EFFECTS OF BORON AND ZINC ON THE GROWTH, YIELD AND NUTRIENTS CONTENT OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF BORON AND ZINC ON THE GROWTH, YIELD AND NUTRIENTS CONTENT OF LENTIL"** 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 IN AGRICULTURAL CHEMISTRY***, embodies the results of a piece of *bona authentic* research work performed by ***MD. MAHMUD HASAN*** Registration. No. **10-04049,** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

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DEDECATED TO

MY

RESPECTED PARENTS

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ABSTRACT

An experiment was carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka and chemical analysis was carried out in the Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from November 2016 to March 2017 to evaluate the effect of three levels of boron viz., 0, 2, 4 kg B ha^{-1} and zinc viz., 0, 5, 10 kg Zn ha^{-1} on growth and yield and nutrients content of lentil (BARI Masur-5). The maximum plant height (31.18 cm) at harvest, branches $plant^{-1}$ (28.73) at harvest, pods $plant^{-1}$ (79.13) at harvest, seed yield (1140.20 kg ha^{-1}), stover yield (1649.73 kg ha^{-1}), 1000 seed weight (23.02 gm) were achieved by 2 kg ha^{-1} B and 5 kg ha^{-1} Zn . The highest amount (4.780 %) of nitrogen content was observed in lentil when the field was fertilized with the dose of boron and zinc 4 kg ha^{-1} B and 0 kg Zn ha^{-1} The highest amount of phosphorus content (0.768 %) was found under treatment 0 kg ha^{-1} B and 5 kg Zn ha^{-1} .The highest amount (1.707 %) of potassium content were observed in lentil when field was fertilized with the dose of 2 kg ha^{-1} B and 5 kg Zn ha^{-1} .The highest amount (10.08 ppm) of boron content was observed in Lentil when the field was treated with 4 kg ha^{-1} B and 5 kg Zn ha^{-1} .The highest amount (62.03ppm) of zinc content was observed in lentil when the field was treated with 2 kg ha^{-1} B and 10 kg Zn ha^{-1} .

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Introduction

CHAPTER I
INTRODUCTION

Lentil (*Lens culinaris* L. Medik) is a pulse crop which takes second position in respect of area and production of Bangladesh. According to FAO (1999) a minimum intake of pulse by a human should be 80 g per head per day, whereas it is only 12 g in Bangladesh (BBS, 2008). This is due to the fact that national production of the pulse is not adequate to meet the national demand. Lentil (*Lens culinaris* L. Medik) is one of the most ancient annual pulse food crops that belongs to the sub family Papilionaceae under the family Fabaceae is in second position in areas (4.34 million hectares) and its annual production is 4.95 million tons and productivity is 1260 kg ha^{-1} respectively but it takes the top position in consumer preference and total consumption (FAOSTAT, 2014). In Bangladesh it is popularly known as Masur and one of the most ancient yearly food crops that have been grown as a vital food source for over 8,000 years (Dhuppar *et al*., 2012). Lentil grain contains 59.8% starch, 25.8% protein, 10% moisture, 4% mineral and 3% vitamins (Gowda and Kaul, 1982). Only red cotyledon type is eaten as food, where it is cooked as soup-like *dhal* and have with flat bread or rice in Bangladesh. *Khichuri* is a popular dish, which is made from a mixture of split lentil seed and pounded wheat or rice. Lentil seed contains 25% protein as against 7.5% protein in rice and 11.9% wheat. It is considered as poor man's meat and low-cost source of protein for poor group of people who cannot afford to buy animal protein in man. It takes a unique place in the world of agriculture by virtue of its high protein content and capacity of fixing atmospheric nitrogen. The stover of the plants with husk popularly known as *bhushi* is highly protein concentrated feed to cattle, horse, pig and sheep (Tomar *et* *al*., 1999). Lentil grains contain high protein, good taste and easily digestible element. It supplies protein in the cereal based low protein diet of the people of Bangladesh but the acreage (213035 acres in 2012) and production (80125 metric tons in 2012) of lentil is steadily declining (BBS, 2012). Cultivation of high yielding varieties of wheat and boro rice has occupied considerable land suitable for lentil cultivation during *rabi* (winter) season of Bangladesh. Besides these, low yield (0.80 t ha^{-1}) potentiality of this crop is responsible for declining the area and production of lentil. It is a legume crop. So, it can fix atmospheric nitrogen through symbiotic rhizobia in root nodules. So, it has potential in crop rotation for maintaining soil fertility (Crook *et al*., 1999). In spite of holding these advantages there are so many constraints in lentil production which limit the crop production by reducing their growth and yield. The area, production, and yield of lentil in Bangladesh were 34628 ha, 37281 tons (t), and 1.07 t ha^{-1}, respectively, in 2014-15 (BBS, 2015). Before 7 years, the area, production, and yield of lentil were 70983 ha, 60537 t, and 0.853 t ha^{-1}, respectively, in 2008-09 (BBS, 2009). Thus, it is prominent that area of lentil decreased 1.74 times and production decreased 1.6 times. So, the area and production of lentil is reducing year after year. However micronutrients boron and zinc play an vital role in growing yield of pulses through their effect on the plant itself and on the Nitrogen fixing by symbiotic process. Deficiencies of these nutrients have been very pronounced under multiple cropping system due to excess removal by HYV of crops and hence their exogenous supplies are urgently required. Boron and zinc deficiency is widespread in the country specially in wetland rice soils, light textured soils and calcareous soils (Jahiruddin *et al*. 1992; Rahman *et al*. 1993; Islam *et al*. 1997). Boron is very vital in cell division and in pod and seed formation (Vitosh *et al*. 1997). Reproductive growth, mainly flowering, fruit, and seed set is more resposive to deficiency of boron than vegetative growth (Noppakoonwong *et al.* 1997). Effects of Boron on the assimilation of N, P, K and its unavailability changed the equilibrium of optimum of those three macronutrients. The N and P concentrations of grain for lentil were influenced by B treatment showing that the B had a positive effect on protein synthesis (Iqtidar and Rahman, 1984) discover that essential amino acid increased with increasing B supply. The basic contribution of zinc includes auxins metabolism, Nitrogen metabolism, influence on the activities of enzymes (e.g. dehydrogenase and carbonic anhydrase, proteinases, and peptidases), and cytochrome complex synthesis, stabilization of ribosomal fractions and defense of cells against stress of oxidation (Tisdale *et al.* 1997; Obata *et al.* 1999). The general symptoms of lack of zinc in field crops are poor growth, interveinal chlorosis and lower leaves necrosis. Seeds that give birth of plant with low concentrations of Zn could be highly susceptible to biotic and abiotic stresses (*Obata et al.* 1999). Seeds that are rich with zinc can perform better with respect to seed germination, seedling health, crop growth and finally yield (Cakmak *et al.* 1996). So, the application of boron and zinc in addition to essential major elements have gained practical significance in growth, yield and nutrient contents of lentil.

Objective:

1. To observe the effects of boron and zinc on growth parameters of lentil,
2. To find out the effects of boron and zinc on yield of lentil and
3. To determine the nutrient contents in lentil seed

Chapter 2
Review of literature

CHAPTER II
REVIEW OF LITERATURE

Though lentil is one of the important protein containing pulse crops, little attention has been paid to improvement of yield by use of micronutrient boron and zinc in soil. Literature in this area is scanty. However in this chapter an attempt has been made to present a brief review of effect of Boron and Zinc on growth, yield and quality of lentil.

Role of Boron in plant:

Boron is necessary for growth of new cells. Without adequate supply of boron, the number and retention of flower reduces and pollen tube growth is less; consequently less fruits are developed (Miller and Donahue, 1997).

Boron plays a vital role in physiological process of plants such as cell maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, acid and phenol metabolisms. The functions of Boron are primarily extra-cellular and related to lignifications and xylem differentiation (Lewis, 1980), membrane stabilization (Pilbeam and Kirkby, 1983) and alteration of enzymatic reactions (Dugger, 1983)

Boron has direct and indirect effect on fertilization. Indirect effects are related to the increase in amount and change in sugar composition of the nectar, whereby the flowers of species that rely on pollinating insects become more attractive to insects (Smith and Johnson, 1969: Drikson, 1979). Direct effects of B are reflected by the close relationship between B supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*,1981). Moreover, B inspires germination, mainly in pollen tube growth. Boron is also essential for sugar translocation. So, it affects in carbon and nitrogen metabolism of plants (Jackson and Chapman, 1975)

The effect of boron on the development of the pollen grain of wheat was studied by Li *et al*., (1978) and Rerkasem *et al.* (1989b). The process of fertilization involves the germination of the pollen grain and the growth of the pollen tube down the style into the ovary. In general, boron shortage produces pollen grains that are small and that do not build up starch. Pollens that develop normally may still be affected by boron deficit (Vaughan, 1977; and Cheng and Rerkasem, 1993).

Some plant species have a low B requirement and may also be sensitive to elevated B level even only slightly above those needed for normal growth. Therefore, toxic effect of B is caused by unnecessary use of B fertilizers (Gupta, 1979). There was a special boron demand for pollen tube growth, in which callose formed at the pollen-style "invasion" was physiologically inactivated by the development of borate-callose complexes (Lewis, 1980). Rerkasem et al. (1993) also opined that extra boron was needed to maintain efficient oxidation of phenols formed in the "inversion" of the style by germination of pollen tube.

Rerkasem et al. (1989a) reported that wheat growing in the low boron soils exhibited symptoms of male sterility, which included poorly developed anthers and nonviable pollen grains. Grain set failure lower seed yield and male sterility symptoms were associated with low boron concentration in the flag leaf. Failure in grain set up to 100% of florets was frequently observed. They also reported that poor grain set in wheat depressed seed yield by 40- 50% on soils having low boron content (0.08-0, 12 mg kg^{-1}).

