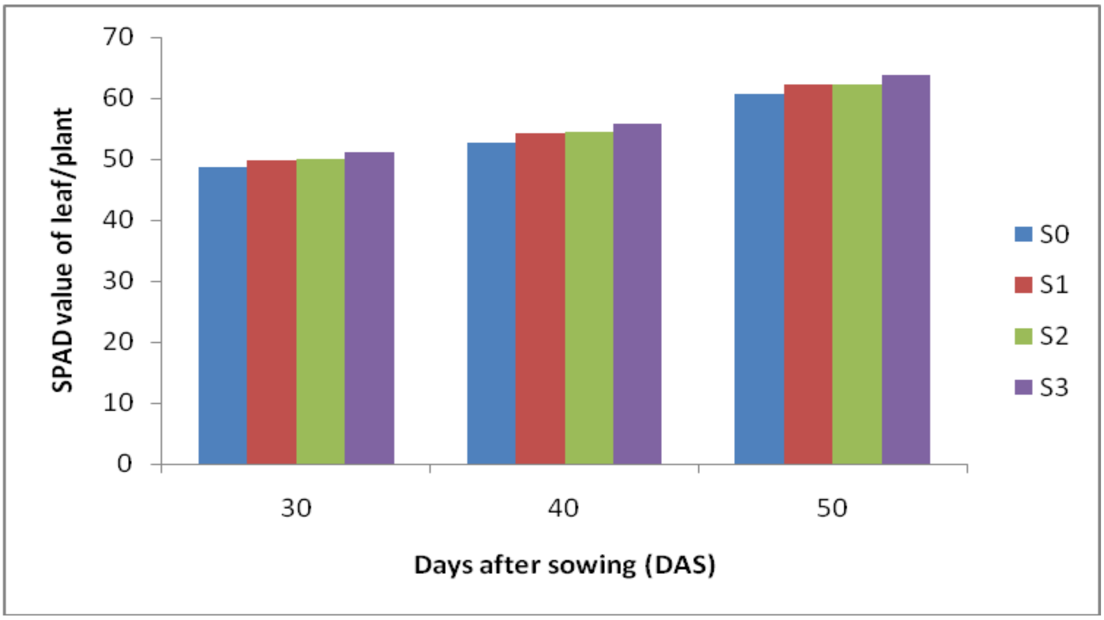

Figure 10. SPAD value of leaf of different mustard varieties as influenced by Se application

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

Table 5. SPAD value of leaf of different mustard varieties as influenced by B and Se application

Treatment	SPAD value of leaf $plant^{-1}$ at		
	30 DAS	40 DAS	50 DAS
V_1S_0	46.73 d	52.23 f	57.71 e
V_1S_1	48.29 cd	54.17 cd	58.03 e
V_1S_2	48.16 cd	53.15 def	58.01 e
V_1S_3	50.36 a	55.61 ab	60.83 d
V_2S_0	50.55 a	52.77 ef	61.47 d
V_2S_1	51.09 a	55.05 bc	64.55 ab
V_2S_2	50.77 a	54.69 bc	63.59 bc
V_2S_3	51.76 a	56.45 a	65.46 a
V_3S_0	48.68 bc	52.73 ef	62.61 cd
V_3S_1	50.17 ab	53.49 de	64.19 abc
V_3S_2	50.97 a	55.29 abc	65.03 ab
V_3S_3	51.42 a	55.55 ab	65.33 ab
$LSD_{0.05}$	1.636	1.199	1.810
CV(%)	3.43	4.24	4.29

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 μM spray), S_3 = B+ Se (1 mM + 25 μM spray)

Effect of B and Se

Different treatments of B and Se exhibited statistically significant differences for SPAD value of leaf of mustard at different growth stages (Figure 10 and Appendix VIII). At 30, 40 and 50 DAS, the treatment S_3 (B+ Se; 1 mM + 25 μM spray) showed the highest SPAD value (51.18, 55.87 and 63.87, respectively) which was significantly different from other treatments followed by S_2 (Se; 25 μM spray) and S_1 (B; 1 mM spray) whereas the lowest SPAD value (48.65, 52.58 and 60.60, respectively) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

Significant interaction effect was recorded between variety and B + Se in consideration of SPAD value of leaf of mustard at different growth stages (Table 5 and Appendix VIII). At 30, 40 and 50 DAS, the highest SPAD value of leaf (51.76, 56.45 and 65.46, respectively) was recorded from the treatment combination of V_2S_3 which was statistically similar with V_2S_1, V_3S_2 and V_3S_3 at 50 DAS. The lowest SPAD value of leaf at 30, 40 and 50 DAS (46.73, 52.23 and 57.71, respectively) was recorded from the treatment combination of V_1S_0 and at 50 DAS it was statistically similar to V_1S_1 and V_1S_2.

4.1.6 Fresh weight of siliqua at 50 DAS

Effect of variety

Remarkable variation was identified on fresh weight of siliqua plant^{-1} at 50 DAS due to the effect of variety (Table 6 and Appendix IX). The highest fresh weight of siliqua plant^{-1} at 50 DAS (24.08 g) was recorded from V_3 (BARI Sarisha-17) that was statistically same to V_1 (BARI Sarisha-16) whereas V_2 (BARI Sarisha-14) showed the lowest fresh weight of siliqua plant^{-1} at 50 DAS (20.59 g).

