INFLUENCE OF FOLIAR APPLICATION OF ZINC AND BORON ON THE GROWTH AND YIELD OF LENTIL

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INFLUENCE OF FOLIAR APPLICATION OF ZINC AND BORON ON THE GROWTH AND YIELD OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled, **"INFLUENCE OF FOLIAR APPLICATION OF ZINC AND BORON ON THE GROWTH AND YIELD OF LENTIL"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **NAHIDA SULTANA, Registration No. 12-04956** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: **Prof. Dr. A. K. M. Ruhul Amin**

Dhaka, Bangladesh **Supervisor**

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ABSTRACT

An experiment was carried out at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the influence of foliar application of zinc (Zn) and boron (B) on the growth and yield of lentil during the period from November 2017 to March 2018. Zn and B were applied as foliar application in different combinations such as F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application and F_3 = Zn and B foliar application at four growth stages, i.e S_0 = control (without Zn and B), S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering and S_3 = at 10 leaf stage + flowering + pod formation were considered for the present study. The experiment was laid out in split plot design with three replications. Data on different growth and yield parameters were recorded and analyzed statistically by using MSTAT-C software program. The level of significance among the treatments was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability. The result revealed that application of Zn and B (F_3) as foliar spray was superior in producing highest yield (1701.7 kg ha^{-1}), as well as higher growth and yield attributes characters. In case of foliar application at 10 leaf + flowering + pod formation stage showed highest yield (1701.3 kg ha^{-1}) yield attributes and growth characters. On the other hand, treatment combination of F_3S_3 (Zn and B foliar application with combination of time of application at 10 leaf stage + flowering + pod formation) showed the highest plant height (38.28 cm), dry weight $plant^{-1}$ (26.29 g), number of branches $plant^{-1}$ (9.33), number of pods $plant^{-1}$ (52.44), number of seeds pod^{-1} (2.12), shelling percentage (43.24%), 1000 seed weight (22.49 g), seed yield (1852.0 kg ha^{-1}), stover yield (1956.3 kg ha^{-1}) and biological yield (3808.3 kg ha^{-1}) where lowest result on the respected parameters were obtained from the treatment combination of F_0S_0 (without Zn and B).

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Lentil (*Lens culinaris* L.) is a pulse crop which takes second position in respect of area and production of Bangladesh. It 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 (434 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 in the world (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).

It is considered as poor man's meat (because of high protein content, and easily digestible element) and low-cost source of protein for poor group of people who cannot afford to buy animal protein. 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 *(Lens culinaris* Medic) is an important grain legume in Asia. It occupies an important position in this region. It is an important source of protein and several essential micronutrients. 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 has with flat bread or rice in Bangladesh. Lentil seed contains 25% protein as against 7.5% protein in rice and 11.9% in wheat.

It synthesizes N in symbiosis with Rhizobia and enriches the soil. It improves the fertility status of soil through atmospheric N fixation. 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 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. 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.

Genetic potential of legume is not obtained at field due to poor soil nutrient status, mineral deficiency, etc. (Maskey *et al*., 2004). However, there is a great possibility to increase lentil production by cultivating HYV with balanced fertilization including micronutrient. Micronutrients play an important role in increasing yield of pulses. Zinc and B deficiency is widespread in the country; much observed in wetland rice soils, light textured soils and calcareous soils (Jahiruddin *et al.* 1992; Rahman *et al.* 1993; Islam *et al.* 1997).

The functional role of Zn includes auxins metabolism, Nitrogen metabolism, influence on the activities of enzymes (e.g. dehydrogenase and carbonic anhydrase, proteinases, and peptidases), and cytochrome synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al.* 1997; Obata *et al.* 1999, Hafeez *et al*., 2013). Ozturk *et al*., (2006) found that Zn in newly-developed radicles and coleoptiles during seed germination was much higher (up to 200 mg kg^{-1}) thus highlighting the involvement of Zn in physiological processes during early seedling development, possibly in protein synthesis, cell elongation membrane function and resistance to abiotic stresses (Cakmak, 2000). Poor growth, interveinal chlorosis and necrosis of lower leaves are the common symptoms of Zn deficiency in field crops. Plants emerged from seeds with low concentrations of

Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al.* 1999). Zinc enriched seeds can perform better seed germination, seedling health, crop growth and finally yield advantage (Cakmak *et al.* 1996). Within plants Zn seems to affect the capacity for water uptake and transport (Kasim, 2007; Disante *et al*., 2010) and to reduce the adverse effects of short periods of heat stress (Peck and McDonald, 2010) or salt stress (Tavallali *et al*., 2010). Since Zn is required for the synthesis of tryptophan (Alloway, 2004), which is a precursor of IAA, this metal also has an active role in the production of auxin, an essential growth hormone (Brennan, 2005). An excess of Zn has been reported to have a negative effect on mineral nutrition (Chaoui *et al*., 1997). In several crops, higher soil phosphorus (P) contents may induce Zn deficiency (Chang, 1999; Foth and Ellis, 1997). Zinc (Zn) deficiency is a major yield-limiting factor of mungbean cultivation and like other pulse crop in several Asian countries (Rehman *et al*., 2015). Foliar application of Zn is a quick and easy way to meet up zinc deficiency in lentil. Singh and Bhatt (2013) found that foliar application of Zn at 0.04% produced maximum lentil seed (1 238.6 kg/ha), whereas lowest (1 063.1 kg ha^{-1}) was recorded under control.

Boron is one of the essential micronutrients required for plant growth and productivity. It is very important in cell division and in pod and seed formation (Vitosh *et al.* 1997, Goldberg and Su, 2007). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Noppakoonwong *et al.* 1997). Boron influence the absorption of N, P, K and its deficiency changed the equilibrium of optimum of those three macronutrients. The N and B concentrations of grain for lentil were markedly influenced by B treatment indicating that the B had a positive role on protein synthesis. Iqtidar and Rahman (1984) found that essential amino acid increased with increasing B supply.

Mary *et al*. (1990) observed that foliar application of boron resulted increase in the number of pods/branches, increased the number of seeds/plant and seed yield plant^{-1} of mungbean and other pulse crops. The response of pulse to boron application varied from 167 to 182 kg ha^{-1} with 2 kg B ha^{-1} (Sakal *et al*., 1995). Photosynthetic activity and metabolic activity enhanced with application of boron (Lalit Bhott *et al*., 2004, Sathya *et al*., 2009). Boron is a micronutrient essential for normal growth of pollen grains, sugar translocation and movement of growth regulators within the plant (Hamasa and Putaiah, 2012). Boron's involvement in hormone synthesis and translocation, carbohydrate metabolisms and DNA synthesis probably contributed to additional growth and yield (Ratna Kalyani *et al*., 1993). Deficiency of B causes severe reductions in crop yield, due to severe disturbances in B-involving metabolic processes, such as metabolism of nucleic acid, carbohydrate, protein and indole acetic acid, cell wall synthesis, membrane integrity and function, and phenol metabolism (Tanaka and Fujiwar, 2008). Foliar application of B is very effective for quick removal of boron deficiency and contributes to achieve higher yield (Bozoglu *et al*., 2008).

Therefore, applications of micronutrients especially Zn and B have gained practical significance. The present study was therefore, undertaken with the following objectives:

1. To find out the effect of Zn and B foliar application in lentil,
2. To select the appropriate growth stage of Zn and B application in lentil, and
3. To find out the interaction effect of Zn and B application at different growth stages of lentil.

CHAPTER II

REVIEW OF LITERATURE

Lentil (*Lens culinaris* L.) is one of the commonly grown and consumed pulse crops in Bangladesh and all over the world. It is considered to be a very important leguminous pulse seed crop in the world. Much attention has been received by a large number of researchers on various aspects of lentil production, processing and utilization. Since review of literature forms a bridge between the past and present research works related to problem, which helps an investigator to draw a satisfactory conclusion. An effort was thus made to present some research works related to the present study in this section.

2.1 Effect of zinc

Oktem (2019) conducted a study aimed to determine the effects of different zinc (Zn) levels on the grain yield and some phenological characteristics of the F.rat-87 red lentil variety (*Lens culinaris* Medic.). The F.rat-87 lentil variety and Zn sulfate ($ZnSO_4.7H_2O$) were used as the plant material and Zn source, respectively. The Zn levels used were the control (0 kg ha^{-1} Zn), 5 kg ha^{-1}Zn, 10 kg ha^{-1} Zn, 15 kg ha^{-1} Zn, 20 kg ha^{-1} Zn, and 25 kg ha^{-1} Zn. The Zn levels were significant (P. $_{0.01}$) for the harvest index, 1000-kernel weight, protein rate, and grain yield. All of the tested characteristics were positively affected by increasing applications of Zn. The grain, leaf, and soil Zn contents were higher with increasing levels of Zn. Although the highest grain yield was at 15 kg ha^{-1} Zn, according to the regression analysis, the optimum Zn level was 17 kg ha^{-1} Zn. However, the economic Zn level was determined as 15 kg ha^{-1} Zn.

Rahman *et al*. (2015) conducted a field experiment to study the effects of Phosphorus and Zinc on the growth and yield of Mungbean (BARI Mug 6). Four levels of phosphorus (P) (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (Zn) (0, 1.5 and 3 kg Zn ha^{-1}) were used in the study. The results revealed that seed and stover yield of mungbean increased with increasing levels of phosphorus and zinc up to certain level. In case of Zn the maximum significant seed yield (1.45 t ha^{-1}) and stover yield (2.42 t ha^{-1}) were obtained with the treatment Zn_2 (3 kg Zn ha^{-1}) and the minimum significant seed yield (1.27 t ha^{-1}) and stover yield (2.21 t ha^{-1}) were obtained with the treatment Zn_0 (0 kg Zn ha^{-1}). The maximum significant plant height (52.05 cm), number of branch $plant^{-1}$ (2.87), number of pods $plant^{-1}$ (20.86), number of seeds pod^{-1} (12.65), shelling percent (36.75%) and weight of 1000-seeds (45.11 g) were also obtained with the treatment of Zn_2 (3 kg Zn ha^{-1}).

Karmakar *et al*. (2015) conducted a field experiment during the kharif season of 2014 to study the effects of Zinc on the concentrations of N, P, K, S and Zn in Mungbean stover and seed (BARI mug 6). Three levels of zinc (Zn) (0, 1.5 and 3 kg Zn ha_{-1}) were used in the study. The results revealed that the N, P, K and S concentration of mungbean plant increased significantly from control to Zn_2 (3 kg Zn ha^{-1}) treatment. Application of zinc increase organic carbon, N, P, K and S status of postharvest soil significantly. Zn_2 (3 kg Zn ha^{-1}) treatment also produced highest pods $plant^{-1}$, seeds pod^{-1} and seed yield ha^{-1}.

Malik *et al*. (2015) conducted an experiment during the years 2011-2012 to study the effect of zinc on plant height (cm), number of productive branches, number of leaves, leaf area (sq.cm.), fresh weight (g), dry weight (g), number of pods per plant, seed yield per plant and 1000 seeds weight (g) (Test weight) of mungbean (*Vigna radiata* L.) var. Pant Mung-4 and Narendra-1. The doses of zinc were 5, 10, 15 and 20 ppm. The results were found significant of both varieties of mungbean with Zn application of different rates. All the parameters were significantly influenced by Zn and highest seed yield per plant was from 10 ppm Zn.

Singh and Bhatt (2013) conducted a field experiment to develop zinc management strategy for late sown lentil (*Lens culinaris* Medik) crop alone or in cropping system mode. Four levels of Zn, *viz*. Zn_1 control (0.0%), Zn_2 (0.02%), Zn_3 (0.04%), Zn_4 (0.08%) were applied foliar twice, first at pre-flowering and second at post podding stage. Highest (42.2 cm) and lowest (32.8 cm) plant height at harvest was recorded with application of 0.08% Zn and in control treatment. Longest (12.1cm) and shortest (7.9cm) root was recorded in the plots treated with 0.08% Zn and control respectively. Zn treatment (0.04%) produced maximum lentil seed (1238.6 kg/ha), whereas lowest (1063.1 kg/ha) was recorded under control. Highest nitrogen concentration (1.98 per cent) and N uptake (55.7 kg/ha) was recorded in plots fertilized with Zn applied @0.08%. Gradual buildup of organic carbon, N, P and K and zinc content in the soil were also noticed. It is recommended that under late sown condition foliar feeding with 0.04 % Zn twice during pre-flowering and post podding stage will increase lentil seed yield by 16.2%.