Effect of boron on yield and yield attributing characters of legumes

Gupta *et al.* (1993) reported from a pot experiment in soil containing 0.4 mg kg^{-1} available B, planting chickpeas or lentils where B was applied 0-6 mg kg^{-1}. They observed that lentils were more susceptible to B than chickpeas.

Singh *et al.* (1994) noted that green pod yield of French beans increased with increase in P application and with B application up to 1 kg ha^{-1} B. Application of more than 1 kg ha^{-1} B caused a toxic effect.

Bolanos *et al.* (1994) reported that in the absence of B the number, size and weight of nodules decreased and nodule development changed leading to an inhibition of nitrogenase activity. It was concluded that B was required for normal development and function of nodules in pea.

Al-Mohammad and Poulain (1996) from greenhouse pot experiments, with febabean (*Vicia faba*) plants watered with solutions containing 0, 2 or 32 mg B/litre stated that both B deficiency and excess inhibited root growth, decreased nodule fresh weight and nitrogen fixation measured by Acetylene Reduction Activity (ARA). They further observed that the absence of B in the nutrient solution resulted in an accumulation of soluble sugars in leaves, particularly sucrose. The negative effect of boron deficiency they explained it to be the limitation of carbon supply to the nodules as well as by its direct effect on the ARA activity. They suggested that B toxicity might affect the activity of nitrogen due to antagonistic effect of Mo.

Talashilkar and Chavan (1996) observed that pod production of groundnut was enhanced significantly with the addition of B by 44 percent. The maximum pod and haulm yields were recorded in the treatment receiving B through boronated super phosphate along with application of FYM, N and P.

Srivastava *et al.* (1996) in a field study with B deficient soil growing chickpea and applying no fertilizers, complete fertilizer (P, K, S, B, Zn, Mo, Cu, Mn, and Fe) or the complete fertilizer minus each of the trace elements observed that flower abortion was highest and no seed was produced in the treatment given no B.

Srivastava *et al.* (1999) observed that the average grain yield of chickpea and other legume crops was 0.1 t ha^{-1} where B was not applied, while the yield was 1.4 t ha^{-1} where 0.5 kg ha^{-1} B was applied.

Srivastava *et al.* (1997) conducted a diagnosis nutrient trial with chickpea in three different places in Nepal. Boron deficiency was established as the dominant nutritional problem causing flower and pod abortion. No pods or grains were formed in the absence of applied B. Application of 0.5 kg ha^{-1} B was found to correct the deficiency optimally.

Lourduraj *et al.*, (1997) revealed that groundnut yield and monetary returns were increased by application of Fe, Zn, B and gypsum, when basal application of NPK was combined with application of 5 kg ha^{-1} borax + 25 kg ha^{-1} $ZnSO_4$ along with application of 500 kg ha^{-1} gypsum and 1% $FeSO_4$ spray on the 45th day, groundnut yield and rectums were maximized.

Role of Zinc in plant:

The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome Tisdale *et al.*, (1994).

Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation Marschner (1995). The regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zn dependent Cakmak (2000). Its deficiency results in the development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility. Micronutrient Zn deficiency can also adversely affect the quality of harvested products; plants susceptibility to injury by high light or temperature intensity and to infection by fungal diseases can also increase Marschner (1995). Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress Kasim *et al.*(2007),. As Zn is required for the synthesis of tryptophan which is a precursor of IAA, it also has an active role in the production of an essential growth hormone auxin Alloway (2004). The Zn is required for integrity of cellular membranes to preserve the structural orientation of macromolecules and ion transport systems. Its interaction with phospholipids and sulphydryl groups of membrane proteins contributes for the maintenance of membranes Tavallali *et al.*, (2010)

Effect of zinc on yield and yield attributing characters of legumes

Zn is one of the essential plant nutrients that functions in diverse metabolic, regulatory, and developmental processes (Broadly *et al.*, 2007). Apart from being a constituent of Zn-metalloenzymes, Zn functions as a constituent of several regulatory proteins like the Zn finger ones that interact with DNA and control gene expression (Liu *et al.*, 2005). Zn plays an important role in plant-reproductive development for initiation of flowering, floral development, male and female gametogenesis, fertilization, and seed development. Even under marginal Zn deficiency condition, the development of anthers in wheat is severely retarded (Sharma *et al.*, 1990). Pandey *et al.* (1995) reported that Zn deficiency induced a change in exine morphology and reduced pollen viability. Zn deficiency has also been shown to change stigmatic size, morphology, and exudations, inhibiting pollen-stigma interaction (Pandey *et al.*, 2006; 2009b). It was recently documented that Zn foliar application is a simple way for making quick correction of plant nutritional status, as reported for maize (Grzebisz *et al.*, 2008) and green gram (Pathak and Pandey, 2010). Most researches on Zn foliar application focused on alleviating its deficiency, particularly on wheat and maize cultivated in semiarid regions of the world (Cakmak, 2008; Potaezycki and Grzebisz, 2009). In the present study we explored the effect of Zn foliar application on the reproductive development of chickpea with a view to assess its effect on pollen stigma interaction and on the Zn content in seeds for improved dietary intake by human

2.1. Zinc status in soil

Zinc is a micronutrient since it is required relatively to a smaller amount than macronutrients. The forms of zinc in soils are: solution zinc absorbed Zn^{2+} (on clay surfaces, organic matter, carbonates and oxide minerals) organically complexes Zn^{2+} and Zn^{2+} substituted for Mg^{2+} in the crystal lattices of clay minerals. The range in maximum zinc absorption by different soils as 60 to 70 $\mu g\ g^{-1}$ for Ca- saturated samples. However, in natural vary in acid soils ($pH<4.0$), zinc concentration in solution was reported to be on an average 7.131 $g\ L^{-1}$ (Itoh and Yuirmura, 1979).

2.2 Boron status in soil

Boron can be found in four forms in the soil are H_3BO_3 $H_2BO_3^-$ HBO_3^{2-} and BO_3^{3-}. These are the plant available forms of the nutrient. The total B content of soils lies between 20 to 200 µg g^{-1} with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 µg g^{-1} (Gupta, 1979). It occurs in soil mainly as undissociated H_3BO_3. Plants absorb B primarily in the form of HBO_3^{2-}. This may be the main reason why B is leached so easily fiom soil. Plants absorb B primary in the fonn of HBO_3^{2-} and to smaller extent as $H_2BO_3^-$, BO_3^{3-}

2.3. Symptoms of Zn deficiency in plant

Interveinal chlorosis, stunted growth, little leaf, rosette of plants and isolated red points are found on leaves (Nambiar and Motiramani, 1981).

2.4. Symptoms of B deficiency in plants

The deficiency symptoms of some B sensitive crops like *Lycopersicon*, *Brassica*, legumes and fruit plants are chlorosis and browning of young leaves, lesion in pith and roots. B deficient stems and leaves were found to be brittle while B deficient leaves and stems are flaccid (Dunn *et al.*, 2005).

2.5. Causes of Zn deficiency in plants

The major causes of increasing Zn deficiencies are high soil pH for calcareous soil, low organic matter content, coarse textured soil, wet land rice cultivation, intensive cropping with HYV and large use of N, P and K fertilizers (Alam *et al.*, 1976).

2.6. Causes of B deficiency in plants

Reproductive growth is more sensitive to B deficiency than vegetative growth (Dear and Lipsett, 1987). Deficiency of B usually occurs in high pH and light textured soils. Boron is once released from soil minerals; it can be leached from soils rapidly (Mengel and Kirkby, 1987).

2.7. Acquisition of Zn

The Zn content of different plant species varies and more over the quantity taken up by any given species is affected by the available supply in the growth medium (Miller, 1955). In naturally grown plant grains and roots need the content of Zn about 21 $\mu g\ g^{-1}$ and 4.510 $\mu g\ g^{-1}$ (Saucheli, 1996).

2.8. Acquisition of B

Plant B concentration increased or decreased with increasing or decreasing rate of applied B (Shanna and Ramchandra, 1998). They reported that uptake values of B were normally 5-10% lowers than the predicted value. Normal crop legumes contained 32-96 $\mu g\ g^{-1}$ B (Gandhi and Mehta,1970).

2.9. Critical levels of Zn

Plant species differ considerably in their Zn levels in tissues used for the prediction of its deficiency often fail at the diagnostic test and that tissue Fe to Zn ratios appear to be more promising for the prediction even of hidden deficiency (Nambiar and Motiramani, 1981). The critical level in plant was found to be around 0.61 $\mu g\ g^{-1}$ with DTPA method (Perveen, 2000).

2.10. Critical levels of B

Boron requirement of different plants is different. Rice cv. BRRI dhan 30 grain and straw normally contain 9 to 11 $\mu g\ g^{-1}$ B and 8 to 24 $\mu g\ g^{-1}$ B , respectively (Kabir, 2003). Legume seed contain $16.4 \pm 2.7 \mu g\ g^{-1}$ B (Osotsapar, 2000).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The study was conducted at the in the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to March 2017 to investigate the effect of different levels of boron and zinc on the yield of lentil. Chemical analysis of lentil seed sample was completed in the laboratory of soil science division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The materials and methods used in performing this experiment are described in this chapter. A brief description of experimental site, soil, and climate, description of planting material, treatments, experimental design, land preparation, intercultural operations, data recording, data processing and chemical analysis are given below.

3.1 Description of experimental site

The experimental site lies at the research field of Sher-e-Bangla Agricultural University, Dhaka which is situated at latitude 23°46′ N and longitude 90°23′ E with an elevation of 8.45 meter the sea level.

