YIELD AND QUALITY OF BROCCOLI (*Brassica oleracea* var. italica L.) AS INFLUENCED BY BORON AND ZINC

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DECEMBER, 2018

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REGISTRATION NO. : 17-08242

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

MASTER OF SCIENCE (MS)

IN

HORTICULTURE

SEMESTER: JULY-DECEMBER, 2018

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CERTIFICATE

This is to certify that the thesis entitled '**Yield and Quality of Broccoli (*Brassica oleracea* var. italica L.) as Influenced by Boron and Zinc**' submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the results of a piece of bona fide research work carried out by **SHAHANA AKTER**, Registration No. **17-08242** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2018
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TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises to the Almightly and Kindfull trust on to 'Almighty Allah' for His never-ending blessing, the author deems it a great pleasure to express her profound gratefulness to her respected parents, who entiled much hardship inspiring for prosecuting her studies, receiving proper education.

The authoress feels proud to express her heartiest sence of gratitude, appreciation and immense indebtedness to her Supervisor, Professor Dr. Md. Jahedur Rahman, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of thesis, without his intense co-operation this work would not have been possible.

The authoress feels proud to express her deepest respect, sincere appreciation and gratefulness to her Co-supervisor, Md. Dulal Sarkar, Assistant Professor, Department of Horticulture, SAU, Dhaka, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

The author expresses her sincere respect and sence of gratitude to Chairman and Professor Dr. Mohammad Humayun Kabir, Departement of Horticulture, SAU, Dhaka for his valuable suggestions and cooperation during the study period.

The author also expresses her heartfelt thanks to all the teachers of the Department of Horticulture, SAU, for their valuable teaching, suggestions and encouragement during the period of the study period.

The authoress expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

YIELD AND QUALITY OF BROCCOLI (*Brassica oleracea* var. italica L.) AS INFLUENCED BY BORON AND ZINC

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ABSTRACT

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during October 2018 to February 2019. The experiment consisted of two factors, such as Factor A: Boron (3 levels) as- B_0: 0.0 kg B ha^{-1}, B_1: 1.0 kg B ha^{-1}, B_2: 2.0 kg B ha^{-1} and Factor B: Zinc (4 levels) as- Zn_0: 0.0 kg Zn ha^{-1}, Zn_1: 1.0 kg Zn ha^{-1}, Zn_2: 2.0 kg Zn ha^{-1}, Zn_3: 3.0 kg Zn ha^{-1} which was laid out in Randomized Complete Block Design with three replications. Different levels of boron and zinc influenced significantly on most of the studied parameters. In case of levels of boron, the highest curd yield (23.30 t ha^{-1}) was recorded from 2.0 kg B ha^{-1} and the lowest yield (19.07 t ha^{-1}) was found from 0.0 kg B ha^{-1}. For levels of zinc, 3.0 kg Zn ha^{-1} performed the highest curd yield (23.40 t ha^{-1}) and the lowest yield (19.01 t/ha) was recorded from 0.0 kg Zn ha^{-1}. For combined effect, the highest curd yield (26.00 t ha^{-1}) was found from B_2Zn_3 and the lowest yield (18.04 t ha^{-1}) from recorded B_0Zn_0. The highest benefit cost ratio (2.50) was observed from treatment combination B_2Zn_3 and the lowest (1.74) was found from B_0Zn_0. So, 2.0 kg B ha^{-1} with 3.0 kg Zn ha^{-1} should better performance in terms of growth, yield and yield contributing characters of broccoli.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
et al.	and others
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
B	Boron
cv	Co-efficient of variation
DAT	Days After Transplanting
etc	Etcetera
FAO	Food and Agriculture Organization
GA_3	Gibberellic Acid
J.	Journal
LSD	Least Significance Difference
MoP	Muriate of Potash
NS	Non significant
ppm	Parts per million
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TSP	Triple Superphosphate
Zn	Zinc

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. italica) belonging to the family of Cruciferae is considered as a most valuable vegetable (Parente *et al*., 2013) and has high nutritional and good commercial value (Yoldas *et al*., 2008). The terminal head rather loose, green in color and the flower stalks are longer than cauliflower (Bose *et al*., 2002). Broccoli is widely grown and consumed all over the world (Pizetta *et al*., 2005) and it is highlighted mainly for its nutritional value as a source of various essential compounds, such as vitamins, minerals, antioxidants (Umar *et al*., 2013). The edible portion of the broccoli plant consists of tender stem and unopened flower buds. The plants form a kind of head consisting of green buds and thick fleshy flower stalk. Nowadays, broccoli attracted more attention due to its multifarious use and great nutritional value (Talalay and Fahey, 2001; Rangkadilok *et al*., 2004). The sprouts in the axils develop strongly specially after removal of terminal head. Both the terminal head and sprouts with buds are consumed by human as food.

Broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible. It is usually boiled or steamed, but may be eaten raw and has become popular as a raw vegetable in trays. Broccoli has high nutritive value especially vitamin A and vitamin C. Therefore, it can be met up some degree of vitamin A and vitamin C requirement and can contribute to solve malnutrition problem in Bangladesh. It is low in sodium food, fat free and calories, high in vitamin C and good source of vitamin A and calcium (Decoteau, 2000). In an average 100 gram broccoli contains carbohydrate 7 g, sodium 33 mg, potassium 316 mg, dietary fiber 2.6 g, sugar 1.7 g, protein 2.8 g, vitamin-A 12 IU, vitamin-C 148 mg along with calcium, iron, Magnesium, Phosphorus (Annon., 2015). There is a good scope of broccoli cultivation in Bangladesh for increasing vegetable diversification and to meet vegetable demand of the country's people (Moniruzzaman *et al*., 2007).

The per capita production of vegetable in Bangladesh is very low as per actual standard requirements and also production as compared to that of other countries of the world (DAE, 2016). In 2016-2017, total vegetable (summer and winter season) production area was 645.04 thousand hectares of land with total production of 1.87 million tons (BBS, 2018). As a newly introduced crop the average yield of broccoli is low in Bangladesh compared to other countries like and the low yield of this crop however is not an indication of low yielding potentiality of this crop. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors fertilizers can play an important role for increasing the production of broccoli in Bangladesh (Manjit Singh, *et al*., 2011). Previous research has indicated that nutrients have important effects on broccolis productivity and quality (Belec *et al*., 2001; Moniruzzaman *et al*., 2007; Ambrosini *et al*., 2015).

Broccoli, being a cole crop, is a heavy feeder of plant nutrients including micronutrients. Mineral fertilizer including micronutrients improves growth and yield of broccoli due to their involvement in the meristematic activity and growth (Singh *et al*., 2018). Among the micro elements, B and Zn play an important role directly and indirectly in improving the growth, yield and quality of broccoli in addition to checking various diseases and physiological disorders. Microelements are crucial substances for crop's growth; however, they are used in lower amounts compared to the macronutrients (Salwa *et al*., 2011). Zinc (Zn) is responsible for many important physiological functions and is an essential nutrient for carbon metabolism in plant. Under Zn deficiency, plasma membranes lose their integrity. Zn is one of the vital nutrients which is required for various biochemical and metabolic process in broccoli such as synthesis of cytochromes and nucleotides, auxin metabolism, production of chlorophyll, activation of several enzymes, membrane integrity, metabolism of carbohydrate, cell wall development, gene expression and respiration (Broadley *et al*., 2007).

Boron (B) is a recognized essential micronutrients required for normal plant growth and development of plant and deficiencies are very common in cole crops (Patel *et al*., 2017). It is known to play role in cell division, water relations, ion absorption, IAA and carbohydrates metabolism, translocation of sugars, fruit and seed development and its deficiency may affect all of these mentioned processes (Chawdhury and Kumar, 2002). B has different role in plants metabolic activities. Cell division, nitrogen and carbohydrate metabolism and water relation in plant are controlled by B. Boron is essential for plant growth and development. Its application to the soil increased head yield of broccoli (Xian *et al*., 2000). In Cole crops like cauliflower and broccoli, boron requirement is high (Hussain *et al*. 2012). Boron deficiency causes many anatomical, physiological and biochemical changes and being existed negative correlation between B concentration in leaves and curds with hollow stem disorder (Sartori and Mello, 2009).

Based on the above mentioned discussion the experiment was conducted with the following objectives-

1. To study the effect of boron on yield and quality of broccoli.
2. To investigate the effect of zinc on yield and quality of broccoli.
3. To observe the combined effects of boron and zinc for higher yield, quality and economic return of broccoli.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Broccoli a newly introduced crop it has less attention by the researchers on various aspects especially micronutrients B and Zn. There are very few studies on the growth and yield of broccoli have been carried out in this aspects in our climatic condition and the research work so far done in this aspects in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to boron and zinc on broccoli so far been done at home and abroad have been reviewed under the following headings-

2.1 Effect of boron on the growth, yield and quality of broccoli

Moniruzzaman *et al*. (2007) carried out a field experiment comprising six levels of boron (B) (0. 0.5, 1, 1.5, 2 and 2.5 kg ha^{-1}) and two levels of nitrogen at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons to find out the suitable doses of B and N for higher yield and good quality head of broccoli. Boron application increased plant height, number of leaves per plant, length and width of the leaf, plant spread, main head weight and head yield both per plant and per hectare significantly up to 1.5 kg ha^{-1}.

Firoz *et al*. (2008) conducted at the Hill Agricultural Research Station (HARS), Khagrachari to find out the effect of boron application on the yield of different varieties of broccoli in hill valley. The treatment consisted of three broccoli varieties, viz., Green Commet, Green King and Green Harmony with three levels of boron viz., Control (0.0 kg ha^{-1}), l .0 kg ha^{-1} and 2.0 kg ha^{-1}. Results revealed that there was a significant and positive effect of boron application on the yield of the crop and 1 .0 kg B ha^{-1} was found to be an optimum rate. The 1 .0 kg B ha^{-1} rate produced the highest yield (512.3 g $plant^{-1}$) followed by 2.0 kg B ha^{-1} showing 508.5 g $plant^{-1}$ and the B control did the lowest (445.4 g $plant^{-1}$). All other characters remained unaffected by B application. However, the application of B at 1.0 kg ha^{-1} had the height curd weight (294.6 g) and 2.0 kg B showed the next result (270.2 g).

Hussain *et al*. (2012) conducted a field experiment was at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to determine the effects of N and B on the yield and hollow stem disorder of broccoli. Four levels of N and four levels of B as 0, 0.5, 1.0 and 1.5 kg ha^{-1} constituting sixteen treatments. Applied B had significant impact on the yield and hollow stem disorder of broccoli. Results revealed that the curd yield of broccoli was significantly increased with boron application up to 1.0 kg ha^{-1}. This rate thus showed a remarkable impact on reduction of hollow stem disorder. A moderately high amount of B application (1.0 kg ha^{-1}) led to minimum incidence of hollow stem disorder, attaining considerably lowest value of hollow stem index of 1.0 as against the maximum value of 1.16 under no application of B.

Singh *et al*. (2015) carried out an investigation to examine the optimum doses of NPK and boron application on broccoli in irrigated agro-ecosystem of western Uttar Pradesh. The results revealed significant response on growth and yield of broccoli for different treatments. Application of 120 kg N+60 kg P_2O_5+40 kg K_2O+15 kg B/ha gave maximum plant height (65.33 cm), number of leaves/plant (18.26), length longest leaf (52.99 cm), width of longest leaf (17.98 cm), spread of plant (55.53 cm) and stem diameter (4.47 cm), whereas in control was minimum pronounced plant height/plant (58.66 cm), number of leaves/plant (12.33), length longest leaf (42.70 cm) width of longest leaf (14.18 cm), spread of plant and stem diameter (3.04 cm).

Singh *et al*. (2016) carried out an experiment to evaluate the effect of different micronutrients on plant growth, yield and flower bud quality of broccoli. The experiment consists of 10 treatment viz, T_0 (control), T_1 (B), T_2 (Mo), T_3 (Mn), T_4 (B + Mo), T_5 (B+ Mn +Zn), T_6 (Mo +Mn), T_7 (B +Mo +Mn +Zn), T_8 (B +Zn), T_9 (Zn) laid out in Randomized Block Design (RBD) with three replications. The micronutrients (B, Mo, Mn and Zn) were applied at the rate of 2 kg (B), 0.5 kg (Mo), 2.5 kg (Mn), 3 kg (Zn) per hectare significantly increased the plant height (51.30 cm), number of leaves(22.92), Plant spread (52.83 cm), diameter of bud or head (16.90 cm), average bud weight of per plant (303.69 gm), yield ha-1(121.48q), vitamin „C" (93.92 mg), TSS (8.37) content, plant fresh weight (908.28 gm), dry plant matter (95.61 gm), root weight (45.02 gm) and dry weight(11.65 gm) and lowest in control.

An experiment was conducted by Ain *et al*. (2016) to study the response of broccoli to foliar application of zinc and boron concentrations was carried out under field condition during 2013-14 at Horticulture Research Farm, The University of Agriculture Peshawar. Zinc at the rate of (0, 0.25, 0.5, and 1.0%) and boron at the rate of (0, 0.25, 0.5, and 1.0%) were applied as a foliar spray. Regarding B maximum plant height (39.31 cm) was observed with 0.25% boron while minimum (32.30 cm) in plants sprayed with 1% boron. B @ 0.5% resulted in maximum number of leaves plant^{-1} (12.83). Maximum leaf weight (10.17 g) and number of curds plant^{-1} (8.41) were noted at 1.0% boron.

Silva *et al*. (2016) conducted an experiment to study broccoli growth and nutritional status as influenced by doses of nitrogen and boron and reported that proper growth and development of broccoli may be affected by the application of B. The experiment was designed with four doses of B (0.25, 0.50, 1.00, and 2.00 mg dm^{-3}) and two doses of N, and the check treatment (no B and no N), with four repetitions. The green color index, the accumulation of B in the plant aerial part, leaf area, and the aerial part dry matter content were evaluated. The interaction between nitrogen and boron was not important for the green color index, leaf area and dry matter production of broccoli in the vegetative phase.

Metwaly (2016) carried out two field experiments were carried out during the two successive winter seasons of 2013-2014 and 2014-2015 at the experimental station, Faculty of Agriculture, Mansoura University to study the effect of nitrogen and boron fertilization on yield and quality of broccoli. Nitrogen fertilizer rates (i.e.; 60, 70, 80 and 90 kg fed^{-1}.) and boron treatments (0.4, 0.8 and 1.2 kg fed^{-1}.) were used for conducting these experiments. The results showed that the B was significant on vegetative growth parameters (i.e.; plant height, leaves area, leaves fresh weight, leaves dry matter percent). Curds yield and its physical quality parameters (i.e.; curd weight, curd diameter and curd dry matter percent), curds chemical quality parameters (i.e.; Vit. C, T.S.S., carotenoids). On contrast the leaves number, curd length (cm) and curd compactness index were not significantly affected.

Patel *et al*. (2017) reported that Boron (B) is an important essential micronutrients required for normal plant growth and development and deficiencies are very common in Cole crops. To combat this and to produce quality broccoli cv. Pusa KTS 1 with more yield the present investigation was conducted during rabi season of 2015-16 at Lucknow, Uttar Pradesh, India. There were ten treatments comprising recommended dose of fertilizers (RDF), Borax at two levels (1.5 and 2.5%), Ammonium molybdate at two levels (1.5 and 2.5%) and control without any fertilizer application and laid out at randomized block design with three replications. The observations and statistical analysis clearly revealed that the vegetative growth (plant height, stem circumference, plant spreading, number of leaves, length and width of leaves etc), curd weight, yield, and curd physico-chemical qualities were improved with application of boron and molybdenum in addition with RDF. However, combined application of boron and molybdenum were more effective than their sole application. Among the several applications, treatment RDF + Borax (1.5%) + Ammonium molybdate (2.5%) was found as the best combination for good growth, better yield and superior quality curd production of broccoli cv. Pusa KTS 1 under Lucknow condition.

Field experiment was conducted by Farooq *et al*. (2018) to study the impact of sulfur (S) and boron (B) on yield and yield component of broccoli. Sulfur was applied @ 0 (control), 20 and 40 kg ha^{-1} as elemental sulfur while B was applied at the rate 0, 1 and 1.5 kg ha^{-1} as borax along with a basal dose of N,P and K @ 120, 90 and 60 kg ha^{-1}. The result revealed that yield and yield parameter increased with increasing levels of B with higher head yield, flower diameter and plant height were observed when 1.5 kg ha^{-1} B were applied.

Singh *et al*. (2018) conducted an experiment for assessment of effect of foliar spray of micronutrients on quantitative and qualitative attributes of broccoli. Foliar spray of micronutrient fertilizers viz., ammonium molybdate {$(NH4)_2MoO_4$}, boric acid (H_3BO_3), copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$) and zinc sulphate ($ZnSO_4$) with each micronutrient consisted of three different concentrations (C) 0.20%, 0.40% and 0.60% and applied as foliar feeding to broccoli crop along with control on broccoli growth and yield were assessed. The result clearly indicated that foliar application of boric acid @ 0.40% resulted in increased fresh curd weight (411.87 g), non-reducing sugar (1.80 %) and it also induced earliness (61.44 days).

