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

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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF CHILI" submitted to the DEPARTMENT OF SOIL SCIENCE, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in SOIL SCIENCE, embodies the results of a piece of bona fide research work carried out by SHAHNAZ SHARMIN, Registration. No. 18-0982, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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Abstract

The research work was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the Rabi season of November, 2019 to March, 2020 to study the effects of zinc (Zn) and boron (B) on the growth and yield of chili. Two factor experiments with Randomized Complete Block Design (RCBD) was followed with 9 treatments (Zn_0B_0, Zn_1B_0, Zn_0B_1, Zn_0B_2, Zn_2B_0, Zn_1B_1, Zn_1B_2, Zn_2B_1 and Zn_2B_2 where Zn_0: 0 kg Zn ha^{-1}, Zn_1: 2 kg Zn ha^{-1}, Zn_2: 4 kg Zn ha^{-1}, B_0: 0 kg B ha^{-1}, B_1: 1.5 kg B ha^{-1} and B_2: 3 kg B ha^{-1}) and replicated thrice. All of the growth and yield parameters of chili were significantly affected and increased with increasing levels of Zn and B. The tallest plant (76.67 cm), maximum value of number of leaves plant^{-1} (79.67), number of branches plant^{-1} (14.67), number of fruits plant^{-1} (74.78), fruit length (6.47cm), number of flowers plant^{-1} (86.67) were found in Zn_2B_1 treatment. The interaction effect of Zn_2B_1 treatment results the highest weight of fruits (304.00g), maximum yield (12.67 t ha^{-1}) and highest percentage of yield increase over control (67.09%). The results of this research work indicated that the plants performed better in Zn_2B_2 treatment over the control treatment (Zn_0B_0). The treatment combination of Zn_1B_1 had shown closest results to Zn_2B_2 treatment. It can be concluded from the above study that the treatment Zn_2B_1 (Zn@ 4 kg ha^{-1} and B @ 1.5 kg ha^{-1}) was found to the most suitable treatment combination for the higher yield of chili in shallow Red Brown Terrace Soils of Bangladesh

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CHAPTER I

INTRODUCTION

Chili (*Capsium annuum L.),* the most important spice crop is grown all over Bangladesh. It is an indispensable spice, which is liked for pungency and spicy taste and the appealing color adds to the curry. Chili occupies about 1,80,000 hectares with a production of 1,50,000 tons (BBS, 2001). However, the average yield of dry chili is low (700-800 kg/ha) in Bangladesh compared to the neighboring countries (1000-1200 kg/ha). One of the reasons of lower yield might be imbalanced use of fertilizers and manure and low levels of available Zn and B in the soils of major chili growing areas.

Chilies are very rich in vitamin C and pro-vitamin A, particularly the red chilies. Yellow and especially green chilies (which are essentially unripe fruit) contain a considerably lower amount of both substances. In addition, peppers are a good source of most B vitamins, and vitamin B6 in particular. They are very high in potassium and high in magnesium and iron. Their high vitamin C content can also substantially increase the uptake of non-heme iron frother ingredients in a meal, such as beans and grains. Chemical analysis of chilli have shown that red chilli fruit contains 15.9% protein, 31.6% carbohydrate, 50 mg/100g vitamin-C and small quantities of vitamin A, B and E (Sparkyby, 2006).

It is realized that productivity of crop is being adversely affected in different areas due to deficiencies of micronutrients (Bose and Tripathi, 1996). The deficiency of micronutrients increased markedly due to intensive cropping, loss of top soil by erosion, loss of micronutrients by leaching, liming of soil and lower availability and use of farm yard manure (Fageria *et al.,* 2002). Micronutrients are usually required in minute quantities, nevertheless are vital to the growth of plant (Benepal, 1967).

Improvement in growth characters as a result of application of micronutrients might be due to the enhanced photosynthetic and other metabolic activity which leads to an increase in various plant metabolites responsible for cell division and elongation as opined by Hatwar et al. (2003).

Zinc (Zn) also played a vital role for successful green chilli production. Singh *et al*. (1989) observed that higher plant height with soil application of zinc sulphate as well as foliar spray. Application of zinc at the rate of 3 ppm noticed maximum number of leaves and number of roots per plant (Sindhu and Tiwari, 1989) and soil plus foliar application of zinc sulphate each at 20 kg/ha and 0.5% respectively produced maximum number of branches per plant (7.52) (Singh et al., 1989) where application of $ZnSO_4.7H_2O$ received by chilli at 20 kg per ha enriched with vermicompost recorded the highest yield (Patil *et al*., 2011). One of the reasons of lower yield might be imbalanced use of fertilizers and manure and low levels of available Zn in the soils of major chilli growing areas (Bose and Tripathi, 1996).

The deficiency of B retards apical growth and development because of its impacts on cell development and on sugar formation and translocation. Boron also plays an important part in flowering and fruiting processes, N metabolism, hormonal action and cell division. The nutrient removal and uptake capacity by capsicum cultivar is higher, which indicates the greater nutrient requirements by chili. Integrated use of both chemical fertilizers and organic manure was found significant in increasing the growth and yield of chili (Sharma *et al.,* 1996; and Hegde, 1997). Nitrogen @ 120 kg/ha and P @ 60 kg/ha produced significantly higher yield of chili (Sharma *et al.,* 1996). Singh and Srivastava (1998) recommended 120 kg N and 60 kg P/ha for high yield. Karnataka (2009) recorded highest yield of chili with N P K @ 100:50:50 kg/ha and secondary and micronutrients. Ahmed and Tanki (1991) worked out the optimum dose of nitrogen and phosphorus to be 120 kg/ha and 82.8 kg/ha, respectively. Potassium had no influence on yield, duration of flowering, plant height, and fruit ripening. Sporadic research works on nutrient management on chili were done where N, P, K, and S fertilizers were considered for recommendation. However, no systematic research work has been done so for to find out the response of chili to zinc and boron fertilization. The photosynthesis enhanced in presence of zinc and boron was also reported by Rawat and Mathpal (1984). Mallick and Muthukrishnan (1979) explained that presence of zinc activates the synthesis of tryptophan, the precursor of IAA and it is responsible for stimulated plant growth.

The potential chili growing soils in north-western regions of Bangladesh was reported to be zinc and boron deficient. Like many other crops, chili might be responsive to zinc and boron fertilization especially for rabi season when the availability of Zn is likely to reduce further due to low temperature. The present study was therefore, undertaken (i) to evaluate the response of zinc and boron on chili and (ii) to find out the optimum dose of zinc and boron for maximizing the yield of chili.

Objectives:

Determine the effect of Zn and B on the yield parameters of chili.

CHAPTER II
REVIEW OF LITERATURE

Nutrient deficiency in soil is the key factor for poor productivity of chili. The extent and magnitude of nutrient deficiency has aggravated in the recent past due to intensive agriculture and indiscriminate use of plant nutrients. Although many research works on chili have been performed extensively in several countries in the world, in Bangladesh, little attention has so far been given for the improvement of mungbean variety or its cultural management. Currently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research work on varietal development and improvement of this crop. A very few studies related to yield and development of chili have been carried out in our country as well as many other countries of the world, which is not adequate and conclusive. In this chapter, an attempt has been made to review the available information at home and abroad regarding the effect of Zn and B on the yield of chili and other solanaceae.

2.1 EFFECT OF ZINC (Zn)

Jamre *et al*.(2010) highlighted the effect of different levels of S and Zn on growth of cauliflower at College of Agriculture, Gwalior (M.P.) Maximum plant height (57.25 cm), plant spread (1918.02 cm^2) and dry matter yield (10.60) were recorded due to soil application of zinc sulphate at 6 kg ha^{-1} compared to control. Similarly, Rohidas *et al*. (2010) conducted an experiment on the effect of micronutrients on yield of chili at Marathwada Agriculture University.

Baloch *et al*. (2008) conducted a study with commercial foliar fertilizer, HiGrow is a composition of various macro and micronutrients was applied on chilies at the concentrations 4, 5, 6, 7 and 8 ml/L water in addition to soil applied NPK fertilizers at 50-50-25 kg ha^{-1} to investigate their associative effect on production of green chilies. Hi Grow at 8 ml/L water resulted 68 cm plant height, 6.93 branches $plant^{-1}$, 118.86 fruits $plant^{-1}$, 4.19 cm fruit length, 395 g fresh chilies fruit weight $plant^{-1}$ and 14977 kg fresh chilies yield ha^{-1}; while decreasing concentration to 7 ml/L water produced 67.86 cm plant height, 6.53 branches $plant^{-1}$, 117.20 fruits $plant^{-1}$, 4.14 cm fruit length, 391.33 g fresh chilies weight $plant^{-1}$ and 14562.33 kg fresh chilies yield ha^{-1}. HiGrow at 6 ml/L water formed 66.46 cm plant height, 5.80 branches $plant^{-1}$, 112.36 fruits $plant^{-1}$, 3.89 cm fruit length, 351.66 g fresh chilies weight $plant^{-1}$ and 12696.33 kg fresh chilies yield ha^{-1}.

Singh *et al*. (1989) conducted an experiment at N. D. University of Agriculture and Technology, Faizabad (U.P.) to study the growth and yield of chili in relation to zinc levels. Results showed higher plant height (40.47 cm) with soil application of zinc sulphate as well as foliar spray (20 kg $ZnSO_4$ + 0.5% foliar spray).

Sindhu and Tiwari (1989) conducted an experiment to study the effect of micronutrients on chilli (CV. Pusa Red) at G.B. Pant University of Agriculture and Technology, Pantnagar (Uttaranchal). Result revealed that, application of zinc @ 3ppm noticed maximum number of leaves and number of roots per plant. Similarly, an experiment was conducted by Singh *et al*. (1989) at N. D. University of Agriculture and Technology, Faizabad (U.P.) to study the growth and yield of chilli in relation to zinc levels. Results showed that, soil + foliar application of zinc sulphate each at 20 kg/ha and 0.5% respectively produced maximum number of branches per plant (7.52).