3.2 Soil

The soil of the experimental plot was a medium high land which belongs to sandy to sandy loam under the General Soil Type, Non-calcareous Dark Grey Floodplain soils. It was loose, organic matter rich well drained soil. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28).(Appendix-4)

3.3 Climate

The experimental site is situated under sub-tropical climate, characterized by rainfall during *Kharif* season (April to September) and scanty rainfall in rabi season (October to March). In *Rabi* season temperature is generally low and there is plenty of sunshine. The atmospheric temperature tends to increase from February, as the season proceeds towards *Kharif*. Monthly maximum, minimum and mean temperatures, rainfall and relative humidity of the experimental area daring the experimental period are given in Appendix-3.

3.4 Description of the planting material

Lentil (*Lens culinaris* Medik.) variety BARI Masur-5 was used as plant material. BARI developed this variety and released in 2006 . BARI Masur-5 is a semi erect and medium stature cultivar with plant height of 38-40 cm, the leaves are dark green with small tendrils, flowers are blue, and the pods and leaves turn to straw color during maturity stage. Seed coat color is reddish brown and cotyledons are bright orange, 1000 seed weight 19.84 g compared to 11.5g or less for the local variety. Size of this variety are larger and wider than local variety.

3.5 Treatments

The experiment consisted of the following treatments:

Boron will be applied based on the following rates:

i) B_0 = Control
ii) B_2= 2 kg/ha
iii) B_4=4 kg/ha

Zinc will be applied based on the following rates:

i) Z_0 = Control
ii) Z_5= 5 kg/ha
iii) Z_{10}=10 kg/ha

The following 9 treatment combinations were used for the present experiment:

1) B_0Z_0 – Control
2) B_0Z_5 – 0 kg ha^{-1} B and 5 kg ha^{-1} Zn
3) B_0Z_{10} – 0 kg ha^{-1} B and 10 kg ha^{-1} Zn
4) B_2Z_0 – 0 kg ha^{-1} B and 0 kg ha^{-1} Zn
5) B_2Z_5 – 2 kg ha^{-1} B and 5 kg ha^{-1} Zn
6) B_2Z_{10} – 2 kg ha^{-1} B and 10 kg ha^{-1} Zn
7) B_4Z_0 – 2 kg ha^{-1} B and 0 kg ha^{-1} Zn
8) B_4Z_5 – 0 kg ha^{-1} B and 5 kg ha^{-1} Zn
9) B_4Z_{10} – 0 kg ha^{-1} B and 10 kg ha^{-1} Zn

3.6 Experimental design

The experiment was laid out in a randomized complete block design with three replications; each representing a block. Each block was divided into 9 unit plots where 9 treatment combinations were allocated at random. The total number of unit plots in the experiment was (9×3) 27, each of size 3.0m×2m. The distance between the plot and block were 0.50 m and 1.0 m respectively having a provision of irrigation channel.

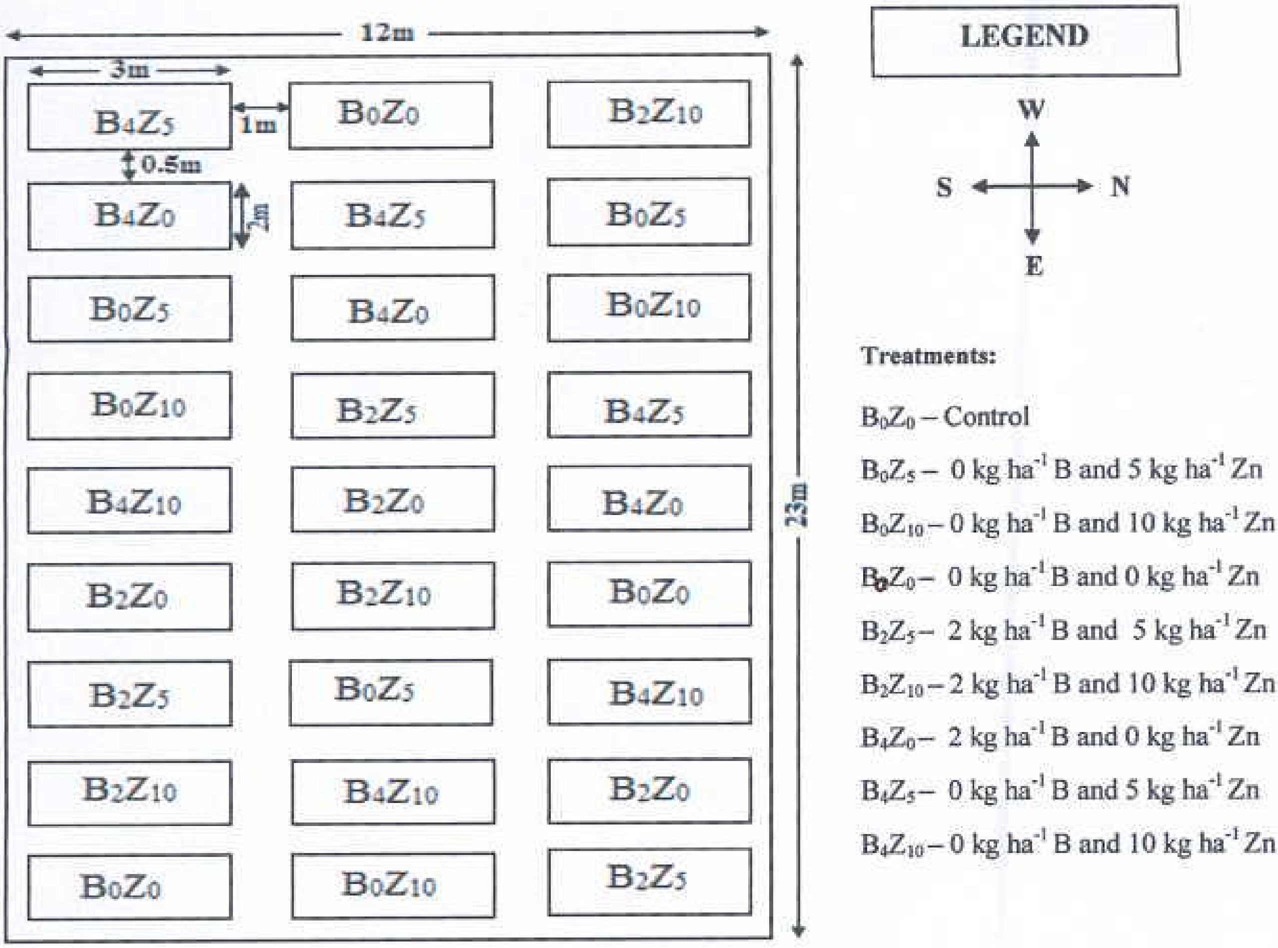


Fig. 1: Layout of Experimental design

3.7 Land preparation

For land preparation the experimental field soil was opened with a tractor drawn disc harrow 10 days before sowing followed by ploughing four times with country plough and laddering for breaking clods and leveling the land. Weeds, stubble and crop residues were removed from the field and left for some days to complete the decomposition. Finally the unit plots were prepared with spade for sowing.

3.8 Fertilizer application

The unit plots were fertilized with 50kg Urea, 90kg TSP and 40kg MOP ha^{-1} respectively as basal dose (BARI Hand Book, 2013). Zinc and boron were applied as per experimental specification through Zinc sulfate (36% Zn) and boric acid (17% B). The whole amount of TSP, MOP, Zinc sulfate, boric acid and urea were applied at the time of final land preparation prior to sowing.

3.9 Seed rate

Seed rate for growing lentil was 30 kg ha^{-1} .

3.10 Seed treatment

Seed was treated before sowing by Provex @ 2 g kg^{-1} of seed for successful crop production.

3.11 Sowing method

Line sowing method was used to saw the seeds. Row to row distance was 30 cm and in rows seed were sown continuously.

3.12 Intercultural operations

Intercultural operations were done in order to ensure and maintain the normal growth of the crops. They are described below:

3.12.1 Irrigation

The plots were irrigated twice after first weeding and then at 55 DAS.

3.12.2 Weeding

Manual weeding was done two times at 18 and 50 days after sowing (DAS).

3.12.3 Crop protection

At seedling stage, Foot Rot (*Fusarium oxysporum*) attacked the young seedlings and The pathogen attacked the collar region of the plant causing slight yellows brown discoloration and rotting of the tissue. The young seedling showed damping off symptoms. The infected crop became chlorotic, quickly died and dried up. Autostin 80WP was sprayed @ 2g l^{-1} on seedling at 20 days interval for 3 times to protect crop.

3.12.4 Thinning

The optimum plant population was maintained by thinning excess plant. Seeds were germinated 6 days after sowing (DAS).Thinning was done twice; First thinning was done at 15 and second was done at 25 days after sowing (DAS) respectively to maintain plant to plant distance as 10 cm.

3.13 Harvesting and threshing

Crop was harvested when 90% of the pods become brown to black in color. The matured crops was harvested and tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.14 Drying and weighing

The seeds and straws were dried in the sun for couple of days. Dried seeds and stovers of each plot was weighed and subsequently converted into ha^{-1} basis.

3.15 Sampling and data recording

For collecting data on crop characters, 5 sample plants per plot were selected at random and uprooted prior to harvesting. The grain and straw yields were recorded plot-wise at 14% moisture level in t ha^{-1}. The data on the following crop parameters were recorded from each plot.

i. Plant height (cm)

ii. Branches plant^{-1}

iii. Number of pods plant^{-1}

iv. Number of seeds plant^{-1}

v. Weight of 1000 seeds (g)

vi. Stover yield (t ha^{-1})

vii. Seed yield (kg ha^{-1})

3.16 Data collection techniques

Five plants are selected and yield and yield contributing characters of lentil are measured at 20,40,60,80 days after sowing (DAS) and at harvesting. A brief outline of the data recording procedure is as follows:

3.16.1 Plant height

Heights of the five selected plants were measured from the ground level to the tip of the plants and their average was calculated at 20,40,60,80 DAS and at harvesting.

