INFLUENCE OF BIOFERTILIZER AND DIFFERENT LEVELS OF BORON PLUS ZINC ON GROWTH AND YIELD OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled ***"INFLUENCE OF BIOFERTILIZER AND DIFFERENT LEVELS OF BORON PLUS ZINC ON GROWTH AND YIELD OF LENTIL"*** *submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in AGRONOMY****, embodies the result of a piece of authentic research work carried out by* ***Shaila Sharmin,*** *Registration No.* ***18-09094*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

A field experiment was accomplished in the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2019 to March, 2020 to observe the influence of biofertilizer and different levels of boron + zinc on growth and yield of lentil. The experiment comprised of two levels of biofertilizer, (factor A) viz., i) B_0 = Control (without biofertilizer), ii) B_1 = biofertilizer and six levels of B + Zn (factor B) viz., i) F_0 = Control (without B+Zn), ii) F_1 = B+Zn at 50% of their recommended dose, iii) F_2 = B+Zn at 75% of their recommended dose, iv) F_3 = B+Zn at their recommended dose, v) F_4 = B+Zn at 125% of their recommended dose and vi) F_5 = B+Zn at 150% of their recommended dose were used in this experiment arranged in split plot design with three replications. Data on different growth and yield attributes parameters were taken in which all the treatment showed significant variations. Results revealed that biofertilizer out yielded over non-biofertilizer applied plot by producing higher yield which may be attributed to higher plant height (42.79 cm), number of branches plant^{-1} (8.92), dry weight plant^{-1} (6.47 g) pods plant^{-1} (58.32), seeds pod^{-1} (1.52), 1000 seed weight (22.51 g), stover yield (4105.33 kg ha^{-1}), biological yield (6366.70 kg ha^{-1}) and harvest index (34.59 %). Considering B+Zn levels, F_3 (Recommended B+Zn) and F_2 (B+Zn, 75% of recommended doze) gave statistically similar but highest seed yield (2451.81 and 2350.20 kg ha^{-1}, respectively) than other treatments. These two treatments also gave higher 1000 seed weight, pods plant^{-1}, seeds pod^{-1} and branches plant^{-1}. In the case of the combination effect the maximum seed yield (2552.83 Kg ha^{-1}) was recorded from B_1F_3. Thus, it was apparent from the above results that the treatment combination of B_1F_3 was found suitable than rest of treatment combinations.

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LIST OF ACRONYMS

AEZ	Agro-ecological Zone
Agric.	Agricultural
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
Biol.	Biology
CV	Coefficient of variance
DAS	Days After Sowing
et al.	And others
Ex.	Experiment
FAO	Food and Agriculture Organization
g	Gram
Hort.	Horticulture
i.e.	That is
J.	Journal
Kg	Kilogram
LSD	Least Significance difference
mm	Millimeter
SPD	Spilt Plot Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
spp.	Species
Technol.	Technology
UNDP	United Nations Development Programme
Viz.	Namely
%	Percent
LAI	Leaf Area Index
RGR	Relative Growth Rate
NAR	Net Assimilation Rate
MSTAT	Michigan State University Statistical Package for Data Analysis
etc.	Etcetera
B	Boron
Atm	Atmospheric
BBS	Bangladesh Bureau of Statistics
No.	Number
m^2	Meter squares
NS	Non significant
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
^0C	Degree Centigrade
hr	Hour(s)
MoP	Muriate of Potash

Kg	Kilogram (s)
HI	Harvest Index
RD	Recommended Dose

CHAPTER I

INTRODUCTION

Pulses are the basic component of a cropping pattern in Bangladesh as these crops suitable in crop rotation and diversified or intercropping systems followed under different agro-ecological regions. Lentil (*Lens culinaris* Medik) locally known as Masoor, is an important winter crop that has been grown as an important pulse for over 8,000 years (Dhuppar *et al.*, 2012). In Bangladesh, lentil placed first position among the pulses in 155965.44 hectares, and production MT-176633 (BBS, 2020). Lentil contains protein, carbohydrates, oils, and ash at the rate of 23.25%, 59%, 1.8% and 0.2% respectively along with iron, calcium, phosphorus and magnesium. A significant amount of vitamin A and B is also provided by lentil (Zafar *et al.*, 2003).