Patil *et al*. (2011) reported the effect of zinc and iron levels on yield of chili at AICRP, Belvatagi, UAS, Dharwad (Karnataka). Results showed that, chili crop receiving application of $ZnSO_4.7H_2O$ and $FeSO_4.7H_2O$ each at 20 kg per ha^{-1} enriched with vermicompost recorded the highest yield (1.85) tonnes per ha. Das (2007) highlighted the importance of zinc in maintaining the integrity of biomembrane viz., pericarp in chillies. It may bind to phospholipid and sulphydryl groups of pericarp component of red chillies to form tetrahedral complexes. Zinc may further protect membrane lipid and proteins against oxidative damage.

Swati Barche *et al*. (2011) conducted an experiment on the effect of foliar application of micronutrients on chilli (Cv Rashmi) at College of Agriculture, JNKVV, (M. P.). Results revealed that maximum plant height (80.40 cm), number of branches (34.43) and number of flowers (41.47) per plant were recorded with the application of Boric acid + $ZnSO_4$ + $CuSO_4$ each at 250 ppm. Similarly Yadav *et al*. (2001) studied the effect of zinc sulphate application on growth of Chili (Cv. Jaffa) at CCS Agricultural University, Hissar (Haryana). Results showed significant increase in plant height (10.71 cm) and plant spread (10.78 cm) with the application of zinc sulphate @ 250 g/plant. Minimum values of plant height (8.11cm) and plant spread (7.40 cm) were recorded under control. Satyapal Singh and Prabhakar Singh (2004) conducted an experiment to know the effect of foliar application of nitrogen and zinc on yield of chili at College of Agriculture, Jobner (Rajasthan).

Mahesh Kumar and Sen (2005) conducted an experiment to study the effect of zinc, boron and gibberallic acid on the yield of chili at Rajasthan College of Agriculture, Udaipur (Rajasthan). Results revealed that, application of zinc upto 30 kg/ ha as $ZnSO_4$ significantly improved the number of fruits per plant (13.34), fruit length (16.82 cm), fruit weight (16.58 g), yield per plant (218.55g) as well as yield/ha (147.20 q/ha).

Halder *et al.* (2007) conducted an experiment to study the effect of soil application of zinc sulphate on yield of ginger at Agriculture Research Institute, Joydebpur, Bangladesh. Results showed that, maximum number of primary fingers (4.5), secondary fingers (5.6) and tertiary fingers (4.0) were due to application of $ZnSO_4$ at 4.5 kg /ha. Similarly weight of fingers (209 g), weight of fingers per plant (261g) and weight of corm (36.3 g) were observed due to application of 4.5 kg /ha of zinc sulphate.

Giridhar Kalidasu *et al.* (2008) reported the influence of micronutrients on yield and yield attributing characters of coriander under rainfed conditions ANGRAU, Hyderabad (A.P.). Results revealed, maximum number of umbels per plant (27.4), number of umbellets per umbel (6.4) and yield per ha (940 kg) in treatment that received combined application of $ZnSO_4$ + $FeSO_4$ + $CuSO_4$ + $MnSO_4$ each at 0.5 per cent concentration.

An experiment was conducted to study the effect of different levels of sulphur and zinc on growth of cauliflower at College of Agriculture, Gwalior (M.P.). Results revealed that, highest fresh weight of curd per plant (0.851 kg/plant) and yield of curd per ha (317.57 q/ha) were recorded due to soil application of zinc sulphate at the rate of 6 kg per hectare (Jamre *et al.* 2010).

Rohidas *et al.* (2010) reported the effect of micronutrients on yield of garlic at Marathwada Agriculture University, Parbhani (Maharashtra). Maximum fresh weight of bulbs(35.55 g), cured weight of bulbs (33.15 g), weight of clove (2.65 g) and bulb yield per ha (155.39 q/ha) were recorded due to foliar application of zinc sulphate at 4 ppm.

Patil *et al.* (2010) conducted an experiment to study the effect of foliar application of micronutrients on yield of tomato (CV. Phule Raja) at College of Agriculture, Latur, Parbhani (Maharashtra). Results revealed that, application of Fe + Zn each at 100 ppm along with boron at 50 ppm significantly increased the total number of fruits (23.88) and number of marketable fruits/plant (20.34).

Shil *et al*. (2013) conducted a field trial on chili (cv. Bogra local) in Grey Terrace Soil under AEZ-25 (Level Barind Tract) at Spice Research Centre. The objectives were to evaluate the response of chili to zinc to find out the optimum dose of zinc for maximizing the yield. Treatments for this study comprised of four levels each of zinc (0, 1.5, 3.0, and 4.5 kg/ha) along with a blanket dose of N130 P60 K80 S20 Mg10 kg/ha. The effect of zinc was significant in case of yield of dry chili and weight of ripe chilli/plant. However, from regression analysis, the optimum economic dose of zinc was found to be 3.91 kg/ha. Hence, a package of (Zn 3.91 kg/ha) along with the said blanket dose may be recommended for maximizing the yield of chili in the study area.

Three micronutrients (Zn, Fe, B) were tried in three concentrations i.e. 0.1, 0.25 and 0.50% foliar spray in a field experiment conducted by Dongre *et al*. (2000). There were ten treatments replicated three times and applied at 30 and 60 days after transplanting. The observation on fruit yield per plant and quality of chili fruits per plant were recorded and analysed statistically. The treatment T_3 ($ZnSO_4$ 0.50%) exhibited the maximum yield (111.75 q/ha) and treatment T5 ($FeSO_4$ 0.25%) produced the maximum number of seeds/fruit (57.93).

The study was conducted with a pot experiment by Datir *et al*. (2012) to determine the effects of foliar application of organically chelated micronutrients on growth and yield in chili (*Capsicum annum* L.). The micronutrients like iron, zinc, copper and manganese were organically chelated with seed amino acids. Forty day's old seedlings of chili were transplanted in the pots. The experimental plants were sprayed with three doses (0.5, 1.5 and 2.0%) of organically chelated micronutrients along with unchelated micronutrients, amino acid solution and untreated control plants on 15^{th} and 30^{th} days after transplantation. The results based on two years mean revealed that out of five different treatments, the application of amino acid-micronutrient chelate at the concentration of 1.5 and 2.0% resulted in maximum plant height, number of primary branches, higher leaf area per plant, fruits per plant and more total yield per plant.

Yogananda *et al*. (2004) conducted an experiment with ten grams seeds of bell pepper [Capsicum annuum] (cv. California Wonder) were soaked in 150 ml. solution each of gibberellic acid (GA_3) at 100 (T_1), 150 (T_2) and 200 ppm (T_3); T_1 + cytokinin at 100 ppm (T_4), T_2 + cytokinin at 50 ppm (T_5), T_3 + cytokinin at 50 ppm (T_6), NAA at 40 ppm (T_7), Miraculon at 200 (T_8), 450 (T_9) and 750 ppm (T_{10}), $CuSO_4$ at 0.2% (T_{11}), $ZnSO_4$ at 0.2% (T_{12}), Borax at 0.4% (T_{13}), $MgSO_4$ at 0.2% (T_{14}), KNO3 at 0.5% (T_{15}) and 1.0% (T_{16}) for 24 hour and dried back to original weight. A control (T_0) was included. Significantly higher germination (91.05%) was obtained with T_3 compared with other concentrations of GA3, combination of GA3 + cytokinin treatments and T_7. However, these treatments recorded higher germination over T_0 (81.5%). Significantly longer root (5.55 cm) and shoot (7.50 cm), higher germination rate (12.75), seedling dry weight (53.5 mg) and seedling vigour index (1174) were obtained from seeds invigourated with T3 compared to the control (4.27 cm, 5.75 cm, 9.04, 42.25 mg and 518, respectively). Seeds invigourated with the micronutrients significantly increased the seed germination. Among the micronutrients, T_{15} recorded significantly higher germination (89.75%) over the control. T_{11}, T_{12}, T_{13} and T_{14} also recorded significantly higher germination, root length, shoot length, seedling dry weight, germination rate and seedling vigour index over the control.

Salam *et al*. (2011) carried out an experiment to investigate the effect of boron, zinc, and cowdung on quality of tomato. There were 16 treatments comprising four rates of boron and zinc viz., B_0Zn_0. $B_{1.5}Zn_2$ B_2Zn_4 and $B_{2.5}Zn_6$ kg/ha and four rates of cowdung viz., CD_0, CD_{10}, CD_{15}, and CD_{20} t/ha. Every plot received 253 kg N, 90 kg P, 125 kg K, and 6.6 kg S per hectare. The results reflected that the highest pulp weight (90.24%), dry matter content (5.82%), ascorbic acid (11.2 mg/100g). lycopene content (147 µg/100g), chlorophyll-a (42.0 µg/l00g), chlorophyll-b (61.0 µg/100g), boron content (36 µg/g), zinc content (51 µg /g), marketable fruits at 30 days after storage (74%) and shelf life (17 days) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cowdung. From the above review of literature it is revealed that Ca and Zn had significant effect on growth, yield contributing characters and yield of green chili.

EFFECT OF BORON (B)

The main effect of boron on the yield and yield component of chili are presented in Table 4. The highest dry yield (917, 933 and 933 kg/ha for the first, second and third year, respectively) was obtained with 2.0 kg B/ha, which was significantly higher over control and the highest dose (3.0 kg B ha^{-1}) but at par with immediate lower dose (1.0 kg B ha^{-1}). Three years' mean yield varied from 759.0 to 927.7 kg ha^{-1} where the highest result was estimated with 2.0 kg B/ha and the lowest in boron control. As a result, boron contributed yield benefit over control by 20.9, 22.2 and 13.0 % for 1.0, 2.0 and 3.0 kg B/ha, respectively. These findings revealed that 1.0-2.0 kg B/ha are sufficient enough for maximizing the yield of chilli. The yield of chilli was increased with boron application as reported by Govindan (1952).