3.16.2 Number of branches plant^{-1}

Number of branches plant^{-1} was counted during 20,40,60,80 DAS and at harvesting and then their average was calculated.

3.16.3 Number of pods plant^{-1}

Number of total pods plant^{-1} from each plot was counted from 80 DAS and at harvesting. Five samples of plants are taken randomly from each plot.

3.16.4 Number of seeds plant^{-1}

Number of seeds plant^{-1} was counted taking five plants of each plot and the average number was recorded.

3.16.5 Thousand seeds weight

The weight (g) of 1000 seeds from each plot was measured taking 5 plants at randomly from each unit plot after harvest and proper drying.

3.16.6 Stover yield

Stover obtained from each unit plot were sun dried and weighed carefully. The dry weight of stover of selected plants from the respective unit plot to record the final yield. The stover yield was finally converted to t ha^{-1}.

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

Seeds obtained from each plots are weighed and converted to kg ha^{-1}.

3.17 Chemical Analysis

Chemical analysis of lentil seed sample was completed in the laboratory of soil science division of Bangladesh Agricultural Research Institute (BARI), Joydebpur,Gazipur

3.17.1 Preparation of sample

Seed samples were cleaned, sun dried and then oven dried at 65°C. The oven dried materials were ground in a grinding mill and preserved in bags for chemical analyses.

3.17.2 Preparation of plant extract

Exactly 1g of finely ground seeds of lentil were taken into a 250 ml conical flask and 10 ml of di-acid mixture (HNO_3:HCl_4 = 2:1) was added to it. Then it was placed on an electric hot plate for heating at 180- 200°C until the solid particles disappeared and white fumes were evolved from the flask. Then it was cooled at room temperature, washed with distilled water and filtered into 100 ml volumetric flasks through Whatman No. 42 filter paper making the volume up to the mark with distilled water following wet oxidation method as described by Jackson (1973).

3.17.3 Nitrogen

The nitrogen content of the samples were determined by Macro Kjeldahl method by digestion with concentrated H_2SO_4 and digestion mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 10: 1: 0.1) and then distilled with 40% NaOH the ammonia distilled over was absorbed in boric acid in presence of mixed indicator (0.066 g methyl red + 0.099 g bromocresol green [$C_{21}dH_{14}O_5Br_4S$]+ 100 ml 95% methanol) and titrated against 0.01 N H_2S0_4 (Jackson, 1973).

3.17.4 Phosphorous

The was used to determine phosphorous content of the sample. In this method, ammonium molybdate $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$) and antimony potassium tartrate ($K(SbO)C_4H_4O_6\cdot \frac{1}{2}H_2O$)react in an acid medium with dilute solutions of orthophosphate to form an intensely colored antimony phospho–molybdate complex. This complex was reduced to an intensely blue – colored complex by ascorbic acid and the absorbance of the complex was measured at 660 ηm.

3.17.5 Potassium

Potassium content in the seed samples was determined with me help of a flame emission spectrophotometer using appropriate potassium filter. About 5 ml of extract of each sample was taken in a 50 ml beaker and was aspirated in a gas flame. The intensity of light emitted by potassium at 768 ηm was directly proportional to the concentration of potassium present in plant samples. The percent emission for potassium was recorded following the procedure suggested by Black(1965).

3.13.4 Boron

The content of boron in samples was determined by spectrophotometric method using Azomethine-H reagent. Exactly a 5 ml of exact was taken in a 25 ml volumetric flask then 4 ml buffer masking solution and 4 ml Azomethine-H was added. Then the volume was made up to the mark. After one hour, absorbence was measured at 420nm wavelength with help of spectrophotometer following the analytical technique outline by Tendon (1995)

3.13.5 Zinc

Zinc was determined by atomic absorption spectrometry by direct aspiration of the sample into an air-acetylene flame. The blank (acidified water) was aspirated to set the automatic zero control. The automatic concentration control was used to set the concentrations of standards. Five standard zinc solutions were used and the instrument was calibrated each time a set of samples was analyzed and checked calibration at reasonable interval

3.15 Statistical analysis

The recorded data were compiled, tabulated and subject to statistical analysis. Analysis of variance was done with the help of computer package programme MSTAT-C. The mean differences were adjudged by Ducan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

A field experiment was carried out at the research field of Sher-e-Bangla Agricultural University and the chemical analysis of lentil seed sample was completed in the laboratory of soil science division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur to study the effects of boron and zinc on the growth, yield and nutrient contents of lentil (BARI Masur-5). The effects of different levels of boron and zinc on different plant characters of lentil has been presented and discussed in this chapter. The results are discussed and interpreted under the following subheads.

4.1 Effect of Boron and Zinc on Morphological Character and Yield Attributes of Lentil.

4.1.1 Plant height

Application of different levels of boron and zinc influenced plant height significantly. At 20 DAS, the maximum plant height (6.867cm) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1}. The shortest plant height (6.25cm) was observed in 20 days after sowing from the control. At 40 DAS, the highest plant height (10.82cm) was found with the application of 2 kg B ha^{-1} and 5 kg Zn ha^{-1} and the lowest plant height (9.347cm) was recorded from control. When the field was fertilized with the application of boron and zinc in 60 days after sowing, the highest plant height (17.68cm) was recorded with the dose of 2 kg B ha^{-1} and 5 kg Zn ha^{-1}. The shortest plant height (13.68cm) was found from control.

The maximum plant height (29.57cm) was found with the application of boron and zinc fertilizer 2 kg Bha^{-1} and 5 kg Zn ha^{-1} at 80 days after sowing. The lowest plant height was observed as 19.60 cm from the control. But after harvest, the maximum plant height was observed as 31.18cm with the application of fertilizer 2 kg B ha^{-1} and zero 5 kg Zn ha^{-1}. But lowest result was recorded as 25.40 cm from control. From the above findings, it may be conclude that the combination of boron and zinc fertilizer significantly influenced the plant height. It might be due to increase in plant height and number of branches per plant as a result of cell wall strength, cell division and sugar transport which are plant functions related to boron. The similar trend was also observed on biological yield (Khattab *et al.,* 2016). The combined application of Zn and B showed significant positive impact on lentil yield than the single application of Zn or B. (Quddus *et al.,* 2014). Sakal *et al.* (1986) also reported the similar trend. Other yield contributing characters such as plant height, pods per plant, seeds per pod and 1000 seed weight were significantly influenced due to the combined application of B and Zn. Bhuiyan *et al.* (2008) found that the yield contributing characters of lentil responded significantly due to combined application of nutrient. Abdo (2001) reported the similar trend with foliar spray of Zn and B.

Table 1: Effect of boron and zinc on plant height (cm) in regular interval of lentils

Treatments	Plant Height at 20 DAS	Plant Height at 40 DAS	Plant Height at 60 DAS	Plant Height at 80 DAS	Plant Height at Harvest
B_0Z_0	6.250 e	9.347 f	13.68 f	19.60 g	25.40 d
B_0Z_5	6.317 e	9.747 e	17.51 ab	25.57 c	27.73 c
B_0Z_{10}	6.573 c	10.28 c	17.51 ab	21.52 e	29.47 b
B_2Z_0	6.657 b	10.75 ab	16.34 d	26.37 b	29.83 ab
B_2Z_5	6.867 a	10.82 a	17.68 a	29.57 a	31.18 a
B_2Z_{10}	6.573 c	9.977 d	17.08 bc	22.54 d	27.76 c
B_4Z_0	6.473 d	10.58 b	15.38 e	25.45 c	29.44 b
B_4Z_5	6.440 d	10.05 d	16.88 c	25.57 c	28.40 bc
B_4Z_{10}	6.437 d	9.507 f	16.91 c	20.77 f	29.43 b
$LSD_{(0.05)}$	0.07671	0.2170	0.4407	0.3912	1.505
CV (%)	0.61	1.26	1.55	0.95	3.06

B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

4.1.2 Branches plant^{-1}

At 20 DAS the maximum branches plant^{-1} (3.733) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1} (Table 2) and the shortest branches plant^{-1} (3.267) was observed from the control, At 40 DAS the highest branches plant^{-1} (6.867) was found with the application of 2kg B ha^{-1} and 5 kg Zn ha^{-1} and the lowest branches plant^{-1} (6.133) was recorded from the control. At 60 DAS the field was fertilized with the application of boron and zincs the highest branches plant^{-1} (12.12) was recorded with the dose of 2 kg Bha^{-1} and 5 kg Zn ha^{-1} and the lowest branches plant^{-1} (11.38) was found from the control which is statistically similar with the application of boron and zinc fertilizer 0 kg B ha^{-1} and 5 kg Zn ha^{-1} . At 80 DAS the maximum branches plant^{-1} (16.15) was found with the application of boron and zinc fertilizer 2 kg B ha^{-1} and 5 kg Zn ha^{-1} and the lowest number of branches plant^{-1} was observed was 15.41 from the control which is statistically similar with the application of boron and zinc fertilizer 0 kg B ha^{-1} and zero 5 kg Zn ha^{-1}. But at harvest, the maximum branches plant^{-1} was recorded as 28.73 with the application of fertilizer 4 kg B ha^{-1} and 5 kg Zn ha^{-1}. But lowest result was recorded as 16.73 from control. The branches plant^{-1} (19) was observed from the application of boric acid (1.5g/L) and 10 from the control Khattab *et al.* (2016). The combined application of Zn and B showed significant positive impact on lentil yield than the single application of Zn or B. Sakal *et al.* (1986) also reported the similar trend. Other yield contributing characters such as plant height, pods per plant, seeds per pod and 1000 seed weight were significantly influenced due to the combined application of B and Zn. Bhuiyan *et al.* (2008) found that the yield contributing characters of lentil responded significantly due to combined application of nutrient. Abdo (2001) reported the similar trend with foliar spray of Zn and B.

