EFFECT OF BORON AND ZINC ON THE GROWTH AND YIELD OF MUSTARD

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CERTIFICATE

This is to certify that thesis entitled, **“EFFECT OF BORON AND ZINC ON THE GROWTH AND YIELD OF MUSTARD”** 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** in **SOIL SCIENCE,** embodies the result of a piece of bonafide research work carried out by **UMME HAFSA TIMMI, Registration No.19-10161** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

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DEDICATED TO
MY
BELOVED PARENTS

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The Author

Effect of Boron and Zinc on the growth and yield of Mustard

ABSTRACT

The field experiment was conducted during rabi season, November 2021 to February 2022 in the experimental field of Sher-e-Bangla Agricultural university, Dhaka to determine effects of boron and zinc on growth and yield of mustard (*Brassica campestris*) variety BARI Sarisha-14. The treatments of the experiment was consisted of three levels of boron i.e., 0 kg B/ha (B_0), 1 kg B/ha (B_1) and 1.5 kg B/ha (B_2); three levels of zinc i.e., 0 kg Zn/ha (Zn_0), 3kg Zn/ha (Zn_1), 5 kg Zn/ha (Zn_2). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Results of this experiment showed a significant variation among the treatments in respect of the majority of the observed parameters. The 1.5 kg B/ha (B_2) gave the highest plant height, number of branches per plant, number of seeds per siliquae, number of siliquae per plant, length of siliquae and 1000 seed weight. Again, B_2 resulted the maximum seed yield (1.70 t/ha), stover yield, biological yield and harvest index. In addition, except siliquae length andharvest index, 3 kg Zn/ha (Zn_2) resulted highest values in all parameters while the lowest values were found in Zn_0 treatment. The interaction between boron and zinc had significant effect on all the growth and yield parameters. Except the harvest index, the B_2Zn_2 treatment combination or 1.5 kg B/ha with 5 kg Zn/ha gave maximum values on all parameters including seed yield (1.82 t/ha). Based on these results, it can be suggested that 1.5 kg B/ha with the combination of 5 kg Zn/ha increased the growth and yield of mustard and this may be the best combination for the growth and yield of mustard.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
B	=	Boron
Zn	=	Zinc
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Murate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
G	=	gram (s)
Kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
Wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

Introduction

Mustard (*Brassica* spp) is one of the most important oil seed crops throughout the world after soybean and groundnut (FAO, 2004). It has a huge demand for producing edible oil in Bangladesh. Mustard stands at the top of the list among the oilseed crops grown in this country in respect of both production and acreage (BBS, 2015).

In the year of 2017-18 it covered 7.59 lakhs acre land and the production was 3.51 lakhs metric tons (Mt), whereas the total oilseed production was 4.53 lakhs Mt and total area covered by oilseed corps was 9.46 lakhs acre. In the year of 2018-19 mustard covered 6.67 lakhs acre land and the production was 3.11 lakhs Mt. (BBS, 2019).

Mustard seeds contain 40-45 % oil and 20-25 % protein (Mondal and Wahab, 2001). It is also an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but these are very costly compared to the oil obtained crops. Oil from oil obtained crops is easily digestible and its nutrition quality is better compared to the animal fats.

Bangladesh is suffering from acute shortage of edible oil in terms of domestic production. Bangladesh is deficit in edible oil, which costs valuable foreign currency for importing seeds and oil. Annually country is producing about 2.80 Lac m tons of edible oil as against the requirement of 9.80 Lac m tons thus import oil is regular phenomenon of this country (BBS, 2010). Every year Bangladesh imports 7 lac m tons of edible oil to meet up the annul requirement of the country, which costs Tk. 64430 million (BBS, 2007). Both the acreage and production of the crop have been decreasing since 1990 mainly due to ingression of cereal crops like-rice, maize, wheat etc. Delayed harvest of transplanted aman rice and wetness of soil are another reason which hinders mustard cultivation in rabi season (BARI, 2008).

Mustard plant belongs to the genus Brassica under the family brassicaceae. The brassica has three species that produce edible oil, *B. napus*, *B. campestris*, *B. juncea*. Of these *B. napus* and *B. campestries* have the greatest importance in the world's oilseed trade. In this subcontinent, *B. juncea* is also an important oilseed crop. Mustard is the most important oilseed crop among other oilseed crops like groundnut, sesame, coconut, castor and linseed of Bangladesh. Moreover, it is very well known to the farmers. Mustard oil is being used as a medium of cooking from time immemorial (Khaleque, 1985).

Mustard is a cold loving crop and grows during Rabi season (October- February) usually under rainfed and low input condition in this country can be attributed to several factors, the nutritional deficiency, among others is highly important. There is very little scope expansion for mustard and other oilseed acreage in the country, due to competition from more profitable alternative crops. Although mustard is the principal oil crop in Bangladesh but its cultivation is neglected. Moreover the yield of mustard is low in Bangladesh as compared to other countries of the world. There is great possibility to increase its production by applying adequate fertilizers, selecting high yielding varieties and adopting proper management practices. One of the common constraints to higher yield is lack of balanced fertilization.

Many previous researches showed that fertilization can be done to boost up growth and yield of crops (Sinha et al. 2003, Shukla et al. 2002, Meena *et al.* 2002 and Zhao *et al*. 1997). Boron is the vital element for plant growth and yield of this crop. Boron increases yield by influencing a number of growth parameters such as number of branches and siliquae plant^{-1}, seeds siliqua^{-1} and 1000-seed weight by producing more vigorous growth and development

(Taylor *et al.,* 1991; Qayyum *et al.,* 1998). Again, boron has impacts on seed protein and physiological functions and supports the plant with rapid growth, increasing seed and oil seed yield (Allen and Morgan 2009). Excessive use of nboron may reduce seed yield and quality appreciably (Cheema *et al.,* 2001; Laaniste *et al.,* 2004).

Zinc is one of the first micronutrients recognized as essential for plants that transported to plant root surface through diffusion (Maqsood *et al.,* 2009). Zn is a micronutrient and in case of its severe deficiency the symptoms may last throughout the entire crop season (Asad and Rafique, 2000). Zn deficient plant also appears to be stunted (Torun *et al.,* 2001) as a result approximately 2 billion people suffer from Zn deficiency all over the world (Asad and Rafique, 2002). The grain yield can be improved by addition of Zn fertilization (Maqsood *et al.,* 2009). Bora and Hazarika, (1997) reported highest stover yield (2770 kg ha^{-1}) with Zn and almost the same trend of seed yield. The seed yield can be improved by addition of Zn fertilization. Chen and Aviad, (1990) found that application of Zn along with other micronutrients improved soil organic matter and resulted in increasing mustard yields. Kutuk *et al.,* (2000) also suggested that the application of Zn has become necessary for improved crop yields.

Application of proper amount of micro nutrients is essential to maximize crop production. Boron and Zinc fertilizer play an important role to increase the mustard production. Zhu et al. (1996) stated that Zn increased the yield of mustard seed 18% over NPK alone. In addition, the fertilizer requirement for maximum growth and yield of newly developed mustard variety BARI Sarisha- 14 is not much investigated. With a view to determine the Boron and Zinc requirement of this new variety a field study was conducted with the fallowing objectives:

- to study the growth and yield performance of Mustard by using different doses of Boron and Zinc fertilizers.
- to find out suitable combination of B and Zn fertilizers for better growth and yield of Mustard.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the common and most important oil crops not only in Bangladesh but also in many countries of the world. In Bangladesh the average mustard production is comparatively low in comparison to the developed countries. Many studies have been carried out in many countries of the world. A brief of the relevant, important and informative works and researches performed in the past are presented in this chapter.

2.1 Effect of Boron on growth and yield of mustard:

Boron is a micronutrient requiring for plant growth relatively to a smaller amount.Plants absorb B principally in the form of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$,H_2BO_3- and HBO_3^{2-}.The element plays a vital role in the physiological processes of plants such as cell nutrition, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, auxin and phenol metabolism. The function of boron is primarily extra cell ul.ar· and related to lignification and xylem differentation (Lewis, 1980), membrane stabilization (Pilbeam and Kirkby, 1983), and altered enzyme reaction (Dugger, (1983).

Boron has both direct and indirect effects on fertilization. Indirect effects are related to the increase in amount and change in sugar composition of the nectare, whereby the flowers of species that rely on pollinating insects become more attractive 10 insects (Smith and Johnson, 1969; Erikson, 1979). Direct effects of Boron are reflected by the close relationship between boron si1pply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.,* 1981).

Moreover,boron stimulate germination capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*,1981).Moreover, boron stimulate germination particularly pollen tube growth.Boron capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.,1981)* Moreover,boron stimulate germination particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants (Jakson and Chapman, 1975).

Gupta (1979) stated that some plant species have a low B requirement and may 11lsn he sensitive to elevated B level even only slightly above those needed for normal growth. Therefore, toxic effects of B arc likely to arise due to excessive use of B fertilizers. Juel (1980) reported from 17 trials that the application of boron at the rate of 2 kg/ha resulted in increased seed yield of mustard and oil content of seed. Gerach *et al.* (1975) reported an increase in yield of winter rape through application of boron fertilizer and recommended an application of l to 2 kg B/ha for increased yield.

Islam and Sarker (1993) reported that the application of boron increased significantly the number of siliquae plant, no. of seeds /siliq ua and seed yield of mustard (cv. ss-75) a Rai1gpur Agricultural Research Station. From another study it was reported that application of boron on mustard (cv.ss-75) significantly increased the seed yield in farmer's field at Jamalpur.

Thomas (1985) reported that the highest yields were achieved on medium to heavy soil with 40 kg N and P, 80 kg K, l kg B and 30 kg S /ha applied before sowing, plus 180 kg to 220 kg N /ha applied as top dressing in two installments in late February to early March.

Chakravarty *et al.,* (1979) stated that boron concentration in all crops increased significantly with increasing level of applied boron.

Yadav and Manchandra, (1982.); Dutta *et al.,* (1984) and Yang *et al.,* (1989) also reported that increased level of boron application in mustard *(B. campestris)* increased tissue B content.