Duraisamy *et al.* (1999) stated that dry matter content of the fruits was favourably influenced by the application of 100% soil test based NPK combined with borax (10 kg/ha), zinc sulphate (50 kg/ha), and coir pith (5 t/ha).

Kavvadias *et al* (2012) stated that the foliar application of Boron concentration in fruits of that treatment was increased in both cultivation years compared to most of the applied treatments. Foliar application of B at flowering, fruit set, and fruit growth, primarily in combination with foliar calcium (Ca) application, showed fruits to be less affected by cracking over all treatments.

Ali *et al.* (2015) studied the effect of foliar application of Zn and B in tomato. Maximum plant height, number of leaves, leaf area, number of branches, number of clusters, were found from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3 while minimum from control. Foliar application of Zn and B was more effective than the individual application of Zn or B on growth and yield for summer season tomato (BARI hybrid tomato 4).

Mashayekhi *et al*. (2015). conducted an experiment to evaluate the influence of plants foliar spray by sucrose and Boron on some characteristics of the fruit and leaves of tomato v. Super-A. Most of the brix, acidity, dry matter, sucrose, glucose, fruit and lycopene related to the interaction of 0.2% of Boron by five percent sucrose. In an aggregation of the best treatment for the purposes of processing and conversion, fresh salad, and drug, treatment 0.2% Boron with a 5% sucrose in order to increase in the amount of brix, acidity, dry weight, glucose and sucrose in fruit lycopene and appropriate values anthocyanins and fresh fruit is recommended.

Oliveira *et al.* (2015) conducted the study to evaluate the effect of the application of boron (B) by foliar spraying for the yield of beet and tomato crops. The highest yield of the tuberous root and the total plant dry matter of beet occurred with B foliar concentration of 0.065 g L^{-1} and it was associated with the B foliar content of 26 mg kg^{-1}. The highest yield of fruit and total plant dry matter of tomato occurred with the B foliar spraying of 0.340 g L^{-1} and it was associated with the B foliar content of 72 mg kg^{-1}.

Suganiya and Kumuthini (2015) studied the effect of boron on flower and fruit setting and yield of ratoon crop of brinjal (*Solanum melongina* L.) in the Eastern Region of Sri Lanka. The results showed that foliar application of boron (H_3BO_3) at 150 ppm increased the number of flower buds/plant flowers/cluster, flower clusters/plant, total flowers/plant, percentage of flower set, percentage of fruit set, fruits/plant and fresh weight of fruits/plant than that of control. It was, therefore, concluded that foliar application of H_3BO_3 at 150 ppm (at flowering stage) could increase the percentage of flowering, fruit set and fruit yield per plant of ratoon crop of brinjal.

El-Feky *et al.* (2012) carried out an experiment to assess the role of elevated concentrations of boron in barley (*Hordeum vulgare* L. cv. Giza 123) growth and yield. The inhibitory effects of boron on barley growth started at concentrations above 3.0 mg L^{-1}, causing decrease in all the measured parameters. The five tested growth modulators alleviated boron toxicity at 3.0 mg L^{-1} at the following sequence: salicylic acid (1 mM), calcium chloride 5 mM ≥, ascorbic acid (2 mM) ≥, glycine (1 mM) and glutamic acid (3 mM).

Saleem *et al.,* (2011) investigated Boron is unique, not only in its chemical properties, but also in its roles in biology. Normal healthy plant growth requires a continuous supply of B, once it is taken up and used in the plant; it is not translocated from old to new tissue. That is why, deficiency symptoms starts with the youngest growing tissues. Therefore, adequate B supply is necessary for obtaining high yields and good quality y of agriculture crops.

Quaggio and Ramos (1986) studied the influence of micronutrient boron on the production of potato. Boron was applied at the rates of 0, 3, 6, 9 and 12 kg/ha as boric acid. The authors found that the effect of boron was more pronounced on the yield of large sized tubers than on the small ones.

Palkovics and Gyori (1984) to determined the effect of boron on the growth and yield of potato cv. Somogy on rusty forest soil. It was observed that the application of boron contributed to yield increments and to the improvement of tuber quality. The critical level of B was 60 mg/kg of foliage and above this, B content depressed yield.

Efkar *et al.* (1995) carried out an experiment to study the response of potato cv. Desiree to the application of boron fertilizer in Pakistan using 4 levels of boron (0, 1, 1.5 and 2 kg/ha). The crop also received a basal dressing of NPK fertilizers and FYM (5 t/ha). Application of 1.5 kg B/ha gave the highest tuber yield of 10.9 t/ha compared with the control yield of 7.9 t/ha.

Chude *et al.* (2001) reported that plant response to soil and applied boron varies widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato (Lycopersicon lycopersicum [Lycopersicon esculentum] cultivars to a range of boron levels in field trials at Kadawa (11° 39' N, 8° 2' E) and Samaru (11° 12', 7° 37' E) in Sudan and northern Guinea savanna, respectively, in Nigeria. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg/ha replicated three times in a randomized complete block design. Treatment effects were evaluated on fruit yield and nutritional qualities of the two tomato cultivars at harvest. There was a highly significant (P=0.01) interaction between B rates and cultivars, with Dandino producing higher yields than Roma VF in both years and locations.

CHAPTER III
MATERIALS AND METHODS

This chapter includes a brief description of the experimental site, experimental period, climatic condition, crop or planting materials, land preparation, experimental design and layout, crop growing procedure, treatments, intercultural operations, data collection, preparation and chemical analysis of soil along with statistical analysis.

3.1 Soil description of experimented area

The Research work was done to study the effects of Zn and B fertilization on the growth, and yield of chili at Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during Rabi Season 2019-2020. The experimental location situated at $23^{0}77$ N and $90^{0}33$ E longitude with an elevation of 8.2 meter from sea level.

3.2 Description of soil

Soil of the experimented field belongs to the Tejgaon series under the Agro ecological Zone, AEZ-28 (Madhupur Tract). In this series soil types are in general is shallow 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 experiment. The collected soil was oven-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. The morphological characteristics of the experimental field and initial physical and chemical characteristics of the soil are presented in Table 3.1, 3.2 and 3.3 respectively.

Table 3.1 Morphological characteristics of experimental field

Morphological features	*Characteristics*
Location	Sher-e-Bangla Agricultural University
AEZ No. and name	AEZ-28, Madhupur Tract
General soil type	Shallow Red Brown Terrace Soil
Soil series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	Medium high land

Table 3.2 Physical properties of the initial soil of the experimental field

%Sand(2-0.02 mm)	32.42
%Silt(0.02-0.002 mm)	32.63
%Clay(<0.002 mm)	34.95
Textural Class	Clay Loam
Particle density	2.20 g cc^{-1}

Table 3.3 Chemical characteristics of the initial soil of the experimental field

pH	6.25
Organic Matter(%)	0.82
Organic Carbon (%)	0.48
Total N (%)	0.11
Available P (ppm)	16
Exchangeable K (meq/100g soil)	0.12
Available S (ppm)	12.09

3.3 Climate

The experimental area has sub-tropical climate characterized by medium temperature, medium rainfall during November, 2019 to March, 2020 and scanty rainfall during rest of the year. The annual precipitation of the site is 2052 mm and potential evapotranspiration is 1286 mm, the average maximum temperature is 26-32^{0}C, average minimum temperature is 12.4^{0}C and the average mean temperature is 28.12^{0}C (BBS, 2019).

3.4 Plant material

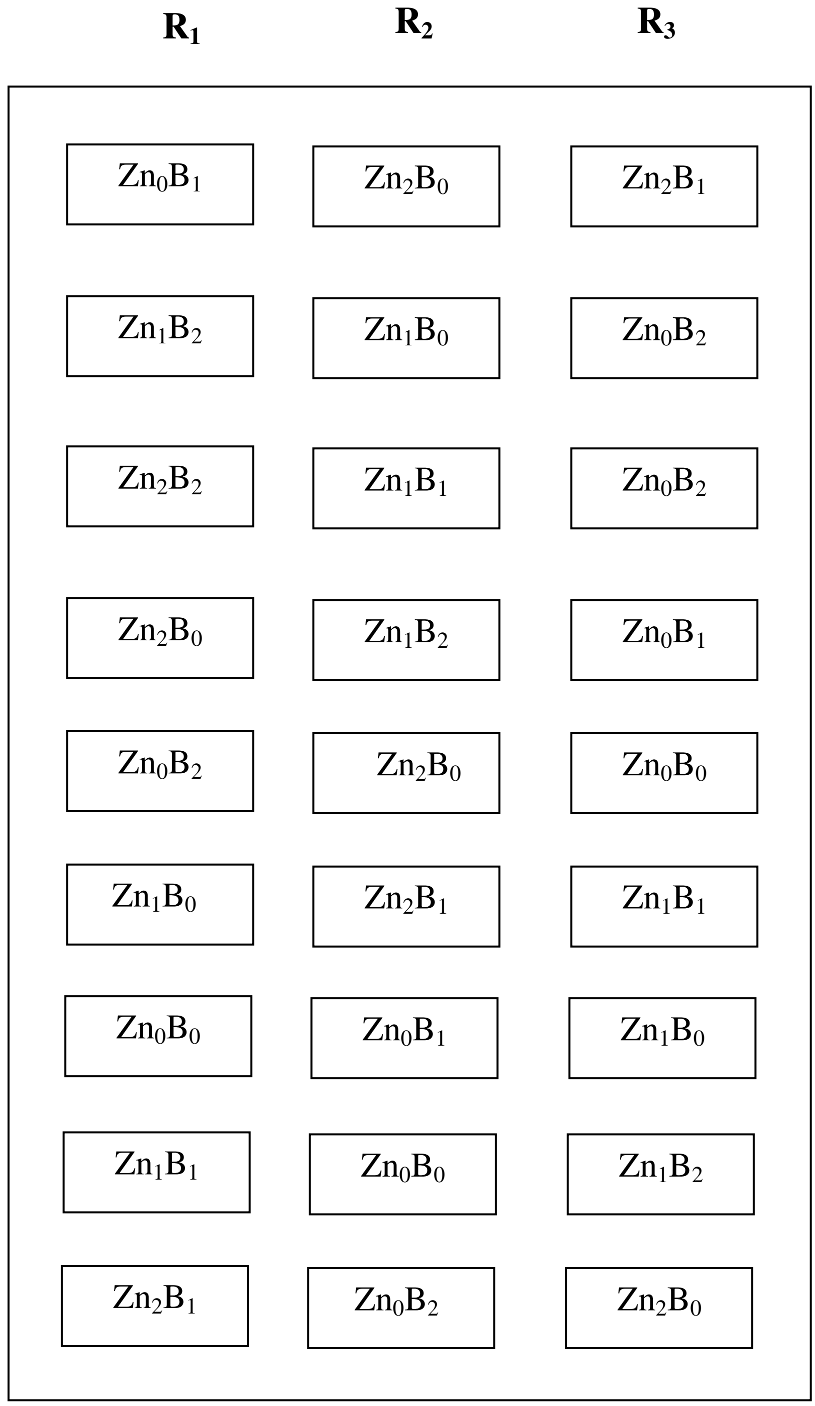
Chili (cv. BARI Morich -2) was used as an experimental material.