Effect of B and Se

Variation on fresh weight of siliqua plant^{-1} at 50 DAS was found by different treatments of B and Se (Table 6 and Appendix IX). Results showed that the treatment S_3 (B+ Se; 1 mM + 25 µM spray) gave the highest fresh weight of siliqua plant^{-1} at 50 DAS (26.19 g) followed by S_1 (B; 1 mM spray) and S_2 (Se; 25 µM spray). The lowest fresh weight of siliqua plant^{-1} at 50 DAS (18.99 g) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

The recorded data on fresh weight of siliqua plant^{-1} at 50 DAS was significantly influence by the combined effect of variety and B + Se (Table 6 and Appendix IX). The highest fresh weight of siliqua plant^{-1} at 50 DAS (27.05 g) was recorded from the treatment combination of V_3S_3 which was statistically similar with the treatment combination of V_1S_3 whereas the lowest fresh weight of siliqua plant^{-1} at 50 DAS (14.18 g) was recorded from V_2S_0 that was significantly different to other treatments.

Table 6. Fresh and dry weight of siliqua of different mustard varieties as influenced by B and Se application

Treatment	Fresh weight and dry weight of siliqua (g)	
	Fresh weight of siliqua at 50 DAS	Dry weight of siliqua at 50 DAS
Effect of variety		
V_1	23.97 a	3.53
V_2	20.59 b	3.81
V_3	24.08 a	3.55
$LSD_{0.05}$	0.8904	0.35
CV(%)	13.63	12.65
Effect of B + Se		
S_0	18.99 c	2.90 c
S_1	23.50 b	3.10 c
S_2	22.84 b	4.01 b
S_3	26.19 a	4.52 a
$LSD_{0.05}$	1.028	0.399
CV(%)	13.63	12.65
Combined effect of variety and B + Se		
V_1S_0	21.34 d	2.57 c
V_1S_1	24.54 b	2.71 c
V_1S_2	23.02 bcd	4.10 ab
V_1S_3	26.96 a	4.76 a
V_2S_0	14.18 e	3.54 b
V_2S_1	21.28 d	3.86 b
V_2S_2	22.35 cd	3.83 b
V_2S_3	24.55 b	4.00 b
V_3S_0	21.46 cd	2.58 c
V_3S_1	24.67 b	2.72 c
V_3S_2	23.15 bc	4.11 ab
V_3S_3	27.05 a	4.79 a
$LSD_{0.05}$	1.781	0.692
CV(%)	13.63	12.65

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

4.1.7 Dry weight of siliqua at 50 DAS

Effect of variety

Non-significant variation was found on dry weight of siliqua plant^{-1} at 50 DAS due to the effect of variety (Table 6 and Appendix IX). However, the highest dry weight of siliqua plant^{-1} at 50 DAS (3.81 g) was recorded from V_2 (BARI Sarisa-14) whereas the variety V_1 (BARI Sarisa-16) showed the lowest dry weight of siliqua plant^{-1} at 50 DAS (3.53 g).

Effect of B and Se

Variation on dry weight of siliqua plant^{-1} at 50 DAS was found by different treatments of B and Se (Table 6 and Appendix IX). Results showed that the treatment S_3 (B+ Se; 1 mM + 25 µM spray) gave the highest dry weight of siliqua plant^{-1} at 50 DAS (4.25 g) followed by S_2 (Se; 25 µM spray). The lowest dry weight of siliqua plant^{-1} at 50 DAS (2.90 g) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

The recorded data on dry weight of siliqua plant^{-1} at 50 DAS was significantly influence by the combined effect of variety and B + Se (Table 6 and Appendix IX). The highest dry weight of siliqua plant^{-1} at 50 DAS (4.79 g) was recorded from the treatment combination of V_3S_3 which was statistically similar with the treatment combination of V_1S_2, V_1S_3 and V_3S_2 whereas the lowest dry weight of siliqua plant^{-1} at 50 DAS (2.57 g) was recorded from V_1S_0 that was statistically similar to V_1S_1, V_3S_0 and V_3S_1.

4.2 Yield contributing parameters

4.2.1 Siliqua length

Effect of variety

Siliqua length was varied significantly among different varieties of mustard (Table 7 and Appendix X). It was observed that the highest length of siliqua (6.52 cm) was recorded from the variety V_2 (BARI Sarisha-14) which was followed by V_3 (BARI Sarisha-17) whereas the lowest length of siliqua (5.84 cm) was recorded from V_1 (BARI Sarisha-16). Similar result was also observed by Ahamed *et al*. (2019).

Effect of B and Se

Different treatments of B and Se levels had non-significant influence on siliqua length of mustard (Table 7 and Appendix X). However, the highest siliqua length (6.33 cm) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment whereas the lowest siliqua length (36.09 cm) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

Siliqua length of mustard was significantly influenced by combined effect of variety and B + Se (Table 7 and Appendix X). Results indicated that the highest siliqua length (6.70 cm) was recorded from the treatment combination of V_2S_3 which was statistically similar with the treatment combination of V_2S_0 and V_2S_1. The lowest siliqua length (5.67 cm) was recorded from the treatment combination of V_1S_0 which was significantly different to other treatment combinations.