According to FAO (1999) a minimum intake of pulse by a human should be 80g per head per day, whereas it is only 12g in Bangladesh (BBS, 2008). This is because of the fact that the national production of pulse is not adequate to meet the national demand. It is considered as poor man's meat as well as cheapest source of protein for under privileged group of people who cannot afford to buy animal protein (Gowda and Kaul, 1982). The protein content of lentil seed is found to vary from 25.70 to 33.40 percent (Singh *et. al.*, 1994). The stover of the plants together with husk popularly known as bushy is highly protein concentrated to feed to cattle, horse, pig and sheep (Tomar *et. al.*, 2000). In crop productivity, nutrients management plays a vital role while less availability of nutrients causes reduction in yield and productivity. The insufficiency of macro and micro nutrients has been recorded in many soils and through various management practices it could be managed properly (Ali *et al.*, 2008).

Moreover, during lentil cultivation, biofertilizer could be one of the most important factors that will increase the yield significantly. Seed inoculation with effective *Rhryzobium* can play a vital role in the formation of nodules to fix atmospheric nitrogen by symbiotic process in the root system of legume crops making the nutrient available to the plant. ln Bangladesh, inoculation with biofertilizer increased 57% effective nodule, 77% matter production, 640% grain yield and 40 % hay yield over uninoculated control in lentil cultivation (Chanda *et al.*, 1991). Sattar and Ahmed (1992) reported that legume crop such as lentil can fix atmospheric nitrogen with the association of *Rhyzobium* inoculants and increase nitrogen content in soil.

Boron is one of the crucial micronutrients needed for plant development and productivity. It is very important in cell division and in pod and seed formation (Goldberg and Su, 2007). Reproductive growth, specially flowering, fruit and seed set is greater touchy to B deficiency than vegetative growth. Boron impact the absorption of N, P, K and its deficiency modified the equilibrium of most beneficial of these three macronutrients. The N and B centralizations of grain for lentil were extraordinarily impacted by B treatment demonstrating that the B had a positive function on protein synthesis. Studies found that essential amino acid increased with increasing B supply.

Mary *et al.* (1990) seen that utilization of boron came about expansion in the quantity of units/branches, expanded the quantity of seeds/plant and seed 4 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 basic for ordinary development of pollen grains, sugar movement and development of growth controllers inside the plant (Hamasa and Putaiah, 2012). Boron's inclusion in hormone combination and movement, carbohydrate digestion systems and DNA amalgamation likely added to extra growth and yield (Ratna Kalyani *et al.,* 1993). Deficiency of B causes intense discounts in crop yield, because of excessive disturbances in B-involving metabolic strategies, consisting of metabolism of nucleic acid, carbohydrate, protein and indole acetic acid, cellular wall synthesis, membrane integrity and characteristic, and phenol metabolism (Tanaka and Fujiwar, 2008). Application of B is very powerful for brief elimination of boron deficiency and contributes to achieve better yield (Bozoglu *et al.,* 2008). consequently, applications of micronutrients especially Zn and B have gained sensible significance.

The role of micronutrients is also very important in growth and development of all the crops (Farooq *et al.,* 2012). In micronutrients, zinc is very important in reproductive phase like fertilization and pollen grain formation as pollen grain contains a high amount of zinc. Most of the zinc is translocated to seeds during fertilization and lower application of zinc causes deficiency of zinc in the seed and also the seed yield is quietly reduced (Jenik and Kathryn, 2005; Pandey and Gautam, 2009; and Reid *et al*., 2011). In dry land agriculture, the application of fertilizer increases the lentil quality (protein %) and quantity (grain yield). For achieving these objectives, it is essential to select the most appropriate levels of phosphorus and zinc fertilizer in each area for the growth and better yield of lentil.

Zinc role is as multifaceted as the interface that reduces its availability. Physiologically its role in a plant is either as a metal constituent in enzymes or as a functional co-factor of number of enzymes reactions. In general zinc deficient plant show signs of low levels of auxins such as indole acetic acid (IAA). Investigation may provide sound footing that zinc is required for synthesis of tryptophan, which in turn is precursor for synthesis of IAA (Guilfoyle and Hagen, 2001 and Liscum and Reed, 2002). After flowering, high concentration of zinc in plant will enhance cell differentiation. Zinc plays a greater role during reproductive phase especially during fertilization. Remarkably pollen grain contains zinc in very high quantity. At the time of fertilization most of zinc is diverted to seed only (Jenik and Barton 2005; Pandey and Gautam, 2009 and Reid *et al.*, 2011).