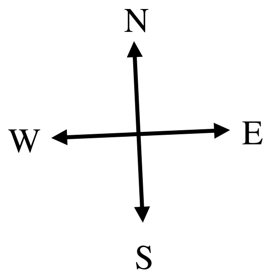
3.5 Seedbed preparation

Seedbed was prepared on 1st November 2019 for raising seedlings of green chili ploughed. Weeds, stubbles and dead roots were removed from the seedbed. The soil was treated by Sevin 50WP @ 5 kg/ha to protect the young plants from the attack of ants and cutworms. Seeds were treated by Vitavex-200 @ 5 g/1kg seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.6 Preparation of the field

The plot selected for conducting the experiment was opened in the first week of December 2019, with a power tiller and left exposed to the sun for a week to kill soil borne pathogens and soil inhabitant insects. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. Weeds, crop residues and stubles were removed from the field. The basal dose of manure and fertilizers were applied at the final ploughing. The plots were prepared according to design and layout of the experiment. The soil of the plot was treated by Sevin 50WP @ 5 kg/ha to protect the young plants from the attack of ants and cutworm.





Each Plot Area: 3 m x 2 m = 6 m^2
Plot to Plot Distance: 1 m
Plot distance from border: 0.50 m
Length of field: 28 m
Breadth of field: 12 m

Figure 1: Layout of experimental plot

3.7 Treatments

Fertilizer treatment consisted of 3 levels of Zn (0, 2 and 4 kg Zn ha^{-1}) and B (0, 1.5 and 3 kg B ha^{-1}) designed as RCBD. The following treatments will be comprised for the experiment.

Rate of Zn:	**Rate of B:**
Zn_0: 0 kg Zn ha^{-1}	B_0: 0 kg B ha^{-1}
Zn_1: 2 kg Zn ha^{-1}	B_1: 1.5 kg B ha^{-1}
Zn_2: 4 kg Zn ha^{-1}	B_2: 3 kg B ha^{-1}

3.8 Application of fertilizers:

Recommended doses of N, P, K and S (40 kg N from Urea, 25 kg P ha^{-1} from TSP, 20 kg K ha^{-1} from MoP and 25 kg S ha^{-1} from gypsum respectively) were applied. The required amounts of TSP (as per treatment), MoP and gypsum (as per treatment) and half of the recommended dose of urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 22 days of germination.

3.9 Seed sowing

Seeds were sown on 5th November 2019 in the seedbed. Sowing was done in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light watering by watering can. Thereafter, the beds were covered with polythene to maintain required temperature and moisture.

3.10 Raising of seedlings

Light watering and weeding were done several times as per needed. No chemical fertilizers were applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 30 days old seedlings were transplanted into the experimental field on 4th December 2019.

3.11 Transplanting

Healthy and uniform 30 days old chili seedlings were transplanted in the experimental plots on 4th December, 2019. 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 and plant to plant was 50 cm and 60 cm, respectively and total 25 plants were accommodated in each plot. The young transplants were shaded by banana leaf sheath during day time 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.

3.12 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 chilli seedlings.

3.13 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. Planted earlier on the border of the experimental plots same as planting time treatment. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting stock. Replacement was done with healthy seedling having a boll of earth. The transplants were given shading and watering for 7 days for their proper establishment.

3.14 Weeding and thinning

Weeds of different types were controlled manually and removed from the field. The weeding and thinning were done after 25 days after sowing, on December 23, 2019. Care was taken to maintain constant plant population (25 plants) per plot.

3.15 Irrigation

Light watering was given by a watering cane at every morning and afternoon. Following transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings.

3.16 Pest Management

To rescue the plant from the infested Cutworm at the seedling stage application of Dursban-25EC @ 2.5ml Litr-^{1} was done twice on December 15 and 30, 2019. Special care was taken to protect the crop from birds especially after sowing and germination stages.

3.17 Harvesting

The crop was harvested at maturity on 19th March, 2020. The harvested crop of each individual plot was bundled separately. Fruit yields were recorded plot wise and the yields were expressed in ton ha^{-1}.

3.18 Collection of sample

Samples were collected from different places of each plot. Ten plants from each plot were selected as samples.

3.19 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Fruits were separated from the plants.

3.20 Drying, cleaning and weighing

The fruits thus collected were dried in the sun for reducing the moisture in the fruits to a constant level. The dried seeds and straw were cleaned and weighed.

3.21 Collection of data

Five (5) plants were randomly selected for data collection from the middle rows of each unit plot for avoiding border effect, except yields of fruits, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth, yield attributes and yields.

Data were collected on the following parameters:

Plant height (cm)
Number of leaves plant^{-1}
Number of primary branches plant^{-1}
Number of flowers plant^{-1}
Number of fruits plant^{-1}
Fruit length (cm)
Weight of fruits plant^{-1} (g)
Yield (t ha^{-1})
Yield increase over control (%)

3.21.1 Plant height

The plant height was measured from the ground level to the top of the plant. Five plants were selected randomly from each plot at harvesting stage. Plant height was measured and averaged.

3.21.2 Number of leaves plant^{-1}

Numbers of leaves were counted at harvesting stage. Five plants were selected randomly from each plot and number of leaves were counted and averaged.

3.21.3 Number of primary branches plant^{-1}

Five plants were selected randomly from each plot at harvesting stage. Number of primary branches were counted and averaged.

3.21.4 Number of flowers plant^{-1}

Flowers were counted at the flowering stage. Five plants were selected randomly from each plot. Number of flowers were counted and averaged.

3.21.5 Number of fruits pod $^{-1}$

It was done at harvesting stage. Five plants were selected randomly from each plot. At first, number of seeds plant^{-1} were counted and averaged. Then it was multiplied with number of fruits plant^{-1} and averaged.

3.21.6 Fruit length

The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 10 randomly selected marketable fruits from each plot and there average was taken and expressed in cm.

3.21.7 Weight of fruits plant^{-1} (g)

Average fruit weight per plant was measured.

3.21.8 Yield (t ha^{-1})

The yield per hectare was calculated from per plot yield data and their average was taken. It was measured by the following formula,

$$\text{Yield per hectare (ton)} = \frac{Yield\ plot^{-1} \times 10000}{Area\ of\ plot\ in\ m^2 \times 1000}$$

3.21.9 Yield increased over control

Yield increased over control was calculated by the following formula

$$\text{Yield increased over control (\%)} = \frac{Treatment\ yield - control\ yield}{Treatment\ yield} \times 100\%$$

3.22 Chemical analysis of the soil samples

a) Nitrogen

Soil samples were digested with 30% H_2O_2, cone. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson. 1973).

b) Phosphorous

Phosphorous extracted by 0.5M $NaHCO_3$ (Olsen *et al*., 1954).

c) Sulphur

Sulphur content in the extract was determined by turbid metric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049)

d) Nitrogen

Plant samples were digested with 30% H_2O_2, cone. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson. 1973).

e) Soil pH

Soil pH was determined by pH meter.

3.23 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatments was estimated by the least significant difference (LSD) test at *5%* and 1*%* level of probability and DMRT was calculated in statistics' 10.

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted at Sher-e-Bangla Agricultural University farm to determine the effects of Zn and B on growth and yield of chili. Data on different yield contributing characters and yield were recorded to find out the optimum levels of Zn and B fertilization on chili. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height

4.1.1 Effect of Zn on the plant height of chili

Different Zn levels showed significant variation on plant height of chili (Figure 4.1.1). Significant variation was observed on the plant height of chili when the field was fertilized with 3 levels of Zn dose (eg. 0, 2, 4 kg Zn ha^{-1}). Among the different doses of Zn, Zn_2 showed the highest plant height (65.79 cm) at harvesting period which was statistically similar (61.33 cm) with Zn_1 treatment. On the other hand, the lowest plant height (41.78 cm) was observed in the Zn_0 treatment where no Zn was applied. This might be due to the lack of Zn in soil which reduced the cell division, carbohydrate and protein synthesis and also lowers the normal activities of the growth promoters. Swati Barche *et al.* (2011) reported that Zn application increased plant height of green chili and also they observed plant height increased 79.4% over control.