Sharma and Ramchandra (J 990) reported that boron deficiency in mustard (B. *campestris)* decreased dry matter yield, Boron deficient plant had low water potential, stomatal pore opening and transpiration,decreased chlorophyll concentration, hill reaction activity, inter-cellular concentration and photosynthesis but there was an increase in accumulation of soluble nitrogen, protein, sugar and starch.

Marschner, (1990) reported that the deficiency symptoms of some boron sensitive crops like legumes, *Brassica,* beets, cele1y, grapes and fruit trees are chlorosis and browning of young leaves, killed growing points. distorted blossom development, lesions in pith and roots and plants, burning of the tips of the leaves and restricted root growth are the boron toxicity symptoms in most crops.

Application of boron significantly increased the yield of mustard and l.5 kg B /ha appeared to be the optimum B level for mustard (Sinha *et al.,* 1991; Dixit and Shukla, 1984). Banuels *et al.* (1990) reported that the application of P, S, Zn, and B raised seed yield of mustard significantly. Combined application of N, K and B increased seed yield in rapeseed (Yang *et al.,* 1989).

Chatterjee *et al.,* (l985) reported that the application of Sulphur at the rate of 20 kg/ha through gypsum in conjugation witl1 borax (10 kg /ha) caused 42% increase in yield of mustard *(B. Juncea).* The straw yield of mustard *crop* increased significantly by boron application (Sinha *et al.,* 1991). Application of B along with N and K promoted co2 assimilation, nitrate reductase activity in leaves and dry matter accumulation Seed glucosinolate and erucic acid content varies among cultivars and generally decreases with increasing K and B, while seed oil content increases (Yang *et al.,* 1989)

Sen and Farid (2005) reported that application of boron I@ l.5 kg/ha produced 37% higher yield over control.

Application of B (I kg /ha) increased leaf area ratio (LAR), leaf area index (LIA), crop growth rate (CGR), no. of brunches plant, no. of siliquae /plant, weight of seed/siliqua and a decrease iii chlorophyll content and net assimilation rate (NAR), but the relative growth rate (RGR), total dry matter and seed yield and some of other growth attributes were unaffected (Dutta and Uddin, 1983; Dutta *et al.*, 1984).
Increasing rate of B application from 0 to 6 ppm had no effect on dry matter and seed yield of mustard (Yadav and Manchanda, 1982).

Sarkar *et al.*, (2004) conducted n field experiment to identify cultivars with tolerance to micronutrient stresses. Doron treatments were: 0, 2 and *5* kg borax (0,0.221 and 0.553 kg B, respectively). Based on the grain yield and its component characters, 14 cultivars or rapeseed mustard can be classified as highly boron responsive, moderately-responsive and non-responsive with respect to response; of the cultivars to boron, applied to the highly boron deficient soil. The genotypes included 10 cultivars of *Brassica juncea*, 2 of *Brassica campestris* var. sarson and 2 of toria *(8. cm11pestris* var. tori a). The cultivars RLM 619, NOR 8602, P13M 16, RK 9082 and C-3 were found to be highly boron responsive. The cultivar T-9 was boron non-responsive, while rest of the cultivars were found to be moderately boron-responsive.

A field experiment was conducted by Melewar. (2001) on a Typic haplustert in Maharashtra. India to investigate the effects of four levels of zinc sulfate (0, 10, 20 and 30 kg/ha) and three levels of borax (0, 5 and 10 kg/ha) on yield. nutrient uptake and seed quality of mustard *(Brassica juneca* cv. Pusa Bold). Stover and seed yield significantly increased with each levels of either zinc or boron. which was attributed to the positive interact ion of the two. Highest total mustard uptake or 7.n and B was 111 30 kg ZnS04 and 10 kg borax/ha, respectively. Zn and B interaction was also reflected in terms of improved seed quality or mustard. Oil and protein content was significantly increased with 30 kg $ZnS0_4$ x 10 kg borax/ha treatment.

Sinha *et al.,* (2000) stated that mustard *(Brassica campestris)* e"·T9 was grown in refined sand at three levels of boron (H): deficient (0.0033 ppm), normal (0.33 ppm), and excess (3.3 ppm), each at d1ree levels of zinc (Zn): low (0.00065 ppm),

adequate (0.065 ppm). and high (6.5 ppm). The B deficiency effects were accentuated by low zinc, viz. the decreased biomass, B and Zn concentrations in leaves and seeds and the activity of carbonic anhydrase [carbonate dehydratase] and accumulation of reducing sugars and stimulated activities of peroxidase, ribonuclease, and acid phosphatase in B deficient leaves were aggravated further. Synergism was also observed between the two nutrients when both B and Zn were in excess together, as excess 13 accelerated the effects of high Zn by lowering further the reduced bionu1ss, economic yield, ru1d carbonic anhydrase activity and raised further the increased concentration of B and Zn in leaves and seeds. reducing sugars and activity of peroxidase obtained in excess Zn. High 7.n levels lowered the high content of non-reducing sugars given by B deficiency.

Gupta *et al.*(l996) reported that mustard *[Brassica juncea]* cv. GSL-1. Pusa Bold and RS-1359 grown in the rabi [winter] seasons of 1992/93 and 1993/94 were given recommended N PK fertilizers plus 1.0 or 20 kg Zn/ha, foliar application of 0.5% Zn, 25 or 50 kg S ha, or 10 or 20 kg B/ha. Seed yield was highest in cv. OSL-1, and was increased more by S and B than by Zn.

In field trials on a sandy loam in West Bengal in rabi [winter] 1989/90, application of 20 kg S and l kg B/ha 10 rape-seed mustard *[Brassica juncea]* significantly increased plant height, leaf area index at flowering and crop growth rate, oil content and seed yield (pradhan and Sarkar, 1993).

A pot experiment was conducted by Rashid and Rafique, (l992). They reported that *B. juncea* cv. Westar was grown in soil and given 0, 0.5, I, 2, 4 and 8 mg D as H_3B0_3'kg soil. DM yield after 4 and 8 weeks growth increased with up to I mg B; application rates > 2 mg B were toxic. The critical B concentration in whole shoots was 57 mg B/kg for 4-week-old plants and 28 mg for 8-week-old plants.

In field trials in 1987-88 wi1h *6* cultivars each of sesame and mustard *[Brassica juncea]* grown with applied NPK + Zn on a 8-deficienl soil, av. sesame seed yields increased from 502 to 569 kg/ha and mustard seed yields increased from 1.14 to 1.35 I/ha when 1.5 kg B/ha was applied; yields were decreased to 518 kg and 1.30 t, resp., with 2.5 kg B/ha. Sesame *cv.* OMT-11-6-3 and RT-54 and mustard cv. Pusa Bold were more tolerant of B deficiency than other cultivars, as they removed more B from the soil given no B. They also showed a lower yield response to applied B than more susceptible cultivars. There was a positive correlation bet ween seed B content and uptake. Yield was positively correlated with seed B uptake (Sakal *et al.,* 1991).

Saini *et al…,* (1985) observed that seed yield *of B. juncea* were increased by increasing N rates from 0 lo 120 kg and I kg B/ha. The response to S, Zn and B increased with increase in. N rates. Oil content decreased slightly with increasing N rates and increased slightly with S, Zn and B.

From the above information it may be inferred 1hal 1he optimum level of boron has a positive effect on seed yield but the growth and yield is depressed due to deficient or toxic level of boron.

2.2 Effect of Zinc on the growth and yield of mustard:

An experiment was carried out by Meena *et al* (2018) in rabi season of 2013- 2014 and investigated that the best yield attributes characters was in treatment T8 (@NPK$_{100}$ + @ Zinc Sulphate$_{100}$) in respect to different levels intervals i.e. 30,60,90 days after sowing (DAS). Number of leaves per plant were 14.06, 19.10 and 20.10 and no. of branches per plant were 6.30, 11.40 and 12.20 found to be significant at 30 DAS, 60 DAS, 90 DAS but, Plant height was 29.10 cm, 99.53 cm and 107.16 cm was significant at 30 DAS and 60 DAS and interaction effect of NPK and Zinc Sulphate was non-significant at 90 DAS. In the same treatment T_8, combination of the Zinc Sulphate and N P K on an average test weight, fresh weight, dry weight and oil content (%) found significant and effect of NPK on test weight found significant and effect of Zinc Sulphate was non-significant. Adequate plant nutrient supply maintains the key for developing the food seed production food security.

S. Singh and V. Singh (2017) carried out a field experiment in two consecutive rabi seasons of 2012-13 and 2013-14 at Panwari village, Agra (Uttar Pradesh) in India to determine the effect of rate and source of zinc on productivity, quality and uptake of nutrients in Indian mustard (*Brassica juncea* (L.) Czern and Cosson). The experiment was conducted in randomized block design with two sources (zinc oxide and zinc sulphate) and five levels of zinc (0, 2, 4, 6 and 8 kg Zn/ha) with three replications. The results showed that significantly taller plants and higher number of siliquae/plant, seed and stover yields were found in zinc sulphate as compared to zinc oxide. The plant height, yield attributes,

i.e. siliquae/plant, seeds/ siliquae and test weight, seed and stover yields of mustard were significantly improved with the increase in the levels of zinc and the highest seed (19.22 q/ha) and stover (55.77 q/ha) yields were found with 6 kg Zn/ha. Application of 6 kg Zn/ ha resulted in 22.2% higher seed and 24.7% stover yield than the yield obtained in the control (16.86 q/ ha seed and 48.60

q/ha stover). The content and yields of protein and oil remained unaffected by sources of zinc but increased significantly with increasing Zn doses, thus mustard fertilized with 6 kg Zn/ha, which was found the maximum yield of protein (384.0 kg/ha) and oil (39.3%, 754.7 kg/ha). The highest value of protein content (21.0%) was recorded with 8 kg Zn/ha. The uptake values of N, P, K and S by mustard seed and straw were not affected by different levels of zinc but uptake of zinc increased significantly with zinc sulphate over zinc oxide. The uptake of nutrients in mustard crop increased significantly up to 6 kg Zn/ha followed by reductions at 8 kg Zn/ha. Nutrient status in postharvest soil was not affected with different levels of zinc but improved significantly with different Zn levels. The availability of B and Zn improved significantly up to 8 kg/ha, on the other hand P, K and S contents increased up to 4 kg Zn/ha.