Table 2: Effect of boron and zinc on branches plant^{-1} in regular in regular interval of lentils

Treatments	Branches/Plant at 20 Days	Brach/Plant at 40 Days	Branches/Plant at 60 Days	Branches/Plant at 80 Days	Branches/Plant at Harvest
B_0Z_0	3.267 d	6.133 d	11.38 d	15.41 d	16.73 f
B_0Z_5	3. 467 c	6.200 d	11.45 d	15.48 d	22.73 c
B_0Z_{10}	3.467 c	6.333 cd	11.72 bc	15.61 cd	25.73 b
B_2Z_0	3.533 b	6.600 b	11.85 b	15.88 b	28.39 a
B_2Z_5	3.733 a	6.867 a	12.12 a	16.15 a	28.73 a
B_2Z_{10}	3.467 bc	6.667 b	11.92 b	15.95 b	28.39 a
B_4Z_0	3.467 bc	6.467 bc	11.85 b	15.88 b	21.06 d
B_4Z_5	3. 267 d	6.333 cd	11.58 cd	15.75 bc	19.39 e
B_4Z_{10}	3.267 d	6.333 cd	11.58 cd	15.61 cd	19.06 e
$LSD_{(0.05)}$	0.06185	0.1956	0.1956	0.1956	1.654
CV (%)	8.89	1.79	0.99	0.73	4.36

B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 :Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

4.1.3 Number of pods plants^{-1}

At 80 DAS the maximum number of pods plant^{-1} (38.46) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1} and the minimum pods plant^{-1} (22.61) was found when the field was under control treatment. The highest number of pods plant^{-1} (79.13) was found with the application of 2 kg B ha^{-1} and 5 kg Zn ha^{-1} at harvest. The lowest number of pods plant^{-1} (48.46) was recorded at harvest under control treatment.

Table 3: Effect of boron and zinc on number of pods plant^{-1} of lentil

Treatments	Number of Pods Plant^{-1} at 80 DAS	Number of Pods Plant^{-1} at Harvest
B_0Z_0	22.61 e	48.46 h
B_0Z_5	29.80 c	50.46 g
B_0Z_{10}	35.80 b	65.43 c
B_2Z_0	36.46 b	71.46 b
B_2Z_5	38.46 a	79.13 a
B_2Z_{10}	37.13 ab	70.20 b
B_4Z_0	36.46 b	60.46 d
B_4Z_5	27.46 d	58.80 de
B_4Z_{10}	26.91 d	52.73 f
$LSD_{(0.05)}$	1.881	1.695
CV (%)	3.34	1.32

B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4 kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

4.1.4 Number of seeds plant^{-1}

At 80 DAS the maximum number of seeds plant^{-1} (75.59) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1} and the lowest numbers of seeds plant^{-1} (51.93) was observed from the control.

At harvest the highest numbers of seeds plant^{-1} (133.4) was found with the application of 2 kg B ha^{-1} and 5 kg Zn ha^{-1} and the minimum number (70.02) of seeds plant^{-1} was recorded from the control.

Table 4: Effect of boron and zinc on number of seeds plant^{-1} of lentil.

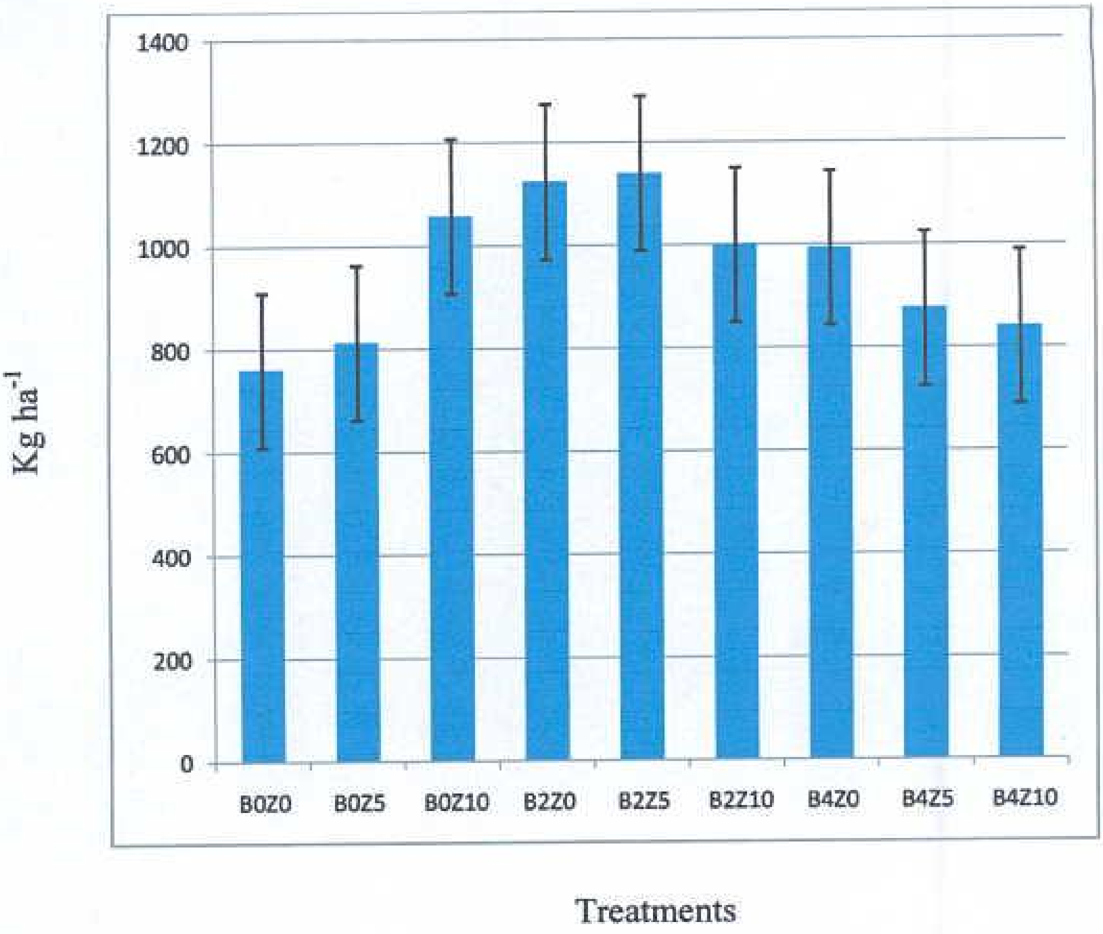
Treatments	Seeds Plant^{-1} at 80 DAS	Seeds Plant^{-1} at Harvest
B_0Z_0	51.93 f	70.20 h
B_0Z_5	71.26 bc	74.68 g
B_0Z_{10}	71.92 bc	94.01 f
B_2Z_0	73.26 bc	131.4 b
B_2Z_5	75.59 a	133.4 a
B_2Z_{10}	70.26 bc	131.4 b
B_4Z_0	69.04 bc	127.7 c
B_4Z_5	62.95 bc	118.0 d
B_4Z_{10}	57.93 f	109.4 de
$LSD_{(0.05)}$	2.015	2.345
CV (%)	1.83	1.32

B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

4.1.5 Seed Yield

The maximum seed yield (1140.20 kg ha^{-1}) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1} (Appendix-1). The minimum seed yield (760.2 kg ha^{-1}) was found from control (Appendix-1).



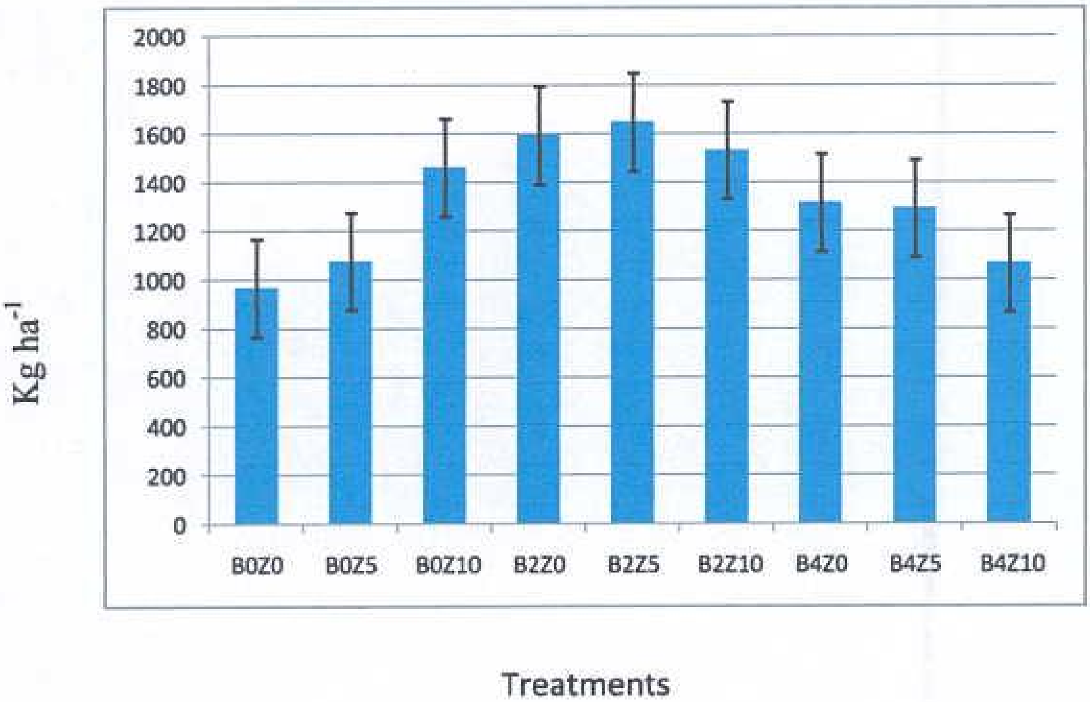
B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 2: Seed yield of lentil at different levels of boron and zinc interaction.