Ram and Katiyar (2013) conducted a field experiment to evaluate the influence of sulphur and zinc on mungbean for two respective summer seasons i.e. 2008-09 and 2009-10. The experiment with four levels of sulphur (0, 20, 40 and 60 Kg S ha^{-1}) and four levels of zinc (0, 5, 7.5 and 10 Kg Zn ha^{-1}). The summer mungbean variety "Narendra Moong-1" was used. The results revealed that application of 10 kg Zn ha^{-1} significantly increased the plant height, number of branches $plant^{-1}$, number of nodules $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, seed yield, protein content (%) and test weight was non-significant. The control (0 kg Zn ha^{-1}) had the poorest performance in respect of yield and protein content of mungbean seed during both the years, respectively. The highest seed yield (14.40 q ha^{-1}) was observed in 10 kg Zn ha^{-1} which was significantly superior over rest of the treatments during 2008-09 and 2009-10, respectively. The minimum seed yield (9.56 and 10.06 q ha^{-1}) was achieved with 5 kg Zn ha^{-1} and least was in control during both the years.

Samreen *et al*. (2013) conducted an experiment using four varieties of mungbeans (Ramazan, Swat mungI, NM92 and KMI) with nutrient solutions with and without Zn. Each variety was applied with Zn solutions at three levels i.e. 0, 1 and 2 µM concentrations. Plant growth, chlorophyll contents, crude proteins and Zn contents were noted to be higher when greater supply of zinc doses was applied. Plant phosphorous contents declined with supply of Zn from 1 μM to 2 μM compared to the control signifying a Zn/P complex foundation possibly in roots of plant, preventing the movement of P to plant. Zinc application at 2 μM concentrations in solution culture turned out to be the best treatment for improving the growth and quality parameters of mungbean.

2.2 Effect of boron

Adhikary *et al*. (2018) conducted a field experiment to assess the effect of foliar applications of Boron on growth, yield attributing characters and yield of lentil, cv. Moitree, (WBL-77). The experiment was carried out in a randomized block design with four treatments and five replications. Results revealed that grain yield increased significantly with foliar application of Boron in to 3 splits (at 15, 40 DAS and at flower initiation stage), along with soil application of NPK over control. Application of boron recorded 26.98% higher seed yield than soil application of sole NPK fertilizers. The maximum plant height (38.86 cm), pod per plant (45.40), seed yield (11.34 q/ha) and BC ratio (2.06) were recorded in soil application of NPK along with 0.5% foliar application of Boron in to 3 splits i.e. at 15, 40 DAS and at flower initiation stage.

Vimalan *et al*. (2017) conducted a pot experiment to assess the response of green gram (CO 8) to the soil application of different levels of boron in a boron deficient soil. It appeared that 1.5 kg of B ha^{-1} significantly increased plant height, number of leaves and branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000 seed weight, seed yield and protein content (%). The control (0 kg of B ha^{-1}) had the poorest performance in respect of yield and protein content of green gram seed.

Hamza *et al*. (2016) conducted a field experiment to investigate the effect of levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and boron (0, 1.0, 1.5 and 2.0 kg ha^{-1}) on growth and yield of summer mungbean cv. BINAmung-8. The results indicated that the crop responded significantly to boron in respect of growth and yield such as plant height, number of branches plant^{-1}, pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000 seed weight, seed yield, stover yield, biological yield and harvest index. The highest seed yield (1.16 t ha^{-1}) was obtained from 1.5 kg B ha^{-1} followed by 2.0 kg B ha^{-1} (1.14 t ha^{-1}) and 1.0 kg B ha^{-1} (1.09 t ha^{-1}) whereas the lowest seed yield (1.04 t ha^{-1}) was obtained from the control plot.

Chander *et al*. (2015) recorded that adding S, B and Zn increased maize grain yield by 13-52% and soybean yield by 16-28% compared to nitrogen (N) and phosphorus (P) fertilization alone. The N, P plus 50% of S, B and Zn application every year recorded highest crop yields and N and P efficiencies indices. This study showed the importance of a deficient secondary nutrient S and micronutrients B, Zn in improving N and P use efficiency while enhancing economic food production.

Ram *et al*. (2014) showed that the response of soybean *[Glycine max* (L.) *Merrill]* to different levels of sulphur and boron. The experiment comprised of 13 treatments including all the combinations of 4 sulphur (S) levels (10, 20, 30 and 40 kg/ha) and 3 boron (B) levels (0.5, 1.0 and 1.5 kg/ha) and absolute control (no S, no B). The highest grain yield, protein, oil content, gross and net returns of soybean were recorded with 40 kg S/ha, which were statistically at par with 30 kg S/ha but significantly higher than other levels of sulphur. The productivity in 40 kg S/ha was enhanced 61.9% over the absolute control. The boron level of 1.5 kg/ha recorded the highest grain yield, gross and net returns, being statistically at par with 1.0 kg B/ha but significantly higher than 0.5 kg B/ha.

Ganie *et al*. (2014) studied the effect of sulphur and boron application on nutrient content and uptake pattern of N, P, K, S and B in French bean. The experiment showed that increase in application of sulphur led to an increase in the concentration and in turn uptake of N, P, K, S and B in pods, seeds as well as stover up to 45 kg/ha. However, the increase in nutrient concentration and uptake parameters with the increase in sulphur from 30 kg/ha to 45 kg/ha showed no significance. Owing to boron application similar trend was followed in N, P, K, S and B concentration and uptake by the crop. The interaction effect between sulphur and boron significantly and synergistically increased N, P, K, S and B content and uptake of French bean at pod picking stage as well as harvesting stage. However, it was found that higher levels of sulphur and boron showed antagonistic effect on nutrient content and uptake of French bean at pod picking stage as well as harvesting stage.

Blandino *et al*. (2014) investigated the effect of N and S application on the yield and quality of wheat grown on different soil types. Varying levels and sources of N and S fertilizers were applied at different growth stages of the crop. The quality parameters evaluated include test weight of 1000 seeds, protein content, flour strength, bread volume, and dough rheological properties. N application at late growth stages markedly influenced the qualitative aspects of the high-protein wheats. The application of sulfur to most deficient soil provided a synergistic effect with N to improve the flour strength and quality.

Sun Ting *et al*. (2013) examined the effects of molybdenum (Mo) and boron (B) on the rhizosphere microorganisms and the soil enzyme activities of soybean. The results showed that Mo and B, alone and in combination increased the soil microbial populations, stimulated the rhizosphere metabolisms, and improved the soil enzyme activities. These stimulatory effects varied in intensity among the treatment groups. The Mo + B treatments was more beneficial for the soybean rhizosphere than that of individual Mo or B treatments, which suggests that the two elements have complementary functions in the biological processes of the soybean rhizosphere.

Vyas and Khandwe (2013) studied the effect of sulphur and boron levels on physiological parameters, productivity, soil fertility and economics of soybean under rainfed conditions. The twenty five treatment combinations comprised of five sulphur levels viz., 0, 10, 20, 30, 40 and five boron levels viz., 0, 0.5, 1.0, 1.5, 2.0 kg per ha as basal. The significant higher value of oil was obtained at 10 kg S per ha and 0.5 kg B per ha whereas, protein was significantly higher at 30 kg S per ha and 2.0 kg B per ha. The interaction effect between sulphur and boron in all the parameters was not significant.

Singh *et al*. (2013) reported that increasing doses of sulphur and boron significantly enhanced the soybean seed yield. Application of sulphur @ 30 kg per ha recorded significantly higher seed yield (2,730 kg/ha), net returns (Rs 19,953) and B:C ratio (1.98) than its lower levels, but it remain at par to 40 kg S per ha. Similarly application of 1.5 kg B per ha significantly enhanced the yield attributes and seed as well as haulm yields of soybean.

Verma *et al*. (2012) evaluated the effect of boron (0, 0.5 and 1.0 kg B ha^{-1}) levels on uptake of nutrients in mustard. Results revealed that the application of 1.0 kg B/ha significantly increased seed yield and nutrients uptake (kg ha^{-1}) of mustard over control.

Sentimenla *et al*. (2012) reported that the influence of levels of phosphorus and boron fertilizer application on the yield, nutrient uptake and protein content of soybean. Treatments consisted of four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) and four levels of boron (0, 0.5, 1.0 and 1.5 kg/ha) including control. Results indicated the application of 60 kg P_2O_5/ha and 1.5 kg B/ha would be beneficial for higher production and quality of soybean.

Singh *et al*. (2012) studied the effect of sulphur and boron fertilization on yield attributes and yield of soybean. There were 25 treatment combinations consisting of five rates of both S (0, 10, 20, 30 and 40 kg S/ha) and B (0, 0.5, 1.0, 2.0 and 4.0 kg B/ha). The results of the experiments revealed that application of 30 kg S/ha recorded better yield attributes viz., branches/plant, pods/plant, seeds/pod and 100-seed weight and higher yield than the other treatments. Similarly, application of boron at 1.0 kg/ha recorded better yield attributes and higher yield of grain and straw.

Khurana and Arora (2012) studied the response of boron from two sources (borax and granubor) and reported that the application of 0.75 kg B ha^{-1} through borax and granubor increased lentil seed yield by 21.4 and 23.3%, respectively, over control indicating 2% higher response with granubor application. Boron content in lentil seed increased from 12.2 micro g g^{-1} in control treatment to the maximum of 24.1 micro g g^{-1} with the application of 1.25 kg B ha^{-1} through granubor. There was 24.6% increase in seed yield of soybean with the application of 1.25 kg B ha^{-1}through either of fertilizer source. Total B content increased to maximum of 59.8% over control when B was applied through borax.

Hajiboland *et al*. (2012) reported that boron (B) is a structural component of plant cell wall and boron deficiency causes disruption in development of plants. Influence of low boron supply on plants morphology and anatomy. Visual boron deficiency symptoms were observed in all studied species including curling of leaf margins in turnip, reduction of red coloration in red cabbage, shoot stunting in tobacco and turning dark purple colors in celery, Hypertrophy of leaf parenchyma cells in tobacco and increased thickening of collenchymas cell walls in the stem of celery were also observed.

Huang *et al*. (2012) investigated the effects of different phosphorous and boron treatments on soybean growth, P and B uptake, and the genetic variations at different growth stages in five soybean genotypes. The results showed that different P and B treatments significantly affected soybean growth, and there were significant interactions between P and B. Among which, P availability was the primary factor on soybean growth and B uptake. At the same B level, increasing P availability could significantly increase soybean plant dry mass, grain yield and P, B uptake. At the normal P level, increasing B availability only increased plant dry mass and P, B uptake of the P efficient genotypes, but not the P inefficient genotypes, particularly at mature stage. Improving B status could significantly increase the yield of P efficient soybean genotypes.

Devi *et al*. (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The experiment comprises five levels of sulphur (0, 10, 20, 30 and 40 kg sulphur per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron per hectare). The overall result revealed that application of 30 kg sulphur per hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum yield, oil and protein content, total uptake of sulphur and boron.

Sathya *et al*. (2011) evaluated the effect of boron (B) in tomato for content and uptake in shoot at various growth stages and fruit and found that application of B significantly increased the uptake of B. Application of 20 Kg borax ha^{-1} recorded the highest content and uptake of B in vegetative, flowering and harvest stage and in fruit. Among the foliar sprays, 0.25 per cent borax spray at 50 and 90 days after planting registered the highest B uptake in both shoot and fruit of tomato. The results also revealed that soil application of B had a more pronounced effect in increasing the uptake of B as compared to foliar sprays and control.

Shamsuddoha *et al*. (2011) studied the effect of boron on nutrients of mungbean and the soil health. Boron application at the rate of 2 kg ha^{-1} showed the highest nutrient concentration and maximum uptake of N, P, K and B in the seed and the stover of mungbean. In case of B application highest available B was recorded from B2 (2 kg B ha^{-1}) and the lowest was found from B0 (control) treatment. The highest soil pH and organic matter was recorded from B2 (2 kg B ha^{-1}) and the lowest pH and organic matter was found from B0 (control) treatment.

Khramoy and Sikharulidze (2011) observed that the effect of different mineral fertilizers on the seed and protein productivity of soybean. Results showed that the combined application of potassium, boron and molybdenum fertilizers was efficient and the application of 30 kg nitrogen fertilizer/ha (as basic and additional fertilizer) was in effective in increasing the seed and protein productivity of soybean, whereas the 60 kg nitrogen/ha treatment was effective in increasing the seed and protein productivity.

Agca and Karanlk (2011) determine spatial variability of boron (B) contents in the soils and to assess their spatial distribution patterns in Amik Plain. A total no. of 264 samples from surface and subsurface soil were collected from 132 sites. Soil samples were analyzed for B (only in the topsoil). Boron content was found to vary between 0.13 and 5.29 mg kg^{-1}. Except one, none of the soil samples contained more than 5 mg kg^{-1} which is a widely accepted critical concentration value for B toxicity in plants. Soil pH had the minimum variability at the depths of 0-20 and 20-40 cm and for pH at 0-20 cm showed moderate spatial dependence.