An experiment was conducted by Sahito HA. *et al.* (2014) to investigate the effects of Zinc on mustard. Two varieties (Early Mustard and S-9) were evaluated against six Zn levels (0, 2, 4, 6, 8 and 10 kg Zn ha -1). Significant improvements in the plant growth, seed yield and oil contents were found with increasing Zn levels. The results showed that there was a significant improvement in the growth, seed yield and oil content with increasing levels of Zinc, irrespectively. The highest Zn level of 10 kg/ha resulted 216 cm plant height, 10.86 branches/plant , took 55.66 days to initiate flowering, 574.50 pods/plant , 17.61 g weight of seeds /plant , 3.63 g seed index, 2037.20 seed yield kg /ha and 36.80 percent oil as the highest output. In case of varieties, S-9 ranked 1st with 216.50 cm plant height, 10.84 branches per plant , took 56.33 days to initiate flowering, 581.11 pods per plant , 17.82 g weight of seeds per plant , 3.66 g seed index, 1960.30 seed yield kg /ha and 36.80 percent oil content; while variety Early Mustard resulted 186.56 cm plant height, 9.25 branches /plant , took 52.72 days to initiate flowering, 484.67 pods /plant , 14.50 g weight of seeds /plant, 2.90 g seed index, 1677.90 seed yield kg /ha and 35.13 percent oil content. It suggests that to achieve economically higher seed yields in mustard, the Zinc application to mustard may be done at the rate of 8 kg /ha.

S. K. Dubey *et al.* (2013) carried out an experiment at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Faizabad (Uttar Pradesh), during the rabi season of 2008- 09 in RBD and replicated three times. The sowing was done on November 20, 2008. The treatments comprised four levels of sulphur (0, 20, 40 and 60 kg S /ha) and four levels of zinc (0, 5, 7.5 and 10 kg Zn /ha). The mustard variety "Varuna" was used as test crop. Applic*ation of 60 kg S /ha and 10 kg Zn /ha, produced significantly higher plant, primary and secondary branches per plant, number of leaves per plant, days taken to flowering, days taken to maturity, number of siliquae per plant, length of siliquae, and number of seeds per siliquae, harvest index and oil content. However, dry matter accumulation per plant, 1000-grain weight (g), biological yield, seed yield, stover yield and protein content significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg /ha.

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Azam M.G. *et al.* (2013) conducted an experiment in the farmer's field at the MLT site Tularampur, Narail (AEZ 11) during the rabi season of 2011-12 to investigate the performance of newly released mustard varieties to Zn fertilization. Three levels of Zinc sulphate- 2, 3, 4 kg/ha was used in Bari Sarisha- 14. It is found that application of Zinc can affect the growth, yield and plant characters of mustard. The supplement of Zinc is important micronutrient to control Zn deficiency in high and medium lands in Jassore region. The seed yield of mustard (cv. BARI Sarisha – 14) increased markedly for the application of Zn in soil, showing 11-25% yield increases over control. In there the yield of BARI Sarisha -14 was the highest in T_2 treatments i.e. application of 5 kg zinc/ha. So, it is suggested that the rate of 5 kg Zn/ha was found optimum for higher seed yield of mustard.

An experiment was carried out by Singh B. *et al*. (2012) to determine the effect of Sulphur and zinc application on growth, yield attributes, seed yield and quality of mustard at Agronomy Research Farm, College of Agriculture, S. K. Rajasthan Agricultural University, Bikaner (Rajasthan) in India during rabi season of 2006-2007 and 2007-2008. Here, treatments consisted of five levels of Sulphur (0, 20, 40, 60 and 80 kg/ha) and four levels of zinc (0, 3, 6 and 9 kg/ha). The findings showed that application of 40 kg S/ha and 6 kg Zn/ha improved growth parameters like plant height, number of branches per plant and yield components viz., number of siliquae per plant, seed per siliqua, seed yield and stover yield as compared to other treatments. Protein content significantly increased up to 40 kg S/ha and 6 kg Zn/ha.

2.3 Combined effect of Boron and zinc on the growth and yield of mustard:

Kumar Vineet *et al.* (2016) conducted a thrice replicated field trial in rabi season 2009-10 to evaluate 5 boron rates and 2 zinc fertilizer rates ongrowth, yield and quality of Indian mustard. The experimental results showed that application of 100 kg B/ha increased significantly maximum growth attributes viz. plant height(cm), number of total (primary + secondary) branches per plant, total dry matter accumulation at 60, 90 DAS and harvest stage, dry matter g/plant husk, stem as well as total and seed, straw as well as total, yield attributes (number of siliquae per plant, length of siliquae per plant,number of seed per siliquae, seed weight per siliquae, 1000 seed weight, seed weight per plant) and yield such as grain yield (1804 kg/ha), biological yield (8406 kg/ha) and harvest index (21.6%), besides achieved better protein content and, protein and oil yield. But the highest oil (42.3%) content was found in a plot where N was absent. Moreover, like as above, application of 20 kg/ha zinc recorded the highest growth, yield and quality of Indian mustard over control plot. Thus, the interaction between Boron @100 kg/ha and zinc @5kg/ha appeared to be more promising to increase the productivity B.juncea on one hand and to improve its quality.

On the other hand,

Rimi et al.(2018) carried out an experiment in the field of Sher-e-Bangla Agricultural University, Dhaka during the rabi season from November 2016 to February 2017 to determine the role of boron (B) and zinc (Zn) on seed yield contributing characters and seed quality of rapeseed (*Brassica campestris L.).* The experiment was factorial with two factors, factor A consisted of three different levels of B viz. 0, 1,1.5 (kg/ha) and factor B consisted of three different Zn levels viz. 0, 3, 5 (kg/ha).

Randomized Complete Block Design (RCBD) with three replications was used in this experiment. Boron significantly increased number of siliquae per plant, thousand seed weight and oil content percent up to 1.5 kg B/ha but the highest dose 1.5 kg/ha failed to produce better results as other doses. The number of siliquae per plant and oil content percent was increased significantly with the increment of Zinc up to 5 kg/ha. Interestingly, seed weight of 100 siliquae, 1000 seed weight did not show any statistical differences with the increment of Zn.

The combination of B and Zn significantly increased seed weight per plant, seed weight of 100 siliquae, 1000 seed weight and oil content of seed. The highest value of seed yield contributing characters and oil content of rapeseed was studied with the combined dose of 1.5 kg B/ha and 5 Kg Zn/ha whereas the lowest values were found from control. The highest oil content (43.29%) was found in 1.5 kg B/ha with 5 Kg Zn/ha treatment combination. Separately, the combined use of B and Zn did not show any significant differences on regulation germination rate of rapeseed. Based on the present results, it is suggested that the combined doses of 1.5 kg B/ha with 5 kg Zn/ha is appropriate for higher yield and quality seed production of rapeseed using cv. BARI Sarisha 14.

A field experiment was conducted at Bichpuri in India by SP Singh and V Singh (2005) to determine the response of indian mustard [*Brassica juncea (L*.) Czenz & Cosson] to different levels of Boron, Sulphur and Zinc. The research

is done during winter season of 2000-2002. The seed yield of mustard significantly increased with increasing levels of applied B, S & Zn. Nitrogen application increased the mean seed yield by 36.2%, while decreased the oil content by 0.5% form the control. Sulphur application increased the mean seed yield and oil content by 35.6% and 6.3%. Zn application increased 12% & 0.7%, respectively over the control. Boron, Sulphur and Zinc application increased significantly the protein contents in seed.

CHAPTER III

Materials and Methods

The experiment was conducted during Rabi season at research farm, Sher e Bangla Agricultural University to determine the effect of Boron and Zinc on the growth and yield of Mustard variety BARI Sarisha-14 (*Brassica campestris).*

3.1 Experimental Site

The field experiment was located at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2021 to February 2022. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone “AEZ-28” of Madhupur Tract , which falls into Deep Red Brown Terrace Soils. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

The soil of the experimental field is slightly acidic in reaction with low organic matter content. Top soil was sandy loam in texture. Soil p^H was 5.47-5.63 and has organic carbon 0.89%. The research field was flat having available irrigation and drainage system and above flood levels. The selected plot was medium high land.

3.3 Climate

The experimental area is situated under the sub-tropical climate and is characterized by less rainfall associated with moderately low temperature during rabi season, October- March and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season April-September. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Bangladesh Meterological Department (Appendix VI).

3.4 Plant material

BARI Sarisha-14 (*Brassica campestries*) developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was used as planting material in this experiment. The seed was collected from the BARI. Before sowing germination test of seeds were done in the laboratory and percentage of germination was found over 95%.

3.5 Experimental treatments

The experiment consisted of two treatment factors as mentioned below:

Factor A: Boron levels designated as: =

$B_{0=}$ 0 kg B ha^{-1} (control)
B_1 = 1 kg B ha^{-1}
B_2 = 1.5 kg B ha^{-1}

Factor B: Zinc levels designated as:

Zn_0 = 0 kg Zn ha^{-1} (control)
Zn_1 = 3 kg Zn ha^{-1}
Zn_2 = 5 kg Zn ha^{-1}

Treatment combinations:

T_1=B_0Zn_0	T_2= B_1Zn_0	T_3= B_2Zn_0
T_4= B_0Zn_1	T_5= B_1Zn_1	T_6= B_2Zn_1
T_7 = B_0Zn_2	T_8= B_1Zn_2	T_9= B_2Zn_2

3.6 Design and layout

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 2 m × 1.5 m = 3 m^2 and total numbers of plots were 27. There were 9 treatment combinations. Layout of the experiment was done on November 19, 2021 with inter plot spacing of 0.75 m and inter block spacing of 0.75 m. Plant spacing was maintained with 30 cm and 5 cm, as of line to line and plant to plant distance, respectively. The layout has been shown in Appendix V.