4.1.6 Stover Yield

The maximum stover yield (1649.73 kg ha^{-1}) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1}(Appendix-1). The minimum stover yield (968.87 kg ha^{-1}) was found from control (Appendix-1). Same studies have been conducted previously on yield response of lentil to Zn application (Thavarajah et al., 2009).



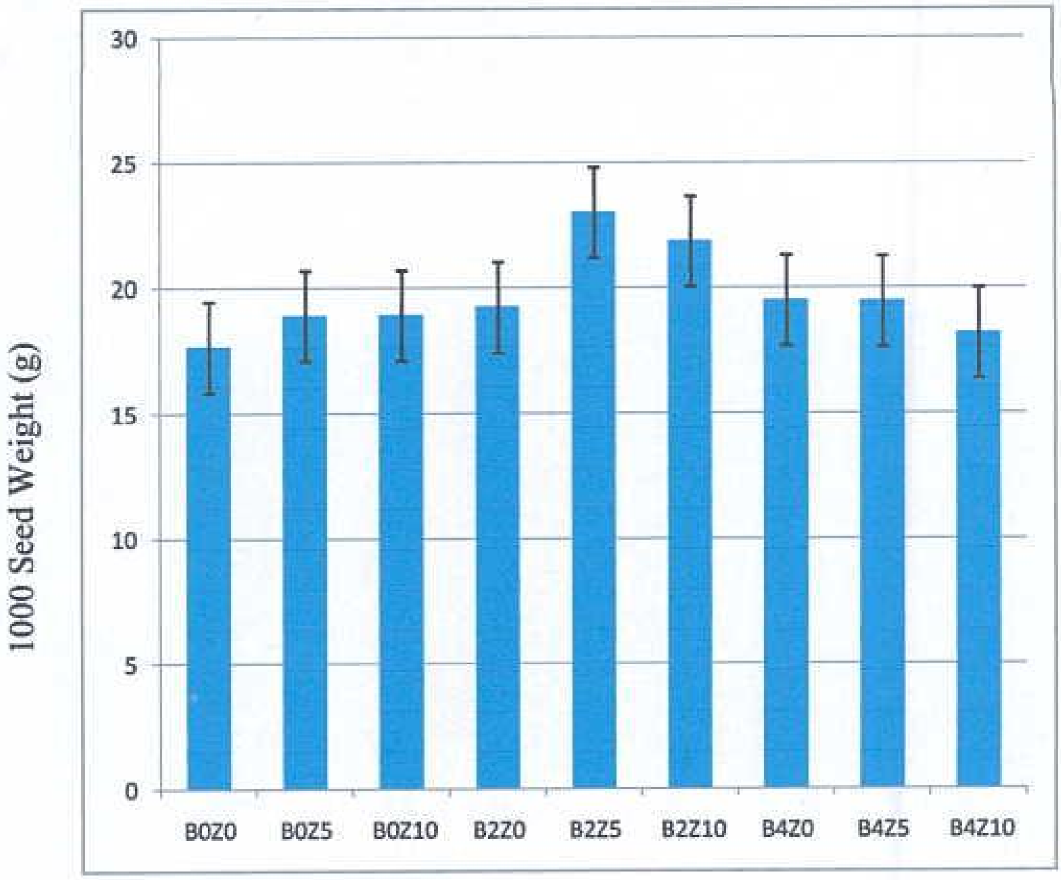
B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4 kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 3: Stover yield of lentil at different levels of boron and zinc interaction.

4.1.7 1000 Seed Weight

The maximum 1000 seed weight (23.02 gm) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1}(Appendix-1). The minimum 1000 seed weight (17.68 gm) was found from control.



Treatments

B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4 kg ha^{-1}

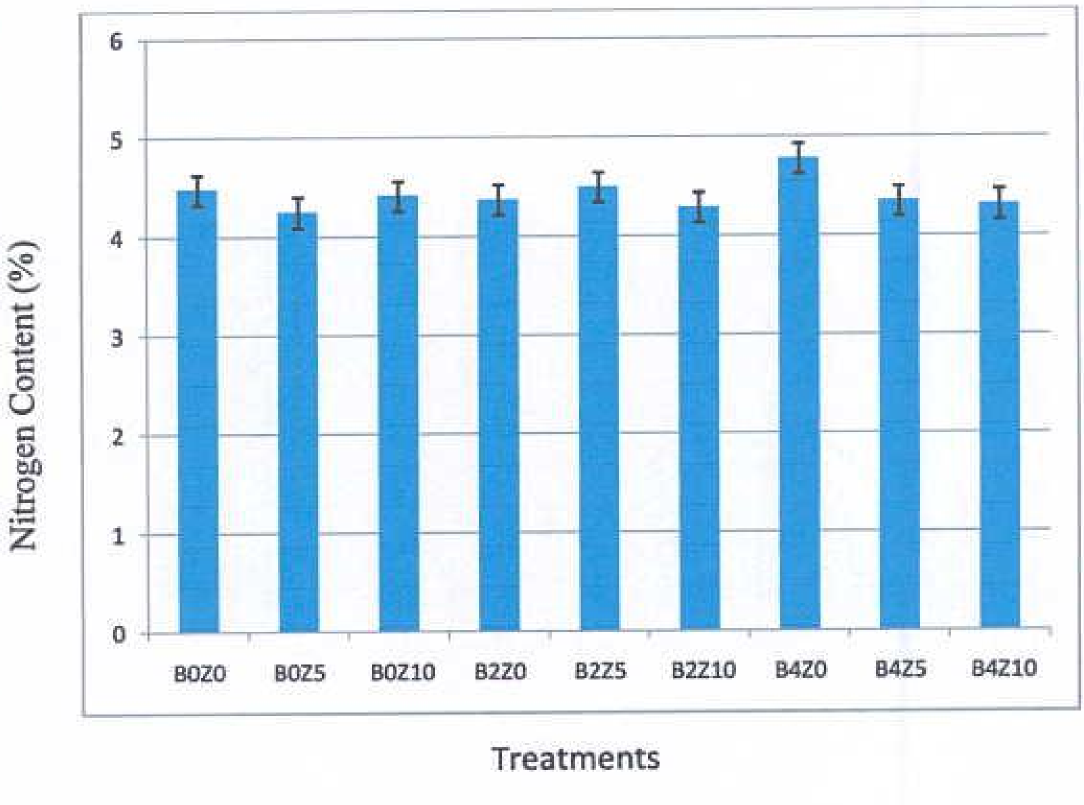
Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 4: Thousand seed weight of lentil seeds at different levels of boron and zinc interaction.

4.2 Nutrient contents in lentil seeds after applying treatments

4.2.1 Nitrogen

The highest amount (4.780%) of nitrogen content was observed in Lentil when the field was fertilized with the dose of boron and zinc 4kg B ha^{-1} and zero (0) kg Zn ha^{-1}(Appendix-2). The lowest amount (4.253%) of nitrogen content was observed in Lentil when the field was fertilized with the dose of boron and zinc zero (0) kg B ha^{-1} and 5 kg Zn ha^{-1} (Appendix-2).



B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4 kg ha^{-1}

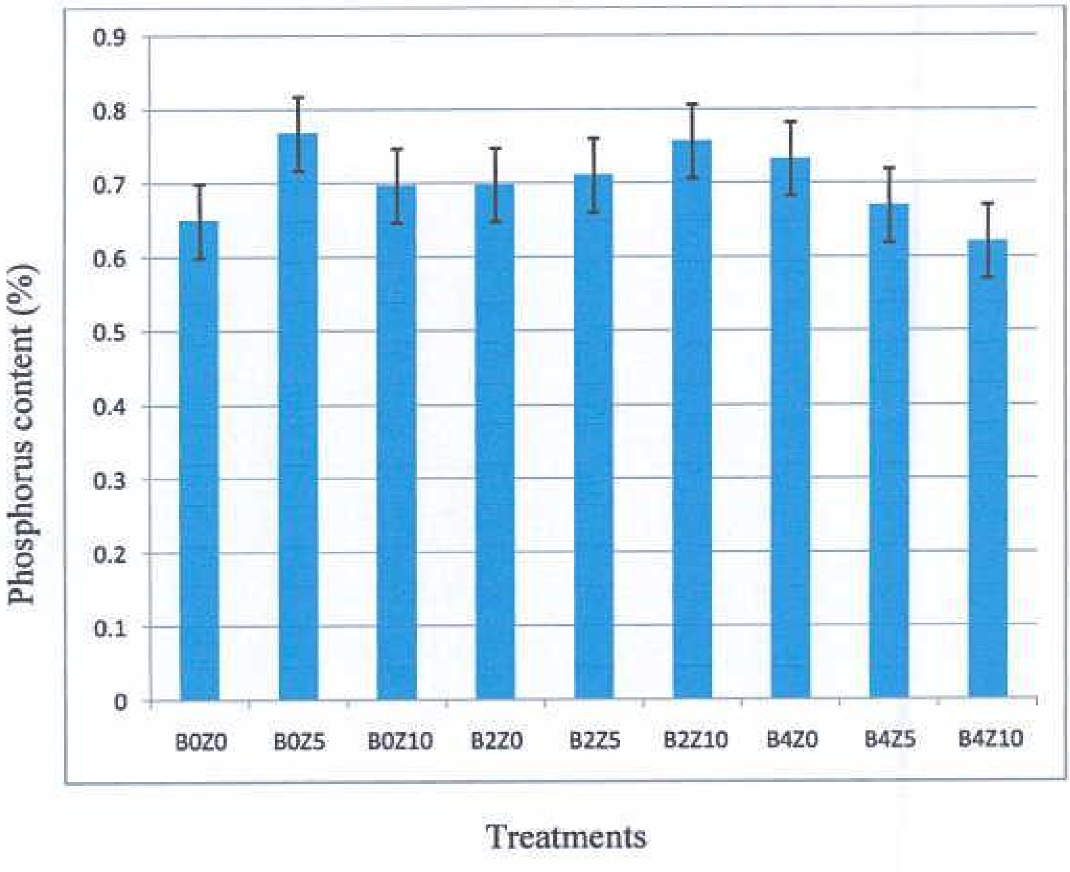
Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 5: Nitrogen content of seeds at different levels of boron and zinc interaction.