Xaxa *et al*. (2018) conducted a field experiment to find out the effect of different micronutrients on plant growth and yield of broccoli at Horticulture Research farm, Department of Horticulture, Naini Agricultural Institute, SHUATS, Allahabad. The findings revealed that 2.5 kg B + 0.5 kg Mn + 2 kg Zn ha^{-1} significantly increased the plant height (53.61 cm), number of leaves (25.23), Plant spread (54.51 cm), diameter of bud or head (17.81 cm), average bud weight of per plant (571.83 gm), yield ha^{-1} (134.05 q), vitamin c (92.34 mg), TSS (8.23) content, plant fresh weight (897.00 gm), dry plant matter (96.48 gm), root weight (46.63 gm) and dry weight (12.63 gm) and these combination was found economically best in treatment of cost benefit ratio i.e. (1:3.47).

The field experiment was conducted by Jakhar *et al*. (2018) at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) to find out the effect of NAA and boron levels on growth and quality of sprouting broccoli. The experiment consisted of sixteen treatment combinations including four NAA and four boron levels (control, boron @ 0.75 kg ha^{-1}, boron @ 1.5 kg ha^{-1} and boron @ 2.25 kg ha^{-1}). The results of the study indicated that boron levels 2.25 kg B ha^{-1} significantly increased the plant height (62.55 cm), stem diameter (2.70 cm), number of leaves $plant^{-1}$ (24.16), leaf area (930.51 cm^2), ascorbic acid content (88.36 mg 100 g^{-1}) protein content (2.29%) as compared to control.

2.2 Effect of zinc on the growth, yield and quality of broccoli

Feng *et al*. (2005) carried out an experiment to study the effects of different concentrations of Zn on growth indexes of broccoli seedling planted in sand, such as height, leaf areas, chlorophyll contents etc. The results showed that 0.05, 5 and 10 mg L^{-1} Zn were benefit to broccoli growth, especially 10 mg L^{-1}. 0, 50, 100, 200 mg/L Zn were unfavorable for broccoli growth. The content of chlorophyll a and chlorophyll b, seedling height, leaf areas and dry weight of single seedling under 10 mg L^{-1} Zn treatment of zinc solution increased 32.78%, 39.02%, 10.01%, 10.85%, 45.81% and 13.13%, respectively, compared with the treatment without zinc.

An experiment was conducted by Yılmaz *et al*. (2013) to investigate the effect of humic acid on intake of zinc in broccoli and humic acid and zinc interaction was investigated. In the study, Zinc application was done as 2500 mg m^{-2} Zn $SO_4.7H_2O$. Ascorbic acid, pH, soluble solid dry matter, titratable acidity, dry weight, plant height, curd diameter, curd yield, number of lateral curd, leaf number and mineral composition of broccoli was investigated and reported that zinc application had no effect on plant height, curd length and dry weight. Leaf number, lateral curd number but marketable total yield of broccoli were increased significantly.

An experiment was conducted by Ain *et al*. (2016) to study the response of broccoli to foliar application of zinc and boron concentrations was carried out under field condition during 2013-14 at Horticulture Research Farm, The University of Agriculture Peshawar. Zinc at the rate of (0, 0.25, 0.5, and 1.0%) and boron at the rate of (0, 0.25, 0.5, and 1.0%) were applied as a foliar spray. Maximum plant height (40.49 cm) and number of leaves $plant^{-1}$ (13.08), were noted at 0.5 % Zn, while Zn @ 1% resulted in maximum leaf weight (9.66 g) and maximum number of curd $plant^{-1}$ (9.17).

Quratul *et al*. (2016) carried out an experiment to assess the effect of foliar spray on broccoli and applied zinc @ 0, 0.25, 0.5, and 1.0% as a foliar spray. Findings revealed that maximum plant height (40.49 cm) and number of leaves $plant^{-1}$

(13.08), were noted at 0.5 % Zn, while Zn @ 1% resulted in maximum leaf weight (9.66 g) and maximum number of curd plant^{-1} (9.17). Among various treatments used zinc levels at the rate of 0.5%, showed better result in most of the growth and yield parameters.

Miroslav *et al.* (2016) carried out an experiment with N and S fertilization on broccoli and observed that the foliar Zn spraying led to a statistically highly significant increase of sulforaphane in broccoli (about 41.1%) compared to the control. Zn application resulted in a return of the vitamin C content, nearly to its level in control. However, the results of this research indicate that nitrogen fertilization combined with zinc application should be expressed mainly by lower nitrate accumulation in the edible parts of broccoli. The experimental data are interesting, and in terms of growing vegetables for consumption with enhanced quality, promising.

Slosar *et al*. (2017) conducted an experiment to study the effect of zinc fertilisation on yield and selected qualitative parameters of broccoli. Three treatments were used in two-year (2014–2015) field experiments with broccoli cv. Bejo 2914 F_1: (1) untreated control; (2) $Zn_{0.75}$ - Zinkuran SC as foliar fertiliser at the rate of 0.75 L ha^{-1} (375 g Zn ha^{-1}); (3) $Zn_{1.50}$ - Zinkuran SC as foliar fertiliser at the rate of 1.50 L ha^{-1} (750 g Zn ha^{-1}). The statistically significant differences of individual broccoli parameters were found after zinc applications. In both experimental years the yield of broccoli with additional zinc fertilisation was significantly higher by about 8.2-14.4% ($Zn_{0.75}$) and 12.5-17.5% ($Zn_{1.50}$), respectively, than in the control. Foliar zinc application significantly increased the sulforaphane content in broccoli florets by about 19.8-32.9% ($Zn_{0.75}$) and 37.2-49.3% ($Zn_{1.50}$), respectively, compared to the control.

Singh *et al*. (2018) conducted an experiment for assessment of effect of foliar spray of micronutrients on quantitative and qualitative attributes of broccoli. Foliar spray of micronutrient fertilizers viz., ammonium molybdate {$(NH4)_2MoO_4$)}, boric acid (H_3BO_3), copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$) and zinc sulphate

($ZnSO_4$) with each micronutrient consisted of three different concentrations (C) 0.20%, 0.40% and 0.60% and applied as foliar feeding to broccoli crop along with control on broccoli growth and yield were assessed. The result clearly indicated that the treatment zinc sulphate @ 0.60% exhibited highest plant height (63.29 cm), leaf length (43.63 cm), leaf width (22.60 cm), fresh plant weight (1908.83 g) and phenol content (8.86%).

Above cited reviews revealed that application B and Zn significantly influences the growth, yield attributes and as well as yield and quality of broccoli. The literature revealed that the effects of B and Zn on broccoli have not been studied well and have no definite conclusion in this aspects for the production of broccoli in the agro climatic condition of Bangladesh.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The materials and methods for this experiment includes a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The details description of the materials and methods for this experiment have been presented below under the following headings-

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted at the period of October 2018 to February 2019.

3.1.2 Experimental location

The present research work was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter capacity 5.8 and 0.76%, respectively and the the soil composed of 27% sand, 43% silt, 30% clay. Details descriptions have been presented in Appendix II.

3.1.4 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III. During this period the maximum temperature (27.2^{0}C) was recorded in the month of February 2019, while the minimum temperature (12.1^{0}C) in the month of January 2019. The highest humidity (84%) was recorded in the month of October, 2018, whereas the highest rainfall (39 mm) was recorded in the month of February 2019 and the highest sunshine hour (6.9 hr) was recorded in the month of December, 2018.

3.2 Experimental details

3.2.1 Planting materials

The seeds of broccoli (*Brassica oleracea var.* italica L.) cv. 'Green Giant' were used as planting materials for this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Boron (3 levels) as

i B_0: 0.0 kg B ha^{-1}

ii. B_1: 1.0 kg B ha^{-1}

iii. B_2: 2.0 kg B ha^{-1}

Factor B: Zinc (4 levels) as

i. Zn_0: 0.0 kg Zn ha^{-1}

ii. Zn_1: 1.0 kg Zn ha^{-1}

iii. Zn_2: 2.0 kg Zn ha^{-1}

iv. Zn_3: 3.0 kg Zn ha^{-1}

There were 12 (3×4) treatments combination such as B_0Zn_0, B_0Zn_1, B_0Zn_2, B_0Zn_3, B_1Zn_0, B_1Zn_1, B_1Zn_2, B_1Zn_3, B_2Zn_0, B_2Zn_1, B_2Zn_2 and B_2Zn_3.

3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 273.54 m^2 with length 29.1 m and width 9.4 m which were divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination allotted at random. There were 36 unit plots and the size of each plot was 1.8 m × 1.8 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.2.4 Preparation of the main field

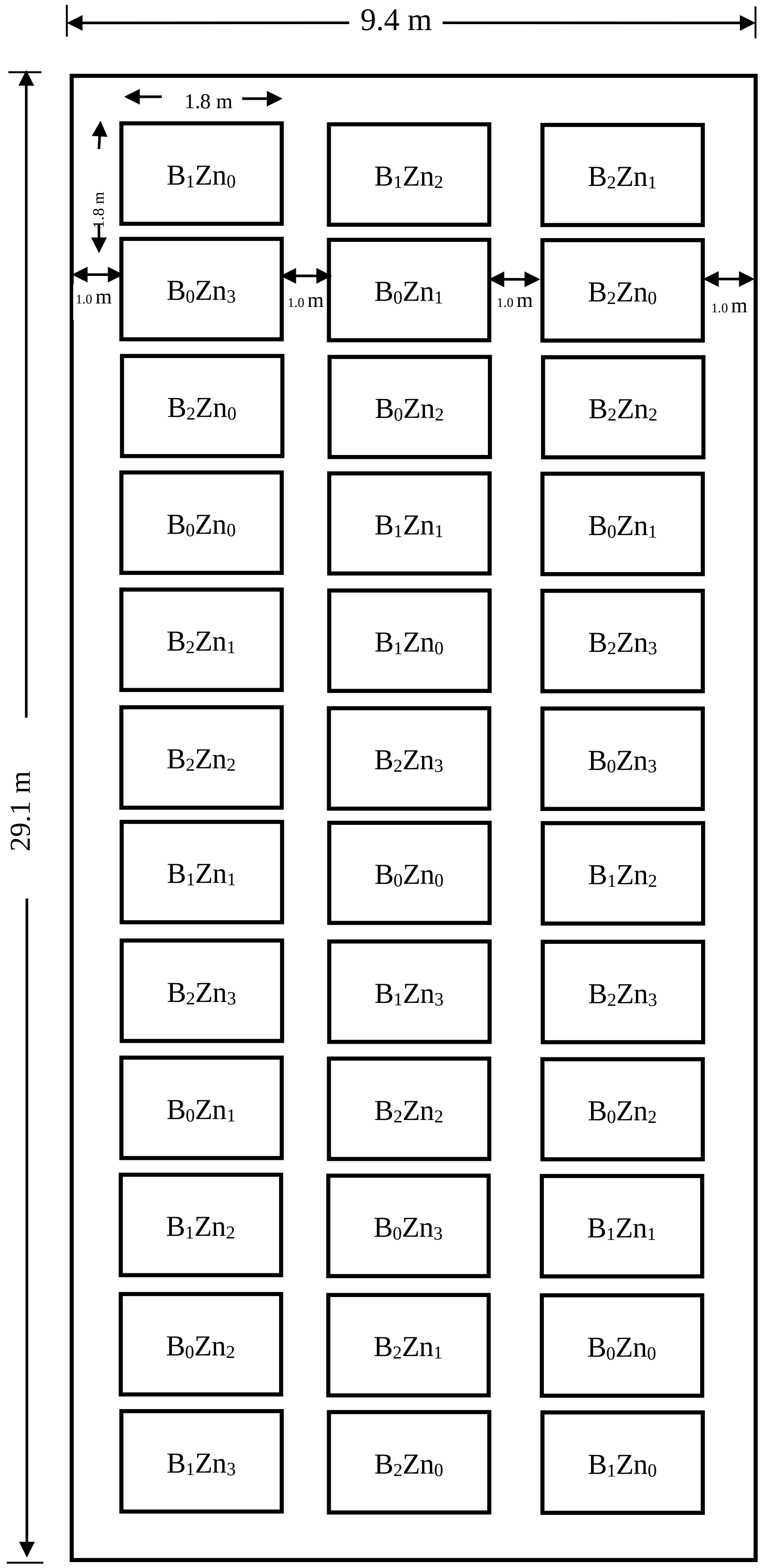
The selected plot of the experiment was opened in the 2nd week of October 2018 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

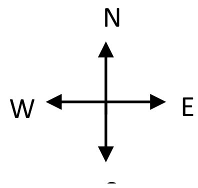
3.2.5 Application of manure and fertilizers

Urea, TSP, MoP, Gypsum were used as the sources of nutrient N, P, K, S, respectively (Farooq *et al*. 2018). A standard dose of NPKS @ 120, 100, 150, 20 kg ha^{-1} was used. B and Zn were appled as per treatment. The following doses of manure and fertlizer were used for the present study.

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

Fertilizers and Manures	Dose ha^{-1}	Application (%) at DAT			
		Basal	15	30	45
Cowdung	20 tonnes	100	--	--	--
Urea	260 kg (N: 120 kg)	--	33.33	33.33	33.33
TSP	208 kg (P: 100 kg)	100	--	--	--
MoP	250 kg (K: 150 kg)	--	33.33	33.33	33.33
Gypsum	20 kg (S: 20 Kg)	100	--	--	--
Boric acid (B)	As per treatment	100	--	--	--
Zinc sulphate (Zn)	As per treatment	100	--	--	--





Plot size: 1.8 m × 1.8 m

Plot spacing: 0.50 m

Between block: 1.00 m

Row to row distance: 60 cm × 60 cm

Plant to plant distance: 60 cm × 60 cm

The experiment consisted of two factors:

Factor A: Boron (3 levels) as

i B_0: 0.0 kg B ha^{-1}

ii. B_1: 1.0 kg B ha^{-1}

iii. B_2: 2.0 kg B ha^{-1}

Factor B: Zinc (4 levels) as

i. Zn_0: 0.0 kg Zn ha^{-1}

ii. Zn_1: 1.0 kg Zn ha^{-1}

iii. Zn_2: 2.0 kg Zn ha^{-1}

iv. Zn_3: 3.0 kg Zn ha^{-1}

Figure 1. Layout of the experimental plot

The total amount of cowdung, TSP, Gypsum, B and Zn was applied as basal dose at the time of land preparation. The total amount of urea and MoP was applied in three equal installments at 15, 30 and 45 day after transplanting.

3.2.6 Collection and application of micronutrients (B and Zn)

Boron as boric acid and zinc as Zinc sulphate were collected from local market and was applied as per treatment as basal dose.

3.3 Growing of crops

3.3.1 Collection of seeds

The seeds of broccoli (*Brassica oleracea var.* italica L.) cv. Green Giant was collected from Siddique Bazar market, Dhaka.

3.3.2 Raising of seedlings

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 1 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t ha^{-1}. Ten (10) grams of seeds were sown in seedbed on October 10, 2018. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth.

3.3.3 Transplanting of seedlings

Healthy and uniform seedlings of 20 days old were transplanted in the experimental plots on October 30, 2018. The seedlings were uprooted carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row was 60 cm and plant to plant was 60 cm. As a result there are 9 seedlings were accommodated in each plot according to the design of the plot size at 1.8 m × 1.8 m. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.3.4 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the broccoli seedlings.

3.3.4.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplants were given shading and watering for 7 days for their proper establishment.

3.3.4.2 Weeding

The hand weeding was done 15, 30 and 45 DAT (days after transplanting) to keep the plots free from weeds.

3.3.4.3 Earthing up

Earthing up was done at 15, 30 and 45 DAT on both sides of rows by taking the soil from the space between the rows by a small spade.

3.3.4.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedling in the field. In spite of Cirocarb 3G applications during final land preparation, few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. Birds pest such as nightingales (common Bulbuli) were seen visiting the broccoli field very frequently. The nightingale visited the fields in the morning and afternoon. The birds found to puncture the newly initiated curd and were controlled by striking a kerosene tin of metallic container frequently during day time.

3.4 Harvesting

Harvesting of the broccoli was not possible on a certain or particular date because the curd initiation as well as curd at marketable size in different plants were not uniform. Only the marketable size curds were harvested with fleshy stalk by using as sharp knife. Before harvesting of the broccoli curd, compactness of the curd was tested by pressing with thumbs.

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of this experiment. Data on plant height, number of leaves/plant, leaf length and breadth were collected at 20, 30, 40 and 50 DAT (days after transplanting) and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.5.1 Plant height (cm)

Plant height was measured from five randomly selected plants by using meter scale in centimeter from the ground level to the tip of the longest leaf at 10 days interval starting from 20 days after transplanting (DAT) and continued upto 50 DAT and at harvest and their mean value was calculated.