Vaiyapuri *et al*. (2010) studied the effect of boron fertilization on yield attributes of soybean. Application of B (0, 0.5, 1.0, 2.0 and 4.0 kg B ha^{-1}) revealed that levels of B (1.5-2.0) kg ha^{-1} recorded better yield attributes (branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and 100 seed weight) than other treatment.

Saxena and Nainwal (2010) evaluated the response of boron nutrition on yield attributes in *kharif* seasons of 2007 and 2008 with five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg B/ha). The effect of different doses of boron application on seed yield of soybean was significant. On mean performance basis, the application of 2.0 kg B per ha gave maximum yield.

Kumar and Sidhu (2010) observed that the treatments included four levels each of soil applied sulfur viz., 0, 6.5, 13.4 and 20.1 mg S/kg and boron viz., 0, 0.22, 0.44 and 0.88 mg/kg at the time of sowing. The highest dry matter yield at 55 days after sowing, (DAS) (19.3 g/pot) and maturity (straw yield -24.3 g/pot and grain yield 6.8 g/pot) was recorded with B 0.44, S 13.4 treatment. The mean boron uptake in straw and grains of soybean increased significantly with increasing levels of sulfur and boron up to 13.4 and 0.44 mg/kg, respectively, and decreased thereafter.

Chakraborty (2009) conducted field experiments to study the effect of B and Mo to the growth, and yield of lentil grown on inherently poor lateritic soil. The lentil (cv. B77) was raised with application of B and Mo either separately or in mixture through foliage or to soil along with NPK fertilizers. The leaf area index, above ground dry matter and crop growth rate increased with the application of B and Mo. Soil application of B coupled with foliar application of Mo enhanced the yield attributing characters and yield of the lentil crop. The study indicated that growing of lentil in lateritic soils depleted the nutrients particularly micronutrients which resulted in loss of yield and could be recovered, if the relevant micronutrients are supplemented through appropriate application methods and dosage.

Bozoglu *et al*. (2008) determining the effect of boron fertilization was on some agronomic characteristics of chickpea. This study designed with randomized completed blocks design with 3 replications. Boron (B_0:0, B_1:0.25 ppm, B_2:0.50 ppm) doses were applied through foliar application when the plants were in vegetative period. The effect of years was found to be statistically significant on characteristics expect for seed yield and ratio of seed above 9 mm sieve. The highest seed yields were found for B_2 dose (1462.2 kg ha^{-1}).

Crak *et al*. (2006) examined the effect of soil and foliar application of boron (66.14% B_2O_3) at different rates (0, 0.5, 1, 1.5 and 2 kg/ha) on plant height, first pod height, pod/plant, boron content of seed, germination rate, 1000-seed weight, oil, protein and ash content of seed and yield of soybean *(Glycine max*) . Increasing boron rates applied either as soil or foliar improved yield (40%), first pod height (17%), boron content of seed (42%), germination rate (11%) and 1000-seed weight (5%) of soybean.

Sinha *et al*. (1994) conducted an experiment on the effect of B, Zn and Mo on morphological characters in lentil and showed that primary branch plant^{-1} and pods plant^{-1} increased significantly due to application of B.

2.3 Combined effect of B and Zn

Karan *et al*. (2019) conducted a field experiment to study the response of lentil cultivars on yield and nutrient balance in the soil in relation to various levels of zinc and boron. Results revealed that lentil cultivar PL 639 produced significantly highest grain, straw and biological yield of lentil than the other cultivars of lentil. Grain, straw and biological yield of lentil was significantly increased with the application of 1 kg B/ha than control. Highest available nutrient viz., N, P, K, S, Zn and B in the soil showed increasing trend with lentil cultivar in sequence in DPL 62< K 75 < PL 406 < PL 639 after two consecutive crop season. The contents of available N, K, Zn and B in the soil showed increasing trend while available P and S showed decreasing trend with the increasing levels of zinc. Highest available N, P, K, S, Zn and B in the soil was restored more in 1 kg B/ha applied plot, however, minimum available N, P, K, S, Zn and B in the soil was obtained in control. Hence, application of zinc @ 8-10 kg and boron @ 1kg/ha is recommended for sustainable lentil production.

Saha *et al*. (2018) conducted a field experiment to study the effect of boron (B) and zinc (Zn) on growth, yield and economics of 'Moitree' lentil *(Lens culinaris* Medik.). Two micronutrients, *viz*. boron (B) and zinc (Zn), with variations in method and time of applications had significant effect on plant height, dry-matter (DM) production, and crop- growth rate (CGR) throughout the cropping season. The crop treated with T_4 [recommended dose of fertilizer (RDF) + soil application of B @ 1.0 kg/ha)] resulted in the highest aerial dry-matter yield (132.7 g/m^2) at 75 days after sowing (DAS) and crop-growth rate (3.23 g/m^2/day) between 46 and 75 DAS compared to the other treatments used in the investigation. Although the foliar spray of both B @ 0.1% and Zn @ 0.25% twice at 40 and 60 DAS (T_{10}) recorded the highest number of pods/plant (102.2) and seed yield (1.21 t/ha), single spraying of B @ 0.1% at 40 DAS (T_5) to lentil recorded moderate yield (1.15 t/ha), maximum net return (f27,009/ha) and benefit: cost ratio (1.86).

Alam and Islam (2016) carried out an experiment to observe the effect of zinc (Zn) and boron (B) on the seed yield and yield contributing characters of mungbean. There were four levels of zinc (0, 1.0, 2.0, and 4.0 kg/ha) and boron (0, 0.75, 1.5, and 3.0 kg/ha) along with a blanket dose of N_{24} P_{20} K_{30} S*15* kg/ha. Experiment was laid out in RCBD with three replications. In case of zinc application, highest seed yield (1.418 ton/ha) was obtained from 1.0 kg Zn/ha which was statistically similar (1.358 t/ha) with dose 1.0 kg Zn/ha and but significantly higher (1.034 t/ha) than the control. Again for boron application, the highest seed yield (1.550 t/ha) was found from the treatment 1.50 kg B/ha which was statistically identical with 3.0 kg B/ha and the lowest (0.927 t/ha) for control. The combined application of zinc and boron showed significant effect on mungbean yield than the single application of zinc and boron. Results showed that the combination of $Zn_{1.0}B_{1.5}$ produced significantly higher yield (1.677 ton/ha) than the control (Zn_0B_0) combination (0.64 ton/ha). Combined application of zinc and boron were observed superior to their single application. Therefore, the combination of 1.0 kg zinc per hectare and 1.5 kg boron per hectare might be considered as suitable dose for mungbean cultivation in acidic soil of Sylhet region of Bangladesh.

Quddus *et al*. (2014) conducted a study was conducted to evaluate the effect of Zinc (Zn) and Boron (B) on the yield and yield contributing characters of lentil *(Lens culinaris* Medic) and to estimate the optimum dose of Zn and B for yield maximization. There were 16 treatment combinations comprising four levels each of Zinc (0, 1.0, 2.0 and 3.0 kg/ha) and Boron (0, 0.5, 1.0 and 1.5 kg/ha) along with a blanket dose of N_{20} P_{16} K_{30} S_{10} kg/ha were used. The treatments were arranged *viz*. T_1= Zn_0B_0; T_2= $Zn_0B_{0.5}$; T_3= $Zn_0B_{1.0}$; T_4= $Zn_0B_{1.5}$; T_5= $Zn_{1.0}$B0; T_6= $Zn_{1.0}B_{0.5}$; T_7= $Zn_{1.0}B_{1.0}$; T_8= $Zn_{1.0}B_{1.5}$; T_9= $Zn_{2.0}B_0$; T_{10}= $Zn_{2.0}B_{0.5}$; T_{11}= $Zn_{2.0}B_{1.0}$; T_{12}= $Zn_{2.0}B_{1.5}$; T_{13}= $Zn_{3.0}B_0$; T_{14}= $Zn_{3.0}B_{0.5}$; T_{15}= $Zn_{3.0}B_{1.0}$ and T_{16}= $Zn_{3.0}B_{1.5}$. The experiment was laid out in RCBD with three replications. Results showed that the combination of $Zn_{3.0}B_{1.5}$ produced significantly higher seed yield (1156 kg/ha). The lowest seed yield (844 kg/ha) was found in control (Zn_0B_0) combination. The combined application of zinc and boron were superior to their single application. Therefore, the combination of Zn and B may be considered as suitable dose for lentil cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was $Zn_{2.85}$ and $B_{1.44}$ for Madaripur, Bangladesh.

Salih (2013) carried out pot experiment under greenhouse conditions to investigate Fe, B and Zn foliar application effects on nutrient concentration and seed protein of cowpea (*Vigna Unguiculata*). Three concentrations (0, 1 and 2 ppm) of micronutrient solutions were applied. Fe, B and Zn were sprayed every 15 days. Parameters measured were values of each nutrients and protein%, also, P, K, Ca, Mg, Na and Cl. The results of the analysis of variance showed that the effect of different treatments on nutrient concentration and seed protein were significant at 1% level. Iron treatment has a greater effect on the nutrient uptake and protein percentage of seed than other treatments. The study results explain that foliar fertilization with micronutrient may have a possibility role for increasing cowpea yield.

Valenciano *et al*. (2010) studied the response of chickpea to the applications of Zn, B and in pot experiments with natural conditions and acidic soils. Five concentrations of Zn (0, 1, 2, 4 and 8 mg Zn pot^{-1}), two concentrations of B (0 and 2 mg B pot^{-1}), and two concentrations of Mo (0 and 2 mg Mo pot^{-1}) were added to the pots. Chickpea responded to the Zn, B and Mo applications. There were differences between soils. The mature plants fertilized with Zn, with B and with Mo had a greater total dry matter production. Harvest Index (HI) improved with the Zn application and with the Mo application. The highest HI was obtained with the $Zn_4 \times B_2 \times Mo_2$ treatment (60.30%) while the smallest HI was obtained with the $Zn_0 \times B_0 \times Mo_0$ treatment (47.65%). The Zn, B and Mo applications improved seed yield, mainly due to the number of pods per plant. This was the yield component that had the most influence on, and the most correlation with seed yield. The highest seed yield was obtained from the $Zn_4 \times B_2 \times Mo_2$ treatment (4.00 g $plant^{-1}$) while the lowest was obtained from the $Zn_0 \times B_0 \times Mo_0$ treatment (2.31 g $plant^{-1}$). There was a low interaction between the three micronutrients. The Zn application was more efficient when it was applied with both B and Mo.

From the above review of literature it can be concluded that zinc plays a significant role for higher lentil production and also other pulse crop. Similarly boron is also very important plant nutrient for successful pulse production especially for lentil.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to March 2018 to study the influence of foliar application of zinc and boron on the growth and yield of lentil. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The location of the experimental field was in Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site is presented in Appendix I.

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details was presented in Appendix II.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.2 Test crop

The lentil variety, BARI Masur-7 was used as test crop for the present study.

3.3 Experimental details

3.3.1 Treatments

Factor A: Foliar application of Zn and B fertilizer

1. F_0 = Control (without Zn and B)
2. F_1 = Zn foliar application
3. F_2 = B foliar application
4. F_3 = Zn and B foliar application

Factor B: Growth stages of Zn and B fertilizer application -4 stages

1. S_0 = Control (without application)
2. S_1 = at10 leaf stage
3. S_2 = at 10 leaf stage + flowering
4. S_3 = at 10 leaf stage + flowering + pod formation

3.3.2 Experimental design and layout

The experiment was laid out in Split Plot Design with three replications. The layout of the experiment was prepared for distributing the combination of doses of Boron (B) and Zinc (Zn). The 16 treatment combinations of the experiment were assigned at random into 48 plots. Foliar application of Zn and B fertilizer was assigned in the main plot and Growth stages of Zn and B fertilizer application was assigned in sub plot. The size of each unit plot 3.0 m × 2.5 m. The distance between blocks and plots were 0.75 m and 0.5 m respectively.

3.4 Growing of crops

3.4.1 Seed collection

The seeds of the test crop i.e., BARI Masur-7 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2 Preparation of the main field

The plot selected for the experiment was opened in the first week of November, 2017 with a power tiller, and was exposed to the sun for a week, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing.

3.4.3 Seed Sowing

Seeds are sown in well prepared land on 7 November 2017 according to the layout and treatments selected.

3.4.4 Fertilizers and manure application

The following doses of fertilizers were used under the present study.