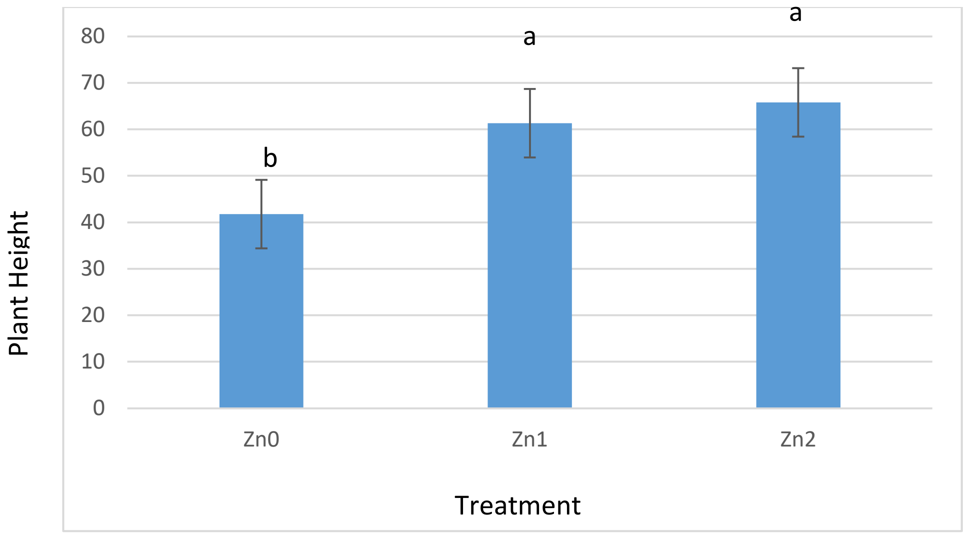


Figure 4.1.1: Effect of Zn on the plant height of chili [SE ± 8.07]

4.1.2 Effect of B on the plant height of chili

A significant variation was observed on chili in respect of plant height when B fertilizers in different doses were applied (Figure 4.1.2). Among the different fertilizer doses, B_2 showed the highest plant height (62.22 cm), which was statistically similar (55.11 cm) with B_1 treatment. On the contrary, the lowest plant height (50.79 cm) was observed in the treatment where no B fertilizer was applied. The crop of the control plot suffered from B deficiency. Rafique *et al.* (2012) reported that B deficiency suffers shortening of chili plant. They also cited that tallest and healthy plant was observed when B applied to the experimental field.

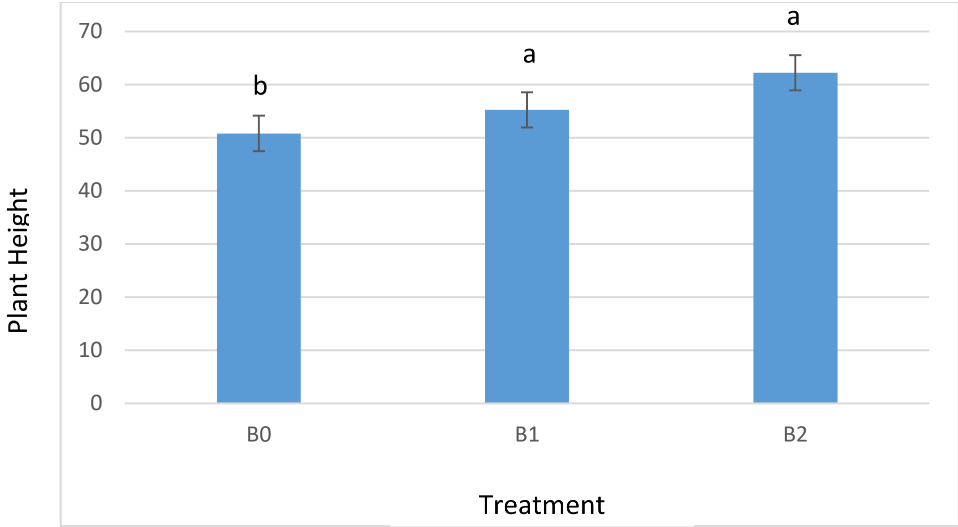


Figure 4.1.2: Effect of B on the plant height of chili [SE ± 11.41]

4.1.3 Interaction effects of Zn and B on the plant height of chili

Combined application of different doses of Zn and B fertilizers had significant effect on the plant height of chili (Table 4.1). The lowest plant height (26.67 cm) was observed in the treatment combination of Zn_0B_0. On the other hand, the highest plant height (76.67 cm) was recorded with Zn_2B_2 treatment which was statistically similar with Zn_2B_1 (71.67 cm), Zn_1B_2 (63.33 cm) and Zn_1B_1 (60.67 cm), treatments. The plant height was increased with the increased dose of Zn and B fertilizers. This might be due to higher availability of Zn and B and their uptake that progressively enhanced the vegetative growth of the plant. Shil *et al.* (2013) observed a similar result. They reported that increasing doses of Zn and B results tallest plant rather than control. Zn deficiency inhibits photosynthesis activity and results dwarf and literally weak plant (Zhao *et al.*, 2017).

4.2 Number of leaves plant^{-1}

4.2.1 Effect of Zn on the number of leaves plant^{-1} of chili

In figure 4.2.1, maximum number of leaves plant^{-1} (64.33) was observed in Zn_2 treatment which was statistically similar with Zn_1 (57.33) treatment. The lowest number of leaves plant^{-1} (44.11) was recorded in the Zn_0 (control) treatment. It may occurs due to Zn deficiency results premature leaves drop and intervenial chlorosis.

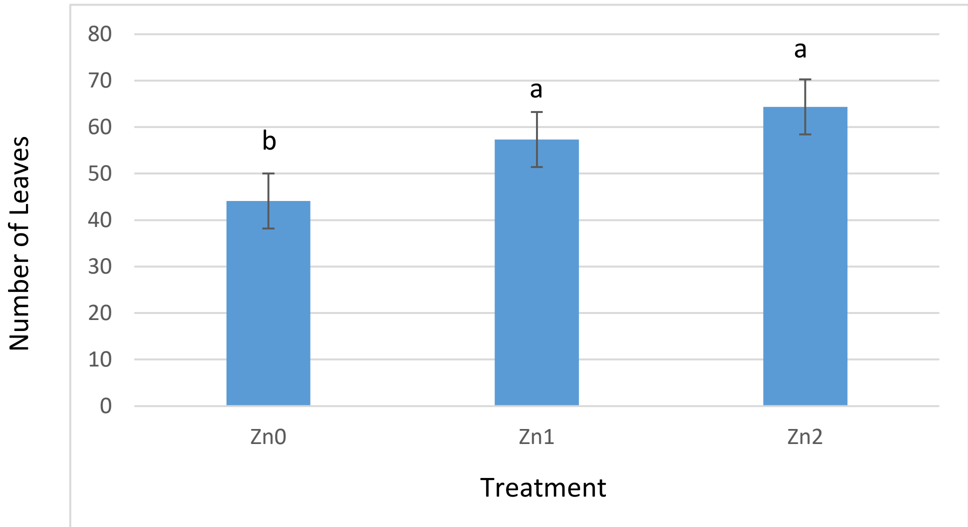


Figure 4.2.1: Effect of Zn on the number of leaves of chili [SE ± 9.59]

4.2.2 Effect of B on the number of leaves plant^{-1} of chili

A significant variation was observed due to the application of different level of B (Figure 4.2.2). The maximum number of leaves per plant (62.22) was recorded in B_2 which was statistically similar with B_1 (58.33) treatments. It was also observed that the minimum number of leaves per plant (45.22) was recorded where no B (B_0) was applied. Increase doses of B resulted maximum number of leaves by cell wall formation, and setting of young leaves (Rafique *et al.*, 2012).

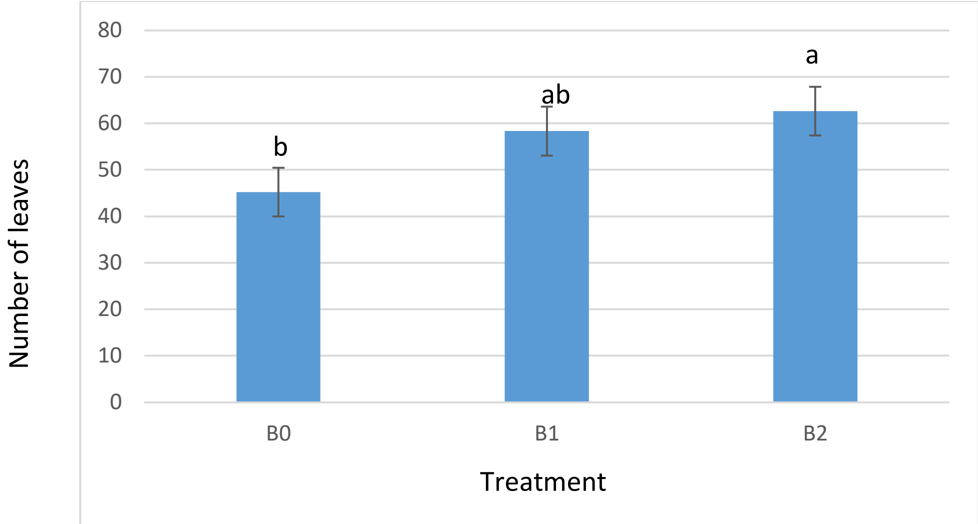


Figure 4.2.2: Effect of B on the number of leaves of chili [SE ± 6.78]

4.2.3 Interaction effects of Zn and B on the number of leaves plant^{-1} of chili

When different level of Zn and B fertilizers are mixed, the number of leaves plant^{-1} of chili varies significantly (Table 4.1). The highest number of leaves plant^{-1} (79.67) was recorded with the treatment combination of Zn_2B_1 which was statistically similar with Zn_2B_2 (74.00), Zn_1B_2 (69.33) and Zn_1B_1 (62.33) treatment. The lowest number of leaves plant^{-1} (39.00) was observed in control (Zn_0B_0). It was also observed (Table 4.3) that the increasing dose of Zn and B combination treatment results increasing the number of leaves plant^{-1} of chili.