3.7 Land preparation

The land of the research field was first opened on November 10, 2021 with a power tiller. Then it was exposed to the sun for 7 days prior to the next ploughing. Then, the land was ploughed and cross-ploughed to have a good tilth. Laddering was done for breaking the soil clods into small pieces after each ploughing. All the weeds and stubbles were removed from the research field. The land operation was completed on 17 November 2022. According to the layout of the experiment, the entire experimental area was divided into blocks and subdivided into plots for the sowing of mustard. Irrigation and drainage channels were also made around the plots.

3.8 Fertilizer application

In this experiment fertilizers were used according to BARI recommendation as follows:

Fertilizers	Rate of application per ha
Urea	250 kg/ha
TSP	170 kg/ha
MoP	80 kg/ha
Gypsum	150 kg/ha
$ZnSO_4$	As per treatment
Boric Acid	As per treatment

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, murate of potash, gypsum, zinc sulphate and boric acid required per plot were calculated. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil during final land preparation. Rest of the urea was top dressed after 30 days after sowing(DAS).

3.9 Seed Sowing

Sowing was done on 19th November, 2021 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 8 kg ha^{-1}. After sowing, the seeds were covered with the soil and slightly pressed by hand. Plant population was kept constant through maintaining plant to plant distant 5 cm in row.

3.10 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.10.1 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 30 November 2021. At the same time first thinning was done. The final weeding and thinning were done after 25 days of sowing, on 13 December 2021. Care was taken to maintain constant plant population per plot.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given on the post sowing. The second irrigation was given at 15 DAS on 2^{th} December, 2021. The final irrigation was given at the stage of seed formation (50 DAS), on 10^{th} January,2022.

3.10.3 Crop protection

The crop was sprayed with Malathion 57 EC@ 2ml L^{-1} of water at siliquae formation stage to control aphids. The crop was kept under constant observations from sowing to harvesting.

3.11 General observations of the experimental field

Constant observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.12 Sampling

Ten sample plants were collected randomly from each plot. These 10 plants were used for taking data for yield attributes.

3.13 Harvest and post-harvest operation

Previous randomly selected ten plants, those were considered for the growth analysis was collected from each plot to study the yield and yield contributing parameters. Rest of the crops was harvested when 80% of the siliquae in terminal raceme turned golden yellow in colour. After collecting sample plants, harvesting was done on February 20. To avoid shattering, harvesting was done in the morning. The harvested crops from each plot were tied into bundles separately and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.14 Drying and weighing

The seeds and stover thus collected were dried in the sun for couple of days. Dried seeds and Stover of each plot was weighed and subsequently converted into yield kg ha^{-1}.

3.15 Data Collection

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Some data were collected from sowing to harvesting with 20 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those taken from selected plants which were marked by tag. Final field data were collected at harvesting stage.

Data were collected on the following parameters:

1. Plant height (cm)

2. Number of branches per plant

3. Number of siliquae per plant

4. Number of seed per siliquae

5. Length of siliquae (cm)

6. Thousand seed weight (g)

7. Seed yield (t/ha)

8. Stover yield (t/ha)

9. Biological yield (t/ha)

10. Harvest Index (%)

3.16 Methods of recording data

3.16.1 Plant height (cm)

The height of the mustard plants was recorded at harvest. The height of 10 preselected sample plants were taken from the ground level to the tip of the shoot. Then the mean of the data were taken and expressed in cm.

3.16.2 Number of branches per plant

Total number of branches was taken at harvest. All the branches present on randomly selected plants were counted and average number of branches per plant was taken.

3.16.3 Number of siliquae per plant

Number of siliquae was counted from randomly selected ten plants after harvest and averaged them to have number of siliquae per plant.

3.16.4 Number of seeds per siliquae

Number of total seeds of 10 randomly preselected sample plants from each plot was recorded and the average number was expressed per siliquae basis.

3.16.5 Length of siliquae (cm)

Number of siliquae was recorded from randomly selected 10 sample plants after harvest and mean number was expressed in cm.

3.16.6 Thousand seed weight (g)

One thousand sun dried and cleaned seeds were counted randomly from the seed stock and weighed of seeds. Then the weight of 1000 seeds were recorded by means of a digital electrical balance and expressed in gram.

3.16.7 Seed yield (t/ha)

Seeds obtained from harvested area of each unit plot were dried in the sun and weighed. The seed weight was expressed in t/ha.

3.16.8 Stover yield (t/ha)

The Stover obtained from the harvested area of each unit plot was dried separately and weight was recorded. These values were expressed in t/ha.

3.16.9 Biological yield (t/ha)

Biological yield was calculated by using the following formula:
Biological yield= Seed yield + Stover yield

3.16.10 Harvest index (%)

Harvest index is the ratio of seed yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

Harvest index = (Seed yield / Biological yield) × 100

3.17 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P and K contents. The soil samples were analyzed by the following standard methods as follows:

3.17.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was estimated by plotting the values of % sand, % silt and % clay to the Marshall's textural triangular co-ordinate following the USDAsystem.

3.17.2 Soil pH

pH of soil was estimated with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1973).

3.17.3 Organic carbon

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973).

3.17.4 Organic matter

Soil organic matter content was determined by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724.

% organic matter = % organic carbon × 1.724

3.17.5 Total nitrogen

Total nitrogen content in soil was estimated by Kjeldahl method by digesting the soil sample with conc. H_2SO_4, 30% H_2O_2 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 10:1:0.1) followed by distillation with 40% NaOH and by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Black, 1965).

The amount of N was calculated using the following formula:

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

Where,

T = Sample titration (ml) value of standard H_2SO_4
B = Blank titration (ml) value of standard H_2SO_4
N = Strength of H_2SO_4
S = Sample weight in gram

3.17.6 Available Phosphorus (ppm)

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ solution pH 8.5 (Olsen et al., 1954). Phosphorus in the extract was measured spectrophotometrically after development of blue colour (Black, 1965).

3.17.7 Exchangeable Potassium (meq/100 g soil)

Exchangeable potassium (K) content of the soil sample was determined by flame photometer on the NH_4OAc extract (Black, 1965).

3.17.8 Available Zinc

Available Zinc content was estimated by extracting the soil with Zncl2 solution as described by Page et al. 1982. The digested Zn was determined by developing turbidity by adding Zncl2 solution. The intensity of turbidity was measured by spectrophotometer at 420 mm wavelengths (Hunter, 1984).

3.18 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program (Russel, 1986). The mean values for all the parameters were calculated and the analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test at 5 % levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

Result and Discussion

The present experiment was carried out to study the effect of different levels of boron and zinc on growth and yield parameters of mustard plants. The analyses of variance (ANOVA) of the data on different components are given in Appendix II and III. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Plant height:

4.1.1 Effect of boron levels:

The results of this study showed that mustard plant height (Fig. 1) was significantly affected by boron (B) levels. Here, the tallest plant (76.69 cm) was recorded with $B_{2,}$ 1.5 kg B ha^{-1}. In contrast, the shortest plants were recorded from control, B_0 and it was 62.20 cm. The requirement of boron fertilizer can differ much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc. These results are in agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003), Singh (2002). Similar results were observed by Tomar *et al.* (1996), FAO (1999), Ali and Ullah (1995), Shamsuddin *et al.* (1987), Ali and Rahman (1986) and Hasan and Rahman (1987). Above all, these findings suggest that higher doses of B increase plant height of mustard.

4.1.2 Effect of zinc levels:

Again, the results showed that Zinc (Zn) levels showed significant effect on mustard plant height. It can be observed from the figure (Fig. 2) that Zn_2 , 3 kg Zn ha^{-1} showed the tallest plant (77.10 cm) and the control, 0 kg Zn ha^{-1} produced the shortest plant (62.94 cm) .

4.1.3 Combined effect of boron and zinc levels on plant height of mustard:

Interaction between B and Zn (Table 4.1) had significant effect on mustard plant height. The tallest plant (78.37 cm) was resulted in B_2Zn_2 treatment combination, 1.5 kg B/ha with 5 kg Zn/ha whereas the shortest plant (59.97 cm) was observed in the control treatment combination. Singh (2002) observed that plant height increased significantly with successive increase in boron up to 1.5 kg/ha. These results showed that mustard plant height increases with combined use of boron and zinc.

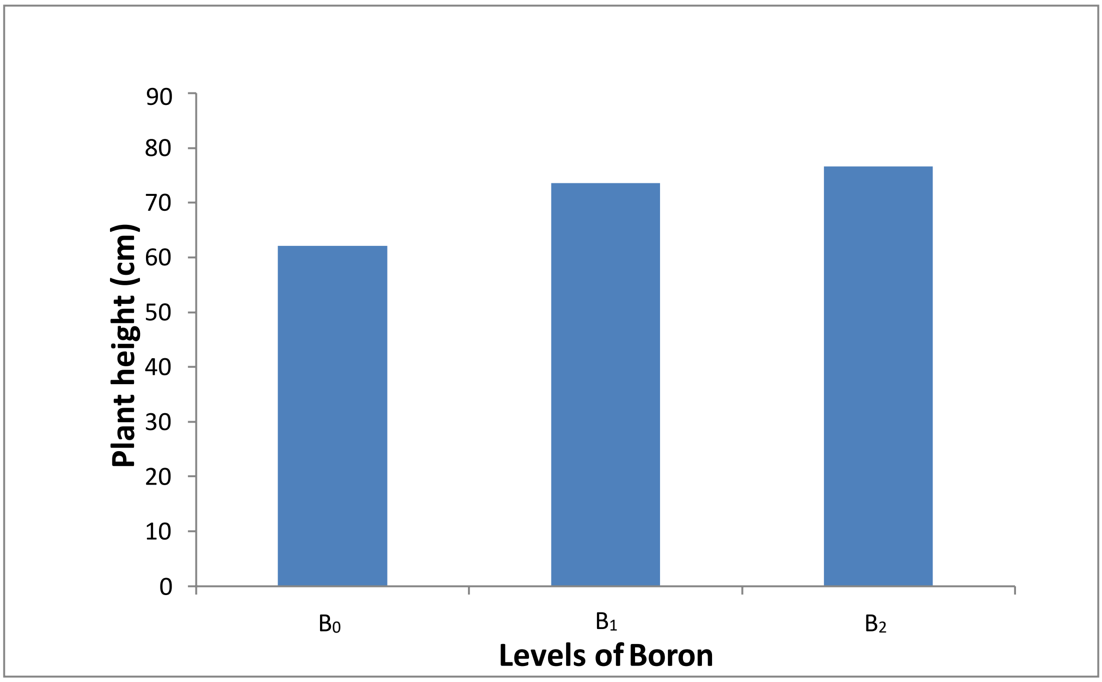

Fig 1: Effect of different levels of Boron on plant height (cm) of Mustard at harvest.