4.2.2 Number of siliqua plant^{-1}

Effect of variety

Statistically significant variation for number of siliqua plant^{-1} of mustard was recorded due to varietal effect (Table 7 and Appendix X). The variety V_1

(BARI Sarisha-16) gave the highest number of siliqua plant^{-1} (168.60) which was followed by V_2 (BARI Sarisha-14) whereas the lowest number of siliqua plant^{-1} (66.75) was recorded from the variety V_3 (BARI Sarisha-17). The result obtained from the present study on number of siliqua plant^{-1} was similar with the findings of Thuan *et al*. (2010) and Singh *et al*. (2012).

Effect of B and Se

Number of siliqua plant^{-1} for different treatments of B and Se showed statistically significant variation (Table 7 and Appendix X). The highest number of siliqua plant^{-1} (111.90) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment which was followed by S_2 (Se; 25 µM spray) whereas the lowest number of siliqua plant^{-1} (90.83) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

Combined effect of variety and B + Se showed a significant difference for number of siliqua plant^{-1} under the present study (Table 7 and Appendix X). Results indicated that the treatment combination of V_1S_3 gave the highest number of siliqua plant^{-1} (185.20) which was significantly different to other treatment combinations followed by V_1S_2. The lowest number of siliqua plant^{-1} (57.47) was recorded from the treatment combination of V_3S_0 which was significantly different from other treatment combinations.

Table 7. Yield contributing parameters of different mustard varieties as influenced by B and Se application

Treatment	Yield contributing parameters			
	Siliqua length (cm)	Number of siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000-seed weight (g)
Effect of variety				
V_1	5.84 c	168.80 a	14.28 b	4.55 a
V_2	6.52 a	71.52 b	29.99 a	3.12 b
V_3	6.18 b	66.75 c	30.36 a	3.28 b
$LSD_{0.05}$	0.096	2.160	1.367	0.283
CV(%)	3.71	14.46	6.49	9.17
Effect of B + Se				
S_0	6.09	90.83 d	23.79 b	3.43 c
S_1	6.20	100.50 c	24.22 b	3.66 b
S_2	6.10	106.20 b	26.08 a	3.73 a
S_3	6.33	111.90 a	25.42 a	3.77 a
$LSD_{0.05}$	0.382	2.494	0.762	0.044
CV(%)	3.71	14.46	6.49	9.17
Combined effect of variety and B + Se				
V_1S_0	5.67 g	147.80 d	13.00 c	4.07 b
V_1S_1	5.89 f	164.00 c	14.63 c	4.59 ab
V_1S_2	5.90 f	178.40 b	14.30 c	4.74 a
V_1S_3	5.93 f	185.20 a	15.20 c	4.78 a
V_2S_0	6.60 a	67.27 g	28.60 b	3.04 c
V_2S_1	6.53 ab	69.17 fg	29.10 b	3.10 c
V_2S_2	6.25 cd	70.67 fg	31.95 a	3.14 c
V_2S_3	6.70 a	78.97 e	30.30 ab	3.18 c
V_3S_0	6.03 ef	57.47 h	29.77 ab	3.18 c
V_3S_1	6.19 cde	68.43 fg	28.93 b	3.28 c
V_3S_2	6.15 de	69.50 fg	31.97 a	3.32 c
V_3S_3	6.36 bc	71.60 f	30.77 ab	3.34 c
$LSD_{0.05}$	0.193	4.320	2.734	0.567
CV(%)	3.71	14.46	6.49	9.17

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

4.2.3 Number of seeds siliqua^{-1}

Effect of variety

Remarkable variation was identified on number of seeds siliqua^{-1} due to the effect of different variety (Table 7 and Appendix X). The highest number of seeds siliqua^{-1} (30.36) was recorded from the treatment V_3 (BARI Sarisha-17) which was statistically similar to the variety V_2 (BARI Sarisha-14) whereas the lowest number of seeds siliqua^{-1} (14.28) was recorded from the variety V_1 (BARI Sarisha-16). Similar result was also observed by Singh *et al*. (2012) and Thuan *et al*. (2010).

Effect of B and Se

The recorded data on number of seeds siliqua^{-1} was significantly influence by different treatments of B and Se (Table 7 and Appendix X). The treatment S_2 (Se; 25 µM spray) gave the highest number of seeds siliqua^{-1} (26.08) which was statistically identical with S_3 (B+ Se; 1 mM + 25 µM spray) whereas the lowest number of seeds siliqua^{-1} (23.79) was recorded from the control treatment S_0 (no B or Se) which was significantly same to S_1 (B; 1 mM spray).

Combined effect of variety and B and Se

Variation on number of seeds siliqua^{-1} was found as significant influenced by combined effect of variety and B + Se (Table 7 and Appendix X). The highest number of seeds siliqua^{-1} (31.97) was recorded from the treatment combination of V_3S_2 which was statistically similar with the treatment combination of V_2S_2, V_2S_3, V_3S_0 and V_3S_3. The lowest number of seeds siliqua^{-1} (13.00) was recorded from the treatment combination of V_1S_0 which was statistically similar with the treatment combination of V_1S_1, V_1S_2 and V_1S_3.