4.3 number of branch plant^{-1}

4.3.1 Effect of Zn on the number of branch plant^{-1} of chili

Different dosages of Zn fertilizer resulted in substantial differences in the number of branches on plant^{-1} (Figure 4.3.1). Among the different doses of Zn, Zn_2 showed the highest number of branches plant^{-1} (11.89) which was significant from others. Patil *et al.* (2011) found that foliar application of Zn results bunch of branches rather than control (no fertilizer application).

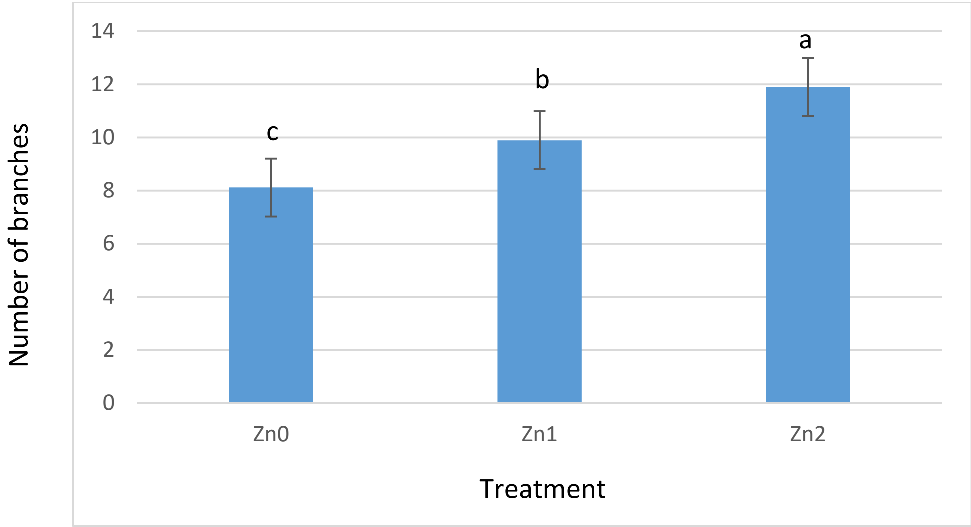


Figure 4.3.1: Effect of Zn on the number of branches of chili [SE ± 4.44]

4.3.2 Effect of B on the number of branch plant^{-1} of chili

A Significant variation was observed in the number of branches plant^{-1} of chili when three levels of B (0, 1.5 and 3 kg B ha^{-1}) were applied (Figure 4.3.2). The highest number of branches plant^{-1} (10.88) was recorded in B_2 treatment where lower number of branch plant^{-1} (7.11) was observed in control. Hatwar *et al.* (2003) reported that B and other micronutrient deficiency is the vital threat for healthy plant development and decreases branch number with production of dwarf chili plant.

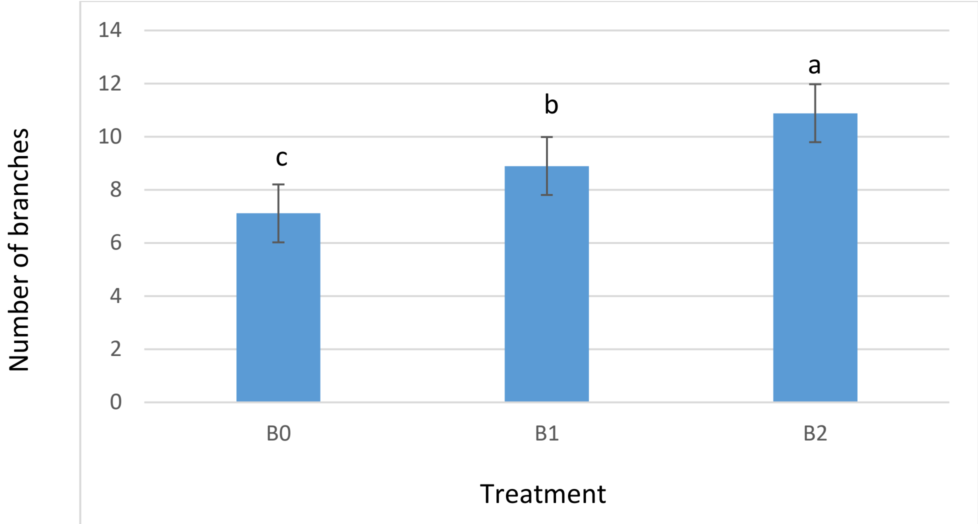


Figure 4.3.2: Effect of B on the number of branches of chili [SE ± 6.09]

4.3.3 Interaction Effects of Zn and B on the number of branch plant^{-1} of chili

A notable variation was observed in the combined effect in a view of combined application of different doses of Zn and B fertilizers on the number of branches plant^{-1} of chili which was recorded in table 4.1. The maximum number of branches plant^{-1} (14.67) was recorded with the treatment combination of Zn_2B_1. Which was statistically similar with Zn_2B_2 (12.33) and Zn_1B_2 (12.00) treatment. On the other hand, the lowest number of branches plant^{-1} (5.78) was found in Zn_0B_0 treatment (control treatment). High level of Zn and B in the soil helps in plant root formation, carbohydrate metabolism, protein synthesis and growth promoters activations which ultimately produces healthy plant with the maximum productive branches of the crop. Lack of Zn and B results in low rate of plant growth and plant branching. The combined use of the findings of Zn and B increases the number of chili plant branches (Shil *et al.* 2013).

Table 4.1: Effect of Zn and B on the plant height, number of leaves plant^{-1} and number of branch plant^{-1} of Chili

Treatment	*Plant height (cm.)*	*Number of leaves plant^{-1}*	*Number of branch plant^{-1}*
Zn_0B_0	26.67^{c}	34.00^{c}	5.78^{c}
Zn_0B_1	34.47^{c}	39.33^{bc}	6.00^{c}
Zn_0B_2	41.89^{bc}	40.33^{bc}	6.67^{c}
Zn_1B_0	49.33^{bc}	43.33^{bc}	8.33^{bc}
Zn_2B_0	55.00^{b}	55.00^{abc}	8.67^{bc}
Zn_1B_1	60.67^{ab}	62.33^{abc}	10.89^{b}
Zn_1B_2	63.33^{ab}	69.33^{ab}	12.00^{ab}
Zn_2B_1	76.67^{a}	79.67^{a}	14.67^{a}
Zn_2B_2	71.67^{ab}	74.00^{ab}	12.33^{ab}
$LSD_{0.05}$	19.77	34..91	3.63
CV(%)	13.43	17.83	16.36

4.4 Number of fruits plant^{-1}

4.4.1 Effect of Zn on the number of fruits plant^{-1} of chili

Application of Zn fertilizers at different doses showed significant variation on the number of fruits plant^{-1} of chili (Table 4.2). Among the different Zn fertilizer doses, Zn_2 showed the maximum fruit number plant^{-1} (58.89) which was statistically similar (53.67) with Zn_1 treatment. The lowest fruit number plant^{-1} (48.44) was recorded in the Zn_0 (control) treatment where no Zn was applied. This might be occurred due to Zn helps in fruit setting on plant. Similar result was also found by Mahesh Kumar and Sen (2005) which was conformity with the present findings.

4.4.2 Effect of B on the number of fruits plant^{-1} of chili

The number of fruits plant^{-1} of chili as affected by different doses of B showed no significant variation (Table 4.3). Among the different doses of B the maximum fruit number plant^{-1} (55.89) was observed in B_2 treatment which was statistically similar (53.44) with B_1 treatment. The lowest fruit number plant^{-1} (47.00) was recorded in the B_0 (control) treatment. This may be due to B is a micronutrient and it has less effect other than Zn on fruit setting on chili.

4.4.3 Interaction effect of Zn and B on the number of fruits plant^{-1} of chili

Combined effect of different doses of Zn and B fertilizers on number of fruits plant^{-1} showed a statistically significant variation (Table 4.4). The highest fruit number plant^{-1} (74.78) was recorded in the treatment combination of Zn_2B_2 which was statistically similar with Zn_2B_1 (64.67) treatment combinations. On the other hand, the lowest fruit number (35.67) was found in Zn_0B_0 treatment (control). It might be occurred due to combined effect of Zn and B helps in fruit setting on plant and develop healthy fruit.

4.5 Weight of fruit

4.5.1 Effect of Zn on weight of fruits plant^{-1} of chili

Different doses of Zn fertilizers showed significant variations in respect of weight of fruit of chili (Table 4.2). Among the different doses of Zn fertilizers, Zn_2 Showed the highest fruit weight plant^{-1} (258.67 g). The lowest weight of fruits (130.00 g) was observed Zn_0 (control) treatment. Similar finding was also observed by Swati barche *et al.* (2011)

4.5.2 Effect of B on weight of fruit of chili

Significant variation was observed on weight of fruit of chili when different doses of B were applied (Table 4.3). The highest fruit weight (203.11 g) was recorded in B_2. On the contrary, the lowest fruit weight (150.67 g) was recorded in the B_0 treatment where no B was applied.