3.5.2 Number of leaves per plant

Number of leaves per plant was counted from five randomly selected plants at 10 days interval starting from 20 days after transplanting (DAT) and continued upto 50 DAT and at harvest and their average was recorded.

3.5.3 Leaf length (cm)

Leaf length was measured from five randomly selected plants in centimeter from lower level to the tip of the longest leaf and then average was calculated. Data were collected at 20, 30, 40, 50 DAT and at harvest.

3.5.4 Leaf breadth (cm)

Leaf breadth was counted from five randomly selected plants at 10 days interval starting from 20 DAT and continued upto 50 DAT and at harvest and their mean value was find out.

3.5.5 Days to 1st curd initiation

Each plant of the experiment plot was kept under close observation to assess days of curd initiation. Total number of days from the date of transplanting to the curd initiation was calculated and recorded.

3.5.6 Stem length (cm)

Stem length was taken from the ground level to base of the curd of plant during harvesting. A meter scale used to measure stem length and was expressed in centimeter (cm).

3.5.7 Stem diameter (cm)

Stem diameter was measured at the point where the central stem was cut off. The diameter of the stem was recorded in three dimensions with scale and the average of three figures was taken into account in centimeter (cm).

3.5.8 Root length

Root length was measured from five randomly selected plant and their average were calculated and expressed in centimeter.

3.5.9 Number of roots plant^{-1}

After harvest selected plant was uprooted carefully and washed in water after that number of roots in each plant was recorded from five randomly selected plants.

3.5.10 Primary curd diameter (cm)

The curds from sample plants were sectioned vertically at the middle position with a sharp knife. The primary curd diameter was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned curd and mean value was recorded.

3.5.11 Primary curd weight (g)

The curds from sample plants were harvested, cleaned and weighted. Every primary curd were weighted in grams by weighing machine and mean values was counted.

3.5.12 Number of secondary curds plant^{-1}

The total number of secondary curds plant^{-1} was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at during harvest.

3.5.13 Secondary curds weight (g)

The secondary curds from sample plants were harvested, cleaned and weighted. The weight of every secondary curd from each plant was weighted by weighing machine and added them in plant wise and finally means values was calculated and recorded.

3.5.14 Curd yield plant^{-1} (g)

Curd yield plant^{-1} was recorded by adding primary and secondary curd and average curd yield plant^{-1} expressed in gram and recorded.

3.5.15 Curd yield hectare^{-1} (ton)

The curd yield hectare^{-1} was measured by converted total curd yield plant^{-1} into yield per hectare and was expressed in ton.

3.5.16 Determination of ascorbic acid (vitamin C) content in fresh broccoli

Quantitative determination of ascorbic acid content of broccoli from different treatment was estimated (AOAC, 2005) at Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. The applied method was as follows:

Reagents

i) Metaphosphoric acid solution (3% HPO_3): Prepared by dissolving pellets of HPO_3 in glass distilled water.

ii) Standard ascorbic acid solution: 100 mg of ascorbic acid was weighted, dissolved and made up to 100 ml with 3% HPO_3 and diluted to 0.1 mg/ml (10 ml HPO_3 of 1 mg/ml) immediately before use.

iii) Dye solution: Fifty milligram of 2, 6-Dichlorophenol indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. The mixture was cooled, diluted with distilled water upto 200 ml, stored in a refrigerator and standardizes every day before use.

Procedure

Five (5) grams of fresh curd sample was crushed in a mortar and mixed well with 3% HPO_3 upto 100 ml in a volumetric flask. It was filtered with whatman filter paper 40. Then 5 ml aliquot of HPO_3 extract of the sample was taken and titrated with dye solution.

3.5.17 Reducing sugar

For determination of reducing sugar two and half gram (2.5 g) of ground broccoli sample was taken in a conical flask and 20 ml of 80% alcohol was added with the sample and was sonicated for one hour. It was then filtered and filtrates was used for total sugars determination. The alcohol was evaporated by using vacuum evaporator. The remaining aqueous solution was carefully transferred to 100 ml volumetric flask and made up to volume. 10 ml solutions were diluted again to 100 ml with distilled water. 1 ml dilute solution was taken in a test tube, 4 ml anthrone reagent added and mixed thoroughly. The content in the tube was heated placing it in a boiling water bath for ten minutes and placing a marble in the opening of the tube evaporation was restricted. The tube was cooled to room temperature and the intensity of the color developed due to the presence of sugar was measured in spectrophotometer (Shimadzu) at 620 nm as optical density. A standard curve was prepared from the known concentration of pure glucose and total sugar in the sample was calculated with reference to the standard curve (Rangana, 1979).

3.5.18 Estimation of total soluble solids (TSS) content

Total soluble solids content of broccoli curd was estimated by using Abbes, Refractometer. A drop of broccoli curd juice squeezed from broccoli curd on the prism of the refractometer. Percent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna (1979).

3.5.19 Carbohydrate estimation

The content of the available carbohydrate was determined as per the equation of Raghuramulu *et al.*, 2003 at BCSIR, Dhaka.

3.5.20 Determination of Carotenoids by spectrophotometer

Carotenoids exhibit certain absorption spectrum exposed to specific wave length. An absorption spectrum depends on the unique absorption characteristics and these absorption properties was utilized for determination of carotene.

Procedure

Two (2) grams of sample (broccoli) was taken in a clean mortar. The sample was then grinded in the mortar with 80% acetone in presence of quartz sand (very small amount) and calcium carbonate (0.5mg). The resulting colored solution was then filtered by continuous washing with 80% acetone. The filtered was collected in a 50 ml volumetric flask and made to a final volume of 50 ml with 80% acetone. The filtered colored solution was carefully transferred to a separator funnel and 20 ml petroleum ether was added to the solution. The funnel was shaken and placed for 20 minutes. The lower aqueous phase was discarded very carefully keeping the ether layer. To the ether layer, about 5 ml ethanol containing 5% KOH was added and shaken well and kept about 10 hours for complete saponification. Then, water was added gently to the saponified solution. By adding water, two distinct phases were visible. The lower aqueous phase was discarded carefully. The upper phase containing β carotene was washed with water several times for complete remove of KOH. The ether layer containing β carotene was transferred to a 25 ml volumetric flask and the flask was volume upto the mark by adding petroleum ether. From the petroleum ether extract, β carotene was estimated with the spectrophotometer at 451 nm wave length against petroleum ether as blank, by using the equation proposed by Shiraishi (1972).

$$\beta \text{ carotene (mg/g)} = 3.984\ (OD_{451})\ V/\ 1000\ W$$

Where,

V = Final volume of the petroleum ether β carotene extract (ml)

W = Fresh weight of the sample taken (g)

OD_{451} = Spectrophotometer reading at 451 nm wave length.

For evidence, the calculated results of β carotene were multiplied by 100.

Standardization of dye

Five (5) milliliter of standard ascorbic acid solution was taken and titrated with dye factor until a faint pink colour persists for 15 seconds.

Dye factor = ml of standard ascorbic acid taken × conc. of ascorbic acid/ml of dye consumed.

Calculation

$$a = bcd\,\frac{100}{ef}$$

Where, a = Ascorbic acid mg/100g

b = Titration reading

c = Dye factor

d = Volume made upto (100 ml)

e = Aliquot of extract (5 ml)

f = Weight of the sample

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different levels of B and Zn on growth, yield attributes, yield and quality of broccoli. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.7 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different levels of B and Zn for broccoli cultivation. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13% in simple rate. The market price of broccoli was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) of the data on different growth, yield attributes, yield and quality parameters of broccoli are presented in Appendices IV-X. The results have been presented with the help of table and graphs with possible interpretations under the following headings:

4.1 Plant height

Plant height of broccoli at 20, 30, 40, 50 days after transplanting (DAT) and at harvest varied significantly due to different levels of boron (Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (29.11, 46.17, 58.14, 66.58 and 69.78 cm, respectively) was recorded from B_2 (2.0 kg B ha^{-1}) which was statistically similar (28.61, 45.22, 56.76, 64.85 and 67.98 cm, respectively) to B_1 (1.0 kg B ha^{-1}), while the shortest plant (24.87, 38.18, 49.66, 55.82 and 58.45 cm, respectively) was observed from B_0 (0 kg B ha^{-1} i.e. control) (Figure 2). The result revealed that better growth of broccoli occurred for the application of different levels of boron. It may be done to the favorable influence and balanced absorption of other nutrients due to boron. Jakhar *et al*. (2018) reported that boron levels 2.25 kg B ha^{-1} significantly increased the plant height (62.55 cm) as compared to control.

Different levels of zinc showed statistically significant differences in terms of plant height of broccoli at 20, 30, 40, 50 DAT and at harvest (Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (29.88, 46.98, 58.91, 67.22 and 69.59 cm, respectively) was found from Zn_3 (3.0 kg Zn ha^{-1}) which was statistically similar (29.41, 45.66, 57.68, 65.25 and 68.09 cm, respectively) to Zn_2 (2.0 kg Zn ha^{-1}) and followed (26.97, 42.17, 53.52, 60.79 and 64.56 cm, respectively) by Zn_1 (1.0 kg Zn ha^{-1}), whereas the shortest plant (23.87, 37.94, 49.30, 56.41 and 59.39 cm, respectively) was recorded from Zn_0 (0.0 kg Zn ha^{-1}) i.e. control) (Figure 3). Singh *et al*. (2018) reported that the treatment zinc sulphate @ 0.60% exhibited the highest plant height (63.29 cm).

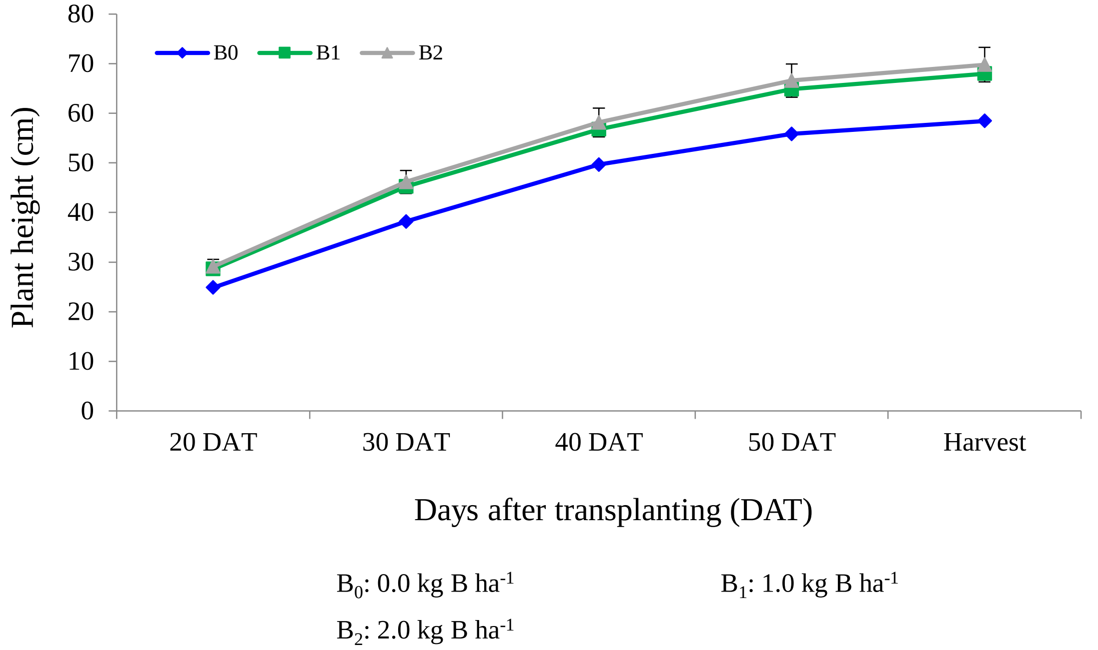


Figure 2. Effect of different levels of boron on plant height of broccoli (Vertical bars represent LSD value at 5% level of probability).

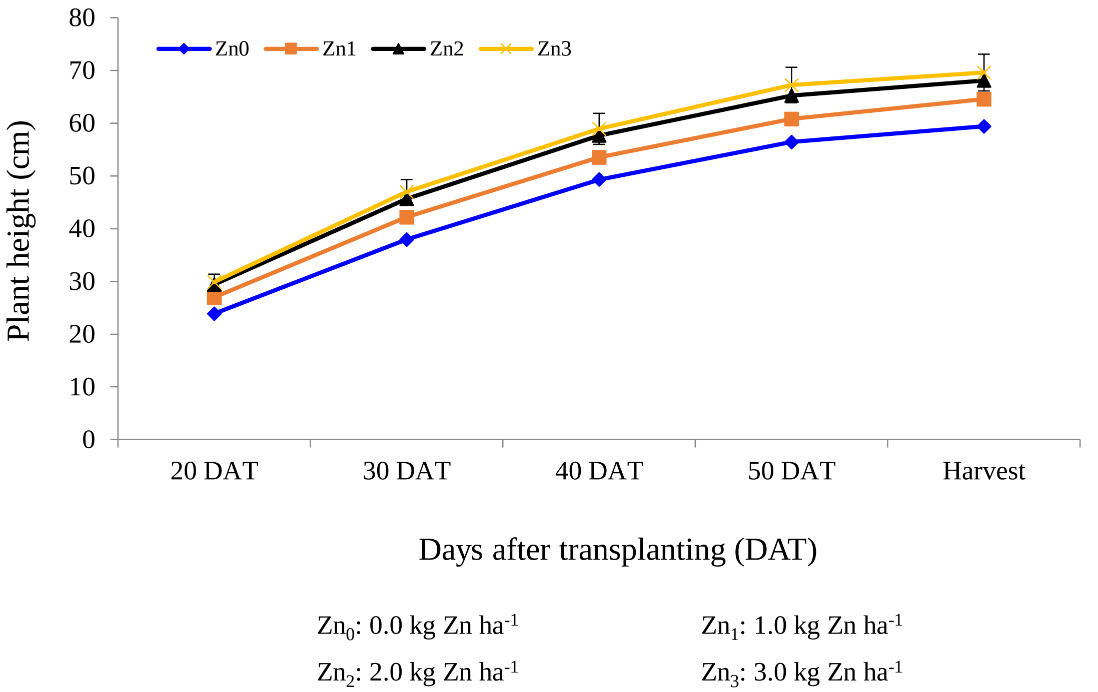


Figure 3. Effect of different levels of zinc on plant height of broccoli (Vertical bars represent LSD value at 5% level of probability).

Combined effect of different levels of boron and zinc showed statistically significant differences on plant height of broccoli at 20, 30, 40, 50 DAT and at harvest (Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (32.96, 49.67, 63.43, 73.29 and 75.81 cm, respectively) was found from B_2Zn_3 (2.0 kg B ha^{-1} and 3.0 kg Zn ha^{-1}) treatment combination and the shortest plant (21.62, 32.31, 44.27, 49.34 and 51.08 cm, respectively) was observed from B_0Zn_0 (0.0 kg B ha^{-1} and 0.0 kg Zn ha^{-1} i.e. control condition) treatment combination (Table 2).

4.2 Number of leaves plant^{-1}

Statistically significant differences was recorded in terms of number of leaves plant^{-1} of broccoli at 20, 30, 40, 50 DAT and at harvest due to different levels of boron (Appendix V). At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (6.77, 12.28, 17.80, 21.93 and 23.17, respectively) was observed from B_2 which was statistically similar (6.50, 11.80, 17.43, 21.35 and 22.33, respectively) to B_1, whereas the minimum number (5.33, 10.35, 15.17, 18.28 and 18.98, respectively) was found from B_0 (Figure 4). Metwaly (2016) reported that leaves number were not significantly affected by boron application.

Different levels of zinc showed statistically significant variation in terms of number of leaves plant^{-1} of broccoli at 20, 30, 40, 50 DAT and at harvest (Appendix V). At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (6.78, 12.31, 18.22, 22.38 and 23.60, respectively) was recorded from Zn_3 which was statistically similar (6.62, 12.02, 17.84, 22.02 and 22.71, respectively) to Zn_2 and followed (6.07, 11.33, 16.76, 20.29 and 21.27, respectively) by Zn_1, while the minimum number (5.33, 10.24, 14.38, 17.40 and 18.40, respectively) was found from Zn_0 (Figure 5). Data revealed that different levels of zinc influences number of leaves plant^{-1} and produced the maximum numbers compared to control. Yılmaz *et al*. (2013) reported that leaf number of broccoli were increased significantly due to zinc application.