4.2.4 Weight of 1000-seed

Effect of variety

Different mustard varieties showed statistically significant differences for 1000-seed weight of mustard (Table 7 and Appendix X). The highest 1000-seed weight (4.55 g) was recorded from the variety V_1 (BARI Sarisha-16) whereas the lowest 1000-seed weight (3.12 g) was recorded from the variety V_2 (BARI Sarisha-14) which was significantly same to V_3 (BARI Sarisha-17). Supported result was also observed by Ahmed and Kashem (2017) and Sarker *et al*. (2021).

Effect of B and Se

Different treatments of B and Se exhibited statistically significant variation for 1000-seed weight of mustard (Table 7 and Appendix X). The highest 1000-seed weight (3.77 g) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment which was statistically identical with S_2 (Se; 25 µM spray) whereas the lowest 1000-seed weight (3.43 g) was recorded from the control treatment S_0 (no B or Se). The results obtained in the study were supported by Riaj *et al*. (2018) who reported significant contribution on 1000-seed weight of mustard due to B application and Sultan *et al*. (2020) reported that 1000-seed weight was significantly improved by Se.

Combined effect of variety and B and Se

Combined effect of variety and B + Se showed a significant variation for 1000-seeds weight of mustard under the present experiment (Table 7 and Appendix X). The highest 1000-seed weight (4.78 g) was recorded from the treatment combination of V_1S_3 which was significantly similar to the treatment combination of V_1S_1 and V_1S_2. The lowest 1000-seed weight (3.04 g) was recorded from the treatment combination of V_2S_0.

4.3 Yield parameters

4.3.1 Seed yield

Effect of variety

Statistically significant variation for seed yield of mustard was recorded due to the effect variety (Table 8 and Appendix XI). The highest seed yield (3008 kg ha^{-1}) was recorded from the variety V_1 (BARI Sarisha-16) followed by V_3 (BARI Sarisha-17) whereas the lowest seed yield (1538 kg ha^{-1}) was recorded from the variety V_2 (BARI Sarisha-14). The results obtained in the study on seed yield were conformity with the findings of Singh *et al*. (2012), Ahamed *et al*. (2019), Ahmed and Kashem (2017) and Sarker *et al*. (2021). They found that seed yield varied significantly due to varietal difference.

Effect of B and Se

Seed yield for different treatments of B and Se showed statistically significant variation (Table 8 and Appendix XI). The highest seed yield (2323 kg ha^{-1}) was recorded from S_3 (B+ Se; 1 mM + 25 µM spray) treatment which was significantly different from other treatments followed by S_2 (Se; 25 µM spray) and S_1 (B; 1 mM spray) whereas the lowest seed yield (2031 kg ha^{-1}) was recorded from the control treatment S_0 (no B or Se). The results obtained in the study were supported by Yanthan and Singh (2021) and Mosam *et al*. (2022) who reported significant contribution on increased yield of mustard due to B application and Sultan *et al*. (2020) reported that seed yield was significantly improved by Se.

Combined effect of variety and B and Se

Interaction effect between variety and B + Se showed a significant difference for the seed yield under the present study (Table 8 and Appendix XI). The highest seed yield (3137 kg ha^{-1}) was recorded from the treatment combination of V_1S_3 which was significantly different from other treatment combinations followed by V_1S_1 and V_1S_2. The lowest seed yield (1373 kg ha^{-1}) was recorded from the treatment combination of V_2S_0 which was significantly different to other treatment combinations.

4.3.2 Stover yield

Effect of variety

Statistically significant variation for stover yield of mustard was recorded due to the effect of variety (Table 8 and Appendix XI). The highest stover yield (6093 kg ha^{-1}) was recorded from the variety V_3 (BARI Sarisha-17) followed by V_1 (BARI Sarisha-16) whereas the lowest stover yield (3678 kg ha^{-1}) was recorded from the variety V_2 (BARI Sarisha-14). Supported result was also observed by Singh *et al*. (2010), Singh *et al*. (2012) and Sarker *et al*. (2021).

Effect of B and Se

Stover yield for different treatments of B and Se showed statistically significant variation (Table 8 and Appendix XI). The highest stover yield (5584 kg ha^{-1}) was recorded from S_3 (B+ Se; 1 mM + 25 μM spray) treatment followed by S_1 (B; 1 mM spray) treatment whereas the lowest stover yield (4626 kg ha^{-1}) was recorded from the control treatment S_0 (no B or Se).

Combined effect of variety and B and Se

Combined effect of variety and B + Se showed a significant difference for stover yield under the present study (Table 8 and Appendix XI). The highest stover yield (6587 kg ha^{-1}) was recorded from the treatment combination of V_3S_3 followed by the treatment combination of V_3S_2 whereas the lowest stover yield (3207 kg ha^{-1}) was recorded from the treatment combination of V_2S_0.

4.3.3 Harvest index

Effect of variety

Remarkable variation was identified on harvest index due to the effect of different variety (Table 8 and Appendix XI). The highest harvest index (34.03%) was recorded from the variety V_1 (BARI Sarisha-16) followed by V_2 (BARI Sarisha-14) whereas the lowest harvest index (25.02%) was recorded from V_3 (BARI Sarisha-17). Similar result was also observed by Singh *et al*. (2012) and Sarker *et al*. (2021).