4.5.3 Interaction effects of Zn and B on weight of fruit of chili

The combined effect of different doses of Zn and B fertilizers on weight of fruit was significant (Table 4.4). The highest Stover yield (304.00 g) was recorded with the treatment combination of Zn_2B_1 treatment. On the other hand, the lowest fruit weight (107.33 g) was found in Zn_0B_0 (control) treatment. It might be occurred due to Zn and B role in maintaining cellular membranes involving structural orientations of macromolecules and develop healthy fruits.

4.6 Number of flowers plant^{-1}

4.6.1 Effect of Zn on the number of flowers plant^{-1} of chili

A significant variation was observed in respect of the number of flowers plant^{-1} by the application of different levels of Zn (Table 4.2). Among the different doses of Zn fertilizers, Zn_2 showed the highest number of flowers (69.44) which was statistically similar (59.67) with Zn_1 treatment. On the contrary, the lowest number of flowers (53.67) was observed with Zn_0 (control) where no Zn fertilizer was applied.

4.6.2 Effect of B on the number of flowers plant^{-1} of chili

Different doses of B fertilizers showed significant variations in respect of the number of flowers plant^{-1} (Table 4.3). The highest number of flowers plant^{-1} (65.67) was recorded in B_2 treatment. On the other hand, the lowest number of flowers plant^{-1} (56.33) was recorded in the B_0 treatment where no B was applied.

4.6.3 Interaction effects of Zn and B on the number of flowers plant^{-1} of chili

A significant variation was observed on the number of flowers plant^{-1} of chili when different doses of Zn and B were applied (Table 4.4). The highest number of flowers plant^{-1} (86.67) was recorded in Zn_2B_1. It was statistically significant with other treatment. The lowest flower number plant^{-1} (42.33) was recorded in the Zn_0B_0 treatment where no Zn and B were applied.

4.7 Fruit length plant^{-1}

4.7.1 Effect of Zn on the fruit length plant^{-1} of chili

Application of Zn fertilizers at different doses showed significant variation on the fruit length of chili (Table 4.2). Among the different Zn fertilizer doses, Zn_2 showed the highest fruit length (6.51 cm) which was statistically similar (6.08 cm) with Zn_1 treatment. The lowest fruit length (5.72 cm) was recorded in the Zn_0 (control) treatment where no Zn was applied.

4.7.2 Effect of B on the fruit length plant^{-1} of chili

The fruit length as affected by different doses of B showed no significant variation (Table 4.3). Among the different doses of B the highest fruit length (6.39 cm) was observed in B_2 treatment which was statistically similar (6.10 cm) with B_1 treatment. The lowest length of fruit (5.63) was observed B_0 treatment.

4.7.3 Interaction effect of Zn and B on the fruit length plant^{-1} of chili

Combined effect of different doses of Zn and B fertilizers on fruit length showed a statistically significant variation compare with control (Table 4.4). The highest fruit length (6.47 cm) was recorded in the treatment combination of Zn_2B_1 which was statistically similar (6.37) with Zn_2B_1 treatment combination. The lowest fruit length (4.79 cm) was found in P_0B_0 treatment (control).

Table 4.2: Effect of Zn on the number of fruits plant^{-1}, weight of fruit, number of flowers plant^{-1} and length of fruit plant^{-1} of Chili

Treatment	Number of Fruits Plant^{-1}	Weight of Fruits plant^{-1} (g)	Number of flowers plant^{-1}	Length of fruit plant^{-1} (cm)
Zn_0	48.44^{b}	130.00^{c}	53.67^{c}	5.72^{b}
Zn_1	53.67^{ab}	160.67^{b}	59.67^{b}	6.08^{ab}
Zn_2	58.89^{a}	258.67^{a}	69.44^{a}	6.51^{a}
$LSD_{0.05}$	5.38	8.21	2.53	0.59
CV(%)	22.33	18.53	16.71	6.31

Table 4.3: Effect of B on the number of Fruits plant^{-1}, weight of fruit, number of flowers plant^{-1} and length of fruit plant^{-1} of Chili

Treatment	Number of Fruits Plant^{-1}	Weight of Fruits plant^{-1} (g)	Number of flowers plant^{-1}	Length of fruit plant^{-1} (cm)
B_0	47.00^{b}	150.67^{c}	56.33^{b}	5.63^{b}
B_1	53.44^{a}	195.56^{b}	64.78^{a}	6.10^{ab}
B_2	55.89^{a}	203.11^{a}	65.67^{a}	6.39^{a}
$LSD_{0.05}$	3.57	7.49	1.83	0.53
CV(%)	22.33	18.53	16.71	6.31

Table 4.4: Interaction effects of Zn and B on the number of Fruits plant^{-1}, weight of fruits plant^{-1}, number of flowers plant^{-1} and length of fruit plant^{-1} of Chili

Treatment	Number of Fruits Plant^{-1}	Weight of Fruits plant^{-1} (g)	Number of flowers plant^{-1}	Length of fruit plant^{-1} (cm)
Zn_0B_0	35.67^{d}	107.33^{h}	42.33^{f}	4.79^{f}
Zn_0B_1	36.57^{cd}	120.33^{g}	48.33^{e}	5.82^{e}
Zn_0B_2	44.89^{cd}	146.33^{f}	52.31^{e}	5.97^{d}
Zn_1B_0	48.17^{c}	166.33^{e}	56.01^{de}	6.03^{d}
Zn_2B_0	50.34^{bc}	176.33^{de}	59.33^{d}	6.11^{cd}
Zn_1B_1	58.67^{bc}	185.33^{d}	69.67^{c}	6.17^{c}
Zn_1B_2	60.33^{b}	225.33^{c}	71.33^{bc}	6.29^{b}
Zn_2B_1	74.78^{a}	304.00^{a}	86.67^{a}	6.47^{a}
Zn_2B_2	64.67^{ab}	286.67^{b}	74.67^{b}	6.37^{ab}
$LSD_{0.05}$	10.89	12.97	4.33	0.11
CV(%)	22.33	18.53	16.71	6.31

4.8 Yield (t ha^{-1})

4.8.1 Effect of Zn on the yield (t ha^{-1}) of chili

Application of Zn fertilizers at different doses showed significant variation on the yield of chili (Figure 4.8.1). Among the different Zn fertilizer doses, Zn_2 showed the highest yield (10.79 t ha^{-1}). The lowest yield (5.41 t ha^{-1}) was recorded in the Zn_0 (control) treatment where no Zn was applied. Zn deficiency inhibits cell elongation, germination and photosynthesis activity which occurs lower growth rate of plant, unsettled fruits and lower yield (Zhao, *et. al.,* 2017).

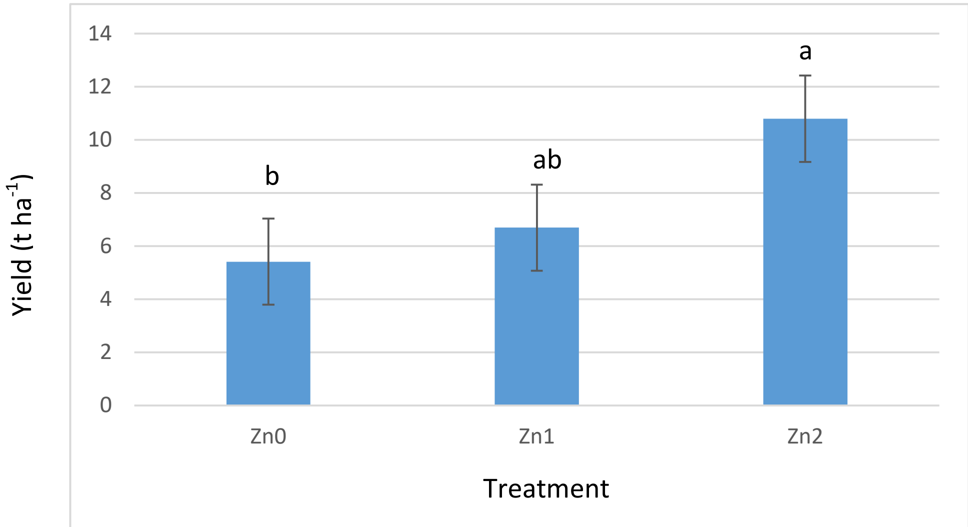


Figure 4.8.1: Effect of Zn on the yield (t ha^{-1}) of chili [SE ± 11.24]

4.8.2 Effect of B on the yield (t ha^{-1}) of chili

The yield affected by different doses of B showed no significant variation (Figure 4.8.2). Among the different doses of B the highest yield (8.46 t ha^{-1}) was observed in B_2 treatment and the lowest yield (6.27 t ha^{-1}) was observed B_0 treatment. Halder *et. al.* (2007) cited that better yield of plant depends on optimum application of boron.