Table 2. Combined effect of different levels of boron and zinc on plant height of broccoli at different days after transplanting (DAT) and at harvest

Treatments	Plant height (cm) at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
B_0Zn_0	21.62 e	32.31 g	44.27 g	49.34 f	51.08 g
B_0Zn_1	24.20 c-e	34.58 g	47.94 fg	52.64 ef	56.99 f
B_0Zn_2	26.35 b-d	41.76 ef	52.54 de	59.42 cd	62.04 d-f
B_0Zn_3	27.31 bc	44.06 c-e	53.89 c-e	61.88 cd	63.71 c-e
B_1Zn_0	26.69 b-d	42.40 d-f	53.10 c-e	63.48 c	66.72 cd
B_1Zn_1	29.37 b	44.92 b-e	57.27 bc	65.14 c	68.49 cd
B_1Zn_2	29.03 b	46.35 a-d	57.23 bc	64.28 c	67.46 cd
B_1Zn_3	29.37 b	47.20 a-c	59.43 ab	66.47 bc	69.25 bc
B_2Zn_0	23.30 de	39.12 f	50.54 ef	56.40 de	60.36 ef
B_2Zn_1	27.35 bc	47.00 a-c	55.34 b-d	64.59 c	68.19 cd
B_2Zn_2	32.84 a	48.87 ab	63.26 a	72.03 ab	74.76 ab
B_2Zn_3	32.96 a	49.67 a	63.43 a	73.29 a	75.81 a
$LSD_{(0.05)}$	3.313	4.093	3.898	6.358	5.872
Level of significance	0.05	0.05	0.05	0.01	0.05
CV(%)	7.11	5.60	4.20	6.02	5.30

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

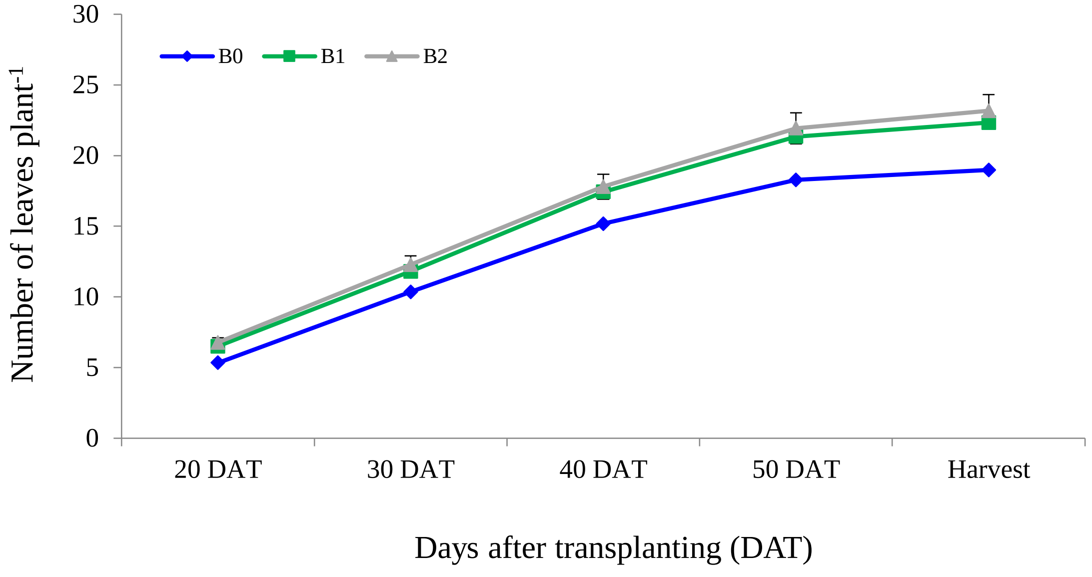
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

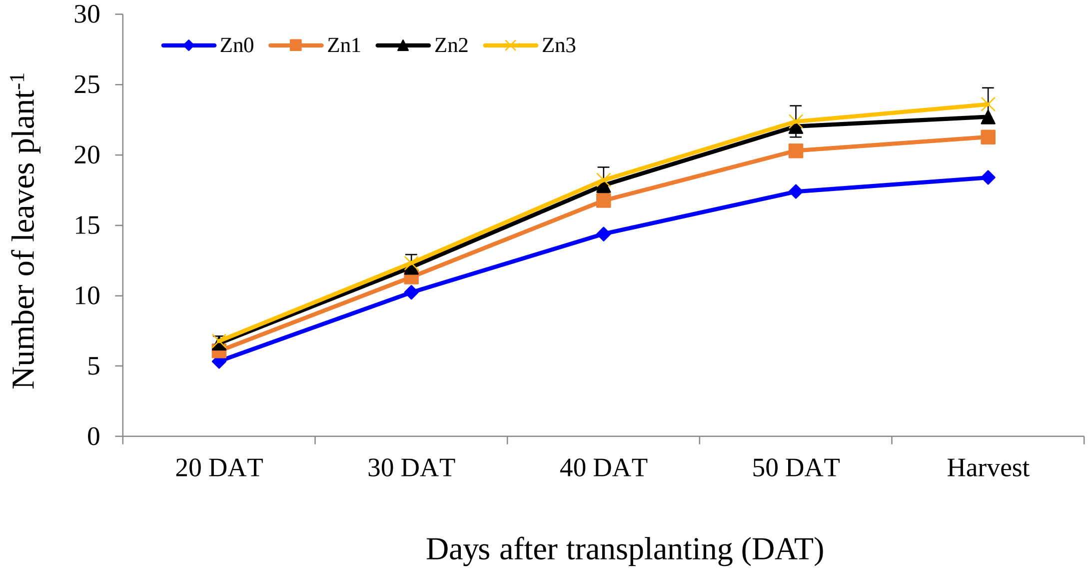
Zn_3: 3.0 kg Zn ha^{-1}



B_0: 0.0 kg B ha^{-1} B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Figure 4. Effect of different levels of boron on number of leaves plant^{-1} of broccoli (Vertical bars represent LSD value at 5% level of probability).



Zn_0: 0.0 kg Zn ha^{-1} Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1} Zn_3: 3.0 kg Zn ha^{-1}

Figure 5. Effect of different levels of zinc on number of leaves plant^{-1} of broccoli (Vertical bars represent LSD value at 5% level of probability).

Number of leaves plant^{-1} of broccoli at 20, 30, 40, 50 DAT and at harvest varied significantly due to the combined effect of different levels of boron and zinc (Appendix V). At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (7.73, 13.47, 19.40, 24.20 and 25.73, respectively) was observed from B_2Zn_3 treatment combination, whereas the minimum number (5.07, 10.07, 13.73, 16.13 and 16.67, respectively) was recorded from B_0Zn_0 treatment combination (Table 3).

4.3 Leaf length

Different levels of boron varied significantly in terms of leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest (Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (16.32, 26.35, 41.01, 44.92 and 46.33 cm, respectively) was found from B_2 which was statistically similar (15.97, 25.79, 39.97, 43.99 and 45.26 cm, respectively) to B_1, whereas the lowest leaf length (14.41, 23.67, 36.58, 39.22 and 41.94 cm, respectively) was recorded from B_0 (Figure 6). Data revealed that application of boron influences leaf length of broccoli. Singh *et al*. (2015) reported longest leaf (14.18 cm) with increasing amount of boron fertilization.

Leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest showed statistically significant differences due to different levels of zinc (Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (16.82, 27.46, 41.49, 44.98 and 46.87 cm, respectively) was observed from Zn_3 which was statistically similar (16.40, 26.97, 40.62, 44.12 and 46.14 cm, respectively) to Zn_2 and followed (15.24, 25.58, 38.72, 42.23 and 44.22 cm, respectively) by Zn_1. On the other hand, the lowest leaf length (13.82, 21.08, 35.90, 39.51 and 40.81 cm, respectively) was found from Zn_0 (Figure 7). Singh *et al*. (2018) reported that the treatment zinc sulphate @ 0.60% exhibited the highest leaf length (43.63 cm) compared to control.

Table 3. Combined effect of different levels of boron and zinc on number of leaves plant^{-1} of broccoli at different days after transplanting (DAT) and at harvest

Treatments	Number of leaves plant^{-1} at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
B_0Zn_0	5.07 e	10.07 d	13.73 e	16.13 g	16.67 g
B_0Zn_1	5.00 e	10.27 d	14.67 de	17.40 fg	18.07 fg
B_0Zn_2	5.67 de	10.47 d	16.20 bc	20.60 de	21.47 de
B_0Zn_3	5.60 de	10.60 cd	16.07 bc	19.00 ef	19.73 ef
B_1Zn_0	5.80 de	10.27 d	15.20 cd	17.80 fg	18.87 f
B_1Zn_1	6.40 cd	11.73 bc	16.93 b	21.27 cd	22.13 cd
B_1Zn_2	6.80 bc	12.33 ab	18.40 a	22.40 a-d	23.00 cd
B_1Zn_3	7.00 a-c	12.87 ab	19.20 a	23.93 ab	25.33 ab
B_2Zn_0	5.13 e	10.40 d	14.20 de	18.27 f	19.67 ef
B_2Zn_1	6.80 bc	12.00 b	18.67 a	22.20 b-d	23.60 bc
B_2Zn_2	7.40 ab	13.27 a	18.93 a	23.07 a-c	23.67 bc
B_2Zn_3	7.73 a	13.47 a	19.40 a	24.20 a	25.73 a
$LSD_{(0.05)}$	0.796	1.138	1.180	1.683	1.947
Level of significance	0.05	0.05	0.01	0.05	0.05
CV(%)	7.58	5.86	4.15	6.84	5.35

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

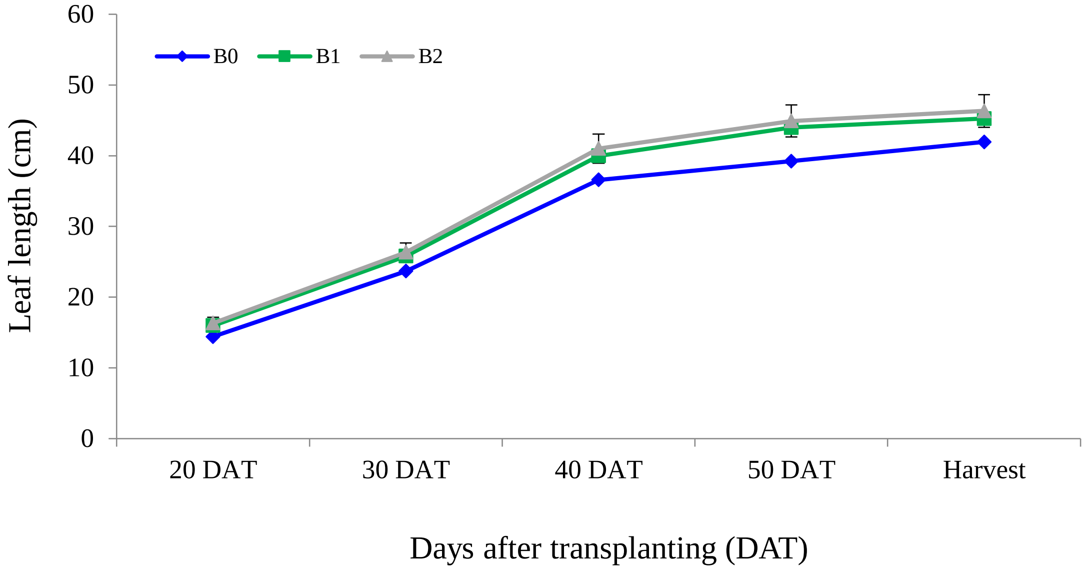
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

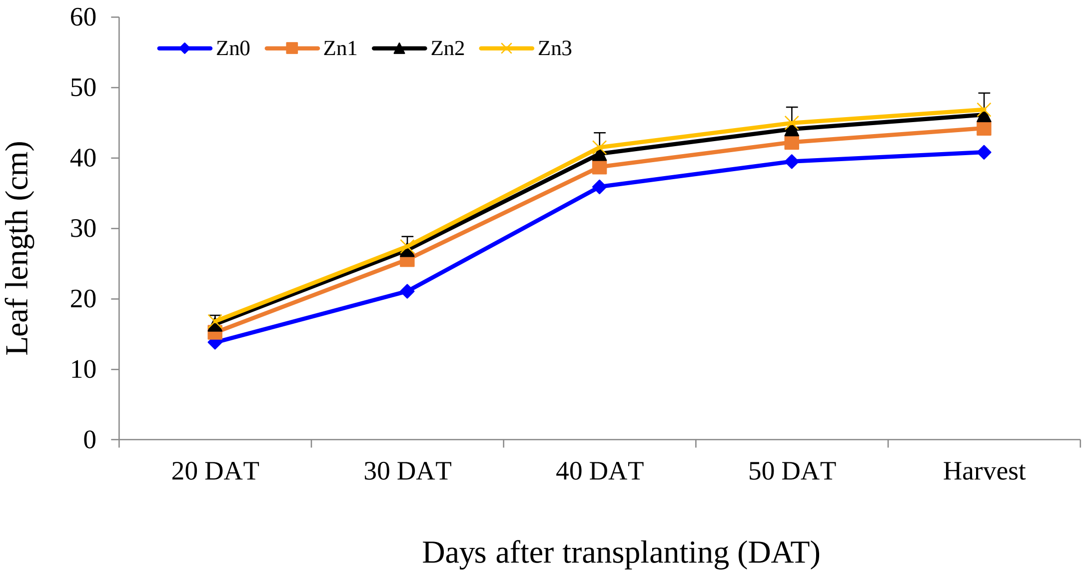
Zn_3: 3.0 kg Zn ha^{-1}



B_0: 0.0 kg B ha^{-1} B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Figure 6. Effect of different levels of boron on leaf length of broccoli (Vertical bars represent LSD value at 5% level of probability).



Zn_0: 0.0 kg Zn ha^{-1} Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1} Zn_3: 3.0 kg Zn ha^{-1}

Figure 7. Effect of different levels of zinc on leaf length of broccoli (Vertical bars represent LSD value at 5% level of probability).

Statistically significant variation was recorded in terms of leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest due to combined effect of different levels of boron and zinc (Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (17.64, 28.83, 43.73, 47.32 and 48.80 cm, respectively) was recorded from B_2Zn_3 treatment combination, while the lowest leaf length (13.17, 20.49, 34.59, 35.48 and 36.98 cm, respectively) was found from B_0Zn_0 treatment combination (Table 4).

4.4 Leaf breadth

Leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest varied significantly due to different levels of boron (Appendix VII). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.35, 13.34, 16.24, 17.70 and 18.23 cm, respectively) was found from B_2 which was statistically similar (8.16, 12.90, 15.82, 17.35 and 17.84 cm, respectively) to B_1, while the lowest leaf breadth (7.46, 11.32, 13.63, 15.03 and 15.55 cm, respectively) was recorded from B_0 (Figure 8). Moniruzzaman *et al*. (2007) reported that boron application increased width of the leaf significantly up to 1.5 kg ha^{-1}.

Statistically significant differences was recorded in terms of leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest due to different levels of zinc (Appendix VII). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.46, 13.49, 16.48, 17.97 and 18.35 cm, respectively) was observed from Zn_3 which was statistically similar (8.40, 13.20, 15.93, 17.42 and 17.90, respectively) to Zn_2 and followed (7.95, 12.33, 15.01, 16.40 and 17.02 cm, respectively) by Zn_1, whereas the lowest leaf breadth (7.15, 11.06, 13.49, 14.97 and 15.57 cm, respectively) was found from Zn_0 (Figure 9). It was observed that different levels of zinc produced different size of leaf breadth and the maximum leaf breadth was recorded with 3.0 kg Zn ha^{-1}. Singh *et al*. (2018) reported that the treatment zinc sulphate @ 0.60% exhibited highest leaf width (22.60 cm) in comparison to control.