Name of fertilizer	Doses kg ha^{-1}
Urea	50
TSP	90
MOP	40
Zn	3 kg
B	1.5 kg

The plant nutrient N, P, K, Zn and B were applied in the form of urea, TSP, MOP, borax and $ZnSO_4$ respectively. Half amount of urea and whole amount of TSP and MOP were applied during final land preparation as basal dose and rest of urea was applied at two installments at 25 and 35 days after sowing (DAS). For Zn and B, 5% $ZnSO_4$ and 5% Borax respectively were applied as per treatment in three times as foliar spray.

3.4.5 Intercultural Operation

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

3.4.5.1 Irrigation and drainage

After sowing of seed, light irrigation was done for proper seed germination. After establishment of seedling to at maturity, irrigation was given at 15 and 45 and 65 DAS.

3.4.5.2 Weeding

Two weedings were done at 20 DAS and 45 DAS to keep the plots free from weeds, which ultimately ensured better growth and development of crop.

3.4.5.3 Thinning

Seeds were germinated five days after sowing. The plots were thinned out on 15 DAS and 20 DAS to maintain 10 cm between plants an uniform plant stand which facilitates proper aeration and light for optimum growth and development of the crops.

3.4.5.4 Plant protection

At seeling stage, fungal diseases (root rot) was observed in the field and some plants were died. For prevention of diseases, Bavistin was sprayed. At vegetative stage of growth few hairy caterpillar and virus vectors (jassid) attacked the young plants and at later stage of growth pod borer (*Maruca testulalis)* attacked the plant. Hairy caterpillar and pod borer were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} at the time of 50% pod formation stage.

3.5 Harvesting, threshing and cleaning

The crop was harvested at full maturity on 25 February, 2018. Harvesting was done manually from each plot. The crop of central 1 m^2 area was harvesting for taking yield and stover data. Moreover 5 sample plants in each plot excluding the harvested area were collected for taking yield attributes data.

The harvested crop of each plot (1 m^2) was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of lentil seed. Fresh weight of seed and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The stover was sun dried and the yields of seed and stover $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.6 Data collection and recording

Five plants were selected randomly from each unit plot and tagged for recording growth characters data.

The following parameters were recorded during the study:

A. Growth parameters

1. Plant height (cm)
2. Dry weight $plant^{-1}$ (g)
3. Number of branches $plant^{-1}$

B. Yield attributes data

1. Number of pods $plant^{-1}$
2. Number of seeds pod^{-1}
3. Shelling (%)
4. 1000 seed weight (g)

C. Yield and harvest index data

1. Seed yield (kg ha^{-1})
2. Stover yield (kg ha^{-1})
3. Biological yield (kg ha^{-1})
4. Harvest index (%)

3.7 Procedure of recording data

The following procedure was followed for data collection

3.7.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 20, 40, 60, 80 DAS and at harvest of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.7.3 Number of branches plant^{-1}

The branches were counted from the 5 randomly selected plants and mean value was determined. It was done at 20, 40, 60, 80 DAS

3.7.4 Dry weight plant^{-1} (g)

Five sample plants in each plot were selected at random in the sample rows outside the centeral 1 m^2 of effective harvesting area and cut close to the ground surface at 20, 40, 60, 80 DAS and at harvest of crop duration. They were first air dried for one hour, then oven dried at 72°±5°C for 48 hours till a constant weight was attained. Mean dry weight was expressed as per plant basis in gram (g).

3.7.7 Number of pods plant^{-1}

Number of total pods of 5 plants from each plot was noted and the mean number was expressed per plant basis.

3.7.8 Number of seeds pod^{-1}

Number of total seeds of twenty pods from each plot was noted and the mean number was expressed per pod basis.

3.7.9 Shelling percentage

Data on shelling percentage was recorded from randomly selected 33 plants from each unit plot and mean values was calculated. The following formula was used to calculate shelling percentage

$$\text{Shelling percentage} = \frac{\text{Weight of shell}}{\text{Seed weight + shell weight}} \times 100$$

3.7.10 Weight of 1000 seeds (g)

One thousand cleaned and dried seeds were counted randomly form each plot and weight by using a digital electric balance and the weight was expressed in gram.

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

The plants of the central 1.0 m^2 from the plot were harvested for taking grain yield. The grains were threshed from the plants, cleaned, dried and then weighed. The yield of grain was converted in kg plot^{-1} and was adjusted at 12% moisture content of grain.

3.7.12 Stover yield (kg ha^{-1})

The stover of the harvested crop in each plot was sun dried to a constant weight. Then the stovers were weighted and thus the stover yield plot^{-1} was determined. The yield of stover from 1 m^2 area in kg plot^{-1} was converted to kg ha^{-1}.

3.7.13 Biological yield (kg ha^{-1})

Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Stover yield.

3.7.14 Harvest index (%)

Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

$$HI (\%) = \frac{\text{Seed yield}}{\text{Biological yield (Seed yield + Stover yield)}} \times 100$$

3.8 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted on 'Influence of foliar application of zinc and boron on the growth and yield of lentil' and the results on effectiveness of various treatments including an untreated control for the management of lentil production have been presented and discussed below in detail under the following heading:

4.1 Growth parameters

4.1.1 Plant height (cm)

Effect of foliar application of Zn and B fertilizer

Effect of foliar application of Zn and B fertilizer had significant influence on plant height at different growth stages except at 20 and 40 DAS (Fig. 1 and Appendix IV). Results revealed that the highest plant height (9.97, 17.18, 23.25, 29.04 and 35.55 cm at 20, 40, 60, 80 DAS and at harvest, respectively) was found from the treatment, F_3 (Zn and B foliar application) which was statistically identical with F_1 (Zn foliar application) and F_2 (B foliar application) at 80 DAS and at harvest. The lowest plant height (9.50, 14.83, 18.28, 24.44 and 30.18 cm at 20, 40, 60, 80 DAS and at harvest, respectively) was achieved from the treatment of F_0 (Control; without Zn and B). Similar result was also observed by Saha *et al*. (2018) and Rahman *et al*. (2015) which supported the present findings.

Effect of time of foliar application

There was a significant variation in plant height as influenced by time of foliar application (Zn and B) at different growth stages (Fig. 2 and Appendix IV). The result revealed that plant height showed a gradual increasing trend from the early to late sampling dates and the highest increase was found at harvest irrespective of time of foliar application. Among the foliar applications, S_3 (at 10 leaf stage + flowering + pod formation) showed the tallest plant (10.17, 17.80, 23.40, 30.41 and 36.67 cm at 20, 40, 60, 80 DAS and at harvest, respectively). The lowest plant height (9.19, 13.84, 18.38, 23.46 and 30.33 cm at 20, 40, 60, 80 DAS and at harvest, respectively) was achieved from the treatment of S_0 (Control).

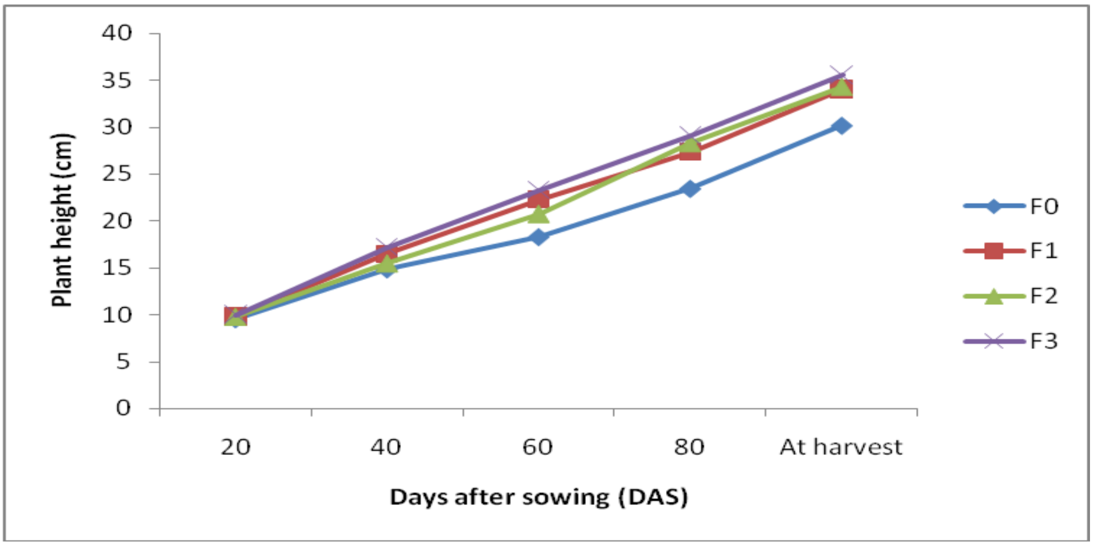

Fig.1. Effect of foliar application of Zn and B on plant height of lentil (SE± = NS, NS, 0.94, 1.15, 1.23 at 20, 40, 60, 80 and at harvest, respectively)

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3= Zn and B foliar application

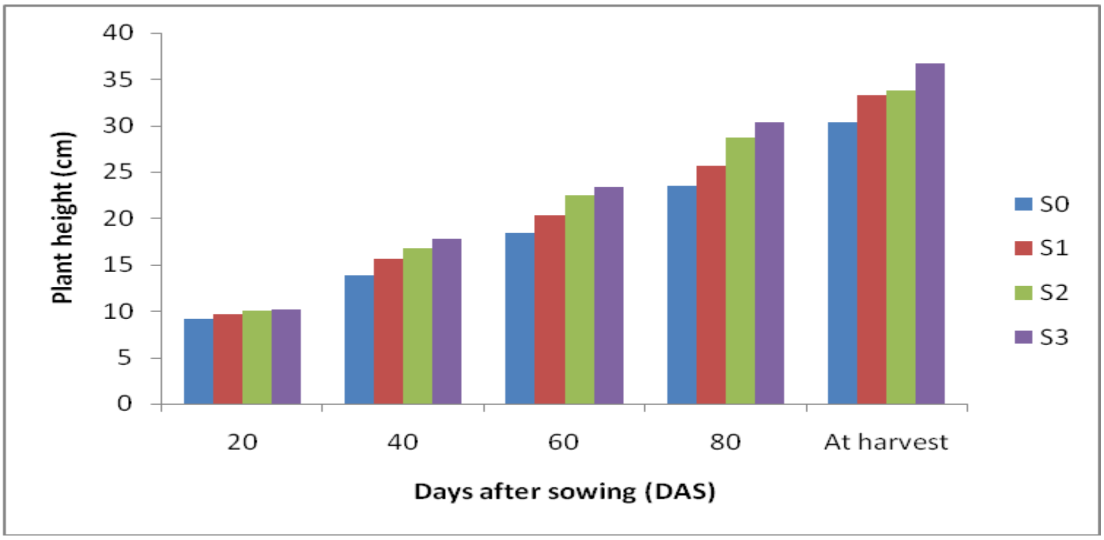

Fig.2. Effect of time of foliar application Zn and B on plant height of lentil (SE± = 0.15, 0.50, 0.91, 0.62 and 1.60 at 20, 40, 60, 80 and at harvest, respectively)

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

Combined effect of Zn and B foliar application and time of application

Plant height was significantly influenced by combined effect of level of Zn and B foliar application and time of application at different growth stages except at 40 and 80 DAS (Table 1 and Appendix IV). Results indicated that the highest plant height (10.39, 19.33, 25.84, 32.45 and 38.28 cm at 20, 40, 60 and 80 DAS, respectively) was found from the treatment combination of F_3S_3 similar with F_1S_3, F_0S_3, F_1S_1, F_1S_2, F_2S_1, F_2S_2, F_2S_3, F_3S_0, $F_3S_1$and F_3S_2 at harvest. The lowest plant height (8.85, 12.37, 15.88, 19.37 and 26.72 cm at 20, 40, 60 and 80 DAS, respectively) was achieved from the treatment combination of F_0S_0 which was statistically similar with F_0S_1, F_0S_2, F_1S_0, F_2S_0 and F_3S_0 at harvest.