Effect of B and Se

The recorded data on harvest index was significantly influence by different treatments of B and Se (Table 8 and Appendix XI). The highest harvest index (30.61%) was recorded from control treatment S_0 (no B or Se) followed by S_2 (Se; 25 µM spray) and S_3 (B+ Se; 1 mM + 25 µM spray) whereas the lowest harvest index (28.54%) was recorded from S_1 (B; 1 mM spray) treatment.

Combined effect of variety and B and Se

Variation on harvest index was found as significant as influenced by combined effect of variety and B + Se (Table 8 and Appendix XI). The highest harvest index (35.32%) was recorded from the treatment combination of V_1S_3 which was statistically similar with the treatment combination of V_1S_0 and V_1S_2. The lowest harvest index (23.84%) was recorded from the treatment combination of V_3S_2 which was statistically similar with the treatment combination of V_3S_1 and V_3S_3.

Table 8. Yield parameters of different mustard varieties as influenced by B and Se application

Treatment	Yield parameters		
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
Effect of variety			
V_1	3008.00 a	5866.00 b	34.03 a
V_2	1538.00 c	3678.00 c	29.86 b
V_3	1968.00 b	6093.00 a	25.02 c
$LSD_{0.05}$	13.66	14.70	0.9642
CV(%)	14.93	12.42	11.34
Effect of B + Se			
S_0	2031.00 c	4626.00 d	30.61 a
S_1	2158.00 b	5429.00 b	28.54 c
S_2	2173.00 b	5210.00 c	29.79 b
S_3	2323.00 a	5584.00 a	29.60 b
$LSD_{0.05}$	15.77	16.97	0.5328
CV(%)	14.93	12.42	11.34
Combined effect of variety and B + Se			
V_1S_0	2860.00 c	5547.00 f	33.91 ab
V_1S_1	3013.00 b	6290.00 c	32.73 bc
V_1S_2	3020.00 b	5827.00 e	34.13 ab
V_1S_3	3137.00 a	5800.00 e	35.32 a
V_2S_0	1373.00 j	3207.00 k	30.60 de
V_2S_1	1500.00 i	3830.00 i	28.61 f
V_2S_2	1507.00 i	3307.00 j	31.38 cd
V_2S_3	1773.00 h	4367.00 h	28.85 ef
V_3S_0	1860.00 g	5123.00 g	27.32 f
V_3S_1	1960.00 f	6167.00 d	24.28 g
V_3S_2	1993.00 e	6497.00 b	23.84 g
V_3S_3	2060.00 d	6587.00 a	24.63 g
$LSD_{0.05}$	27.32	29.39	1.928
CV(%)	14.93	12.42	11.34

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

V_1 = BARI Sarisha-16, V_2 = BARI Sarisha-14, V_3 = BARI Sarisha-17

S_0 = Control (no B or Se), S_1 = B (1 mM spray), S_2 = Se (25 µM spray), S_3 = B+ Se (1 mM + 25 µM spray)

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted at the Agronomy experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2020 to February 2021 to determine the growth and yield response of different brassica oilseeds species to B and Se. The experiment consisted of two factors *viz*. Factor A: Variety (three) *viz*. V_1 (BARI Sarisha-16), V_2 (BARI Sarisha-14) and V_3 (BARI Sarisha-17) and Factor B: B and/or Se (four treatments) *viz*. control treatment S_0 (no B or Se), S_1 (B; 1 mM spray), S_2 (Se; 25 µM spray) and S_3 (B+ Se). There were 12 treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Six foliar spray of B, Se and B + Se were applied according to treatments started at 20 days after sowing (DAS) and continued to 55 DAS at 7 days intervals.

Most of the parameters affected significantly due to varietal performance. Results indicated that, maximum plant height at 50 DAS and at harvest (85.76 and 164.10 cm, respectively) was achieved by the variety V_1 (BARI Sarisha-16) whereas the minimum plant height (75.37 and 86.75 cm, respectively) was recorded from V_2 (BARI Sarisha-14). Similarly, at 40 and 50 DAS, the maximum number of leaves plant^{-1} (14.59 and 19.94, respectively) was recorded from V_2 (BARI Sarisha-14) whereas the minimum (8.47, 17.69, respectively) was found from V_1 (BARI Sarisha-16). Again, at 50 DAS, V_1 (BARI Sarisha-16) showed the highest fresh weight of stem plant^{-1} (271.60 g) and stem dry weight plant^{-1} (33.19 g) whereas the variety V_3 (BARI Sarisha-17) gave the lowest fresh weight of stem plant^{-1} (271.60 g) and stem dry weight plant^{-1} (19.12 g) but the maximum SPAD value of leaf plant^{-1} (64.32) and dry weight of siliqua plant^{-1} (3.81 g) at 50 DAS was recorded from V_2 (BARI Sarisha-14) whereas V_1 (BARI Sarisha-16) showed minimum result (58.65 and 3.53 g, respectively). The highest number of siliqua plant^{-1} (168.80), 1000-seed weight (4.55 g), Seed yield (3008 kg ha^{-1}) and harvest index (34.03%) was recorded from V_1 (BARI Sarisha-16) variety but V_2 (BARI Sarisha-14) gave maximum siliqua length (6.52 cm) and V_3 (BARI Sarisha-17) gave maximum number of seeds $siliqua^{-1}$ (30.36) and stover yield (6093 kg ha^{-1}) whereas the lowest siliqua length (5.84 cm) and number of seeds $siliqua^{-1}$ (14.28) was found from V_1 (BARI Sarisha-16) but the lowest number of siliqua $plant^{-1}$ (66.75) and harvest index (25.02%) was found from V_3 (BARI Sarisha-17) and the lowest 1000-seed weight (3.12 g), seed yield (1538 kg ha^{-1}) and stover yield (3678 kg ha^{-1}) was found from V_2 (BARI Sarisha-14).