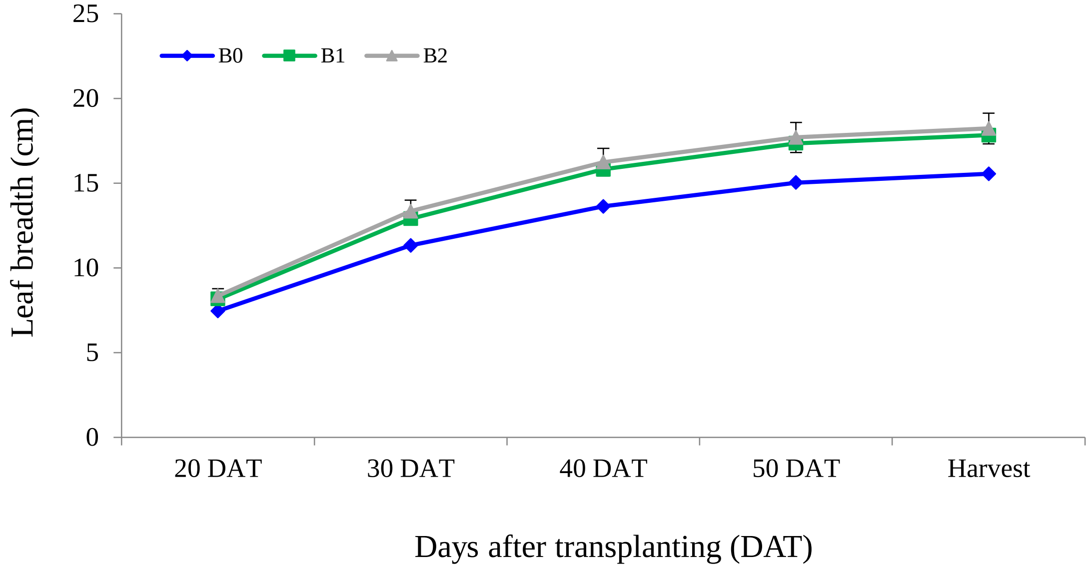
Table 4. Combined effect of different levels of boron and zinc on leaf length of broccoli at different days after transplanting (DAT) and at harvest

Treatments	Leaf length (cm) at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
B_0Zn_0	13.17 g	20.49 d	34.59 f	35.48 i	36.98 e
B_0Zn_1	13.67 fg	22.76 c	36.56 ef	38.44 h	42.36 d
B_0Zn_2	15.18 de	25.38 b	37.04 d-f	40.81 gh	43.72 cd
B_0Zn_3	15.63 cd	26.07 b	38.13 c-e	42.14 d-g	44.68 b-d
B_1Zn_0	14.47 ef	21.81 cd	36.10 ef	41.82 e-g	42.59 d
B_1Zn_1	15.76 cd	27.02 ab	39.36 cd	43.82 c-f	45.26 b-d
B_1Zn_2	16.48 bc	26.87 ab	41.79 ab	44.86 a-d	46.07 a-c
B_1Zn_3	17.17 ab	27.47 ab	42.62 a	45.47 a-c	47.12 ab
B_2Zn_0	13.83 fg	20.95 cd	37.02 d-f	41.23 fg	42.87 d
B_2Zn_1	16.29 bc	26.97 ab	40.24 bc	44.43 b-e	45.04 b-d
B_2Zn_2	17.54 a	28.66 a	43.04 a	46.68 ab	48.62 a
B_2Zn_3	17.64 a	28.83 a	43.73 a	47.32 a	48.80 a
$LSD_{(0.05)}$	0.932	2.035	2.247	2.563	2.853
Level of significance	0.05	0.05	0.05	0.01	0.05
CV(%)	3.54	4.23	5.39	3.54	5.79

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

B_0: 0.0 kg B ha^{-1}
B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

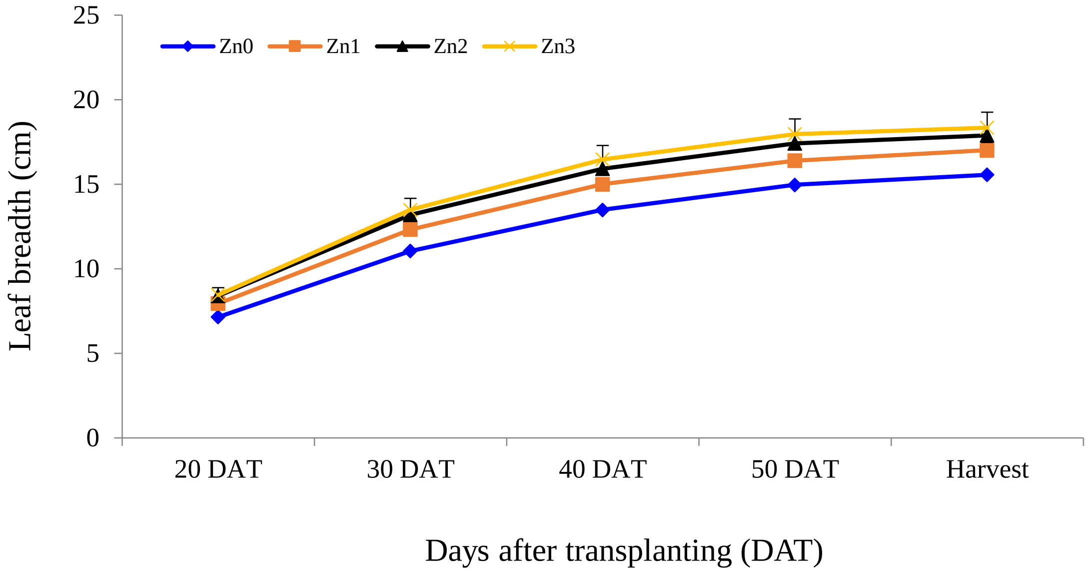
Zn_0: 0.0 kg Zn ha^{-1}
Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1}
Zn_3: 3.0 kg Zn ha^{-1}



B_0: 0.0 kg B ha^{-1} B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Figure 8. Effect of different levels of boron on leaf breadth of broccoli (Vertical bars represent LSD value at 5% level of probability).



Zn_0: 0.0 kg Zn ha^{-1} Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1} Zn_3: 3.0 kg Zn ha^{-1}

Figure 9. Effect of different levels of zinc on leaf breadth of broccoli (Vertical bars represent LSD value at 5% level of probability).

Combined effect of different levels of boron and zinc showed statistically significant differences on leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest (Appendix VII). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (9.20, 14.78, 17.83, 19.39 and 19.67 cm, respectively) was recorded from B_2Zn_3 and the lowest leaf breadth (7.13, 10.55, 12.79, 14.12 and 14.64 cm, respectively) was found from B_0Zn_0 treatment combination (Table 5).

4.5 Days to 1^{st} curd initiation

Different levels of boron showed statistically significant differences in terms of days to curd initiation of broccoli (Appendix VIII). The maximum days (59.25) to 1^{st} curd initiation was observed from B_0 and the minimum days (56.75) was recorded from B_2 which was statistically similar (56.98) to B_1 (Table 6). Singh *et al*. (2018) reported that foliar application of boric acid @ 0.40% induced earliness (61.44 days).

Days to 1^{st} curd initiation of broccoli showed statistically significant differences due to different levels of zinc (Appendix VIII). The maximum days (59.69) to 1^{st} curd initiation was recorded from Zn_0, while the minimum days (55.89) was found from Zn_3 (Table 6).

Statistically significant differences was observed due to the combined effect of different levels of boron and zinc in terms of days to 1^{st} curd initiation of broccoli (Appendix VIII). The maximum days to 1^{st} curd initiation (60.00) was observed from B_2Zn_0 treatment combination, whereas the minimum days (54.67) was recorded from B_2Zn_3 treatment combination (Table 7).

4.6 Stem length

Stem length of broccoli varied significantly due to different levels of boron (Appendix VIII). The longest stem (26.14 cm) was recorded from B_2 which was statistically similar (25.61 cm) to B_1, whereas the shortest stem (22.47 cm) from B_0 (Table 6). Hussain *et al*. (2012) recorded the longest stem with boron application up to 1.0 kg ha^{-1} which partially supports the present findings.

Table 5. Combined effect of different levels of boron and zinc on leaf breadth of broccoli at different days after transplanting (DAT) and at harvest

Treatments	Leaf breadth (cm) at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
B_0Zn_0	7.13 e	10.55 e	12.79 e	14.12 g	14.64 e
B_0Zn_1	7.25 e	10.64 e	12.58 e	14.12 g	14.71 e
B_0Zn_2	7.71 de	12.32 cd	14.61 cd	16.05 d-f	16.57 cd
B_0Zn_3	7.74 de	11.76 d	14.52 cd	15.82 ef	16.31 cd
B_1Zn_0	7.26 e	11.30 de	13.87 de	15.30 fg	15.99 de
B_1Zn_1	8.57 a-c	13.21 bc	16.48 ab	18.01 a-c	18.62 ab
B_1Zn_2	8.40 bc	13.17 bc	15.84 bc	17.40 b-d	17.69 bc
B_1Zn_3	8.42 bc	13.94 ab	17.08 ab	18.69 ab	19.07 ab
B_2Zn_0	7.08 e	11.33 de	13.82 de	15.50 fg	16.07 de
B_2Zn_1	8.04 cd	13.13 bc	15.96 bc	17.08 c-e	17.72 bc
B_2Zn_2	9.07 ab	14.12 ab	17.33 ab	18.81 ab	19.45 a
B_2Zn_3	9.20 a	14.78 a	17.83 a	19.39 a	19.67 a
$LSD_{(0.05)}$	0.625	0.982	1.415	1.368	1.357
Level of significance	0.01	0.05	0.05	0.05	0.05
CV(%)	4.62	6.63	5.49	4.84	6.66

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

B_0: 0.0 kg B ha^{-1}
B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}
Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1}
Zn_3: 3.0 kg Zn ha^{-1}

Table 6. Effect of different levels of boron and zinc on yield attributes of broccoli

Treatments	Days to 1^{st} curd initiation	Stem length (cm)	Stem diameter (cm)	Root length (cm)	Number of roots $plant^{-1}$
Levels of boron					
B_0	59.25 a	22.47 b	1.86 c	19.63 b	12.57 b
B_1	56.98 b	25.61 a	2.21 b	21.09 a	14.35 a
B_2	56.75 b	26.14 a	2.32 a	21.37 a	14.77 a
$LSD_{(0.05)}$	1.297	0.760	0.104	0.675	0.567
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of zinc					
Zn_0	59.69 a	22.39 c	1.85 c	19.13 c	12.82 c
Zn_1	57.42 b	24.28 b	2.07 b	20.43 b	13.58 b
Zn_2	57.64 b	25.82 a	2.26 a	21.39 a	14.47 a
Zn_3	55.89 c	26.46 a	2.34 a	21.83 a	14.71 a
$LSD_{(0.05)}$	1.498	0.878	0.120	0.780	0.654
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.66	4.63	5.73	3.85	4.82

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}

Table 7. Combined effect of different levels of boron and zinc on yield attributes of broccoli

Treatments	Days to 1st curd initiation	Stem length (cm)	Stem diameter (cm)	Root length (cm)	Number of roots plant^{-1}
B_0Zn_0	59.47 a	20.75 g	1.71 e	18.46 e	11.40 f
B_0Zn_1	59.80 a	21.03 g	1.72 e	18.94 de	12.00 f
B_0Zn_2	59.87 a	23.71 ef	2.03 cd	20.39 b-d	13.13 e
B_0Zn_3	57.87 ab	24.39 de	1.99 d	20.72 bc	13.73 c-e
B_1Zn_0	59.60 a	23.69 ef	1.93 de	19.87 c-e	13.80 c-e
B_1Zn_1	56.53 bc	25.54 cd	2.24 bc	21.50 ab	14.27 c-e
B_1Zn_2	56.67 bc	26.23 bc	2.25 bc	21.13 bc	14.67 a-c
B_1Zn_3	55.13 bc	26.96 a-c	2.42 ab	21.86 ab	14.67a-c
B_2Zn_0	60.00 a	22.73 f	1.91 de	19.05 de	13.27 de
B_2Zn_1	55.93 bc	26.27 bc	2.25 bc	20.86 bc	14.47 b-d
B_2Zn_2	56.40 bc	27.53 ab	2.51 a	22.66 a	15.60 ab
B_2Zn_3	54.67 c	28.04 a	2.62 a	22.91 a	15.73 a
$LSD_{(0.05)}$	2.595	1.520	0.207	1.350	1.133
Level of significance	0.05	0.05	0.05	0.05	0.01
CV(%)	5.66	4.63	5.73	3.85	4.82

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}

Different levels of zinc showed statistically significant differences in terms of stem length of broccoli (Appendix VIII). The longest stem (26.46 cm) was found from Zn_3 which was statistically similar (25.82 cm) to Zn_2 and followed (24.28 cm) by Zn_1, while the shortest stem (22.39 cm) was recorded from Zn_0 (Table 6). Slosar *et al*. (2017) reported statistically significant differences of stem length by zinc applications.

Combined effect of different levels of boron and zinc showed statistically significant differences on stem length of broccoli (Appendix VIII). The longest stem (28.04 cm) was found from B_2Zn_3 treatment combination and the shortest stem (20.75 cm) was observed from B_0Zn_0 treatment combination (Table 7).

4.7 Stem diameter

Different levels of boron varied significantly in terms of stem diameter of broccoli (Appendix VIII). The highest stem diameter (2.32 cm) was found from B_2, while the lowest (1.86 cm) was recorded from B_0 (Table 6). Jakhar *et al*. (2018) reported that boron levels 2.25 kg B ha^{-1} significantly increased stem diameter (2.70 cm) as compared to control which supports the present findings.

Stem diameter of broccoli varied significantly due to different levels of zinc (Appendix VIII). The highest stem diameter (2.34 cm) was recorded by the treatment Zn_3 which was statistically similar to Zn_2 (2.26 cm), whereas the lowest (1.85 cm) was found from Zn_0 where no zinc was applied (Table 6).

Statistically significant differences was recorded in terms of stem diameter of broccoli due to the combined effect of different levels of boron and zinc (Appendix VIII). The highest stem diameter (2.62 cm) was recorded from B_2Zn_3 treatment combination, while the lowest (1.71 cm) was found from B_0Zn_0 treatment combination (Table 7).

4.8 Root length

Different levels of boron showed statistically significant differences in terms of root length of broccoli (Appendix VIII). The longest root (21.37 cm) was recorded from B_2 which was statistically similar to B_1 (21.09 cm), whereas the shortest root (19.63 cm) was observed from B_0 where no boron was applied(Table 6). Similar results also reported by Singh *et al*. (2016).

Statistically significant variation was observed in terms of root length of broccoli due to different levels of zinc (Appendix VIII). The longest root (21.83 cm) was found from Zn_3 which was statistically similar (21.39 cm) to Zn_2, while the shortest root (19.13 cm) was recorded from Zn_0 (Table 6). Slosar *et al*. (2017) reported statistically significant differences of root length by the application of various zinc level.

Root length of broccoli showed statistically significant differences due to the combined effect of different levels of boron and zinc under the present trial (Appendix VIII). The longest root (22.91 cm) was recorded in B_2Zn_3 treatment combination and the shortest root (18.46 cm) was produced by the treatment combination B_0Zn_0 (Table 7).

4.9 Number of roots plant^{-1}

Number of roots plant^{-1} of broccoli varied significantly due to different levels of boron (Appendix VIII). The maximum number of roots plant^{-1} (14.77) was found from B_2 which was statistically similar to B_1 (14.35), whereas the minimum number (12.57) was recorded from B_0 (Table 6). Ain *et al*. (2016) recorded the highest number of roots with 1.0% boron.

Different levels of zinc showed statistically significant differences in terms of number of roots plant^{-1} of broccoli (Appendix VIII). The maximum number of roots plant^{-1} (14.71) was observed from Zn_3 which was statistically similar to Zn_2 (14.47), while the minimum number (12.82) was found from Zn_0 (Table 6).

Combined effect of different levels of boron and zinc showed statistically significant differences on number of roots plant^{-1} of broccoli (Appendix VIII). The maximum number of roots plant^{-1} (15.73) was recorded from B_2Zn_3 treatment combination, whereas the minimum number (11.40) was found from B_0Zn_0 treatment combination (Table 7).

4.10 Primary curd diameter

Different levels of boron showed statistically significant differences in terms of primary curd diameter of broccoli (Appendix IX). The highest primary curd diameter (8.97 cm) was observed from B_2 which was statistically similar to B_1 (8.75 cm), while the lowest (7.75 cm) was found from B_0 (Table 8). Farooq *et al.* (2018) observed that the higher curd diameter and the highest value were observed when 1.5 kg ha^{-1} B were applied.

Primary curd diameter of broccoli showed statistically significant differences due to different levels of zinc (Appendix IX). The highest primary curd diameter (9.11 cm) was observed from Zn_3 which was statistically similar to Zn_2 (8.89 cm), whereas the lowest (7.71 cm) from Zn_0 (Table 8). Slosar *et al.* (2017) reported statistically significant differences of primary curd diameter for zinc applications.

Statistically significant variation was observed due to the combined effect of different levels of boron and zinc showed on primary curd diameter of broccoli (Appendix IX). The highest primary curd diameter (9.89 cm) was recorded from B_2Zn_3 treatment combination and the lowest (7.39 cm) was observed from B_0Zn_0 treatment combination (Table 9).

4.11 Primary curd weight

Primary curd weight of broccoli varied significantly due to different levels of boron (Appendix IX). The highest primary curd weight (587.42 g) was recorded from B_2 which was statistically similar (578.58 g) to B_1 and the lowest weight (511.06 g) was found from B_0 (Table 8). Singh *et al.* (2018) reported that foliar application of boric acid @ 0.40% increased fresh curd weight (411.87 g).