Table 1. Interaction effect of Zn and B foliar application and time of foliar spray on plant height of lentil

Treatment	Plant height (cm) at different days after sowing				
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**	At harvest
F_0S_0	8.85 f	12.37	15.88 g	19.37	26.72 d
F_0S_1	9.37 c-f	14.54	17.97 e-g	20.82	29.753 cd
F_0S_2	9.83 a-e	17.28	19.07 d-g	25.91	29.91b-d
F_0S_3	9.94 a-d	17.77	20.19 c-f	27.65	34.160 a-c
F_1S_0	9.15 e-f	14.37	18.66 e-g	24.26	30.55b-d
F_1S_1	9.78 a-e	16.02	20.79 b-f	26.47	33.86a-c
F_1S_2	9.95 a-d	16.47	23.87 a-c	28.95	33.82 a-c
F_1S_3	10.24 ab	19.14	24.22 ab	29.78	38.15 a
F_2S_0	9.35 d-f	13.40	17.42 fg	24.92	31.50b-d
F_2S_1	9.93 a-d	14.79	19.39 d-g	27.62	34.33a-c
F_2S_2	9.87 a-e	16.17	22.83 a-d	28.74	35.15a-c
F_2S_3	10.11 a-c	14.95	23.36 a-c	31.78	36.07a-c
F_3S_0	9.40 c-f	15.20	21.59 b-e	25.31	32.53a-d
F_3S_1	9.74 b-e	16.91	25.03 a-d	27.43	35.07 a-c
F_3S_2	10.33 ab	17.29	24.17 ab	30.98	36.33ab
F_3S_3	10.39 a	19.33	25.84 a	32.45	38.28a
SE	**0.3023**	**NS**	**1.8224**	**NS**	**3.1958**
CV(%)	**3.79**	**7.67**	**10.56**	**5.65**	**11.68**

NS = Not significant

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

4.1.2 Dry weight plant^{-1} (g)

Effect of foliar application of Zn and B fertilizer

Significant variation was observed on dry weight plant^{-1} at different growth stages influenced by foliar application of Zn and B fertilizer (Fig. 3 and Appendix V). The result revealed that dry weight plant^{-1} of lentil increase gradually from 20 DAS to at harvest, irrespective of levels of foliar application of Zn and B treatments. At early stage of growth 30-80 DAS, the rate of increase was much slower than later stage. At later stage 80 DAS- at harvest, the rate of increase was much higher. However, the highest dry weight plant^{-1} (0.33, 0.66, 2.15, 5.79 and 19.78 g at 20, 40, 60, 80 DAS and at harvest, respectively) was found from the treatment, F_3 (Zn and B foliar application) followed by F_1 (Zn foliar application) at all growth stages. The lowest dry weight plant^{-1} (0.18, 0.47, 1.36, 4.39 and 12.73 g at 20, 40, 60, 80 DAS and at harvest, respectively) was observed from the treatment of F_0 (Control; without Zn and B) followed by F_2 (B foliar application) at all growth stages. Malik *et al*. (2015) also found similar result with the present study.

Effect of time of foliar application

Dry weight plant^{-1} was significantly varied due to time of foliar application (Zn and B) at different growth stages of lentil (Fig. 4 and Appendix V). It can be inferred from the figure that dry weight plant^{-1} increased rapidly at later stage of growth (80 DAS - at harvest), irrespective of time of foliar application treatments. At early stage of growth the rate of increase of dry weight was much slower for all treatments. The highest dry weight plant^{-1} (0.44, 0.72, 2.03, 6.03 and 19.71 g at 20, 40, 60, 80 DAS and at harvest, respectively) was found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) followed by S_2 (at 10 leaf stage + flowering). The lowest dry weight plant^{-1} (0.17, 0.43, 1.33, 3.82 and 12.24 g at 20, 40, 60, 80 DAS and at harvest, respectively) was obtained from the treatment of S_0 (Control).

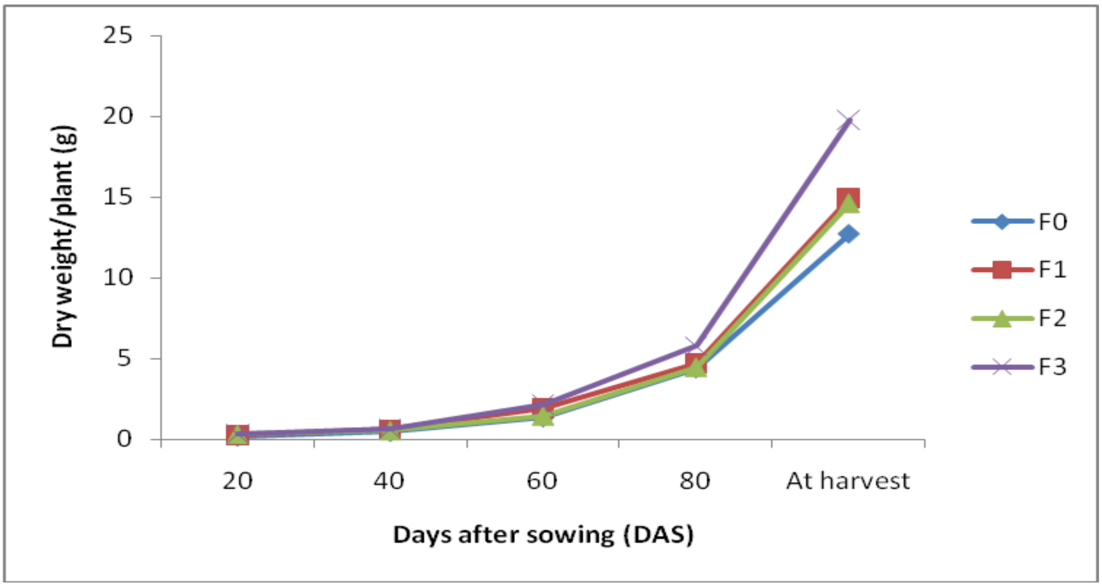

Fig. 3. Effect of foliar application of Zn and B on plant dry weight of lentil (SE± = 0.017, 0.036, 0.088, 0.137 and 0.56 at 20, 40, 60, 80 and at harvest, respectively)

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

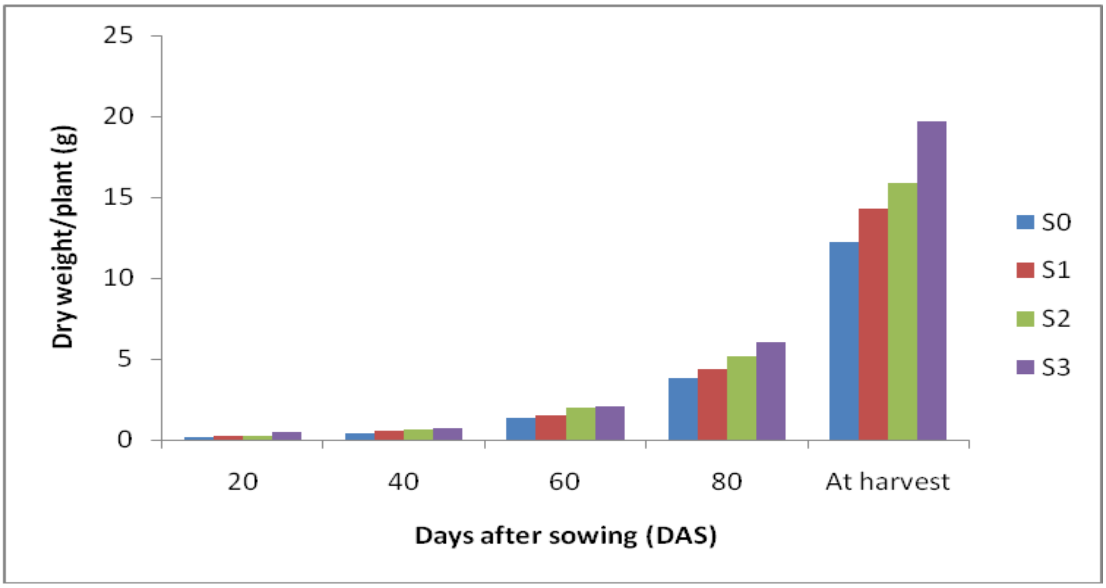

Fig. 4. Effect of time of foliar application of Zn and B on plant dry weight of lentil (SE± = 0.013, 0.019, 0.088, 0.273 and 0.618 at 20, 40, 60, 80 and at harvest, respectively)

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

Combined effect of Zn and B foliar application and time of application

Remarkable variation was observed on dry weight plant^{-1} of lentil due to the combined effect of Zn and B foliar application and time of application at all growth stages except 40 DAS (Table 2 and Appendix V). The highest dry weight plant^{-1} (0.62, 0.81, 2.32, 7.67 and 26.29 g at 20, 40, 60, 80 DAS and at harvest, respectively) was found from the treatment combination of F_3S_3 followed by F_3S_2. The lowest dry weight plant^{-1} (0.15, 0.37, 1.15, 3.15 and 10.52 g at 20, 40, 60, 80 DAS and at harvest, respectively) was achieved from the treatment combination of F_0S_0 which was statistically similar with F_0S_1, F_0S_2, F_1S_0, F_2S_0 and F_2S_1.

Table 2. Interaction effect of Zn and B foliar application and time of foliar spray on plant dry weight of lentil

Treatment	**Dry weight plant^{-1} at different days after sowing**				
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**	At harvest
F_0S_0	0.15 g	0.37	1.15 f	3.51 g	10.52 h
F_0S_1	0.20 e-g	0.41	1.20 ef	4.66 d-f	12.32 gh
F_0S_2	0.20 e-g	0.47	1.46 c-f	4.98 c-e	12.97 f-h
F_0S_3	0.18 e-g	0.62	1.62 b-d	5.26 cd	14.99 ef
F_1S_0	0.16 fg	0.40	1.58 b-e	3.76 fg	12.23 gh
F_1S_1	0.19 e-g	0.54	1.92 b	4.04 e-g	13.88 e-g
F_1S_2	0.21 d-g	0.74	2.66 a	4.54 d-g	14.93 ef
F_1S_3	0.50 b	0.81	2.43 a	5.24 cd	18.76 bc
F_2S_0	0.23 c-e	0.43	1.16 f	3.94 e-g	10.67 h
F_2S_1	0.27 c	0.52	1.32 d-f	3.89 fg	12.95f-h
F_2S_2	0.28c	0.53	1.58b-d	4.56 d-g	16.32c-e
F_2S_3	0.45 b	0.65	1.73bc	5.95 bc	18.8 bc
F_3S_0	0.17 e-g	0.49	1.39 c-f	4.11 e-g	15.52 df
F_3S_1	0.22 c-f	0.61	1.67 b-d	4.78d-f	17.90 b-d
F_3S_2	0.27cd	0.71	2.32a	6.59ab	19.39b
F_3S_3	0.62a	0.81	2.32a	7.67a	26.29a
SE	**0.0264**	**NS**	**0.175**	**0.5463**	**1.2365**
CV(%)	**11.98**	**8.10**	**12.46**	**13.81**	**9.75**

NS = Not significant

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

4.1.3 Number of branches plant^{-1}

Effect of foliar application of Zn and B fertilizer

Significant influence was noted on number of branches plant^{-1} due to growth stages affected by foliar application of Zn and B fertilizer at all growth stages (Fig. 5 and Appendix VI). Number of branches plant^{-1} increased incrementally with increases of growth stages, irrespective of number of foliar application and the highest number of branches plant^{-1} was found at 80 DAS. Among the treatments F_3 (Zn and B foliar application) was found superior by producing highest number of branches plant^{-1}, irrespective of sampling dates and that of lowest was recorded from F_0 (Control; without Zn and B) treatment. Numerically, the highest number of branches plant^{-1} (2.26, 4.19, 6.34 and 7.25 at 20, 40, 60 and 80 DAS, respectively) was found from the treatment F_3 (Zn and B foliar application). The lowest number of branches plant^{-1} (1.78, 3.59, 4.47 and 6.07 at 20, 40, 60 and 80 DAS, respectively) was found from the treatment of F_0 (Control without Zn and B). Similar result was also observed by Malik *et al*. (2015) in respect of number of branches plant^{-1} of lentil.

Effect of time of foliar application

Number of branches plant^{-1} varied significantly due to time of foliar application (Zn and B) at different growth stages of lentil (Fig. 7 and Appendix VI). The figure shows a steady increase in trend with the advances of growth period and the highest result was found with the last sampling date (80 DAS), irrespective of time of foliar application. The result revealed that the highest number of branches plant^{-1} (2.59, 4.49, 6.35 and 7.69 at 20, 40, 60 and 80 DAS, respectively) was found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) followed by S_2 (at 10 leaf stage + flowering). The lowest number of branches plant^{-1} (1.82, 3.16, 4.56 and 5.30 at 20, 40, 60 and 80 DAS, respectively) was achieved from the treatment of S_0 (Control) followed by S_1 (at 10 leaf stage).