Considering the effect of B + Se, most of the studied parameters affected significantly. The highest plant height at harvest (119.10 cm) was recorded from S_3 (B+ Se) treatment whereas the lowest (111.00 cm) was recorded from control treatment S_0 (no B or Se). The treatment S_3 (B+ Se) also showed the maximum number of leaves $plant^{-1}$ (20.49), fresh weight of stem $plant^{-1}$ (240.10 g), stem dry weight $plant^{-1}$ (27.99 g), SPAD value of leaf $plant^{-1}$ (63.87), fresh weight of siliqua (26.19 g) and dry weight of siliqua (4.52 g) at 50 DAS whereas control treatment S_0 (no B or Se) showed the minimum number of leaves $plant^{-1}$ (17.43), fresh weight of stem $plant^{-1}$ (165.70 g), stem dry weight $plant^{-1}$ (19.50 g), SPAD value of leaf $plant^{-1}$ (60.60), fresh weight of siliqua (18.99 g) and dry weight of siliqua (2.390 g) at 50 DAS. Similarly, the highest number of siliqua $plant^{-1}$ (111.90), 1000-seed weight (3.77 g), seed yield (2323 kg ha^{-1}) and stover yield (5584 kg ha^{-1}) were recorded from S_3 (B+ Se) treatment but the highest number of seeds $siliqua^{-1}$ (26.08) was recorded from S_2 (Se; 25 µM spray) whereas control treatment S_0 (no B or Se) gave lowest number of siliqua $plant^{-1}$ (90.83), number of seeds $siliqua^{-1}$ (23.79), 1000-seed weight (3.43 g), seed yield (2031 kg ha^{-1}) and stover yield (4626 kg ha^{-1}).

In case of treatment combination of variety and B+ Se, significant variation was found for most of the parameters. At harvest, the maximum plant height (169.10 cm) was given by the treatment combination of V_1S_3 whereas the minimum (82.32 cm) was found from V_2S_0. At 50 DAS, the highest number of leaves plant^{-1} (22.07) and SPAD value of leaf plant^{-1} (65.46) was achieved from V_2S_3 whereas the lowest (16.07 and 57.71, respectively) was recorded from V_1S_0. Again, the highest fresh weight of stem plant^{-1} (309.90 g) and stem dry weight plant^{-1} (37.89 g) at 50 DAS was found from V_1S_3 whereas the lowest (130.00 g and 14.45 g, respectively) was recorded from V_3S_0. At 50 DAS, the maximum fresh weight of siliqua (27.05 g) and dry weight of siliqua (4.79 g) was recorded from V_3S_3 whereas the minimum fresh weight of siliqua (14.18 g) and minimum dry weight of siliqua (2.57 g) was recorded from V_2S_0 and V_1S_0, respectively. Similarly, the highest number of siliqua plant^{-1} (185.20), 1000-seed weight (4.78 g), seed yield (3137 kg ha^{-1}) and harvest index (35.32%) were achieved from V_1S_3 but the highest Siliqua length (6.70 cm), number of seeds siliqua^{-1} (31.91) and stover yield (6587 kg ha^{-1}) were recorded from V_2S_3, V_3S_2 and V_3S_3, respectively. The lowest siliqua length (5.67 cm) and number of seeds siliqua^{-1} (13.00) were found from V_1S_0 but the lowest seed yield ha^{-1} (1373 kg ha^{-1}) and stover yield ha^{-1} (6587 kg ha^{-1}) were found from V_2S_0 whereas the lowest number of siliqua plant^{-1} (57.47), 1000-seed weight (3.04 g) and harvest index (23.84%) were recorded from the treatment combination of V_3S_0, V_2S_0 and V_3S_2, respectively.

From the above results, it may be concluded that among variety, V_1 (BARI Sarisha-16) gave better results in terms of yield and yield contributing parameters compared to V_2 (BARI Sarisha-14) and V_3 (BARI Sarisha-17). Again, in case of B and/or Se treatment, S_3 (B+ Se) gave better performance for the most of the parameters and showed the highest yield. In terms of combined effect, V_1S_3 gave the best performance regarding maximum yield contributing parameters and yield of mustard. So, the treatment combination of V_1S_3 (BARI Sarisha-16 with B+ Se) can be considered as the 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