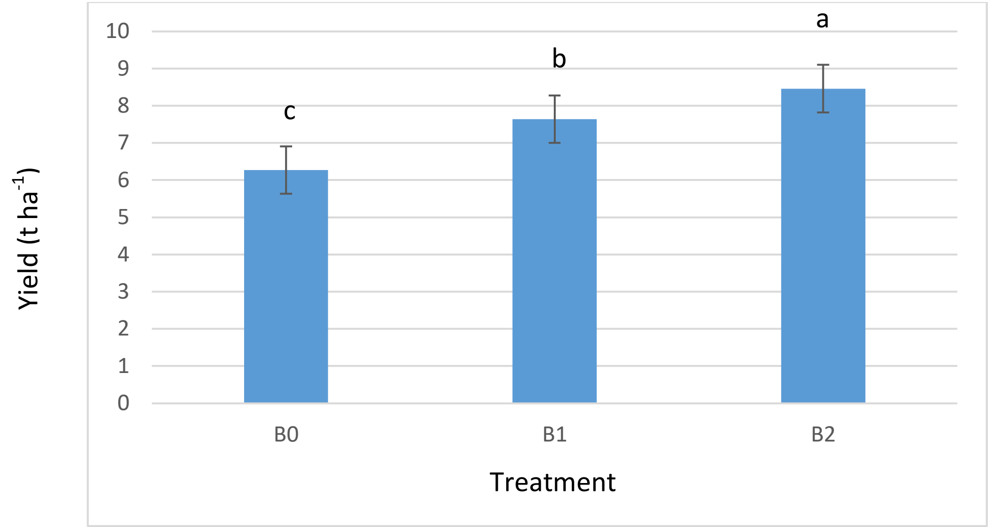


Figure 4.8.2: Effect of B on the yield (t ha^{-1}) of chili [SE ± 13.22]

4.8.3 Interaction effect of Zn and B on the yield (t ha^{-1}) of chili

Combined effect of different doses of Zn and B fertilizers yield showed a statistically significant variation compared with control (Table 4.7). The highest yield (12.67 t ha^{-1}) was recorded in the treatment combination of Zn_2B_1 which was statistically similar (11.94 t ha^{-1}) with Zn_2B_2 treatment combination. The lowest yield (4.17 t ha^{-1}) was found in Zn_0B_0 treatment (control). Hatwar *et al.* (2003) found similar results. Shil *et al.* (2013) reported that interaction effect of Zn and B on the yield of chili is positive. Yield of chili is becoming higher with the combined application of zn and B compare to control (Baloch *et. al.,* 2008).

Yield increase over control (%)

4.8.1 Effect of Zn on the yield increase over control (%) of chili

Application of Zn fertilizers at different doses showed significant variation on the yield increase over control of chili (Table 4.5). Among the different Zn fertilizer doses, Zn_2 showed the highest yield increase over control (49.86%). The lowest yield increase over control (19.13%) was recorded in the Zn_0 (control) treatment where no Zn was applied.

4.8.2 Effect of B on the yield increase over control (%) of chili

The yield increase over control affected by different doses of B showed no significant variation (Table 4.6). Among the different doses of B the highest yield increase over control (25.89%) was observed in B_2 treatment the lowest yield increase over control (17.93%) was observed B_1 treatment.

4.8.3 Interaction effect of Zn and B on the yield increase over control (%) of chili

Combined effect of different doses of Zn and B fertilizers yield increase over control showed a statistically significant variation compared with control (Table 4.7). The highest yield increase over control (67.09%) was recorded in the treatment combination of Zn_2B_1 which was statistically similar (65.08%) with Zn_2B_2 treatment combination. The lowest yield increase over control (17.19%) was found in Zn_0B_1 treatment (control).

Table 4.5: Effect of Zn on yield increase over control of Chili

Treatment	*Yield increase over control (%)*
Zn_0	--
Zn_1	19.13^{b}
Zn_2	49.86^{a}
$LSD_{0.05}$	8.80
CV(%)	9.01

Table 4.6: Effect of B on yield increase over control of Chili

Treatment	*Yield increase over control (%)*
B_0	--
B_1	17.93^{b}
B_2	25.89^{a}
$LSD_{0.05}$	6.17
CV(%)	9.01

Table 4.7: Interaction effects of Zn and B on yield and yield increase over control of Chili

Treatment	*Yield* *(t ha^{-1})*	*Yield increase over control* *(%)*
Zn_0B_0	4.17^{e}	--
Zn_0B_1	5.03^{d}	17.19^{e}
Zn_0B_2	5.84^{d}	28.60^{d}
Zn_1B_0	6.09^{cd}	31.53^{d}
Zn_2B_0	7.34^{c}	43.19^{c}
Zn_1B_1	8.22^{bc}	49.27^{b}
Zn_1B_2	8.72^{b}	52.18^{b}
Zn_2B_1	12.67^{a}	67.09^{a}
Zn_2B_2	11.94^{a}	65.08^{a}
$LSD_{0.05}$	1.33	4.56
CV(%)	16.67	9.01

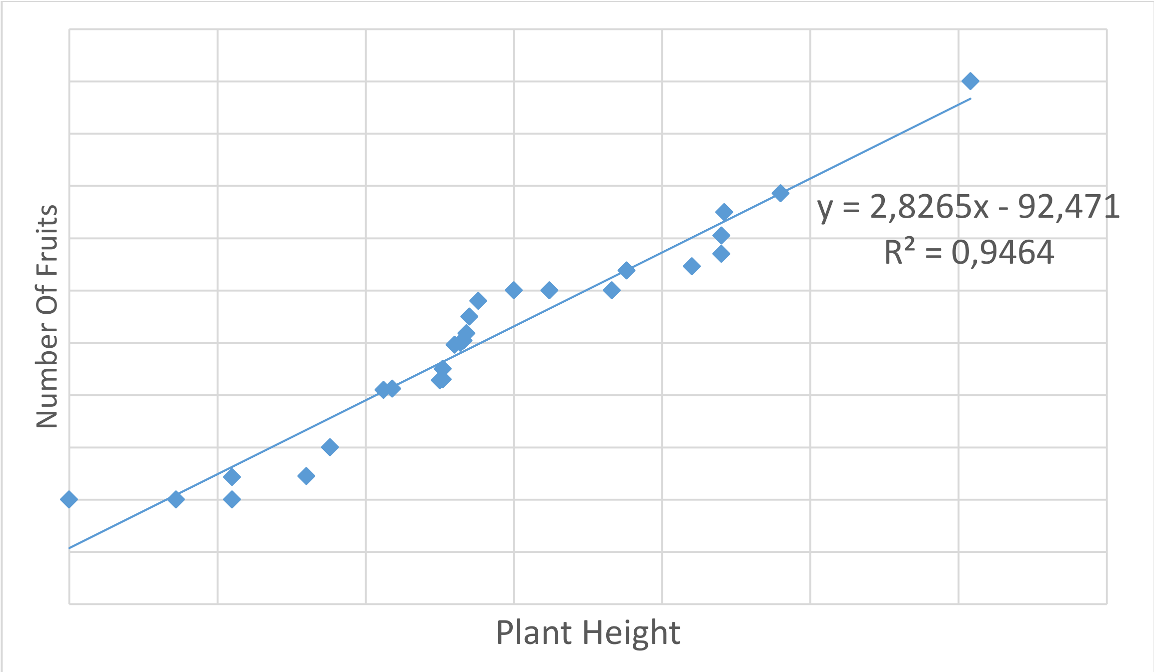


Figure 4.9: Linear relationship between plant height and number of fruits plant^{-1}

Correlation study was done to establish the relationship between plant height and number fruits of chili. From the study it revealed that highly significant correlation (R^2=0.9464) was observed between the parameters (Figure 2). It was evident from the Figure 2 that the equation y = 2.8265x - 92.471 gave a good fit to the data, and the co-efficient of determination (R^2= 0.9464) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that fruit number of chili was strongly (R^2= 0.9297) correlated with the plant height, i.e., the fruit number of chili increased with the increase of plant height.

CHAPTER V
SUMMERY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University Farm (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2019 to March 2020 to study the effect of Zn and B on growth and yield of chili. The variety "BARI Morich 2" was used as experimental materials. The experiment consisted of two factors: Factor A: Zn application (3 levels) as; (i) Zn_0: 0 kg Zn ha^{-1} (ii) Zn_1: 2 kg Zn ha^{-1} (iii) Zn_2: 4 kg Zn ha^{-1} and Factor B: B application (3 levels) as;(i) B_0: 0 kg B ha^{-1} (ii) B_1: 1.5 kg B ha^{-1} (iii) B_2: 3 kg B ha^{-1}. The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on growth, yield contributing characters and yields were recorded and statistically significant variation was observed for different treatment. Different levels of Zn application had significant variation on growth and yield contributing parameter of green chili. Results showed that in terms of Zn effect, the highest plant height (65.79 cm), number of leaves $plant^{-1}$ (64.333) and number of branch $plant^{-1}$ (11.89) were recorded from Zn_2. Again the highest number of fruit (58.89), fruit weight (258.67 g), number of flowers (69.44), fruit length (6.51 cm), yield (10.79 t ha^{-1}) and yield increase over control (49.84%) were observed from Zn_2 treatment.

The individual treatment of B application also showed significant variations on the growth and yield contributing parameters of chili. Results showed that in terms of B effect, the highest plant height (62.22 cm), number of leaves $plant^{-1}$ (62.22) and number of branch $plant^{-1}$ (10.88) were recorded from B_2. Apart from the highest number of fruit (55.89), fruit weight (203.11), number of flowers (65.67), fruit length (6.39 cm), yield (8.46 t ha^{-1}) and yield increase over control (25.89%) were observed from B_2 treatment.

Considering combined effect of Zn and B, the tallest plant (76.67 cm), maximum number of leaves plant^{-1} (79.667) and maximum number of the branch (14.67) were recorded from Zn_2B_1 treatment. The statistical value similar with Zn_2B_2, Zn_1B_2 and Zn_1B_1 treatment. The yield contributing parameter as number of flowers plant^{-1} (74.78), number of fruits plant (304.00), fruit length (86.67 cm), fruit weight (6.47 g). Yield (12.67 t ha^{-1}) and yield increase over control (67.09%) were also recorded from Zn_2B_2.

The results of this research work indicated that the plants performed better in respect of weight of fruits from Zn_2B_1 treatment over the control treatment (Zn_0B_0). It was also observed that some of the parameters statistically similar results and most of the parameters showed closest results those were found at Zn_1B_1 treatment. It can be concluded from the above study that the treatment of Zn_2B_2 (application of Zn @ 4 kg Zn ha^{-1} application of B @ 3 kg ha^{-1}) was found to the most suitable treatment combination for the higher yield of chili in shallow Red Brown Terrace Soils of Bangladesh.

CHAPTER VI
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