Table 8. Effect of different levels of boron and zinc on yield of broccoli

Treatments	Primary curd diameter (cm)	Primary curd weight (g)	Secondary curd weight (g)	Curd yield plant^{-1} (g)	Curd yield hectare^{-1} (ton)
Levels of boron					
B_0	7.75 b	511.06 b	65.42 b	686.39 b	19.07 b
B_1	8.75 a	578.58 a	74.86 a	812.78 a	22.58 a
B_2	8.97 a	587.42 a	76.75 a	838.68 a	23.30 a
$LSD_{(0.05)}$	0.365	21.13	2.759	40.21	1.117
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of zinc					
Zn_0	7.71 c	514.29 c	65.16 c	684.40 c	19.01 c
Zn_1	8.26 b	559.00 b	70.71 b	770.05 b	21.39 b
Zn_2	8.89 a	578.15 ab	75.59 a	820.30 a	22.79 a
Zn_3	9.11 a	584.65 a	77.92 a	842.39 a	23.40 a
$LSD_{(0.05)}$	0.422	24.40	3.186	46.43	1.290
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.08	4.46	4.51	6.09	6.09

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

B_0: 0.0 kg B ha^{-1}
B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}
Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1}
Zn_3: 3.0 kg Zn ha^{-1}

Table 9. Combined effect of different levels of boron and zinc on yield of broccoli

Treatments	Primary curd diameter (cm)	Primary curd weight (g)	Secondary curd weight (g)	Curd yield plant^{-1} (g)	Curd yield hectare^{-1} (ton)
B_0Zn_0	7.39 d	500.82 d	60.26 f	649.36 c	18.04 c
B_0Zn_1	7.47 d	506.19 d	61.35 f	661.51 c	18.38 c
B_0Zn_2	8.17 cd	519.68 d	68.87 de	708.37 c	19.68 c
B_0Zn_3	7.97 cd	517.54 d	71.18 cd	726.32 c	20.18 c
B_1Zn_0	8.02 cd	535.82 d	70.03 c-e	727.50 c	20.21 c
B_1Zn_1	8.74 bc	590.09 a-c	75.21 bc	825.94 b	22.94 b
B_1Zn_2	8.78 bc	585.45 bc	75.70 bc	832.91 b	23.14 b
B_1Zn_3	9.46 ab	602.98 a-c	78.49 ab	864.76 ab	24.02 ab
B_2Zn_0	7.71 d	506.25 d	65.19 ef	676.33 c	18.79 c
B_2Zn_1	8.56 c	580.71 c	75.56 bc	822.69 b	22.85 b
B_2Zn_2	9.73 a	629.30 ab	82.18 a	919.63 a	25.55 a
B_2Zn_3	9.89 a	633.42 a	84.08 a	936.09 a	26.00 a
$LSD_{(0.05)}$	0.730	42.25	5.518	80.42	2.234
Level of significance	0.05	0.01	0.01	0.05	0.05
CV(%)	5.08	4.46	4.51	6.09	6.09

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

B_0: 0.0 kg B ha^{-1}
B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}
Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1}
Zn_3: 3.0 kg Zn ha^{-1}

Different levels of zinc showed statistically significant differences in terms of primary curd weight of broccoli (Appendix IX). The highest primary curd weight (584.65 g) was recorded from Zn_3 which was statistically similar to Zn_2 (578.15 g), while the lowest weight (514.29 g) from Zn_0 (Table 8). Quratul *et al*. (2016) observed that zinc levels @ 0.5%, showed better result on primary curd weight.

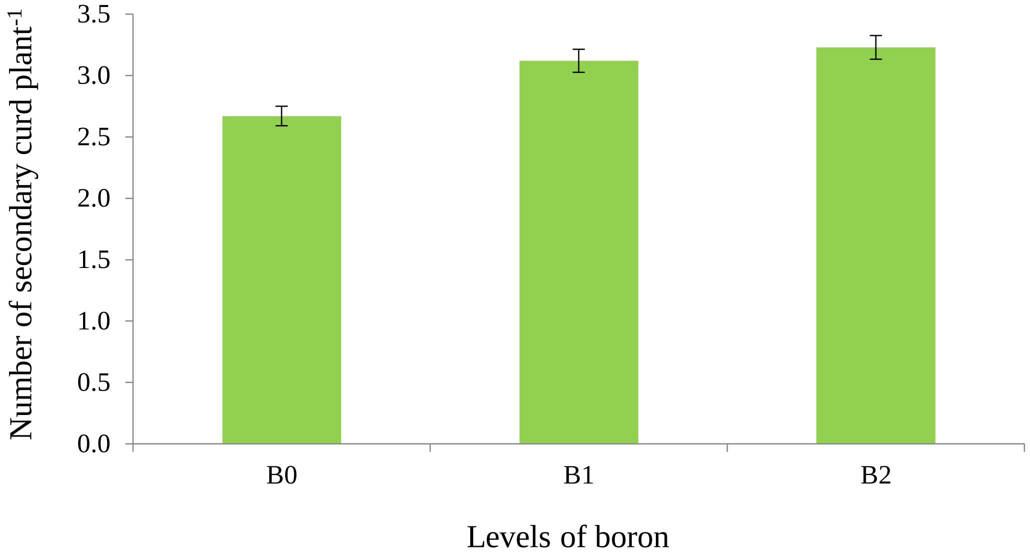
Combined effect of different levels of boron and zinc showed statistically significant differences on primary curd weight of broccoli (Appendix IX). The highest primary curd weight (633.42 g) was recorded from B_2Zn_3 treatment combination, whereas the lowest weight (500.82 g) was found from B_0Zn_0 treatment combination (Table 9).

4.12 Number of secondary curd plant^{-1}

Statistically significant variation was recorded in terms of number of secondary curd plant^{-1} of broccoli due to different levels of boron (Appendix IX). The maximum number of secondary curd plant^{-1} (3.23) was recorded from B_2 which was statistically similar (3.12) to B_1, while the minimum number (2.67) was observed from B_0 (Figure 10). Ain *et al*. (2016) recorded maximum number of curds plant^{-1} (2.41) with 1.0% boron.

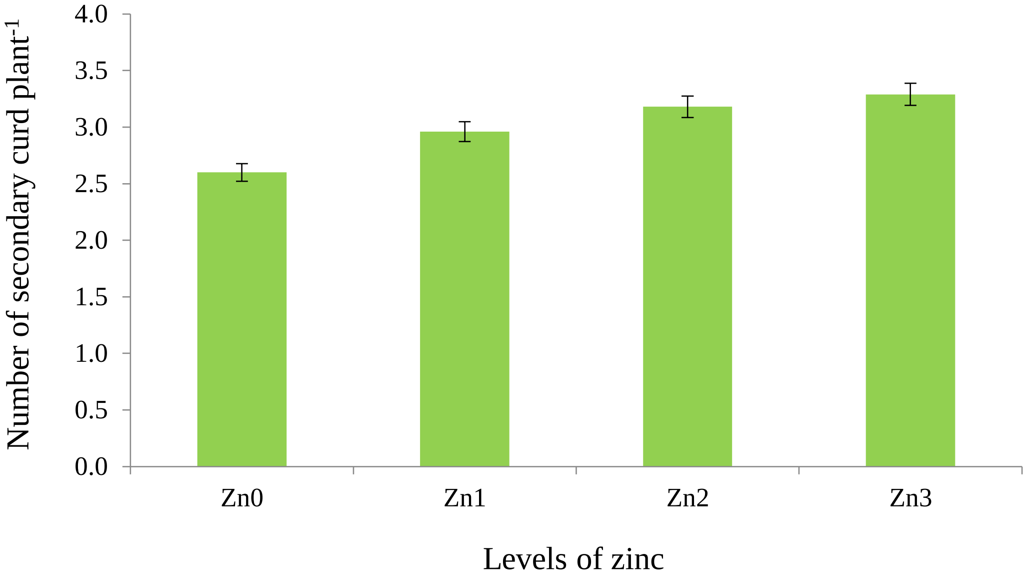
Different levels of zinc showed statistically significant differences in terms of number of secondary curd plant^{-1} of broccoli (Appendix IX). The maximum number of secondary curd plant^{-1} (3.29) was found from Zn_3 which was statistically similar (3.18) to Zn_2, whereas the lowest number (2.60) was recorded from Zn_0 (Figure 11). Yılmaz *et al*. (2013) reported that lateral curd number were increased significantly due to zinc application.

Number of secondary curd plant^{-1} of broccoli varied significantly due to the combined effect of different levels of boron and zinc (Appendix IX). The highest number of secondary curd plant^{-1} (3.60) was found from B_2Zn_3 treatment combination, while the minimum number (2.47) was observed from B_0Zn_0 treatment combination (Figure 12).



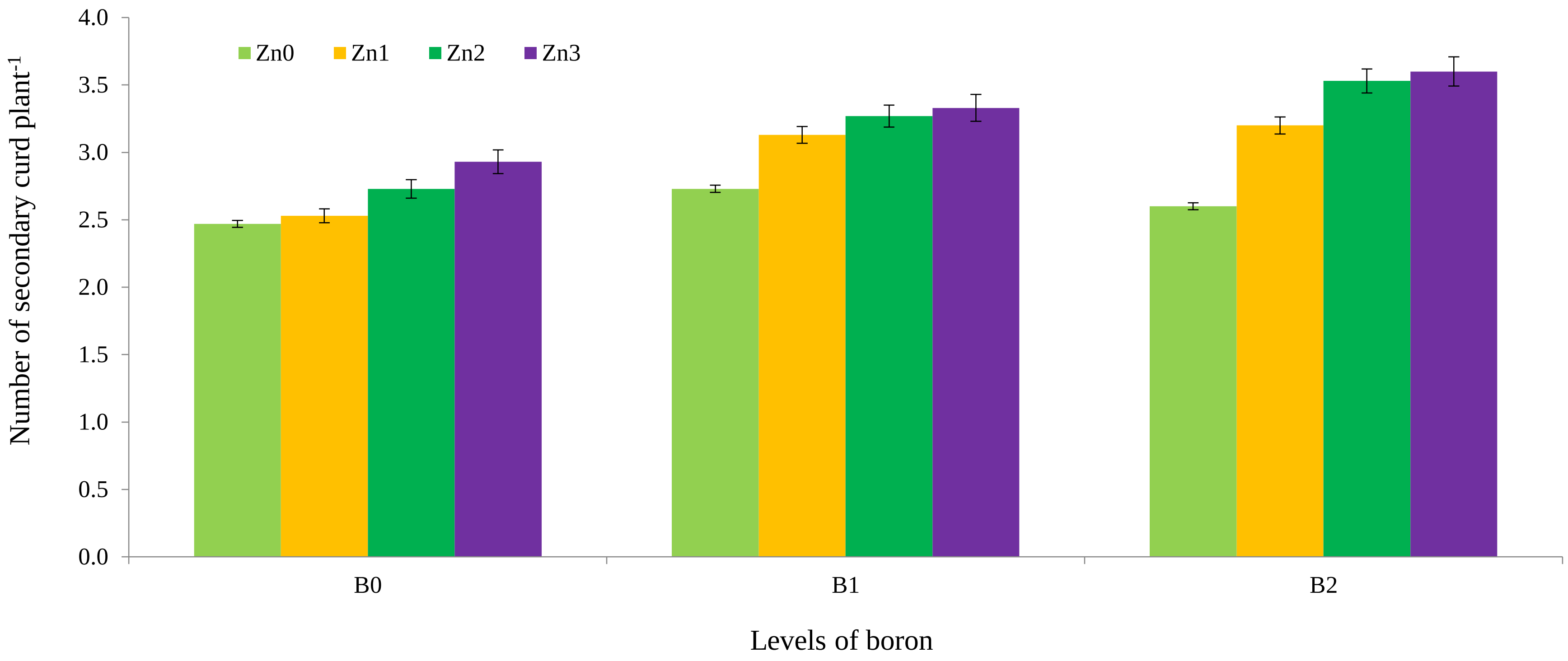
B_0: 0.0 kg B ha^{-1} B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

Figure 10. Effect of different levels of boron on number of secondary curd plant^{-1} of broccoli (Vertical bars represent LSD value at 5% level of probability).



Zn_0: 0.0 kg Zn ha^{-1} Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1} Zn_3: 3.0 kg Zn ha^{-1}

Figure 11. Effect of different levels of zinc on number of secondary curd plant^{-1} of broccoli (Vertical bars represent LSD value at 5% level of probability).



B_0: 0.0 kg B ha^{-1} B_1: 1.0 kg B ha^{-1} Zn_0: 0.0 kg Zn ha^{-1} Zn_1: 1.0 kg Zn ha^{-1}

B_2: 2.0 kg B ha^{-1} Zn_2: 2.0 kg Zn ha^{-1} Zn_3: 3.0 kg Zn ha^{-1}

Figure 12. Combined effect of different levels of boron and zinc on number of secondary curd plant^{-1} of broccoli (Vertical bars represent LSD value at 5% level of probability).

4.13 Secondary curd weight

Secondary curd weight of broccoli varied significantly due to different levels of boron (Appendix IX). The highest secondary curd weight (76.75 g) was observed from B_2 which was statistically similar (74.86 g) to B_1, whereas the lowest weight (65.42 g) was found from B_0 (Table 8). Patel *et al*. (2017) also recorded highest weight of secondary curd with 2.5% borax.

Different levels of zinc showed statistically significant differences in terms of secondary curd weight of broccoli (Appendix IX). The highest secondary curd weight (77.92 g) was recorded from Zn_3 which was statistically similar (75.59 g) to Zn_2 and followed (70.71 g) by Zn_1, while the lowest weight (65.16 g) was found from Zn_0 (Table 8).

Combined effect of different levels of boron and zinc showed statistically significant differences on secondary curd weight of broccoli (Appendix IX). The highest secondary curd weight (84.08 g) was recorded from B_2Zn_3 treatment combination and the lowest weight (60.26 g) was observed from B_0Zn_0 treatment combination (Table 9).

4.14 Curd yield plant^{-1}

Different levels of boron varied significantly in terms of curd yield plant^{-1} of broccoli (Appendix IX). The highest curd yield plant^{-1} (838.68 g) was found from B_2 which was statistically similar (812.78 g) to B_1 and the lowest curd yield plant^{-1} (686.39 g) was recorded from B_0 (Table 8). Moniruzzaman *et al*. (2007) reported that boron application increased head yield plant^{-1} significantly up to 1.5 kg ha^{-1}.

Curd yield plant^{-1} of broccoli showed statistically significant differences due to different levels of zinc (Appendix IX). The highest curd yield plant^{-1} (842.39 g) was observed from Zn_3 which was statistically similar (820.30 g) to Zn_2 and followed (770.05 g) by Zn_1, while the lowest curd yield plant^{-1} (684.40 g) was found from Zn_0 (Table 8). Quratul *et al*. (2016) observed that among various treatments used zinc levels at the rate of 0.5%, showed better result curd yield.

Statistically significant differences was observed due to the combined effect of different levels of boron and zinc in terms of curd yield plant^{-1} of broccoli (Appendix IX). The highest curd yield plant^{-1} (936.09 g) was observed from B_2Zn_3 treatment combination, whereas the lowest curd yield plant^{-1} (649.36 g) was found from B_0Zn_0 treatment combination (Table 9).

4.15 Curd yield hectare^{-1}

Different levels of boron varied significantly in terms of curd yield hectare^{-1} of broccoli (Appendix IX). The highest curd yield hectare^{-1} (23.30 ton) was recorded from B_2 which was statistically similar (22.58 ton) to B_1, while the lowest curd yield hectare^{-1} (19.07 ton) was observed from B_0 (Table 8). Different levels of boron application promoted vegetative growth and different yield attributes and finally yield of broccoli. Moniruzzaman *et al*. (2007) reported that boron application increased head yield hectare^{-1} significantly up to 1.5 kg ha^{-1}. Farooq *et al*. (2018) observed that with increasing levels of B with higher head yield and the highest value was observed when 1.5 kg ha^{-1} B were applied.

Statistically significant differences was observed due to different levels of zinc in terms of curd yield hectare^{-1} of broccoli (Appendix IX). The highest curd yield hectare^{-1} (23.40 ton) was found from Zn_3 which was statistically similar (22.79 ton) to Zn_2, whereas the lowest curd yield hectare^{-1} (19.01 ton) was recorded from Zn_0 (Table 8). Data revealed that 3.0 kg Zn ha^{-1} ensured better growth and maximum yield of broccoli. Yılmaz *et al*. (2013) reported that marketable total yield of broccoli were increased significantly due to zinc application.

Curd yield hectare^{-1} of broccoli showed statistically significant differences due to the combined effect of different levels of boron and zinc (Appendix IX). The highest curd yield hectare^{-1} (26.00 ton) was found from B_2Zn_3 treatment combination, while the lowest curd yield hectare^{-1} (18.04 ton) was observed from B_0Zn_0 treatment combination (Table 9).

4.16 Ascorbic acid

Ascorbic acid of broccoli varied significantly due to different levels of boron (Appendix X). The highest content of ascorbic acid (84.95 mg 100 g^{-1} FW) was obtained from B_2 which was statistically similar (83.26 mg 100 g^{-1} FW) to B_1, while the lowest content of ascorbic acid (81.64 mg 100 g^{-1} FW) was found from B_0 (Table 10). Jakhar *et al*. (2018) reported that boron levels 2.25 kg B ha^{-1} significantly increased ascorbic acid (88.36 mg 100 g^{-1}) as compared to control.