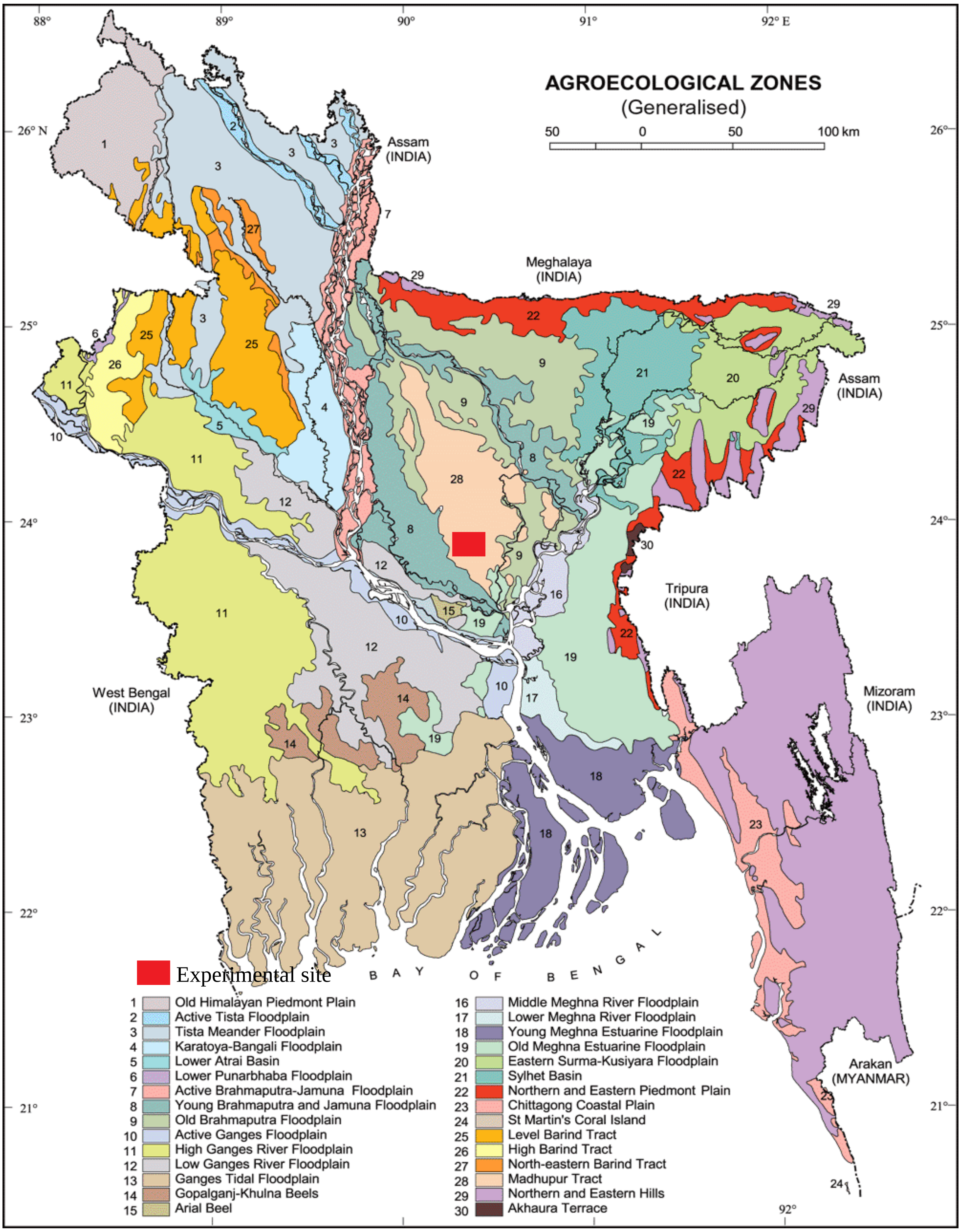

Figure 11. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2020 to February 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	November	28.60	8.52	18.56	56.75	14.40
2020	December	25.50	6.70	16.10	54.80	0.0
2021	January	23.80	11.70	17.75	46.20	0.0
2021	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. Plant height of different mustard varieties as influenced by boron and selenium application

Sources of variation	Degrees of freedom	Plant height (cm)			
		30 DAS	40 DAS	50 DAS	At harvest
Replication	2	25.417	100.509	123.298	103.588
Factor A	2	2.955^{NS}	22.492*	421.390*	2166.06*
Factor B	3	4.750^{NS}	31.114*	118.684*	103.796*
AB	6	0.403^{NS}	4.119**	19.651**	6.106**
Error	22	3.541	2.512	2.492	6.780

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

Appendix V. Number of leaves plant^{-1}of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAS	40 DAS	50 DAS
Replication	2	2.441	7.893	29.941
Factor A	2	9.382*	140.90*	15.677*
Factor B	3	0.643^{NS}	5.880*	15.467*
AB	6	0.042**	0.510**	1.174*
Error	22	0.313	1.745	1.166

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

Appendix VI. Fresh weight of stem plant^{-1} of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Fresh weight of stem plant^{-1}		
		30 DAS	40 DAS	50 DAS
Replication	2	1063.1	6003.537	2129.095
Factor A	2	32.194*	9595.453*	50159.65*
Factor B	3	72.118*	3781.026*	8471.100*
AB	6	24.495*	542.003*	810.573*
Error	22	4.039	16.336	23.094