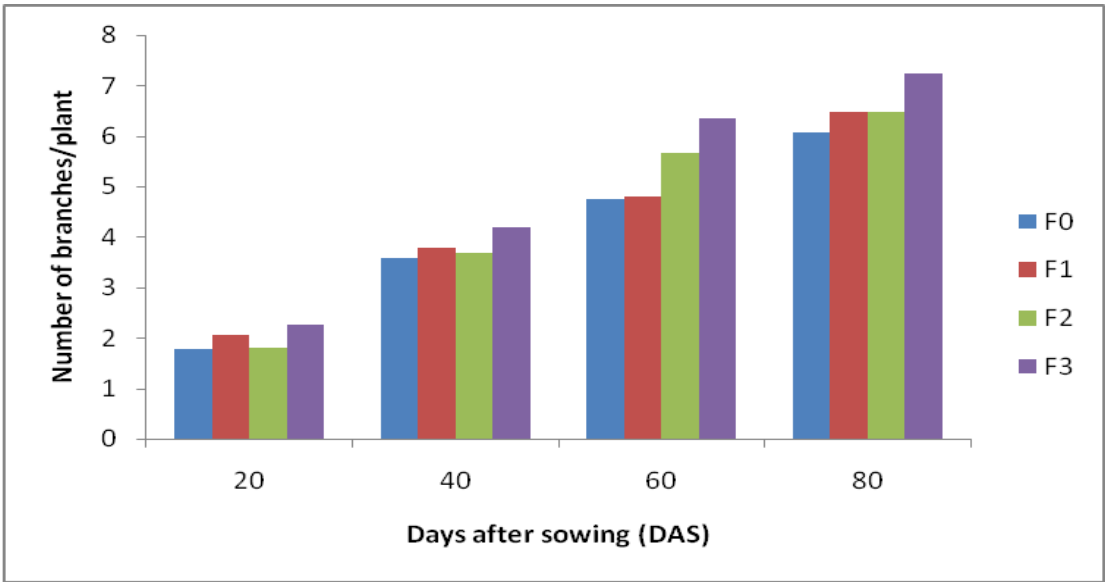

Fig. 5. Effect of foliar application of Zn and B on branch number of lentil (SE± = 0.115, 0.154, 0.169 and 0.231 at 20, 40, 60 and 80 DAS, respectively)

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

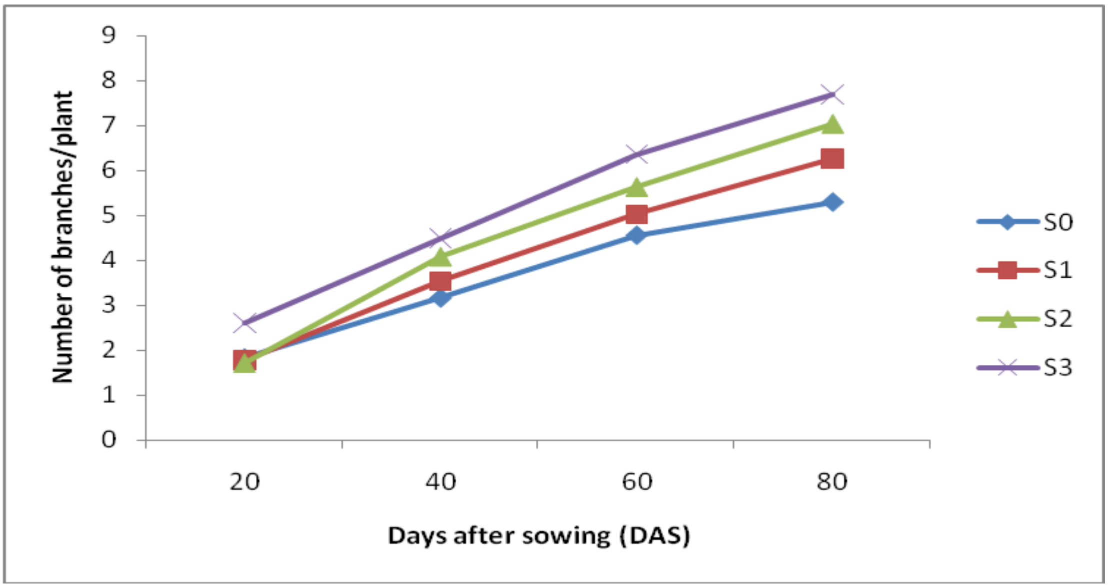

Fig. 6. Effect of time of foliar application of Zn and B on branch number of lentil (SE± = 0.084, 0.171, 0.183 and 0.174 t 20, 40, 60 and 80 DAS, respectively)

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

Combined effect of Zn and B foliar application and time of application

Significant variation was remarked on number of branches plant^{-1} at different growth stages as influenced by combined effect of levels of Zn and B foliar application and time of application (Table 3 and Appendix VI). The highest number of branches plant^{-1} (2.50, 5.00, 7.60 and 9.33 at 20, 40, 60 and 80 DAS, respectively) was found from the treatment combination of F_3S_3 followed by F_3S_2. The lowest number of branches plant^{-1} (1.60, 2.62, 3.90 and 5.12 at 20, 40, 60 and 80 DAS, respectively) was achieved from the treatment combination of F_0S_0 which was statistically similar with F_2S_0, F_1S_0 and F_3S_0 at harvest.

Table 3. Interaction effect of Zn and B foliar application and time of foliar spray on branch number of lentil

Treatment	Number of branches plant^{-1} at different days after sowing			
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**
F_0S_0	1.60	2.62 h	3.90 h	5.12 g
F_0S_1	1.80	3.46 e-g	4.33 f-h	6.07 d-f
F_0S_2	1.73	3.66 d-g	5.06 d-f	6.33 de
F_0S_3	2.00	4.13 b-e	5.66 b-e	6.73 cd
F_1S_0	2.08	3.74 c-g	3.89 h	5.33 fg
F_1S_1	2.00	4.20 b-d	4.26 gh	6.33 de
F_1S_2	1.93	4.23 b-d	5.26 c-e	6.90 cd
F_1S_3	3.00	4.60 ab	5.80 b-d	7.36 bc
F_2S_0	1.74	3.15 gh	5.02 e-g	5.19 g
F_2S_1	1.61	3.36 fg	5.53 c-e	6.53cd
F_2S_2	1.06	4.03b-f	5.80b-d	6.86cd
F_2S_3	2.86	4.23b-d	6.33 b	7.33 bc
F_3S_0	1.86	3.12 gh	5.42 c-e	5.57 e-g
F_3S_1	1.73	3.13gh	5.93bc	6.10 d-f
F_3S_2	2.13	4.40ac	6.40b	8.00b
F_3S_3	2.50	5.00a	7.60a	9.33a
SE	**NS**	**0.3426**	**0.3630**	**0.3484**
CV(%)	**10.38**	**10.99**	**8.32**	**6.49**

NS = Not significant

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3= Zn and B foliar application

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

4.2 Yield contributing characters

4.2.1 Number of pods plant^{-1}

Effect of foliar application of Zn and B fertilizer

Number of pods plant^{-1} was found significant with foliar application of Zn and B fertilizer in lentil (Table 4 and Appendix VII). The highest number of pods plant^{-1}(48.02) was found from the treatment, F_3 (Zn and B foliar application) which was statistically similar with F_1 (Zn foliar application). The lowest number of pods plant^{-1} (39.69) was observed from the treatment of F_0 (Control without Zn and B) which was statistically similar with F_2 (B foliar application). The result obtained from the present study was similar with the findings of Rahman *et al*. (2015) Malik *et al*. (2015).

Effect of time of foliar application

Variation in number of pods plant^{-1} was noted due to time of foliar application (Zn and B) (Table 5 and Appendix VII). The highest number of pods plant^{-1} (49.29) was found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) which was significantly different from other treatments. The lowest number of pods plant^{-1} (38.11) was achieved from the treatment of S_0 (Control).

Combined effect of Zn and B foliar application and time of application

Number of pods plant^{-1} of lentil affected significantly by combined effect of Zn and B foliar application and time of application (Table 6 and Appendix VII). The highest number of pods plant^{-1} (52.44) was obtained from the treatment combination of F_3S_3 which was statistically identical with the treatment combination of F_1S_3, F_1S_2, F_2S_3, F_3S_1 and F_3S_2. The lowest number of pods plant^{-1} (33.82) was observed from the treatment combination of F_0S_0 which was statistically similar with F_0S_1, F_1S_0, F_2S_0 and F_2S_1.

4.2.2 Number of seeds pod^{-1}

Effect of foliar application of Zn and B fertilizer

The recorded data on number of seeds pod^{-1} was significant due to foliar application of Zn and B fertilizer in lentil (Table 4 and Appendix VII). The highest number of seeds pod^{-1} (1.92) was found from the treatment, F_3 (Zn and B foliar application) which was statistically identical with F_1 (Zn foliar application). The lowest number of seeds pod^{-1} (1.00) was observed from the treatment of F_0 (Control without Zn and B). Rahman *et al*. (2015) also found similar result with the present study.

Effect of time of foliar application

Significant influence was observed on number of seeds pod^{-1} persuaded by time of foliar application (Zn and B) (Table 5 and Appendix VII). The highest number of seeds pod^{-1} (1.95) was found from the treatment S_3 (at 10 leaf stage + flowering + pod formation) which was significantly different from other treatments. The lowest number of seeds pod^{-1} (1.25) was achieved from the treatment of S_0 (Control). The result obtained from other treatments showed intermediate results compared to highest and lowest value.

Combined effect of Zn and B foliar application and time of application

Remarkable variation was identified in number of seeds pod^{-1} due to the combined effect of Zn and B foliar application and time of application in lentil (Table 6 and Appendix VII). The highest number of seeds pod^{-1} (2.12) was obtained from the treatment combination of F_3S_3 which was statistically similar with the treatment combination of F_1S_3, F_3S_2, F_1S_2, F_2S_3 and F_3S_1. The lowest number of seeds pod^{-1} (0.72) was observed from the treatment combination of F_0S_0 which was statistically similar with the treatment combination of F_0S_2.

4.2.3 Shelling percentage (%)

Effect of foliar application of Zn and B fertilizer

There was a significant variation in shelling percentage of lentil due to foliar application of Zn and B fertilizer at different growth stages (Table 4 and Appendix VII). The highest shelling percentage (35.66%) was found from the treatment, F_3 (Zn and B foliar application). The lowest shelling percentage (24.52%) was observed from the treatment of F_0 (Control without Zn and B) which was statistically identical with F_1 (Zn foliar application) and F_2 (B foliar application). Similar result was also observed by Rahman *et al*. (2015) in respect of shelling percentage.

Effect of time of foliar application (Zn and B)

Shelling percentage was significantly influenced by time of foliar application (Zn and B) in lentil (Table 5 and Appendix VII). The highest shelling percentage (29.28%) was found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) which was statistically similar with S_1 (at 10 leaf stage) and S_2 (at 10 leaf stage + flowering). The lowest shelling percentage (25.68%) was achieved from the treatment of S_0 (Control) which was also similar with S_1 (at 10 leaf stage) and S_2 (at 10 leaf stage + flowering).

Combined effect of Zn and B foliar application and time of application

Significant variation was observed in shelling percentage of lentil due to combined effect of Zn and B foliar application and time of application (Table 6 and Appendix VII). The highest shelling percentage (43.24%) was obtained from the treatment combination of F_3S_3 which was significantly different from all other treatment combinations. The lowest shelling percentage (16.83%) was observed from the treatment combination of F_0S_0which was similar with the treatment combination of F_0S_1, F_1S_2, F_1S_3, F_2S_0 and F_2S_1.

4.2.4 Weight of 1000 seeds (g)

Effect of foliar application of Zn and B fertilizer

Weight of 1000 seed was significantly varied due to foliar application of Zn and B fertilizer in lentil (Table 4 and Appendix VII). The highest 1000 seed weight (20.72 g) was found from the treatment F_3 (Zn and B foliar application) which was statistically identical with F_1 (Zn foliar application). The lowest 1000 seed weight (17.45 g) was observed from the treatment of F_0 (Control/without Zn and B) which was statistically identical with F_2 (B foliar application). Rahman *et al*. (2015) and Malik *et al*. (2015) also found similar result with the present study.

Effect of time of foliar application

Remarkable variation was observed in 1000 seed weight due to time of foliar application (Zn and B) (Table 5 and Appendix VII). The highest 1000 seed weight (21.17 g) was found from the treatment S_3 (at 10 leaf stage + flowering + pod formation) which was significantly different from other treatments. The lowest 1000 seed weight (16.14 g) was achieved from the treatment of S_0 (Control).

Combined effect of Zn and B foliar application and time of application

Significant influence was noted on 1000 seed weight of lentil as affected by combined effect of Zn and B foliar application and time of application (Table 6 and Appendix VII). The highest 1000 seed weight (22.49 g) was obtained from the treatment combination of F_3S_3 which was statistically similar with the treatment combination of F_3S_2, F_1S_3, F_1S_3 and F_3S_1, F_0S_3 and F_1S_2. The lowest 1000 seed weight (14.58 g) was observed from the treatment combination of F_0S_0 which was statistically similar with the treatment combination of, F_0S_1, F_1S_0, F_2S_0 and F_2S_1.