4.2.2 Phosphorus

The highest amount (0.768 %) of phosphorus content were observed in Lentil when the field was fertilized with the dose of boron and zinc zero (0) kg B ha^{-1} and 5 kg Zn ha^{-1}(Appendix-2).

The lowest amount of P content (0.6213%) was observed from the application dose of 4 kg B ha^{-1} and 10 kg Zn ha^{-1}.



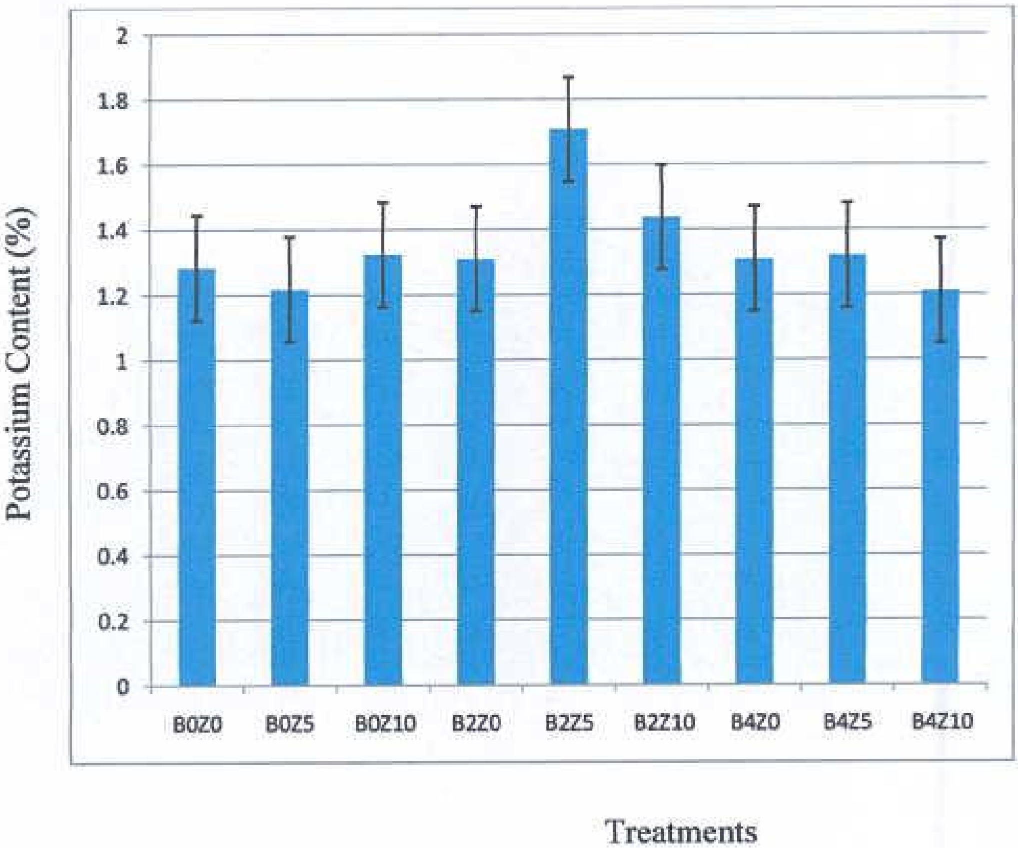
B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 6: Phosphorus content of seeds at different levels of boron and zinc interaction.

4.2.3 Potassium

The highest amount (1.707%) of potassium content was observed in Lentil seeds when the field was fertilized with the dose of boron and zinc 2kg B ha^{-1} and 5 kg Zn ha^{-1}(Appendix-2). The lowest amount (1.2107%) of potassium content was observed in Lentil seeds when the field was fertilized with the dose of boron and zinc 4 kg B ha^{-1} and 10 kg Zn ha^{-1}(Appendix-2).



B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

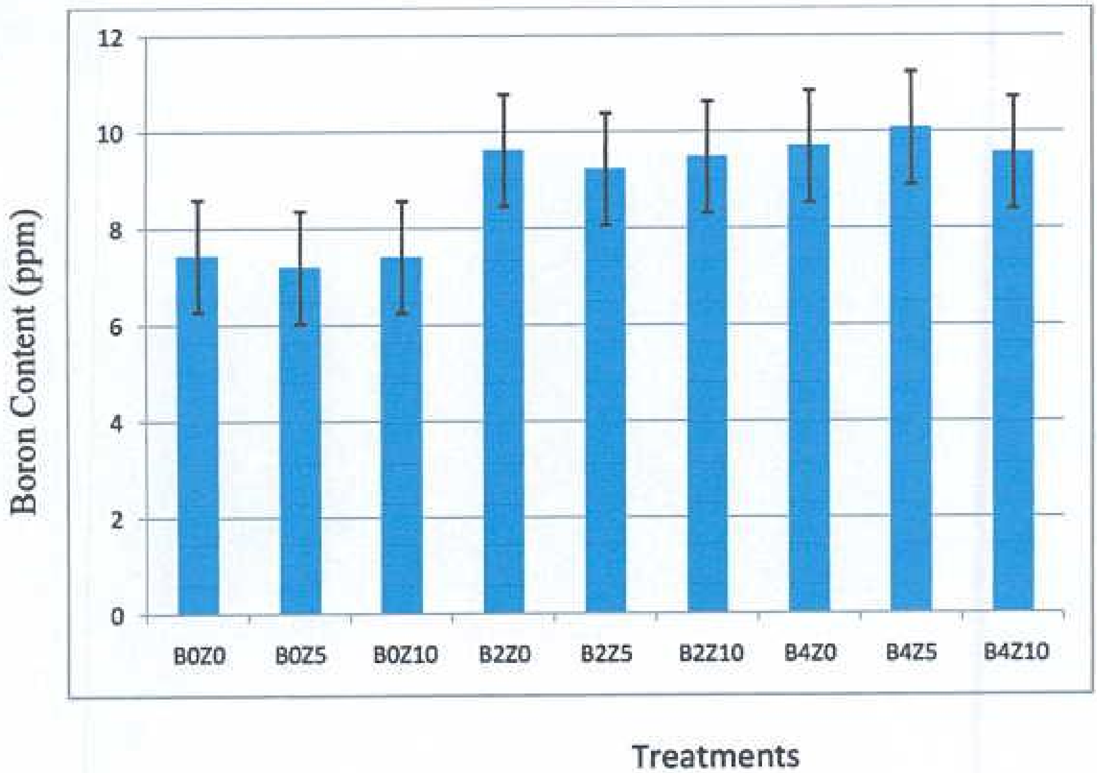
Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 7: Potassium content of seeds at different levels of boron and zinc interaction.

4.2.4 Boron

The highest amount (10.08ppm) of boron content was observed in Lentil when the field was fertilized with the dose of boron and zinc 4 kg B ha^{-1} and 5 kg Zn ha^{-1} (Appendix-2).

But the lowest boron content was found as 7.20ppm, when the field was fertilized with the application of boron and zinc zero (0) kg B ha^{-1} and 5 kg Zn ha^{-1}.



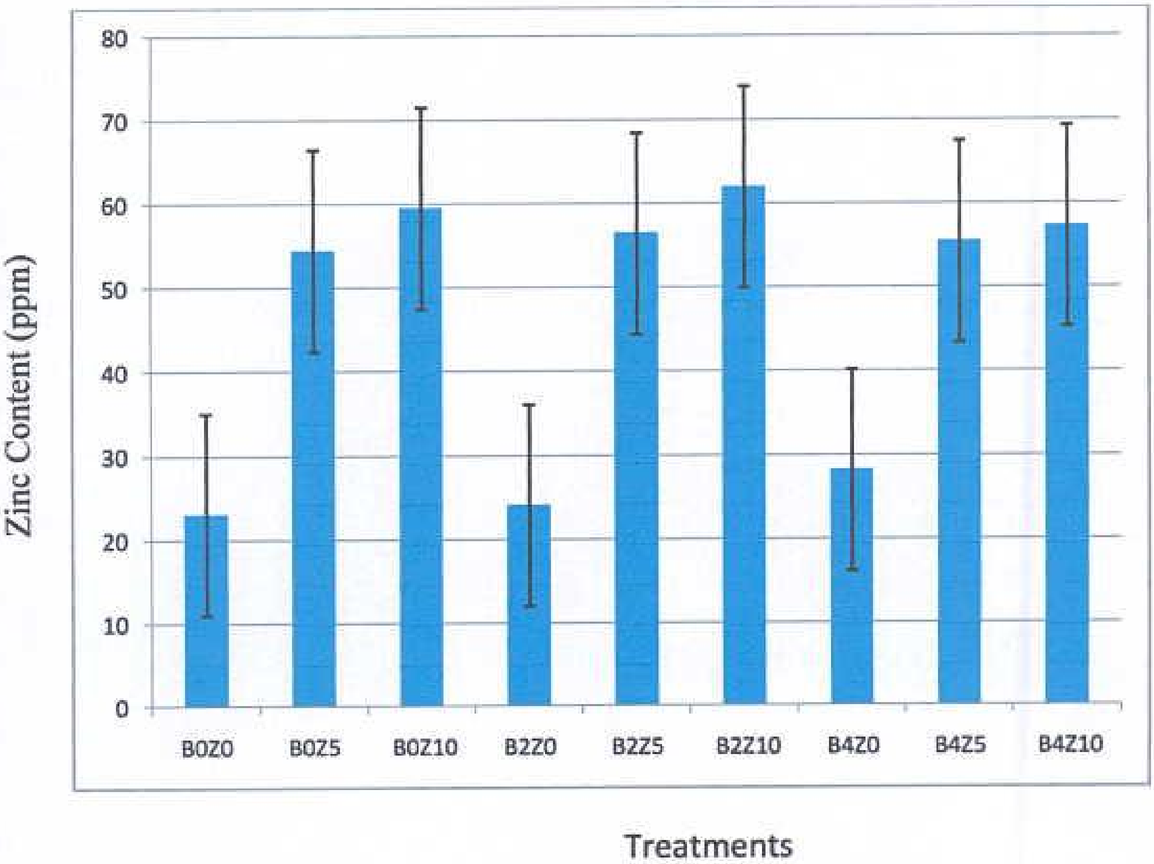
B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 8: Boron content of seeds at different levels of boron and zinc interaction.