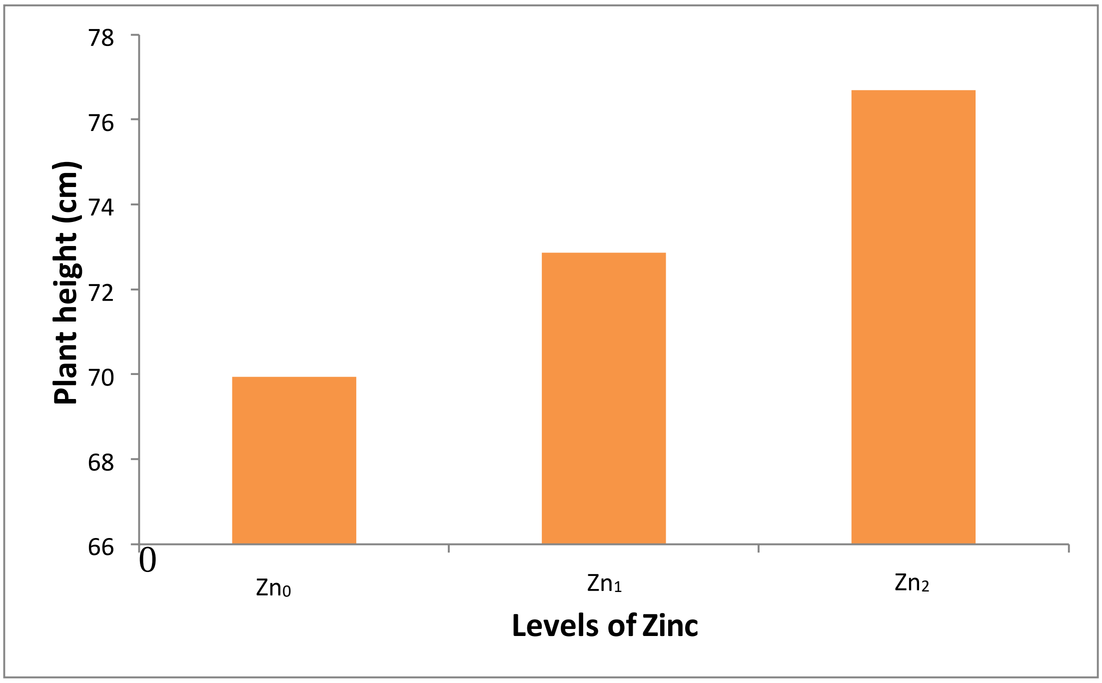

Fig 2: Effect of different levels of Zinc on plant height (cm) of Mustard at harvest.

4.2 Number of branches per plant:

4.2.2 Effect of boron levels:

The significant result was found in branches per plant of mustard by the different levels of boron application. The figure (Fig. 3) indicated that B_2
1.5 kg B ha^{-1} produced the maximum number branches per plant (5.18) whereas B_0 , the control produced the minimum number of branches per plant (3.99). Khan *et al.* (2002) and Uddin *et al.* (1992) suggested that number of branches $plant^{-1}$ increased significantly with increasing boron levels up to 1.5and 3 kg B ha^{-1}, respectively.

4.2.2 Effect of zinc levels:

A statistically significant variation was found in number of branches per plant by different levels of Zinc application. The maximum number of branches per plant (4.85) was recorded by $Zn_{2,}$ 5 kg Zn ha^{-1}. On the other hand minimum number of branches per plant (4.65s) was recorded by $Zn_{0,}$ the control (Fig. 4).

4.2.3 Combined effect of boron and zinc levels:

The combined effect of boron and zinc was found significant in number of branches per plant (Table 4.1). The highest number of branches per plant (5.99) was resulted in B_2Zn_2 treatment combination, 1.5 kg B/ha and 5 kg Zn/ha whereas the lowest number of branches per plant (3.66) was resulted in B_0Zn_0, control treatment. The result of this study suggested that combined use of boron and zinc increases mustard yield.

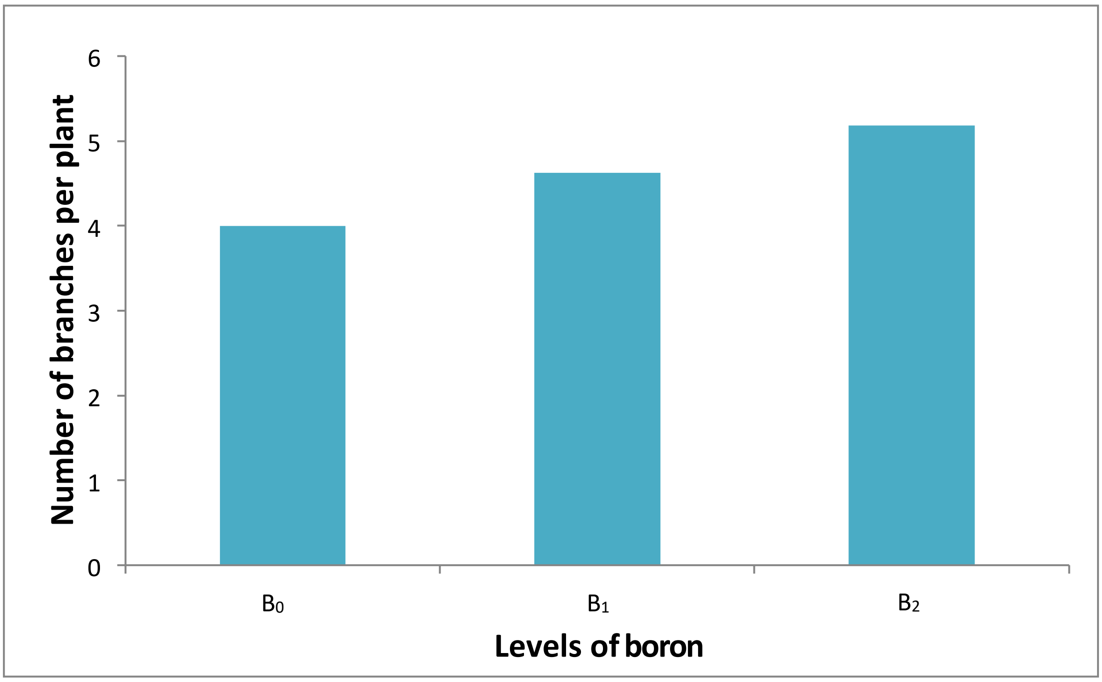

Fig 3: Effect of different levels of Boron on number of branches per plant of Mustard.

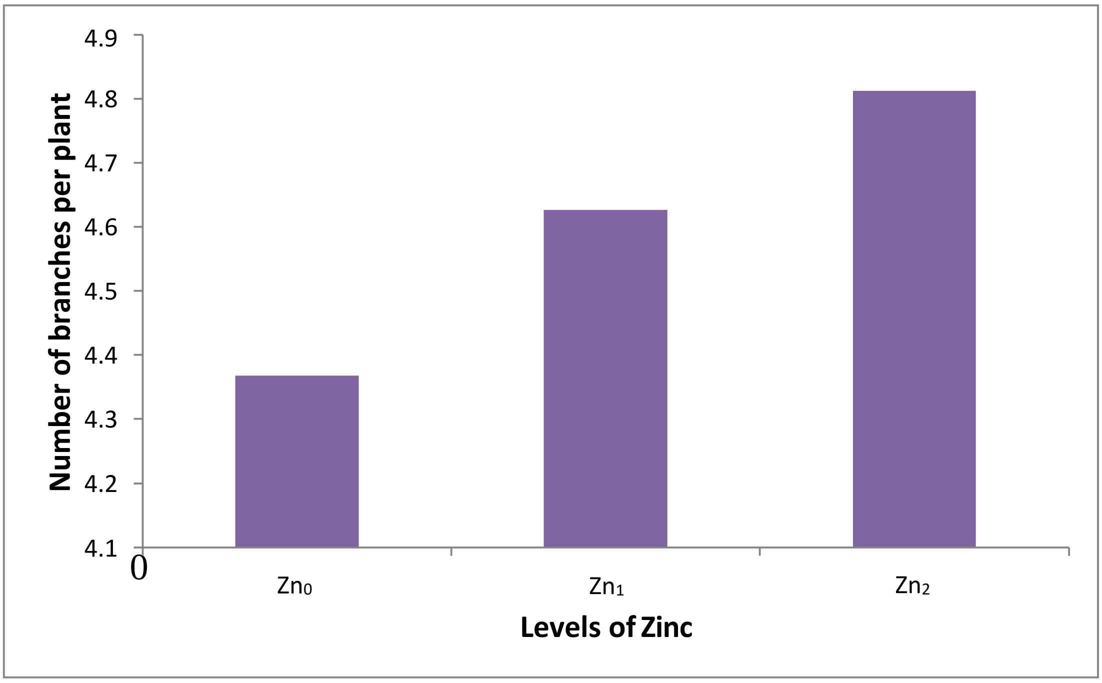

Fig 4: Effect of different levels of Zinc on number of branches per plant of Mustard.

Table 4.1: Combined effect of different levels of Boron and Zinc on plant height (cm), Number of branches per plant of Mustard.