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

Appendix VII. Stem dry weight plant^{-1} of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Stem dry weight plant^{-1} (g)		
		30 DAS	40 DAS	50 DAS
Replication	2	2.314	49.039	2.330
Factor A	2	1.261**	206.07*	784.74*
Factor B	3	1.734**	19.860*	112.62*
AB	6	0.158**	1.240**	9.472*
Error	22	0.177	0.624	1.241

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

Appendix VIII. SPAD value of leaf of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	SPAD value of leaf		
		30 DAS	40 DAS	50 DAS
Replication	2	7.643	7.900	18.263
Factor A	2	21.93*	2.708*	116.85*
Factor B	3	9.614*	16.29*	16.120*
AB	6	1.358*	1.261**	1.720**
Error	22	0.934	0.501	1.142

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

Appendix IX. Fresh and dry weight of siliqua of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Fresh weight and dry weight of siliqua (g)	
		Fresh weight of siliqua at 50 DAS	Dry weight of siliqua at 50 DAS
Replication	2	247.78	16.54
Factor A	2	47.191*	0.290^{NS}
Factor B	3	79.297*	5.272*
AB	6	7.536*	0.883**
Error	22	1.106	0.167

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

Appendix X. Yield contributing parameters of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Yield contributing parameters			
		Siliqua length (cm)	Number of siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000 seed weight (g)
Replication	2	0.093	1188.636	1.479	0.066
Factor A	2	1.370*	39828.5*	1010.5*	7.356*
Factor B	3	0.109^{NS}	726.636*	10.056*	0.206**
AB	6	0.051**	149.595*	2.208**	0.072**
Error	22	0.013	6.508	2.607	0.112

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

Appendix XI. Yield parameters of different mustard varieties as influenced by boron and selenium application

Treatment	Degrees of freedom	Yield parameters		
		Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
Replication	2	5036.111	2318786.111	27.087
Factor A	2	6846436.11*	21353619.44*	243.86*
Factor B	3	128862.037*	1589029.630*	6.514*
AB	6	7762.037*	454182.407*	4.832**
Error	22	260.354	301.263	1.297

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

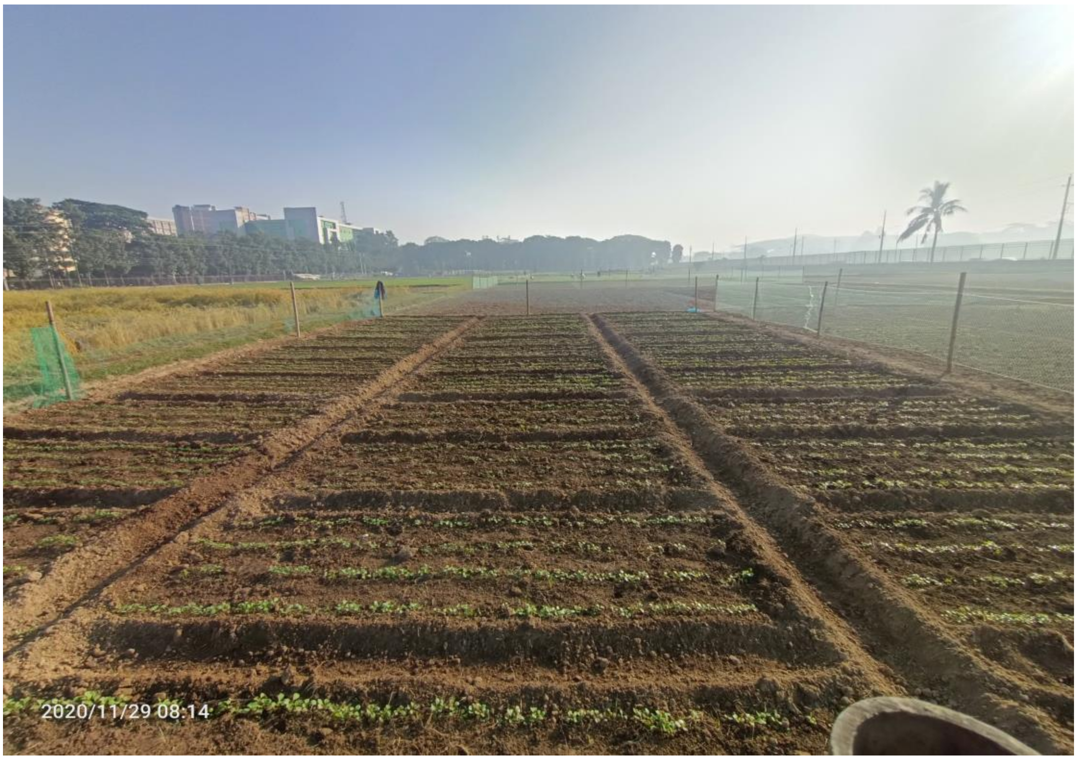

Plate 1. Overall field view of experiment field at seedling stage

Plate 2. Overall field view of experiment field at vegetative stage


Plate 3. Comparison of treatment effect at vegetative and harvesting stage of BARI Sarisha 16


Plate 4. Comparison of treatment effect at vegetative and harvesting stage of BARI Sarisha 14


Plate 5. Comparison of treatment effect at vegetative and harvesting stage of BARI Sarisha 17