4.2.5 Zinc

The highest amount of zinc content (62.03ppm) was observed in Lentil when the field was fertilized with the dose of boron and zinc 2 kg B ha^{-1} and 10 kg Zn ha^{-1}(Fig. 9). But the lowest Zn content was found as 24.13ppm, when the field was fertilized with the application of boron and zinc 2 kg B ha^{-1} and zero (0 kg Zn ha^{-1}, whereas the Zn content (23.12ppm) was observed from the control.



B_0 : Control; B_2 : 2 kg ha^{-1}; B_4 : 4kg ha^{-1}

Z_0 : Control; Z_5 : 5 kg ha^{-1}; Z_{10} : 10 kg ha^{-1}

Fig. 9: Zinc content of seeds at different levels of boron and zinc interaction.

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka and chemical analysis was carried out in the Laboratory of Division of Soil Science Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from November 2016 to March 2017. Three levels of boron viz., 0,2, 4 kg B ha^{-1} and zinc levels as 0, 5,10 kg Zn ha^{-1} are applied to evaluate the effects on growth, yield and nutrient contents of lentil (BARI Masur-5). The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments namely B_0Z_0 (control), B_0Z_5 (0 kg B, 5 kg Zn ha^{-1}) B_0Z_{10} (0 kg B,10 kg Zn ha^{-1}), B_2Z_0 (2 kg B, 0 kg Zn ha^{-1}), B_2Z_5 (2 kg B, 5 kg Zn ha^{-1}), B_2Z_{10} (2 kg B,10 kg Zn ha^{-1}), B_4Z_0 (4 kg B, 0 kg Zn ha^{-1}), B_4Z_5 (4 kg B,5 kg Zn ha^{-1}) and B_4Z_{10} (0 kg B,5 kg Zn ha^{-1}) and three replications. There were 27 unit plots and the size of the plot was 12m × 23m i.e. 276 m^2. The experimental plots were fertilized as per treatments with boric acid and zinc sulfate. The total amount of boric acid and zinc sulfate were applied at the time of final land preparation. Weeding and irrigation were done once before boric acid application.

At 20,40,60,80 days after seedling (DAS) and after harvest the maximum plant heights were 6.867cm, 10.82 cm, 17.68 cm, 29.54 cm and 31.18 cm when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1}. At same intervals, the minimum plant heights were 6.250cm, 9.347 cm, 13.68 cm, 19.60 cm and 25.40 cm were observed under control. At 20,40,60,80 DAS and at harvest the maximum numbers of branches $plant^{-1}$ observed were 3.733, 6.867, 12.12, 16.15 and 28.29 when plots were fertilized with 2 kg B, 5 kg Zn ha-1. At same intervals, the minimum numbers of branches $plant^{-1}$

found were 3.267, 6.133, 11.38, 15.41 and 16.73 were observed under control.

At 80 DAS and after harvest maximum numbers of pods plant^{-1} observed were 38.80 and 79.13 when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1} and minimum numbers of pods plant^{-1} observed were 21.25 and 79.13 from control treatment.

At 80 DAS and after harvest maximum numbers seeds plant^{-1} observed were 75.59 and 133.4 when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1} and minimum numbers of seeds plant^{-1} observed were 51.93 and 70.20 from the control.

The maximum seed yield (1140.20 kg ha^{-1}) was found when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1}. The lowest amount of seed yield (760.2kg ha^{-1}) was recorded from the control. The maximum stover yield (1649.73 kg ha^{-1}) was found when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1}. In case of control, the lowest amount of stover yield (968.87kg ha^{-1}) was recorded. The maximum 1000 seed weight (23.02 gm) was found when the crop was fertilized with 2 kg B ha^{-1} and 5 kg Zn ha^{-1}(Appendix-1). In case of control, the lowest amount of 1000 seed weight (17.68gm) was recorded.

The highest amount (4.780%) of nitrogen content were observed in Lentil when plots were fertilized with 2 kg B, 5 kg Zn ha^{-1} (Appendix-2) and the lowest amount (4.253%) was observed at 0 kg B, 5 kg Zn ha^{-1}.

The highest amount of phosphorus content (0.768%) was found under treatment 0 kg B, 5 kg Zn ha^{-1} .The lowest amount of Phosphorus content

(0.621%) was observed from the application of treatment 4 kg B, 10 kg Zn ha^{-1}

The highest amount (1.707%) of potassium content were observed in lentil when the field was fertilized with the dose of boron and zinc 2 kg B, 5 kg Zn ha^{-1} (Appendix-2). The lowest amount of Potassium content (1.217 %) was observed from treatment of 0 kg B, 4 kg Zn ha^{-1},

The highest amount (10.08 ppm) of boron content was observed in Lentil when the field was treated with 4 kg B, 5 kg Zn ha^{-1} (Appendix-2). But the lowest B content was found as 7.20 ppm, when the field was treated with 0 kg B, 5 kg Zn ha^{-1}.

The highest amount (62.03ppm) of zinc content was observed in Lentil when the field was treated with 2 kg B, 10 kg Zn ha^{-1} (Appendix-2). But the lowest Zn content was found as 24.13ppm, when the field was treated with 2 kg B, 0 kg Zn ha^{-1} .

It may be inferred from the present study that the growth, yield and nutrient quality of lentil increased with the application of 2 kg B, 5 kg Zn ha^{-1}. So, better physiological efficiency and successfully lentil production is possible by using optimum B and Zn fertilizers. Excessive use of Zn and B fertilizers showed retarding effect and not brings further yield improvement.

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Appendices

APPENDICES

APPENDIX-1: Effect of different levels of boron and zinc interaction on yield of lentil.

Treatments	SEED YIELD (kg ha^{-1})	STOVER YIELD (kg ha^{-1})	1000 SEED WEIGHT (g)
B_0Z_0	760.2 f	968.87 e	17.68 g
B_0Z_5	813.3 ef	1077.51 d	18.92 f
B_0Z_{10}	1058.2 bc	1462.92 b	18.93 de
B_2Z_0	1124.6 ab	1595.98 bc	19.25 de
B_2Z_5	1140.2 a	1649.73 a	23.02 a
B_2Z_{10}	1000.3 c	1533.62 ab	21.86 b
B_4Z_0	993.7 c	1317.36 c	19.52 c
B_4Z_5	875.5 d	1294.23 c	19.49 d
B_4Z_{10}	840.3 de	1068.87 d	18.21 fg
$LSD_{(0.05)}$	54.25	121.32	1.716
CV (%)	23.30	17.11	43.68

APPENDIX-2: Nutrient contents of seeds of lentil at different levels of boron and zinc interaction

Treatments	N (%)	P (%)	K (%)	B (ppm)	Zn (ppm)
B_0Z_0	4.480 b	0.650 e	1.283 d	7.44 d	23.12 f
B_0Z_5	4.253 e	0.768 a	1.217 e	7.20 e	54.52 d
B_0Z_{10}	4.413 bc	0.697 d	1.323 c	7.41 de	59.56 ab
B_2Z_0	4.373 cd	0.698 d	1.310 c	9.62 b	24.13 f
B_2Z_5	4.497 b	0.711 cd	1.707 a	9.23 c	56.51 cd
B_2Z_{10}	4.290 de	0.757 ab	1.437 b	9.48 b	62.03 a
B_4Z_0	4.780 a	0.733 bc	1.310 c	9.70 b	28.25 e
B_4Z_5	4.350 cd	0.670 e	1.320 c	10.08 a	55.52 cd
B_4Z_{10}	4.317 de	0.621 f	1.210 e	9.57 b	57.35 bc
$LSD_{(0.05)}$	0.08913	0.02426	0.01715	0.2276	2.538
CV (%)	3.74	6.78	2.64	4.74	3.16

APPENDIX-3: Weather data, 2016-2017, Dhaka

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
2016	October	33.1	18.0	25.6	77	130	5.4
2016	November	32.0	15.0	23.5	67	14	7.8
2016	December	28.2	13.5	20.9	79	8	3.8
2017	January	24.5	11.5	18.0	72	6	5.7
2017	February	33.1	12.9	23.0	55	10	8.1

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

APPENDIX 4: Experimental site showing in the map under the present study