Treatment	Plant height (cm)	Number of branches per plant
T_1	59.97 h	3.66 d
T_2	62.35 g	4.11 cd
T_3	63.40 f	4.22 c
T_4	69.68 e	4.33 c
T_5	77.50 b	5.33 b
T_6	73.65 d	4.22 c
T_7	77.17 b	5.11 b
T_8	74.53 c	4.44 c
T_9	78.37 a	5.99 a
$LSD_{(0.05)}$	0.3677	0.46
CV (%)	0.31%	5.98%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1=B_0Zn_0 T_2= B_1Zn_0 T_3= B_2Zn_0

T_4= B_0Zn_1 T_5= B_1Zn_1 T_6= B_2Zn_1

T_7 = B_0Zn_2 T_8= B_1Zn_2 T_9= B_2Zn_2

4.3 Number of siliquae per plant:

4.3.1 Effect of boron levels:

The number of siliquae per plant was not found significant by different levels of boron application (Table 4.2). B_2, 1.5 kg B/ha produced the maximum number of siliquae per plant (48.89). On the other hand, control treatment, B_0 produced the minimum number of siliquae per plant (41.00), that are correlate with the findings of Shukla et al.(2002) different levels of boron increased siliquae per plant of mustard ensuring proper growth of plant. Sharawat *et al*. (2002) recorded maximum number of siliquae/plant with 1.5 kg B/ha.

4.3.2 Effect of zinc levels:

Different levels of zinc had no significant differences for siliquae per plant (Table 4.3). The highest number of siliquae per plant (47.52) was produced by Zn_2, 5 kg Zn/ha whereas lowest number of siliquae per plant (43.81) was resulted by the Zn_1, 3 kg Zn/ha.

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4.3.3 Combined effect of boron and zinc levels:

Interaction between boron and zinc had significant effect on number of siliquae per plant (Table 4.4). The highest number of siliquae per plant (57.00) was resulted in B_2Zn_2, 1.5 kg B/ha with 5 kg Zn/ha, whereas the lowest number of siliquae per plant (39.33) was found in B_0Zn_0, the control in where no boron and zinc applied.

4.4 Number of seeds per siliquae:

4.4.1 Effect of boron levels:

The results of this study showed that number of seeds per siliquae was significantly affected by different B levels (Table 4.2). Here, the highest number of siliquae per plant (23.56) was found in B_2, 1.5 kg B/ha. In contrast, the lowest number of siliquae per plant (20.92) was obtained from control, B_0, 0 kg B/ha combination. The results are in full agreement with findings of Singh (2002), Tarafder and Mondal (1990).

4.4.2 Effect of zinc levels:

A statistically significant variation was found in number of seeds per plant by different levels of Zinc application (Table 4.3). The highest number of branches per plant (22.91) was found in $Zn_{2,}$ 5 kg Zn ha^{-1}. On the other hand lowest number of seed per siliquae (21.72) was found in $Zn_{0,}$ the control plots where no zinc was applied.

4.4.3 Combined effect of boron and zinc levels:

A significant variation indicated among the treatment combinations of B and Zn in number of seeds per siliquae (Table 4.4). The highest number of siliquae per plant (24.77) was recorded by B_2Zn_2, whereas the lowest number of seeds per siliquae (20.11) was recorded by the control plots, B_0Zn_0 treatment combination.

4.5 Length of Siliquae :

4.5.1 Effect of boron levels:

Different levels of boron showed significant effect on siliquae length of mustard (Table 4.2). The maximum length of siliquae (4.53 cm) was obtained from B_2Zn_2, 1.5 kg B/ha whereas the minimum (4.33 cm) length of siliquae was found from the control (0 kg B/ha) treatment. These results are in conformity with the finding by Shukla et al. (2002) and El-Kholy *et al.* (2007).

4.5.2 Effect of zinc levels:

The results of this study showed that mustard siliquae length was significantly affected by different levels of Zinc (Table 4.3). Here, the maximum length of siliquae (4.48 cm) was recorded with Zn_{1}, 3 kg Zn/ha. In contrast, the minimum siliquae length (4.37 cm) was obtained from control, Zn_0, 0 kg Zn/ha combination.

4.5.3 Combined effect of boron and zinc levels:

Interaction of nitrogen and zinc application showed significant effect on length of siliquae of mustard (Table 4.4). The maximum length of siliquae (4.60 cm) was found in the B_2Zn_2 treatment combination, 1.5 kg B/ha and 5 kg Zn/ha whereas the minimum (4.30 cm) was obtained from control plots, B_0Zn_0 treatment combination.

4.6 Thousand Seed weight:

4.6.1 Effect of boron levels:

Different boron levels had significant effect on thousand seed weight of mustard (Table 4.2). The maximum thousand seed weight (2.88 g) was found in the B_2, 1.5 kg B ha^{-1} and the minimum (2.11 g) was obtained from the control treatment plots, B_0. Ozer (2003), Singh (2002) and Shamsuddin *et al.* (1987) also found highest 1000-seed weight with 1.5 kg B ha^{-1}.

4.6.2 Effect of zinc levels:

The application of zinc influenced significantly on the thousand seed weight (Table 4.3). The maximum thousand seed weight (2.72 g) was produced by Zn_2, and Zn_0 produced the minimum thousand seed weight (2.40 g).

4.6.3 Combined effect of boron and zinc levels:

Combination of boron and zinc application showed significant effect on thousand seed weight of mustard (Table 4.4). The highest thousand seed weight (3.14 g) was found in the B_2Zn_2 treatment combination, 1.5 kg B/ha and 5 kg Zn/ha whereas the lowest (1.92 g) was found from control plots, B_0Zn_0 treatment combination.

Table 4.2: Effect of different levels of boron on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustards

B Dose	Number of siliquae per plant	Number of seeds per siliquae	Siliquae length (cm)	1000 seed weight (g)
B_0	41.00 a	20.92 c	4.33 c	2.11 c
B_1	47.44 a	22.33 b	4.44 b	2.74 b
B_2	48.89 a	23.56 a	4.53 a	2.88 a
$LSD_{(0.05)}$	8.50	0.11	0.07	0.07
CV (%)	19.18%	0.53%	1.80%	3.01%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0: 0 kg B/ha (control) B_1: 1 kg B/ha B_2: 1.5 kg B/ha

Table 4.3: Effect of different levels of zinc on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustard

Zn Dose	Number of siliquae per plant	Number of seeds per siliquae	Siliquae length (cm)	1000 seed weight (g)
Zn_0	46.00 a	21.72 c	4.37 b	2.40 c
Zn_1	43.81 a	22.19 b	4.48 a	2.60 b
Zn_2	47.52 a	22.91 a	4.45 ab	2.72 a
$LSD_{0.05}$	8.50	0.11	0.07	0.07
CV (%)	19.18%	0.53%	1.80%	3.01%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0: 0 kg Zn/ha (control) Zn_1: 3 kg Zn/ha Zn_2: 5 kg Zn/ha

Table 4.4: Combined effect of different levels of boron and zinc on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustard

Treatment	Number of siliquae per plant	Number of seeds per siliquae	Siliquae length (cm)	1000 seed weight (g)
T_1	39.33bc	20.11g	4.30 d	1.92 g
T_2	41.44 abc	20.54 f	4.34 cd	2.13 f
T_3	42.22 abc	22.12 c	4.35 cd	2.27 e
T_4	43.44 abc	21.38 e	4.35 cd	2.49 d
T_5	55.55 ab	23.78 b	4.59 a	2.98 b
T_6	43.33 abc	21.83 d	4.40 bcd	2.75 c
T_7	55.22 ab	23.67 b	4.48 abc	2.79 c
T_8	34.44 c	22.24 c	4.53 ab	2.71 c
T_9	57.00 a	24.77 a	4.60 a	3.14 a
$LSD_{0.05}$	14.73	0.1986	0.13	0.13
CV(%)	19.18%	0.53%	1.80%	1.84%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0: 0 kg B/ha (control) B_1: 1 kg B/ha B_2: 1.5 kg B/ha

Zn: 0 kg Zn/ha (control) Zn_1: 3 kg Zn/ha Zn_2: 5 kg Zn/ha

4.7 Seed yield:

4.7.1 Effect of boron levels:

Different levels of boron exhibited statistically significant variation for seed yield (Table 4.5). The seed yield of mustard was converted into metric tons per hectare. The maximum seed yield (1.70 ton/ha) was obtained from the 1.5 kg B/ha and the minimum yield (1.03 ton/ha) was found from the control (0 kg B/ha) treatment. The increase in seed yield under all the doses of the boron was significantly higher as compared to 0 kg of B/ha. The results are in full agreement with those findings of Seyedeh *et al.* (2012), Singh et al. (1998) and Tuteja et al. (1996). Moreover, Cheema *et al.* (2001) reported that the seed yield of *Brassica* increased with increased B application from 0 to 1 kg/ha, while at the highest B application (1.5 kg/ha), *Brassica* seed yield was significantly reduced.

4.7.2 Effect of zinc levels:

Application of zinc at different level had statistically significant differences for seed yield per hectare (Table 4.6). The highest seed yield (1.49 ton/ha) was recorded from Zn_2 treatment, 5 kg Zn/ha. On the other hand the lowest seed yield (1.31 ton/ha) was found in the Zn_0 treatment, the control.

4.7.3 Combined effect of boron and zinc levels:

A significant variation indicated among the treatment combinations of B and Zn in seed yield (Table 4.7). The maximum seed yield (1.82 ton/ha) was found by B_2Zn_2, whereas the minimum seed yield (1.01 ton/ha) was obtained from the control plots, B_0Zn_0 treatment combination. Boron increases crop yield by influencing growth parameters and by producing more vigorous growth and development through increasing plant height, leaf area index, total plant weight and seeds per plant (Allen and Morgan, 2009). So, the results indicate that the combined use of 1.5kg B/ha and 5 kg Zn/ha produce the highest seed yield.

4.8 Stover Yield:

4.8.1 Effect of boron levels:

Different doses of Boron fertilizer had significant variation on the stover yield of mustard (Table 4.5). The maximum stover yield (2.79 t/ha) was recorded from the 1.5 kg B ha^{-1} and the minimum stover yield (2.06 t/ha) was found in the control (0 kg B/ha) treatment. This result is similiar with the findings of Mohiuddin *et al.* (2011). But, Meena *et al.* (2002) reported that higher stover yield at 60 kh B/ha.

4.8.2 Effect zinc levels:

Stover yield of mustard for different levels of zinc also showed statistically significant variation (Table 4.6). The highest significant increase in stover yield (2.60 t/ha) was obtained from Zn_2 treatment. On the other hand the lowest stover yield (2.37 t/ha) was obtained from the Zn_0 treatment, the control plots.