Table 4. Effect of foliar application of Zn and B on yield attributes of lentil

Treatment	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Shelling percentage (%)	1000 seed weight (g)
F_0	39.69 c	1.00 c	24.52 b	17.45 b
F_1	45.20 ab	1.84 a	26.17 b	19.27 a
F_2	42.14 bc	1.41 b	24.17 b	17.53 b
F_3	48.02 a	1.92 a	35.66 a	20.72 a
SE	**1.7961**	**0.151**	**1.6936**	**0.6642**
CV(%)	**10.05**	**11.82**	**15.01**	**8.68**

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

Table 5. Effect of time of foliar application of Zn and B on yield attributes of lentil

Treatment	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Shelling percentage (%)	1000 seed weight (g)
S_0	38.11 c	1.25 c	25.68 b	16.14 c
S_1	42.08 b	1.50 b	28.54 ab	18.21 b
S_2	45.57 b	1.56 b	27.02 ab	19.45 b
S_3	49.29 a	1.95 a	29.28 a	21.17 a
SE	**1.7018**	**0.113**	**1.4046**	**0.6578**
CV(%)	**9.35**	**8.85**	**12.45**	**8.60**

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

Table 6. Interaction effect of Zn and B foliar application and time of foliar spray on yield attributes of lentil

Treatment	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Shelling percentage (%)	1000 seed weight (g)
F_0S_0	33.82 h	0.72 j	16.83 g	14.58 f
F_0S_1	38.31 f-h	0.98 hi	23.03 d-g	17.13 d-f
F_0S_2	42.13 b-g	0.90 ij	25.73c-f	17.56 c-e
F_0S_3	44.51 b-f	1.75 c-e	28.56 b-d	20.53 ab
F_1S_0	38.85 e-h	1.56 ef	31.35 bc	16.31 d-f
F_1S_1	43.24 b-g	1.85 b-d	34.56 b	18.64 b-d
F_1S_2	46.53 a-d	1.95 a-c	21.95 e-g	20.53 ab
F_1S_3	52.17 a	2.02 ab	20.75 e-g	21.60 a
F_2S_0	36.71 gh	1.13 g-i	19.59 fg	15.38 ef
F_2S_1	40.65 d-h	1.25d	22.51 d-g	16.80 d-f
F_2S_2	43.17 b-g	1.35 fg	26.11 c-e	17.86 b-e
F_2S_3	48.05 a-c	1.92 a-c	28.48 b-d	20.06 a-c
F_3S_0	43.07 c-g	1.61 d-f	31.03 bc	18.29 b-d
F_3S_1	46.13 a-e	1.2 a-c	34.06 b	20.27 a-c
F_3S_2	50.45 ab	2.05 ab	34.30 b	21.83 a
F_3S_3	52.44 a	2.12 a	43.24 a	22.49 a
SE	**3.404**	**0.227**	**2.809**	**1.316**
CV(%)	**9.35**	**8.85**	**12.45**	**8.60**

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

4.3 Yield parameters

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

Effect of foliar application of Zn and B fertilizer

Seed yield varied significantly due to foliar application of Zn and B fertilizer (Table 7 and Appendix VIII). In general foliar application of Zn and B increased seed yield than control (untreated). The highest seed yield (1701.7 kg ha^{-1}) was found from the treatment, F_3 (Zn and B foliar application) which was statistically similar with F_1 (Zn foliar application) and F_2 (B foliar application).

The result indicated that F_3 increased seed yield over F_2 and F1 by 8.24% and 6.01%, respectively. The lowest seed yield (1466.8 kg ha^{-1}) was observed from the treatment of F_0 (Control without Zn and B). The result obtained from the present study was similar with the findings of Alam and Islam (2016), Saha *et al*. (2018) and Quddus *et al*. (2014).

Effect of time of foliar application

Significant variation was remarked in seed yield as influenced by time of foliar application (Zn and B) (Table 8 and Appendix VIII). The highest seed yield (1701.3 kg ha^{-1}) was found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) which was statistically similar with S_2 (at 10 leaf stage + flowering). It can be inferred from the result that S_3 showed higher seed yield over S1 and S2 by 113.00 and 75.1 kg ha^{-1}, respectively. The lowest seed yield (1430.2 kg ha^{-1}) was achieved from the treatment of S_0 (Control).

Combined effect of Zn and B foliar application and time of application

Seed yield of lentil varied significantly with the combined effect of Zn and B foliar application and time of application (Table 9 and Appendix VIII). The highest seed yield (1852.0 kg ha^{-1}) was obtained from the treatment combination of F_3S_3which was statistically similar with F_2S_2, F_1S_2, F_1S_3, F_2S_3, F_3S_1 and F_3S_2. The lowest seed yield (1314.0 kg ha^{-1}) was observed from the treatment combination of F_0S_0 which was statistically similar with the treatment combinations of F_2S_0 and F_1S_0.

4.3.2 Stover yield (kg ha^{-1})

Effect of foliar application of Zn and B fertilizer

Significant variation in stover yield of lentil was noted by foliar application of Zn and B fertilizer (Table 7 and Appendix VIII). The highest stover yield (1880.8 kg ha^{-1}) was found from the treatment F_3 (Zn and B foliar application) which was statistically similar with F_1 (Zn foliar application) that means F_3 produced 5.62% higher stover yield than F_1. The lowest stover yield (1685.6 kg ha^{-1}) was observed from the treatment of F_0 (Control/without Zn and B) which was statistically similar with F_2 (B foliar application) and F_1 (Zn foliar application).

Effect of time of foliar application

Stover yield of lentil affected significantly due to time of foliar application (Zn and B) was significant (Table 8 and Appendix VIII). The highest stover yield (1908.3 kg ha^{-1}) was found from the treatment S_3 (at 10 leaf stage + flowering + pod formation) followed by S_1 (at 10 leaf stage) and S_2 (at 10 leaf stage + flowering). The lowest stover yield (1641.2 kg ha^{-1}) was achieved from the treatment of S_0 (Control).

Combined effect of Zn and B foliar application and time of application

The recorded data on stover yield was significant due to combined effect of Zn and B foliar application and time of application (Table 9 and Appendix VIII). The highest stover yield (1956.3 kg ha^{-1}) was obtained from the treatment combination of F_3S_3 which was statistically similar with the treatment combination of F_0S_3, F_1S_2, F_1S_3, F_3S_2. and F_3S_1. The lowest stover yield (1524.0 kg ha^{-1}) was observed from the treatment combination of F_0S_0 which was statistically similar with the treatment combination of F_0S_1, F_1S_0, F_2S_0, F_2S_1 and F_2S_2.

4.3.3 Biological yield (kgha^{-1})

Effect of foliar application of Zn and B fertilizer

Biological yield of lentil exerted significant variation due to foliar application of Zn and B fertilizer (Table 7 and Appendix VIII). The highest biological yield (3582.4 kg ha^{-1}) was found from the treatment F_3 (Zn and B foliar application) which was statistically similar with F_2 (B foliar application). The lowest biological yield (3152.4 kg ha^{-1}) was observed from the treatment of F_0 (Control without Zn and B) which was statistically identical with F_1 (Zn foliar application).

Effect of time of foliar application (Zn and B)

Remarkable variation was identified on biological yield due to the effect of time of foliar application (Zn and B) in lentil (Table 8 and Appendix VIII). The highest biological yield (3609.6 kg ha^{-1}) was found from the treatment S_3 (at 10 leaf stage + flowering + pod formation). The lowest biological yield (3071.4 kg ha^{-1}) was achieved from the treatment of S_0 (Control). S_1 and S_2 showed the intermediate levels of biological yield.

Combined effect of Zn and B foliar application and time of application

Non-significant variation on biological yield was noted due to combined effect of Zn and B foliar application and time of application (Table 9 and Appendix VIII). However, the highest biological yield (3808.3 kg ha^{-1}) was obtained from the treatment combination of F_3S_3 and the lowest biological yield (2838.0 kg ha^{-1}) was observed from the treatment combination of F_0S_0.

4.3.4 Harvest index (%)

Effect of foliar application of Zn and B fertilizer

Harvest index values of lentil had non-significant difference due to foliar application of Zn and B fertilizer (Table 7 and Appendix VIII). However, neumerically the highest harvest index (47.72%) was found from the treatment F_2 (B foliar application) and the lowest harvest index (46.65%) was observed from the treatment of F_0 (Control without Zn and B).

Effect of time of foliar application

Non-significant variation was identified on harvest index due to the effect of time of foliar application (Zn and B) (Table 8 and Appendix VIII). However, the highest harvest index (47.71%) was found from the treatment S_2 (at 10 leaf stage + flowering) and the lowest harvest index (46.74%) was achieved from the treatment of S_0 (Control).

Combined effect of Zn and B foliar application and time of application

Non-significant variation on harvest index was noted in lentil due to the combined effect of Zn and B foliar application and time of application (Table 9 and Appendix VIII). However, the highest harvest index (48.76%) was obtained from the treatment combination of F_2S_2 and the lowest harvest index (46.32%) was observed from the treatment combination of F_0S_0.

Table 7. Effect of foliar application of Zn and B on yield and harvest index of lentil

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
F_0	1466.8 b	1685.6 b	3152.4 b	46.65
F_1	1605.3 ab	1780.7 ab	3295.6 b	47.34
F_2	1572.2 ab	1723.4 b	3386.1 ab	47.72
F_3	1701.7 a	1880.8 a	3582.4 a	47.47
SE	**62.166**	**58.592**	**113.99**	**NS**
CV(%)	**9.60**	**8.12**	**8.32**	**3.10**

NS = Non-significant

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

Table 8. Effect of time of foliar application of Zn and B on yield and harvest index of lentil

Treatment	Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
S_0	1430.2 c	1641.2 c	3071.4 c	46.74
S_1	1588.3 b	1741.5 b	3329.8 b	47.70
S_2	1626.2 ab	1779.5 b	3405.7 b	47.71
S_3	1701.3 a	1908.3 a	3609.6 a	47.03
SE	**40.498**	**36.962**	**44.538**	**NS**
CV(%)	**6.25**	**5.12**	**3.25**	**5.12**

NS = Non-significant

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

Table 9. Interaction effect of Zn and B foliar application and time of foliar spray on yield and harvest index of lentil

Treatment	Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
F_0S_0	1314.0 g	1524.0 i	2838.0	46.32
F_0S_1	1500.0 d-f	1655.0g-i	3155.0	47.565
F_0S_2	1510.0 d-f	1718.3 d-h	3228.3	46.881
F_0S_3	1543.3 b-f	1845.0 a-f	3388.3	45.269
F_1S_0	1454.7 e-g	1659.0 f-i	3113.7	46.748
F_1S_1	1593.3 b	1746.0 c-h	3339.3	47.693
F_1S_2	1653.3a-d	1801.3 a-g	3454.7	47.653
F_1S_3	1720.0a-c	1916.7ab	3636.7	47.293
F_2S_0	1418.7 fg	1602.0 hi	3020.0	46.990
F_2S_1	1570.0 b-f	1685.0 f-i	3255.0	48.240
F_2S_2	1610.0 ab	1691.7e-i	3301.7	48.764
F_2S_3	1690.0 a-d	1915.0a-c	3605.0	46.878
F_3S_0	1533.3 c-f	1780.0 b-h	3313.0	46.900
F_3S_1	1690.0 a-d	1880.0 a-e	3570.0	47.341
F_3S_2	1731.3 ab	1906.7a-d	3638.0	47.558
F_3S_3	1852.0 a	1956.3a	3808.3	48.664
SE	**80.996**	**73.924**	**NS**	**NS**
CV(%)	**6.25**	**5.12**	**3.25**	**5.12**

NS = Non-significant

F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application, F_3 = Zn and B foliar application

S_0 = control, S_1 = at 10 leaf stage, S_2 = at 10 leaf stage + flowering, S_3 = at 10 leaf stage + flowering + pod formation

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the influence of foliar application of zinc (Zn) and boron (B) on the growth and yield of lentil. The experiment comprised of two different factors *viz*. Factor A: Foliar application of Zn and B fertilizer - 4 levels; F_0 = Control (without Zn and B), F_1 = Zn foliar application, F_2 = B foliar application and F_3 = Zn and B foliar application and Factor B: Time of Zn and B fertilizer application - 4 levels; S_0 = Control (without Zn and B) S_1 = at10 leaf stage, S_2 = at 10 leaf stage + flowering and S_3 = at 10 leaf stage + flowering + pod formation. The experiment was set up in Split Plot Design with three replications. There were 16 treatment combinations. The experimental plot was fertilized as per treatment. Data on different growth and yield parameters were recorded and analyzed statistically.