Different levels of zinc showed statistically significant differences in terms of ascorbic acid of broccoli (Appendix X). The highest content of ascorbic acid (84.69 mg 100 g^{-1} FW) was observed from Zn_3 which was statistically similar (83.63 mg 100 g^{-1} FW) to Zn_2 and (82.93 mg 100 g^{-1} FW) to Zn_1, whereas the lowest ascorbic acid (81.88 mg 100 g^{-1} FW) was found from Zn_0 (Table 10).

Combined effect of different levels of boron and zinc showed statistically significant differences on ascorbic acid of broccoli (Appendix X). The highest content of ascorbic acid (87.47 mg 100 g^{-1} FW) was recorded from B_2Zn_3 treatment combination and the lowest content of ascorbic acid (80.47 mg 100 g^{-1} FW) was found from B_0Zn_0 treatment combination (Table 11).

4.17 Reducing sugar

Statistically significant differences was observed in terms of reducing sugar of broccoli due to different levels of boron (Appendix X). The highest content reducing sugar (0.74%) was recorded from B_2 which was followed (0.72%) by B_1, whereas the lowest content of reducing sugar (0.67%) was observed from B_0 (Table 10). Singh *et al*. (2018) reported that foliar application of boric acid @ 0.40% resulted in increased reducing sugar (0.75 %).

Reducing sugar of broccoli varied significantly due to different levels of zinc (Appendix X). The highest content of reducing sugar (0.74%) was found from Zn_3 which was statistically similar (0.73%) to Zn_2 and followed (0.70%) by Zn_1, while the lowest content of reducing sugar (0.67%) was obtained from Zn_0 (Table 10).

Table 10. Effect of different levels of boron and zinc on quality of broccoli

Treatments	Ascorbic acid (mg 100 g^{-1} FW)	Reducing sugar (%)	Total soluble solid (%)	Carbohydrate (%)	Carotenoids (mg 100 g^{-1} FW)
Levels of boron					
B_0	81.64 c	0.67 c	6.29 b	31.35 c	21.90 c
B_1	83.26 b	0.72 b	6.82 a	33.53 b	22.73 b
B_2	84.95 a	0.74 a	6.88 a	34.78 a	23.59 a
$LSD_{(0.05)}$	1.512	0.009	0.144	0.914	0.674
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of zinc					
Zn_0	81.88 b	0.67 c	6.21 d	31.33 c	20.94 c
Zn_1	82.93 ab	0.70 b	6.58 c	32.80 b	22.04 b
Zn_2	83.63 ab	0.73 a	6.85 b	34.02 a	23.73 a
Zn_3	84.69 a	0.74 a	7.02 a	34.74 a	24.25 a
$LSD_{(0.05)}$	1.746	0.010	0.167	1.056	0.778
Level of significance	0.05	0.01	0.01	0.01	0.01
CV(%)	2.14	3.01	2.56	3.25	3.50

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}

Table 11. Combined effect of different levels of boron and zinc on quality of broccoli

Treatments	Ascorbic acid (mg 100 g^{-1} FW)	Reducing sugar (%)	Total soluble solid (%)	Carbohydrate (%)	Carotenoids (mg 100 g^{-1} FW)
B_0Zn_0	80.47 d	0.65 g	6.09 e	30.19 f	20.66 f
B_0Zn_1	81.10 cd	0.66 fg	6.13 e	31.14 ef	21.02 f
B_0Zn_2	82.69 b-d	0.68 de	6.36 de	32.00 ef	22.93 cd
B_0Zn_3	82.29 cd	0.68 de	6.59 cd	32.05 ef	22.98 cd
B_1Zn_0	82.47 cd	0.67 ef	6.29 de	31.57 ef	20.88 f
B_1Zn_1	84.04 bc	0.73 c	6.79 bc	33.05 c-e	22.65 de
B_1Zn_2	82.23 cd	0.72 c	7.03 ab	34.13 b-d	23.25 cd
B_1Zn_3	84.31 a-c	0.75 b	7.18 a	35.38 ab	24.14 bc
B_2Zn_0	82.69 b-d	0.69 d	6.24 e	32.22 d-f	21.28 ef
B_2Zn_1	83.67 b-d	0.72 c	6.81 bc	34.22 bc	22.45 de
B_2Zn_2	85.97 ab	0.78 a	7.17 a	35.92 ab	25.00 ab
B_2Zn_3	87.47 a	0.79 a	7.30 a	36.78 a	25.61 a
$LSD_{(0.05)}$	3.025	0.017	0.288	1.828	1.347
Level of significance	0.05	0.01	0.05	0.05	0.05
CV(%)	2.14	3.01	2.56	3.25	3.50

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

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}

Combined effect of different levels of boron and zinc showed statistically significant differences on reducing sugar of broccoli (Appendix X). The highest content of reducing sugar (0.79%) was found from B_2Zn_3 treatment combination, whereas the lowest content of reducing sugar (0.65%) was recorded from B_0Zn_0 treatment combination (Table 11).

4.18 Total soluble solid

Total soluble solid of broccoli varied significantly due to different levels of boron (Appendix X). The highest total soluble solid (6.88%) was found from B_2 which was statistically similar (6.82%) to B_1 and the lowest total soluble solid (6.29%) was observed from B_0 (Table 10). Metwaly (2016) observed that B was significant effect on TSS.

Different levels of zinc showed statistically significant differences in terms of total soluble solid of broccoli (Appendix X). The highest total soluble solid (7.02%) was recorded from Zn_3 which was followed (6.85%) by Zn_2, while the lowest total soluble solid (6.21%) was found from Zn_0 (Table 10).

Statistically significant differences was observed due to the combined effect of different levels of boron and zinc in terms of total soluble solid of broccoli (Appendix X). The highest total soluble solid (7.30%) was obtained from B_2Zn_3 treatment combination, whereas the lowest total soluble solid (6.09%) was found from B_0Zn_0 treatment combination (Table 11).

4.19 Carbohydrate

Carbohydrate of broccoli varied significantly due to different levels of boron (Appendix X). The highest content of carbohydrate (34.78%) was observed from B_2 which was followed (33.53%) by B_1, while the lowest content of carbohydrate (31.35%) was recorded from B_0 (Table 10). Patel *et al*. (2017) also reported that application of borax influenced carbohydrate content in broccoli.

Statistically significant differences in terms of carbohydrate of broccoli due to different levels of zinc (Appendix X). The highest content of carbohydrate

(34.74%) was obtained from Zn_3 which was statistically similar (34.02%) to Zn_2 and followed (32.80%) by Zn_1, whereas the lowest content of carbohydrate (31.33%) was found from Zn_0 (Table 10).

Combined effect of different levels of boron and zinc showed statistically significant differences on carbohydrate of broccoli (Appendix X). The highest content of carbohydrate (36.78%) was found from B_2Zn_3 treatment combination and the lowest content carbohydrate (30.19%) was observed from B_0Zn_0 treatment combination (Table 11).

4.20 Carotenoids

Different levels of boron showed statistically significant differences in terms of carotenoids content of broccoli (Appendix X). The highest content of carotenoids (23.59 mg 100 g^{-1} FW) was found from B_2 which was followed (22.73 mg 100 g^{-1} FW) to B_1, whereas the lowest content of carotenoids (21.90 mg 100 g^{-1} FW) was observed from B_0 (Table 10). Metwaly (2016) observed that B was significant effect on carotenoids.

Statistically significant variation was observed due to different levels of zinc in terms of carotenoids of broccoli (Appendix X). The highest content of carotenoids (24.25 mg 100 g^{-1} FW) was recorded from Zn_3 which was statistically similar (23.73 mg 100 g^{-1} FW) to Zn_2 and followed (22.04 mg 100 g^{-1} FW) by Zn_1, while the lowest content of carotenoids (20.94 mg 100 g^{-1} FW) was observed from Zn_0 (Table 10).

Carotenoids of broccoli showed statistically significant differences due to the combined effect of different levels of boron and zinc (Appendix X). The highest content of carotenoids (25.61 mg 100 g^{-1} FW) was recorded from B_2Zn_3 treatment combination, whereas the lowest content of carotenoids (20.66 mg 100 g^{-1} FW) was found from B_0Zn_0 treatment combination (Table 11).

4.21 Economic analysis

Cost of production and benefit cost of broccoli cultivation presented in Table 12 and Appendix XI. Price of broccoli was considered as per present market price. The economic analysis presented under the following heads-

4.21.1 Cost of production

Costs for land preparation, boron, zinc, seeds, manpower and all operational cost from seeds sowing to harvesting of broccoli were recorded as per plot and converted into hectare.

4.21.2 Gross return

In consideration of gross return, the combination of different levels of boron and zinc showed different value under the present trial (Table 12). The highest gross return (780,000.00 Tk. ha^{-1}) was recorded from the treatment combination B_2Zn_3 and the second highest gross return (766,500.00 Tk. ha^{-1}) was observed in B_2Zn_2, while the lowest gross return (541,200.00 Tk. ha^{-1}) was found from B_0Zn_0.

4.21.3 Net return

In case of net return, application of different levels of boron and zinc showed different values (Table 12). The highest net return (468,192.00 Tk. ha^{-1}) was obtained from the treatment combination B_2Zn_3 and the second highest net return (454,860.00 Tk. ha^{-1}) was obtained from the combination B_2Zn_2 and the lowest (230,566.00 Tk. ha^{-1}) net return was obtained B_0Zn_0.

4.21.4 Benefit cost ratio

Benefit cost ratio of broccoli varied due to the application of different levels of boron and zinc, the highest benefit cost ratio (2.50) was found from the combination of B_2Zn_3 and the second highest (2.46) was estimated from the combination of B_2Zn_2. The lowest benefit cost ratio (1.74) was obtained from B_0Zn_0 (Table 12). From economic point of view, it is apparent from the above results that the combination of B_2Zn_3 was best than rest of the combination in broccoli cultivation.

Table 12. Cost and return of broccoli cultivation as influenced by different levels of boron and zinc

Treatments	Cost of production (Tk. ha^{-1})	Yield of broccoli (t ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Benefit cost ratio
B_0Zn_0	310,634	18.04	541,200	230,566	1.74
B_0Zn_1	310,802	18.38	551,400	240,598	1.77
B_0Zn_2	310,969	19.68	590,400	279,431	1.90
B_0Zn_3	311,137	20.18	605,400	294,263	1.95
B_1Zn_0	310,969	20.21	606,300	295,331	1.95
B_1Zn_1	311,137	22.94	688,200	377,063	2.21
B_1Zn_2	311,305	23.14	694,200	382,895	2.23
B_1Zn_3	311,473	24.02	720,600	409,127	2.31
B_2Zn_0	311,305	18.79	563,700	252,395	1.81
B_2Zn_1	311,473	22.85	685,500	374,027	2.20
B_2Zn_2	311,640	25.55	766,500	454,860	2.46
B_2Zn_3	311,808	26.00	780,000	468,192	2.50

Price of broccoli @ Tk. 30 kg^{-1}

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka at the period of October 2018 to February 2019 to find out the yield and quality of broccoli as influenced by boron and zinc. The seeds of broccoli Green Giant were used as planting materials for this experiment. The experiment consisted of two factors: Factor A: Boron (3 levels) as- B_0: 0.0 kg B ha^{-1}, B_1: 1.0 kg B ha^{-1}, B_2: 2.0 kg B ha^{-1} and Factor B: Zinc (4 levels) as- Zn_0: 0.0 kg Zn ha^{-1}, Zn_1: 1.0 kg Zn ha^{-1}, Zn_2: 2.0 kg Zn ha^{-1}, Zn_3: 3.0 kg Zn ha^{-1}. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on yield attributes, yield and quality parameters of broccoli were recorded and statistically significant variation was recorded for different treatment.

In case of different levels of boron, at 20, 30, 40, 50 DAT and at harvest, the tallest plant (29.11, 46.17, 58.14, 66.58 and 69.78 cm, respectively) was recorded from B_2, while the shortest plant (24.87, 38.18, 49.66, 55.82 and 58.45 cm, respectively) from B_0. At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (6.77, 12.28, 17.80, 21.93 and 23.17, respectively) was observed from B_2, whereas the minimum number (5.33, 10.35, 15.17, 18.28 and 18.98, respectively) from B_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (16.32, 26.35, 41.01, 44.92 and 46.33 cm, respectively) was found from B_2 and the lowest (14.41, 23.67, 36.58, 39.22 and 41.94 cm, respectively) from B_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.35, 13.34, 16.24, 17.70 and 18.23 cm, respectively) was found from B_2, while the lowest (7.46, 11.32, 13.63, 15.03 and 15.55 cm, respectively) from B_0.

The maximum days to 1st curd initiation (59.25) was observed from B_0 and the minimum days (56.75) from B_2. The longest stem (26.14 cm) was recorded from B_2, whereas the shortest stem (22.47 cm) from B_0. The highest stem diameter (2.32

cm) was found from B_2, while the lowest (1.86 cm) from B_0. The longest root (21.37 cm) was recorded from B_2, whereas the shortest root (19.63 cm) from B_0. The maximum number of roots plant^{-1} (14.77) was found from B_2, whereas the minimum number (12.57) from B_0. The highest primary curd diameter (8.97 cm) was observed from B_2, while the lowest (7.75 cm) from B_0. The highest primary curd weight (587.42 g) was recorded from B_2 and the lowest weight (511.06 g) from B_0. The maximum number of secondary curd plant^{-1} (3.23) was recorded from B_2, while the minimum number (2.67) from B_0. The highest secondary curd weight (76.75 g) was found from B_2, whereas the lowest (65.42 g) from B_0. The highest curd yield plant^{-1} (838.68 g) was found from B_2 and the lowest (686.39 g) from B_0. The highest curd yield hectare^{-1} (23.30 ton) was recorded from B_2, while the lowest (19.07 ton) from B_0.

The highest content of ascorbic acid (84.95 mg 100 g^{-1} FW) was obtained from B_2, while the lowest (81.64 mg 100 g^{-1} FW) from B_0. The highest content reducing sugar (0.74%) was recorded from B_2, whereas the lowest (0.67%) from B_0. The highest total soluble solid (6.88%) was found from B_2 and the lowest (6.29%) from B_0. The highest content of carbohydrate (34.78%) was observed from B_2, while the lowest (31.35%) from B_0. The highest content of carotenoids (23.59 mg 100 g^{-1} FW) was found from B_2, whereas the lowest (21.90 mg 100 g^{-1} FW) from B_0.

For different levels of zinc, at 20, 30, 40, 50 DAT and at harvest, the tallest plant (29.88, 46.98, 58.91, 67.22 and 69.59 cm, respectively) was found from Zn_3, whereas the shortest plant (23.87, 37.94, 49.30, 56.41 and 59.39 cm, respectively) from Zn_0. At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (6.78, 12.31, 18.22, 22.38 and 23.60, respectively) was recorded from Zn_3, while the minimum number (5.33, 10.24, 14.38, 17.40 and 18.40, respectively) from Zn_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (16.82, 27.46, 41.49, 44.98 and 46.87 cm, respectively) was observed from Zn_3 and the lowest (13.82, 21.08, 35.90, 39.51 and 40.81 cm, respectively) from Zn_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.46, 13.49, 16.48, 17.97 and 18.35 cm, respectively) was observed from Zn_3, whereas the lowest (7.15, 11.06, 13.49, 14.97 and 15.57 cm, respectively) from Zn_0.

The maximum days to 1st curd initiation (59.69) was recorded from Zn_0, while the minimum days (55.89) from Zn_3. The longest stem (26.46 cm) was found from Zn_3, while the shortest stem (22.39 cm) from Zn_0. The highest stem diameter (2.34 cm) was observed from Zn_3, whereas the lowest (1.85 cm) from Zn_0. The longest root (21.83 cm) was found from Zn_3, while the shortest root (19.13 cm) from Zn_0. The maximum number of roots plant^{-1} (14.71) was observed from Zn_3, while the minimum number (12.82) from Zn_0. The highest primary curd diameter (9.11 cm) was observed from Zn_3, whereas the lowest (7.71 cm) from Zn_0. The highest primary curd weight (584.65 g) was recorded from Zn_3, while the lowest weight (514.29 g) from Zn_0. The maximum number of secondary curd plant^{-1} (3.29) was found from Zn_3, whereas the lowest number (2.60) from Zn_0. The highest secondary curd weight (77.92 g) was recorded from Zn_3, while the lowest weight (65.16 g) from Zn_0. The highest curd yield plant^{-1} (842.39 g) was observed from Zn_3, while the lowest (684.40 g) from Zn_0. The highest curd yield hectare^{-1} (23.40 ton) was found from Zn_3, whereas the lowest curd yield hectare^{-1} (19.01 ton) from Zn_0.