4.8.3 Combined effect of boron and zinc levels:

Significant interaction effect was also obtained between boron and zinc in consideration of stover yield under the present experiment. The maximum stover yield (2.91 t/ha) was obtained from the treatment combination B_2Zn_2 comprising of 1.5 kg B/ha and 5 kg Zn/ha, while the minimum stover yield (1.98 t/ha) was obtained from B_0Zn_0 i.e. no boron no zinc (Table 4.7).

4.9 Biological Yield:

4.9.1 Effect of boron levels:

A statistically significant variation was found in biological yield of mustard by different levels of boron application (Table 4.5).The biological yield of mustard was converted into metric tons per hectare. The maximum biological yield (4.49 t/ha) was obtained by B_2, 1.5 kg B/ha. On the other hand minimum biological yield (3.09 t/ha) was recorded by B_0, the control. These results are in consonance to result reported by Singh and Kumar (2014).

4.9.2 Effect of zinc levels:

Different levels of zinc exhibited statistically significant variation for biological yield (Table 4.6).The maximum biological yield (4.10 t /ha) was obtained from the 5 kg Zn/ha, Zn_2 and the minimum yield (3.69 t /ha) was found from the control (0 kg Zn/ha) treatment.

4.9.3 Combined effect of boron and zinc levels:

Interaction between B and Zn (Table 4.7) had significant effect on mustard plant height. The maximum biological yield (4.74 t/ha) was found in B_2Zn_2 treatment combination, 1.5 kg B/ha with 5 kg Zn/ha while the minimum biological yield (2.99 t/ha) was observed in the control treatment combination, B_0Zn_0. From this study it suggests that proper combination of boron and zinc increases biological yield.

4.10 Harvest Index:

4.10.1 Effect of boron levels:

Harvest index is an important attribute in determining economic yield and represents an increased physiological capacity to mobilize photosynthates and translocate them to organs of economic value (Jamal *et al.,* 2006; Malhi *et al.,* 2007). Harvest index may be termed as the ratio of economic yield to biological yield. A statistically significant variation was found in harvest index by different levels of boron application (Table 4.5). The maximum harvest index (37.87) was obtained by B_2 , 1.5kg B ha^{-1} whereas the minimum harvest index (33.11) was recorded by B_0 , the control. This result is similar with the findings of Shukla and Kumar (1997).

4.10.2 Effect of zinc levels:

Harvest index of mustard for different levels of zinc also had statistically significant variation (Table 4.6). The maximum harvest index (36.27) was obtained from Zn_2 treatment. On the other hand the minimum harvest index (34.97) was obtained from the Zn_0 treatment, the control plots.

4.10.3 Combined effect of boron and zinc levels:

Significant interaction effect was also obtained between boron and zinc in consideration of harvest index under the present experiment (Table 4.7). The maximum harvest index (38.64s) was recorded from the treatment combination B_2Zn_2, while the minimum stover yield (33.77) was recorded from B_0Zn_0 i.e. no boron no zinc.

Table 4.5: Effect of different levels of boron on Seed yield, Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

B Dose	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
B_0	1.03 c	2.06 c	3.09 c	33.11 c
B_1	1.52 b	2.65 b	4.18 b	36.48 b
B_2	1.70 a	2.79 a	4.49 a	37.87 a
$LSD_{0.05}$	0.03	0.04	0.05	0.50
CV (%)	1.84%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

B_0: 0 kg B/ha (control), B_1: 1 kg B/ha B_2: 1.5 kg B/ha

Table 4.6: Effect of different levels of zinc on Seed yield (t/ha), Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

Zn Dose	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Zn_0	1.31 c	2.37 c	3.69 c	34.97 b
Zn_1	1.45 b	2.52 b	3.97 b	36.27 a
Zn_2	1.49 a	2.60 a	4.10 a	36.23 a
$LSD_{0.05}$	0.03	0.04	0.05	0.50
CV (%)	1.84%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Zn: 0 kg Zn/ha (control) Zn_1: 3 kg Zn/ha Zn_2: 5 kg Zn/ha

Table 4.7: Combined effect of different levels of boron and zinc on Seed yield, Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
T_1	1.01 h	1.98 g	2.99 h	33.77 e
T_2	1.04 g	2.04 f	3.08 g	33.80 d
T_3	1.22 f	2.29 e	3.52 f	34.75 c
T_4	1.36 e	2.50 d	3.86 e	35.47 c
T_5	1.78 ab	2.84 ab	4.62 b	38.54 a
T_6	1.44 d	2.61 c	4.04 d	35.41 c
T_7	1.75 b	2.78 b	4.53 b	38.51 a
T_8	1.53 c	2.67 c	4.21 c	36.47 b
T_9	1.82 a	2.91 a	4.74 a	38.64 a
$LSD_{0.05}$	0.07	0.07	0.09	0.87
CV (%)	3.13%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1=B_0Zn_0 T_2= B_1Zn_0 T_3= B_2Zn_0

T_4= B_0Zn_1 T_5= B_1Zn_1 T_6= B_2Zn_1

T_7 = B_0Zn_2 T_8= B_1Zn_2 T_9= B_2Zn_2

Chapter V

Summary and Conclusion

The experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during rabi season, from November 2021 to February 2022 to find the effect of different levels of boron (B) and zinc (Zn) on growth and yield contributing characters of mustard. The experiment was formed by two factors. Factor A: Boron (3 levels) i.e. 0 kg B/ha (B_0), 1 kg B/ha (B_1) and 1.5 kg B/ha (B_2); Factor B: zinc (3 levels) i.e. 0 kg Zn/ha (Zn_0), 3 kg Zn/ha (Zn_1), 5 kg Zn/ha (Zn_2). There were 9 treatments combinations. The total number of plots was 27. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications.

Data were collected in respect of the plant growth and yield characters for different levels of boron and zinc. Plant height, Number of primary branches per plant, Number of siliquae per plant, Length of siliquae, Number of seed per siliquae, 1000 seed weight, Seed yield, Stover yield, Biological yield and Harvest index were recorded. The data obtained for these characters were statistically analyzed to find out the significance of the boron and zinc. The mean differences among the treatments were compared by Least Significant Difference (LSD) test at 5% level of significance.

Boron had significant effect almost on all parameters in mustard except number of siliquae per plant. The tallest plant height (76.69 cm) and the maximum number of branches per plant (5.18) were recorded from B_2 treatment. Again, the highest number of seed per siliquae (23.56), maximum length of siliquae (4.549 cm) and the maximum weight of thousand seeds (2.89 g) were obtained from B_2 treatment. Minimum values of these parameters were found in B_0 (control). Maximum number of siliquae per plant

(48.89) was also observed by $B_{2,}$ 1.5 kg N/ha. The maximum seed yield (1.706 t/ha) was recorded from B_2 whereas the lowest seed yield (1.0 t/ha) was recorded from control condition, $B_{0.}$ The highest stover yield (2.792 t/ha), highest biological yield (4.498 t/ha) and maximum harvest index (37.87%) were recorded from B_2, 1.5 kg B/ha. Lowest values of these parameters were also recorded from the control, B_0 treatment combination.

Number of siliquae per plant did not show any statistical difference for Zinc. The tallest plant height (73.10 cm), the highest number of branches per plant (4.81), the highest number of seeds per siliquae (22.91) were recorded from Zn_2 treatment combination, 5 kg Zn/ ha. Lowest values of these parameters obtained from the control, Zn_0. The highest number of siliquae per plant (47.52) was recorded from Zn_2 treatment whereas the lowest value (43.81) of this parameter was recorded from the Zn_1 treatment, 3 kg Zn/ ha. Again, the maximum 1000 seed weight (2.72 g), maximum length of siliquae (4.488 cm), maximum seed yield (1.50 t/ha) were obtained from Zn_1 treatment and the minimum (1.313 t/ha) was obtained from the Zn_0 treatment. Highest stover yield (2.609 t/ha) and highest biological yield (4.10 t/ha) were also recorded from Zn_2 treatment and minimum from $Zn_{0.}$ However the maximum harvest index (36.27%) was obtained from $Zn_{1,}$ 3 kg Zn /ha and the minimum was recorded from the control.

The combination of Boron and Zinc showed significant effect on almost all parameter. The tallest plant height (78.37 cm), the highest number of branches (5.99), the highest number of siliquae per plant (57.00) and the highest number of seeds per siliquae (24.77) were recorded from B_2Zn_2 combination,
1.5 kg B/ha and 5 kg Zn/ha. Lowest values of these parameters recorded from the control plots where no boron and no zinc were applied. The maximum siliquae length (4.60 cm), maximum 1000 seed weight (3.14 g) and highest seed yield (1.82 t/ha) were recorded from B_2Zn_2 combination. On the other hand minimum values of siliquae length (4.30 cm), minimum 1000 seed weight

(1.92 g) and seed yield (1.01 t/ha) were obtained from B_0Zn_0 treatment combination. The highest stover yield (2.91 t/ha) and highest biological yield (4.74 t/ha) were also obtained from B_2Zn_2 treatment combination. The lowest values of these parameters also obtained from the control. However, the maximum harvest index (38.64%) was recorded from B_2Zn_2 treatment combination whereas minimum value (33.77%) was obtained from B_0Zn_0, the control.

Considering the above results of this experiment, it may be summarized that growth and yield contributing parameters of mustard are positively correlated with B and Zn application. Therefore, the present experimental results suggest that the combined use of 1.5 kg B/ha and 5 kg Zn/ha fertilizer combination along with recommended doses of other fertilizer would be beneficial to increase the seed yield of mustard variety BARI sarisha-14 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka and similar environment elsewhere in Bangladesh.

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

- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh to investigate regional adaptability and other performance.
- It needs to conduct more researches of Boron and Zinc to investigate the growth and yield BARI Sarisha- 14.
- It needs to conduct more advanced and related experiments with other varieties of mustard and also in different climate and soil condition.