Application of Zn and B showed significant variation on different growth and yield parameters of lentil. Considering growth parameters, the highest plant height (9.97, 17.18, 23.25, 29.04 and 35.55 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (0.33, 0.66, 2.15, 5.79 and 19.78 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches plant^{-1} (2.26, 3.79, 6.34 and 7.25 at 20, 40, 60 and 80 DAS respectively) were found from the treatment F_3 (Zn and B foliar application). Regarding yield and yield contributing parameters, the highest number of pods plant^{-1} (48.02), number of seeds pod^{-1} (1.92), shelling percentage (35.66%), 1000 seed weight (20.72 g), seed yield (1701.7 kg ha^{-1}), stover yield (1880.8 kg ha^{-1}) and biological yield (3582.4 kg ha^{-1}) were also found from the treatment, F_3 (Zn and B foliar application) but the harvest index was non-significant which was numerically highest value (47.72%) was found from the treatment F_2 (B foliar application). The lowest plant height (9.50, 14.83, 18.28, 24.44 and 30.18 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (0.18, 0.47, 1.36, 4.39 and 12.73 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches plant^{-1} (1.78, 3.59, 4.47 and 6.07 at 20, 40, 60 and 80 DAS respectively) were found from control treatment of F_0 (without Zn and B). Again, the lowest number of pods plant^{-1} (39.69), number of seeds pod^{-1} (1.00), shelling percentage (24.52%), 1000 seed weight (17.45 g), seed yield (1466.8 kg ha^{-1}), stover yield (1685.6 kg ha^{-1}), biological yield (3152.4 kg ha^{-1}) and harvest index (46.65%) were also observed from control treatment of F_0 (Control without Zn and B).

Effect of time of foliar application (Zn and B) also showed significant variation in different growth and yield parameters of lentil. Regarding growth parameters, the tallest plant (10.17, 17.80, 23.40, 30.41 and 36.67 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (0.44, 0.72, 2.03, 6.03 and 19.71 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches plant^{-1} (2.59, 4.49, 6.35 and 7.69 at 20, 40, 60 and 80 DAS, respectively) were found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation). Similarly, considering yield and yield contributing parameters, the highest number of pods plant^{-1} (49.29), number of seeds pod^{-1} (1.95), shelling percentage (29.28%), 1000 seed weight (21.17 g), seed yield (1701.3 kg ha^{-1}), stover yield (1908.3 kg ha^{-1}) and biological yield (3609.6 kg ha^{-1}) were also found from the treatment, S_3 (at 10 leaf stage + flowering + pod formation) but the highest harvest index (47.71%) was found from the treatment, S_2 (at 10 leaf stage + flowering). Again, the lowest plant height (9.19, 13.84, 18.38, 23.46 and 30.33 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (0.17, 0.43, 1.33, 3.82 and 12.24 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches plant^{-1} (1.82, 3.16, 4.56 and 5.30 at 20, 40, 60 and 80 DAS, respectively) was achieved from the treatment, S_0 (Control). Similarly, the lowest number of pods plant^{-1} (38.11), number of seeds pod^{-1} (1.25), shelling percentage (25.68%), 1000 seed weight (16.14 g), seed yield (1430.2 kg ha^{-1}), stover yield (1641.2 kg ha^{-1}), biological yield (3071.4 kg ha^{-1}) and harvest index (46.74%) were also achieved from the treatment of S_0 (Control).

Combined effect of foliar application of Zn and B and time of application showed considerable effect on different growth and yield parameters of lentil. Considering growth parameters, the tallest plant (10.39, 19.33, 25.84, 32.45 and 38.28 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight $plant^{-1}$ (0.62, 0.81, 2.32, 7.67 and 26.29 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches $plant^{-1}$ (2.50, 5.00, 7.60 and 9.33 at 20, 40, 60 and 80 DAS, respectively) were found from the treatment combination of F_3S_3. Regarding yield and yield contributing parameters, the highest number of pods $plant^{-1}$ (52.44), number of seeds pod^{-1} (2.12), shelling percentage (43.24%), 1000 seed weight (22.49 g), seed yield (1852.0 kg ha^{-1}), stover yield (1956.3 kg ha^{-1}) and biological yield (3808.3 kg ha^{-1}) were also obtained from the treatment combination of F_3S_3 but the highest harvest index (48.76%) was obtained from the treatment combination of F_2S_2. The shortest plant (8.85, 12.37, 15.88, 19.37 and 26.72 cm at 20, 40, 60, 80 DAS and at harvest, respectively), dry weight $plant^{-1}$ (0.15, 0.37, 1.15, 3.15 and 10.52 g at 20, 40, 60, 80 DAS and at harvest, respectively) and number of branches $plant^{-1}$ (1.60, 2.62, 3.90 and 5.12 at 20, 40, 60 and 80 DAS, respectively) was achieved from the treatment combination of F_0S_0. Likewise, the lowest number of pods $plant^{-1}$ (33.82), number of seeds pod^{-1} (0.72), shelling percentage (16.83%), 1000 seed weight (14.58 g), seed yield (1314.0 kg ha^{-1}), stover yield (1524.0 kg ha^{-1}), biological yield (2838.0 kg ha^{-1}) and harvest index (46.32%) were also observed from the treatment combination of F_0S_0.

Conclusion

From the above result it may be concluded that i) Zn + B applied as foliar application (F_3) performed best by producing higher yield as well as growth and yield attribute characters in lentil ii) Foliar application applied at 10 leaf stage + flowering + pod formation stage (S_3) seems promising by producing higher growth characters, yield attributes and yield of lentil, and iii) the combination of Zn and B foliar application and foliar application at 10 leaf stage + flowering + pod formation stage (F_3S_3) is the best combination for the maximum growth and yield of lentil compared to other treatment combinations.

Recommendations

To reach a specific conclusion and recommendation, more research work regarding this issue on lentil should be done in different agro ecological zones of Bangladesh with these treatment variables.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

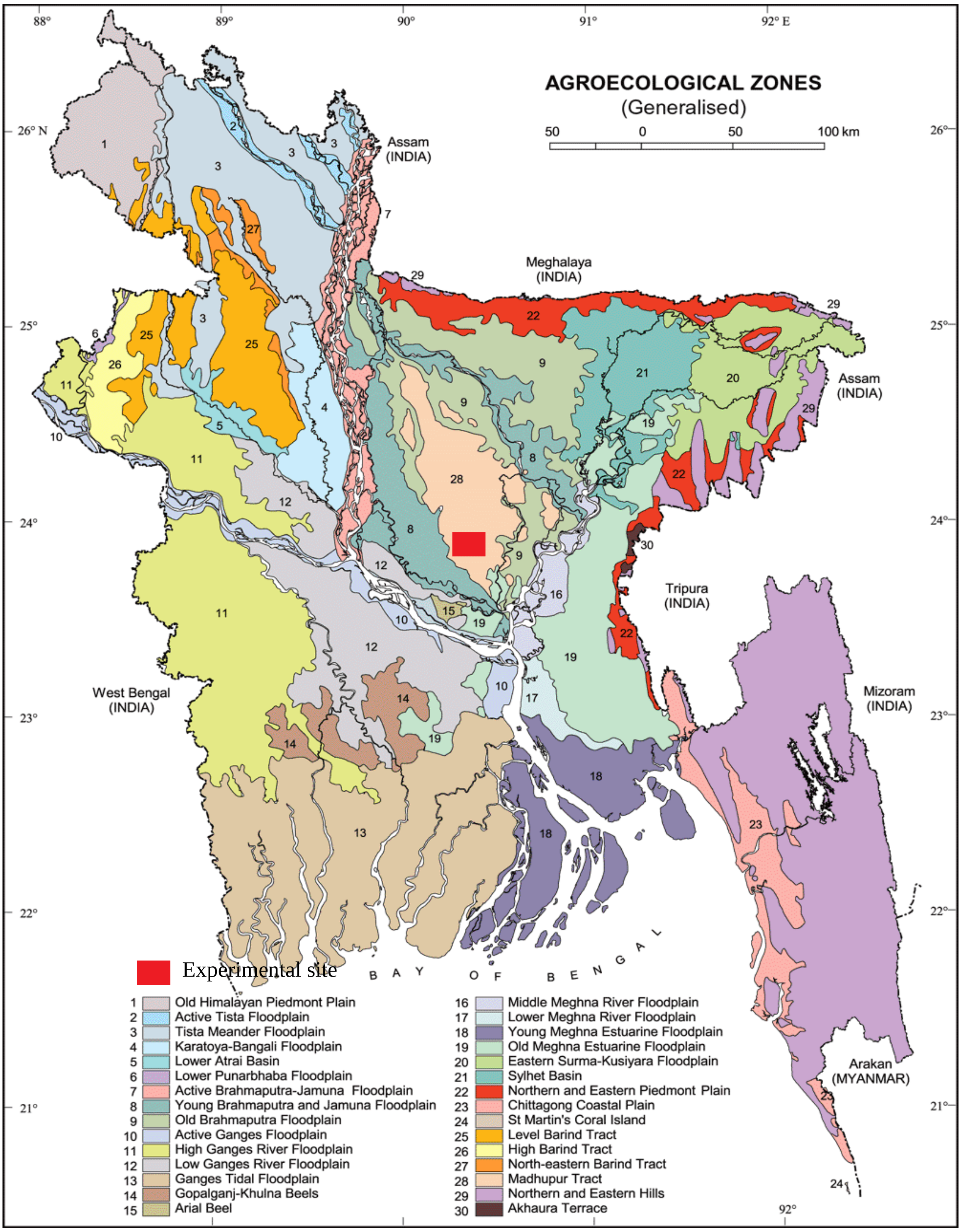

Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2017 to March 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0
2018	March	35.20	21.00	28.10	52.44	20.4

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Effect of number of Zn and B foliar application and time of foliar spray on plant height of lentil

Sources of variation	Degrees of freedom	Plant height (cm) at different days after sowing				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication	2	2.44	8.24	5.24	7.27	5.87
Factor A	3	NS	NS	56.53*	74.32*	65.86*
Error	6	0.29	6.23	5.25	7.86	9.12
Factor B	3	2.21*	35.01*	60.84*	115.48*	80.93*
AB	9	0.05**	NS	2.81*	NS	1.76*
Error	24	0.13	1.50	4.98	2.32	5.32

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

Appendix V. Effect of number of Zn and B foliar application and time of foliar spray on plant dry weight of lentil

Sources of variation	Degrees of freedom	Dry weight plant^{-1} at different days after sowing				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.02	0.082	0.533	5.13	8.02
Factor A	3	0.04*	0.089*	1.732*	4.98*	107.84*
Error	6	0.001	0.007	0.046	0.11	1.88
Factor B	3	0.159*	0.197*	1.466*	11.14*	120.27*
AB	9	0.024**	NS	0.085*	0.84*	5.52*
Error	24	0.001	0.082	0.045	0.44	2.29

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

Appendix VI. Effect of number of Zn and B foliar application and time of foliar spray on branch number of lentil

Sources of variation	Degrees of freedom	Number of branches plant^{-1} at different days after sowing			
		20 DAS	40 DAS	60 DAS	80 DAS
Replication	2	0.15	3.80	4.82	3.69
Factor A	3	0.58*	0.82*	6.96*	2.93*
Error	6	0.07	0.14	0.17	0.32
Factor B	3	2.02*	4.14*	7.24*	12.65*
AB	9	NS	0.40**	0.13**	0.87*
Error	24	0.28	0.17	0.20	0.18

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

Appendix VII. Effect of number of Zn and B foliar application and time of foliar spray on yield attribute of lentil

Sources of variation	Degrees of freedom	Yield contributing parameters			
		Number of pods plant^{-1}	Number of seeds pod^{-1}	Shelling (%)	1000 seed weight (g)
Replication	2	40.470	0.24	62.60	13.38
Factor A	3	157.675*	7.35*	352.63*	29.38*
Error	6	19.355	0.13	17.21	2.64
Factor B	3	274.460*	4.04*	30.86*	53.87*
AB	9	2.304*	0.34**	111.60	0.79
Error	24	17.378	0.24	11.83	2.59

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

Appendix VIII. Effect of number of Zn and B foliar application and time of foliar spray on yield and harvest index of lentil

Sources of variation	Degrees of freedom	Yield parameters			
		Yield (kgha^{-1})	Stover yield (kgha^{-1})	Biological yield (kgha^{-1})	Harvest index (%)
Replication	2	175.33	568.43	399.724	12.468
Factor A	3	866.19*	1125.74*	3890.07*	NS
Error	6	20.59	231.88	779.67	2.15
Factor B	3	1462.78*	1568.14*	5937.18*	NS
AB	9	42.15*	14.97**	33.83*	NS
Error	24	81.97	9841	119.02	5.85

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

Plate 1. Field view at early vegetative stage of lentil

Plate 2. Flowering stage of lentil

Plate 3. Data collection

Plate 3. Data collection