The highest content of ascorbic acid (84.69 mg 100 g^{-1} FW) was observed from Zn_3, whereas the lowest (81.88 mg 100 g^{-1} FW) from Zn_0. The highest content of reducing sugar (0.74%) was found from Zn_3, while the lowest (0.67%) from Zn_0. The highest total soluble solid (7.02%) was recorded from Zn_3, while the lowest (6.21%) from Zn_0. The highest content of carbohydrate (34.74%) was obtained from Zn_3, whereas the lowest (31.33%) from Zn_0. The highest content of carotenoids (24.25 mg 100 g^{-1} FW) was recorded from Zn_3, while the lowest (20.94 mg 100 g^{-1} FW) from Zn_0.

Due to the combined effect of boron and zinc, at 20, 30, 40, 50 DAT and at harvest, the tallest plant (32.96, 49.67, 63.43, 73.29 and 75.81 cm, respectively) was found from B_2Zn_3 treatment combination and the shortest plant (21.62, 32.31, 44.27, 49.34 and 51.08 cm, respectively) from B_0Zn_0. At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves plant^{-1} (7.73, 13.47, 19.40, 24.20 and 25.73, respectively) was observed from B_2Zn_3 treatment combination, whereas the minimum number (5.07, 10.07, 13.73, 16.13 and 16.67, respectively) from B_0Zn_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf length (17.64, 28.83, 43.73, 47.32 and 48.80 cm, respectively) was recorded from B_2Zn_3 treatment combination, while the lowest (13.17, 20.49, 34.59, 35.48 and 36.98 cm, respectively) from B_0Zn_0. At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (9.20, 14.78, 17.83, 19.39 and 19.67 cm, respectively) was recorded from B_2Zn_3 treatment combination and the lowest (7.13, 10.55, 12.79, 14.12 and 14.64 cm, respectively) from B_0Zn_0.

The maximum days to 1st curd initiation (60.00) was observed from B_2Zn_0 treatment combination, whereas the minimum days (54.67) from B_2Zn_3. The longest stem (28.04 cm) was found from B_2Zn_3 and the shortest stem (20.75 cm) from B_0Zn_0. The highest stem diameter (2.62 cm) was recorded from B_2Zn_3 treatment combination, while the lowest (1.71 cm) from B_0Zn_0. The longest root (22.91 cm) was found from B_2Zn_3 treatment combination and the shortest root (18.46 cm) from B_0Zn_0. The maximum number of roots plant^{-1} (15.73) was recorded from B_2Zn_3, whereas the minimum (11.40) from B_0Zn_0. The highest primary curd diameter (9.89 cm) was recorded from B_2Zn_3 and the lowest (7.39 cm) from B_0Zn_0 treatment combination. The highest primary curd weight (633.42 g) was recorded from B_2Zn_3, whereas the lowest (500.82 g) from B_0Zn_0. The highest number of secondary curd plant^{-1} (3.60) was found from B_2Zn_3, while the minimum number (2.47) from B_0Zn_0. The highest secondary curd weight (84.08 g) was recorded from B_2Zn_3 treatment combination and the lowest weight (60.26 g) from B_0Zn_0. The highest curd yield plant^{-1} (936.09 g) was observed from B_2Zn_3 treatment combination, whereas the lowest (649.36 g) from B_0Zn_0. The highest curd yield hectare^{-1} (26.00 ton) was found from B_2Zn_3 treatment combination, while the lowest (18.04 ton) from B_0Zn_0.

The highest content of ascorbic acid (87.47 mg 100 g^{-1} FW) was recorded from B_2Zn_3 and the lowest (80.47 mg 100 g^{-1} FW) from B_0Zn_0 treatment combination. The highest content of reducing sugar (0.79%) was found from B_2Zn_3 treatment combination, whereas the lowest (0.65%) from B_0Zn_0. The highest total soluble solid (7.30%) was obtained from B_2Zn_3 treatment combination, whereas the lowest (6.09%) from B_0Zn_0. The highest content of carbohydrate (36.78%) was found from B_2Zn_3 treatment combination and the lowest (30.19%) from B_0Zn_0. The highest content of carotenoids (25.61 mg 100 g^{-1} FW) was recorded from B_2Zn_3 treatment combination, whereas the lowest content of carotenoids (20.66 mg 100 g^{-1} FW) from B_0Zn_0.

In economic analysis, in consideration of gross return, the highest gross return (780,000.00 Tk. ha^{-1}) was recorded from the treatment combination B_2Zn_3, while the lowest gross return (541,200.00 Tk. ha^{-1}) was found from B_0Zn_0. In case of net return, the highest net return (468,192.00 Tk. ha^{-1}) was obtained from the treatment combination B_2Zn_3 and the lowest (230,566.00 Tk. ha^{-1}) net return was obtained B_0Zn_0. The highest benefit cost ratio (2.50) was found from B_2Zn_3 and the lowest benefit cost ratio (1.74) was obtained from B_0Zn_0.

Conclusion

- Among differnt levels of boron, 2.0 kg B ha^{-1} showed better yield and yield attributes than other doses;
- Among differnt levels of zinc, broccoli showed better response to 3.0 kg Zn ha^{-1} and
- Finally, 2.0 kg B ha^{-1} with 3.0 kg Zn ha^{-1} encouraged superior growth, yield contributing characters, yield and quality of broccoli.

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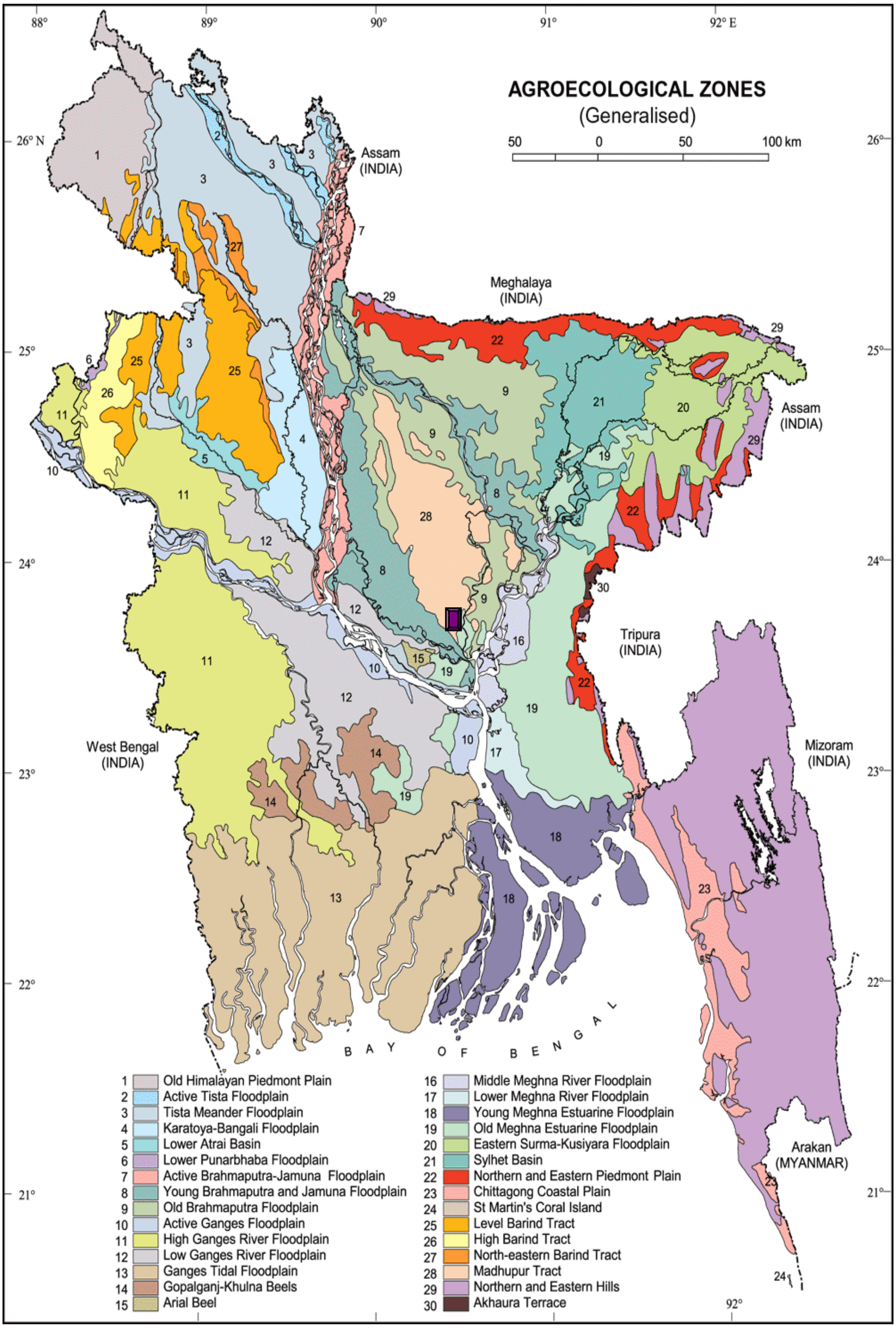
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Farm , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Sandy loam
pH	5.8
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.76
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2018 to February 2019

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2018	26.3	19.2	84	34	6.8
November, 2018	25.9	16.5	75	00	6.7
December, 2018	23.1	13.8	79	18	6.9
January, 2019	24.7	12.1	66	00	5.9
February, 2019	27.2	16.7	68	39	6.6

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix IV. Analysis of variance of the data on plant height at different days after transplanting (DAT) and at harvest of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Plant height (cm) at				
		Mean square				
		20 DAT	30 DAT	40 DAT	50 DAT	Harvest
Replication	2	0.691	1.706	4.635	6.666	6.875
Levels of Boron (A)	2	64.505**	228.565**	248.459**	400.268**	444.519**
Levels of Zinc (B)	3	68.216**	147.107**	171.178**	209.364**	184.821**
Interaction (A×B)	6	10.750*	15.471*	13.885*	58.206**	34.116*
Error	22	3.828	5.842	5.298	14.098	12.024

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

Appendix V. Analysis of variance of the data on number of leaves plant^{-1} at different days after transplanting (DAT) and at harvest of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Number of leaves plant^{-1} at				
		Mean square				
		20 DAT	30 DAT	40 DAT	50 DAT	Harvest
Replication	2	0.063	0.028	0.093	0.274	0.148
Levels of Boron (A)	2	6.973**	12.148**	24.413**	46.134**	58.834**
Levels of Zinc (B)	3	3.843**	7.599**	26.948**	46.487**	46.623**
Interaction (A×B)	6	0.683*	1.169*	2.041**	2.560*	3.546*
Error	22	0.221	0.452	0.486	0.988	1.322

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

Appendix VI. Analysis of variance of the data on leaf length at different days after transplanting (DAT) and at harvest of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Leaf length (cm) at				
		Mean square				
		20 DAT	30 DAT	40 DAT	50 DAT	Harvest
Replication	2	0.010	0.495	0.479	0.374	0.130
Levels of Boron (A)	2	12.398**	23.970**	64.336**	112.193**	63.075**
Levels of Zinc (B)	3	16.213**	75.935**	55.121**	52.756**	65.948**
Interaction (A×B)	6	1.039*	3.045*	4.245*	13.479**	14.588*
Error	22	0.303	1.144	1.761	2.291	2.839

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

Appendix VII. Analysis of variance of the data on leaf breadth at different days after transplanting (DAT) and at harvest of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Leaf breadth (cm) at				
		Mean square				
		20 DAT	30 DAT	40 DAT	50 DAT	Harvest
Replication	2	0.016	0.044	0.083	0.486	0.302
Levels of Boron (A)	2	2.645**	13.601**	23.561**	25.232**	25.029**
Levels of Zinc (B)	3	3.251**	10.704**	15.328**	15.597**	13.545**
Interaction (A×B)	6	0.564**	1.036*	1.862*	1.752*	1.826*
Error	22	0.136	0.336	0.698	0.653	0.642

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

Appendix VIII. Analysis of variance of the data on yield attributes of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Mean square				
		Days to 1st curd initiation	Stem length (cm)	Stem diameter (cm)	Root length (cm)	Number of roots plant^{-1}
Replication	2	0.554	0.403	0.001	0.126	0.215
Levels of Boron (A)	2	22.884**	47.223**	0.692**	10.535**	16.382**
Levels of Zinc (B)	3	21.930**	29.644**	0.429**	12.913**	6.733**
Interaction (A×B)	6	6.822*	1.863*	0.039*	2.978*	2.222**
Error	22	2.348	0.806	0.015	0.636	0.448

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

Appendix IX. Analysis of variance of the data on yield of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Mean square					
		Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curds plant^{-1}	Secondary curd weight (g)	Curd yield plant^{-1} (g)	Curd yield hectare^{-1} (ton)
Replication	2	0.177	193.202	0.008	5.212	182.261	0.141
Levels of Boron (A)	2	5.096**	20937.449**	1.074**	442.446**	79673.832**	61.477**
Levels of Zinc (B)	3	3.628**	9069.208**	0.833**	287.721**	44260.809**	34.152**
Interaction (A×B)	6	0.505*	2141.782**	0.073*	44.832**	6506.340*	5.020*
Error	22	0.186	622.699	0.025	10.621	2255.784	1.741

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

Appendix X. Analysis of variance of the data on quality of broccoli as influenced by different levels of boron and zinc

Treatments	Degrees of freedom	Mean square				
		Ascorbic acid (mg 100 g^{-1} FW)	Reducing sugar (%)	TSS (%)	Carbohydrate (%)	Carotenoids (mg 100 g^{-1} FW)
Replication	2	1.931	0.0001	0.024	0.571	0.084
Levels of Boron (A)	2	32.891**	0.017**	1.265**	36.350**	8.540**
Levels of Zinc (B)	3	12.589*	0.008**	1.150**	20.095**	20.901**
Interaction (A×B)	6	10.743*	0.003**	0.072*	3.616*	1.852*
Error	22	3.191	0.0001	0.029	1.166	0.633

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

Appendix XI. Per hectare production cost of broccoli

A. Input cost

Treatments	Labour cost	Ploughing cost	Seedling cost	Water for plant establishment	Cost of manure and fertilizers				Insecticide/ pesticides	Sub total (A)
					Cowdung	Fertilizer	B	Zn		
B_0Zn_0	65,000	50,000	18,000	35,000	10,000.00	3,500	0	0	22,000	203,500
B_0Zn_1	65,000	50,000	18,000	35,000	10,000.00	3,500	0	150	22,000	203,650
B_0Zn_2	65,000	50,000	18,000	35,000	10,000.00	3,500	0	300	22,000	203,800
B_0Zn_3	65,000	50,000	18,000	35,000	10,000.00	3,500	0	450	22,000	203,950
B_1Zn_0	65,000	50,000	18,000	35,000	10,000.00	3,500	300	0	22,000	203,800
B_1Zn_1	65,000	50,000	18,000	35,000	10,000.00	3,500	300	150	22,000	203,950
B_1Zn_2	65,000	50,000	18,000	35,000	10,000.00	3,500	300	300	22,000	204,100
B_1Zn_3	65,000	50,000	18,000	35,000	10,000.00	3,500	300	450	22,000	204,250
B_2Zn_0	65,000	50,000	18,000	35,000	10,000.00	3,500	600	0	22,000	204,100
B_2Zn_1	65,000	50,000	18,000	35,000	10,000.00	3,500	600	150	22,000	204,250
B_2Zn_2	65,000	50,000	18,000	35,000	10,000.00	3,500	600	300	22,000	204,400
B_2Zn_3	65,000	50,000	18,000	35,000	10,000.00	3,500	600	450	22,000	204,550

B_0: 0.0 kg B ha^{-1}
B_1: 1.0 kg B ha^{-1}
B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}
Zn_1: 1.0 kg Zn ha^{-1}
Zn_2: 2.0 kg Zn ha^{-1}
Zn_3: 3.0 kg Zn ha^{-1}

Appendix XI. Per hectare production cost of broccoli

A. Overhead cost (Tk. ha^{-1})

Treatments	Cost of lease of land (13% of value of land Tk. 12,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
78,000	10,175	18,959	107,134	310,634	78,000
78,000	10,183	18,969	107,152	310,802	78,000
78,000	10,190	18,979	107,169	310,969	78,000
78,000	10,198	18,990	107,187	311,137	78,000
78,000	10,190	18,979	107,169	310,969	78,000
78,000	10,198	18,990	107,187	311,137	78,000
78,000	10,205	19,000	107,205	311,305	78,000
78,000	10,213	19,010	107,223	311,473	78,000
78,000	10,205	19,000	107,205	311,305	78,000
78,000	10,213	19,010	107,223	311,473	78,000
78,000	10,220	19,020	107,240	311,640	78,000
78,000	10,228	19,031	107,258	311,808	78,000

B_0: 0.0 kg B ha^{-1}

B_1: 1.0 kg B ha^{-1}

B_2: 2.0 kg B ha^{-1}

Zn_0: 0.0 kg Zn ha^{-1}

Zn_1: 1.0 kg Zn ha^{-1}

Zn_2: 2.0 kg Zn ha^{-1}

Zn_3: 3.0 kg Zn ha^{-1}