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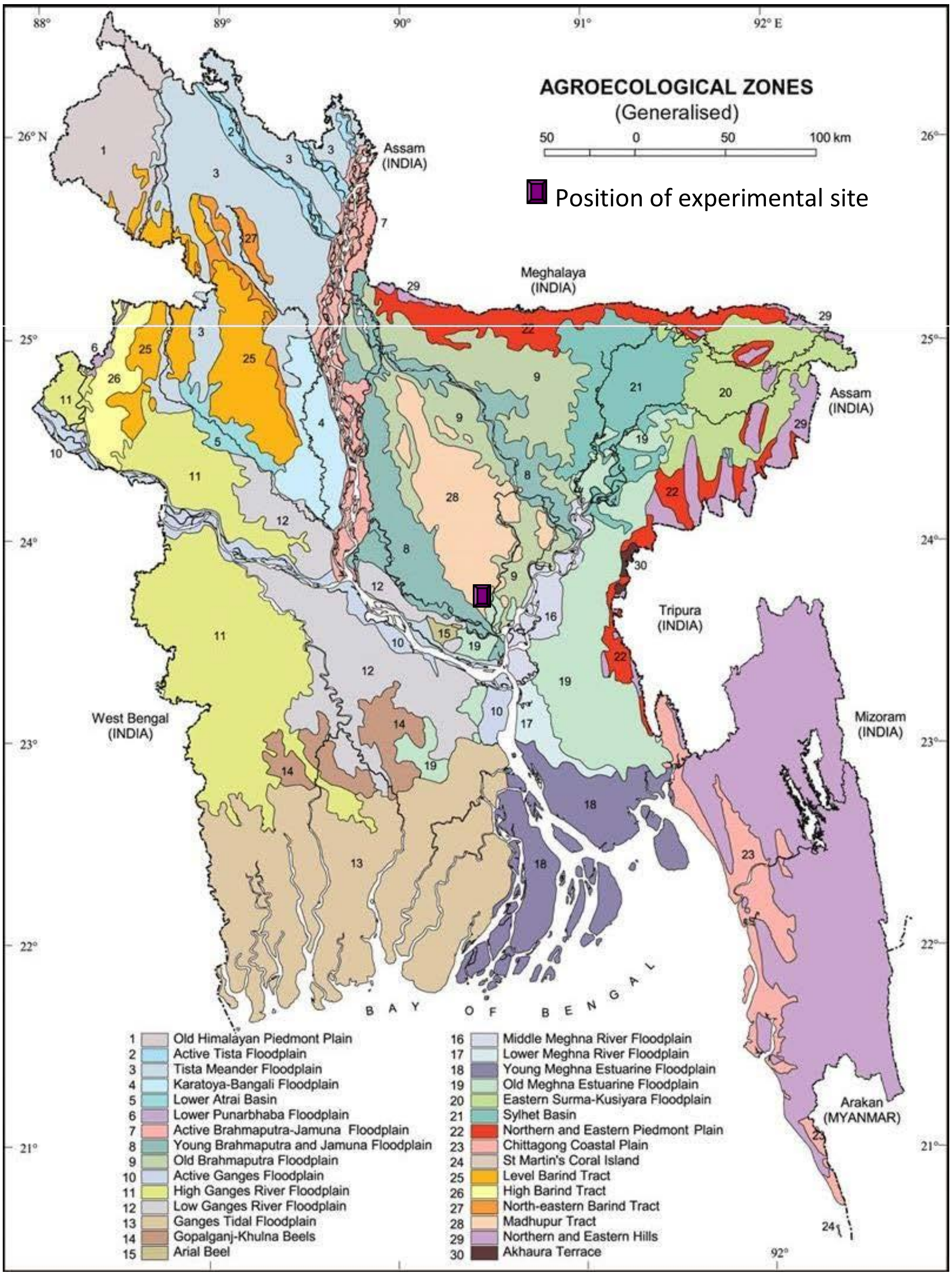
Appendices

Appendix I. Map showing the experimental site under study



Appendix II. Analysis of variance (mean square) of the data for Plant Height(cm), Number of branches/plant, Number of seeds/siliquae, Number of siliquae /plant,Length of Siliquae(cm).

Source of variation	Degrees of Freedom	Plant height	Number of branches/ Plant	Number of seeds per siliquae	Number of siliquae per plant	Silique length
ReplicatioN	2	0.231	0.127	0.014	64.186	0.001
Factor A	2	294.905	3.161	15.655	158.974	0.097
Factor B	2	27.884	0.448	3.217	31.212	0.028
Factor AB	4	22.761	1.382	4.928	297.708	0.016
Error	16	0.048	0.076	0.014	77.070	0.006

Appendix III. Analysis of variance (mean square) of the data for 1000 seed weight(g), Seed yield (t/ha) , Stover yield(t/ha), Biological yield, Harvest index(%) of Mustard.

Source of variation	Degrees of Freedom	Seed yield	1000 seed weight	Stover yield	Biological yield	Harvest index
Replication	2	0.001	0.006	0.003	0.005	0.003
Factor A	2	1.105	1.525	1.348	4.881	0.003
Factor B	2	0.083	0.237	0.121	0.398	4.915
Factor AB	4	0.128	0.097	0.081	0.413	11.002
Error	16	0.001	0.006	0.002	0.003	0.271

Appendix IV. Physical and chemical properties of the initial soil

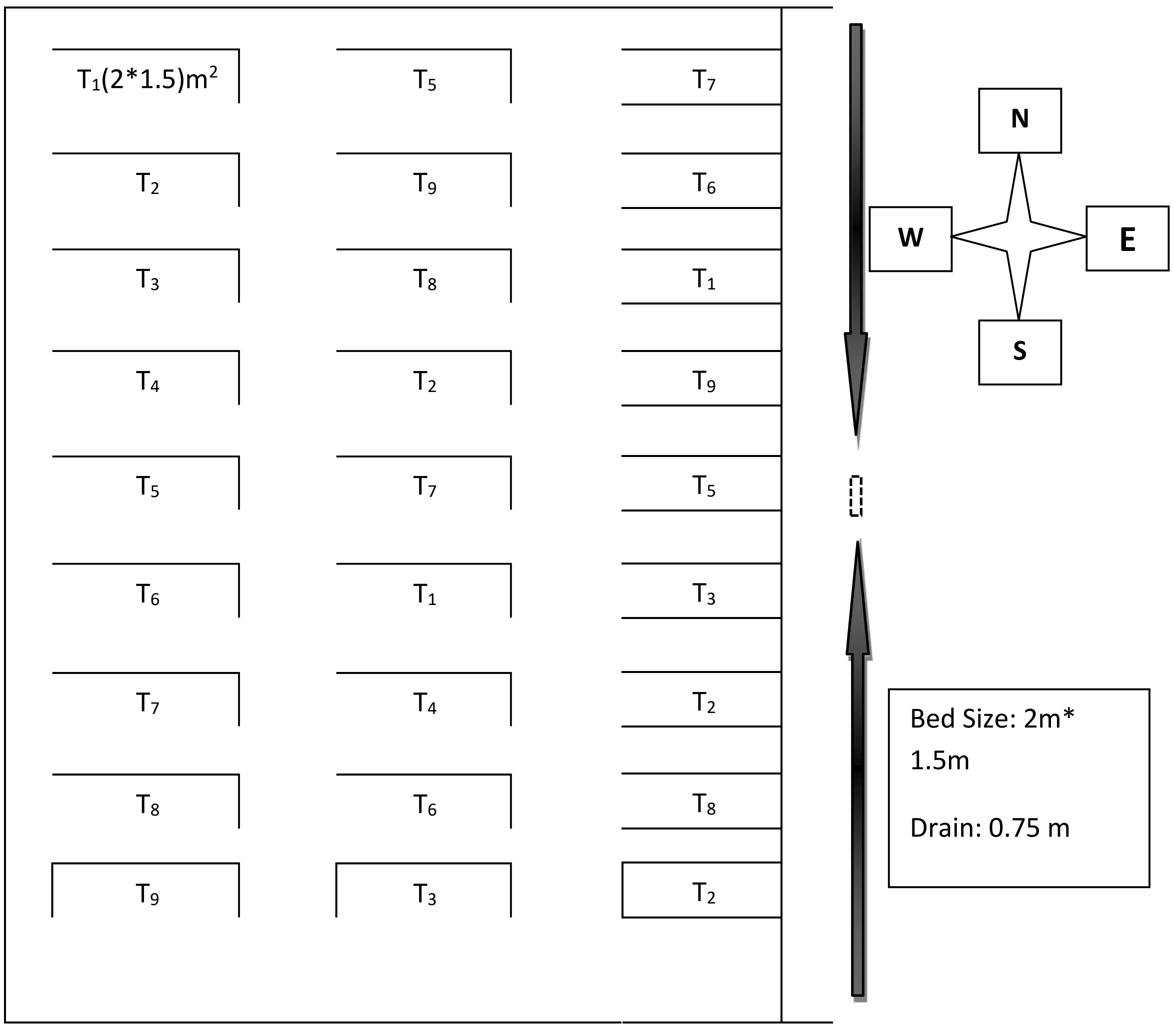
Physical composition of soil

Soil separates	Value
Sand (%)	**29.8**
Silt (%)	**39.1**
Clay (%)	**31.1**
Textural class	**Clay loam**

B. Chemical properties of soil

Chemical properties	Value
P^H	5.56
Organic carbon	0.75
Organic matter	1.29
Total Nitrogen (%)	0.08
Available P (ppm)	31.5
Exchangeable K (me/100g soil)	0.16
Available Zinc (mg/g soil)	4.78

Appendix V. Layout of the experimental site



Appendix VI. Monthly records of air temperature, relative humidity and rainfall during the period from November 2021 to February 2022

Year	Month	Air Temperature (^0C)			Relative humidity (%)	Rainfall (mm)
		Max	**Min**	**Mean**		
2021	November	28.50	8.52	18.56	56.75	14.40
2021	December	25.50	6.70	16.10	54.80	0.0
2022	January	23.70	11.70	17.75	46.20	0.0
2022	February	22.75	14.26	18.51	36.80	0.0

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

Fig : At The time Of Seed Bed Preparation

Fig: At The Time Of Seed Sowing

Fig : At The Time Of Data Collection

Fig : Flowering Stage

Fig : Pod Stage

Fig : Harvesting Stage