So, it is necessary to examine the effects of different levels of those nutrients and assess their best combination in relation to enhanced growth and productivity of lentil. In view of these points the present study was undertaken to fulfill the following objectives:

- To observe the influence of different levels of boron and zinc on growth and yield of lentil;
- To examine the effect of different combinations of boron and zinc on growth and yield of lentil; and
- To find out the interaction effect of biofertilizer and different combinations of boron and zinc on growth and yield of lentil.

CHAPTER II
REVIEW OF LITERATURE

Lentil (*Lens culinaris* L.) is one of the important pulse crops in Bangladesh as well as many countries of the world. The crop has conventional and given less concentration by the researcher on various aspects because normally it grows with less care and management practices. For that a very few studies related to growth, yield and development of lentil have been carried out in our country as well as many other countries of the world. So, the research so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the biofertilizer, boron and zinc so far been done at home and abroad on this crop have been reviewed in this chapter –

2.1. Effect of bio-fertilizer on nodulation, growth and yield

Biofertilizers are gaining importance as they are ecofriendly, non-hazardous and non-toxic. A substantial number of bacterial species, mostly those associated with the plant rhizosphere, may exert a beneficial effect upon plant growth. Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting micro-organism. Inoculating pulse crops with rhizobia to add nitrogen is routine for most growers. The presence of efficient and specific strains of Rhizobium in the rhizosphere is one of the most important requirements for proper establishment and growth of grain legume plant. Phosphate solubilizing bacteria partly solubilizes inorganic and insoluble phosphate and improves applied phosphorus use efficiency stimulating plant growth by providing hormone, vitamin and other growth promoting substances (Gyaneshwar *et al.,* 2002).

The application of biofertilizers, micronutrients and RDF enhanced the plant height appreciably at harvest stages. Increase in plant height might be attributed to the fact that the better nourishment causes beneficial effects such as accelerated rate of photosynthesis, assimilation, cell division and vegetative growth. These results are in agreement with the findings of Singh *et al.*, (2007).

Dhingra *et al.* (1988) results revealed that the interactions between phosphorus and Rhizobium inoculation was significantly in 3 out of 5 years, indicating that the combination of Rhizobium and 20 kg P_2O_5 ha^{-1} gave yield equivalent to 40 4 kg P_2O_5 ha^{-1} without Rhizobium. Gupta and Sharma (1992) reported from the result of an experiment that yield of lentil 0.87-1.30 t/ha with 0-32 kg phosphorus and no inoculation, and 0.89-1.68 t/ha with 0–32 kg phosphorus and inoculation. Seeds protein content increased with application of phosphorus and inoculation.

Rajput and Kushwah (2005) studied that the application of bio-fertilizer on production of pea. On the basis of three years pooled data, the highest yield was recorded with the application or recommended doses of fertilizer followed by soil application of bio-fertilizer mixed 25 kg FYM along with 50% recommended dose of fertilizer and were at par statistically. So the use of biofertilizer saved 50% N, P (10 kg N, 25 kg P2O5). It also saved the financial resource as well as FYM.

Sharma and Sharma (2004) determined the effects of P (0, 20 and 40 kg/ha), potassium (0 or 20 kg/ha) and Rhizobium inoculation on the growth and yield of lentil cv. L-4147. The mean number of branches, nodules and pods per plant; 100-seed weight and seed yield were highest with the application of 40 kg P/ha, whereas mean plant height and plant stand row length were highest with the application of 20 kg P/ha. Application of K resulted in the increase in number of branches and pods per plant and seed yield, whereas inoculation with Rhizobium increased the mean plant height; number of branches, nodules and pods per plant, 100-seed weight and seed yield.

Hossain and Suman (2005) carried out an experiment to evaluate the effect of Azotobacter, Rhizobium and different levels of urea N on growth, yield and N uptake of lentil. Among the treatments Azotobacter plus Rhizobium inoculation had significant effect on nodule formation, plant height, number of seeds, seed and stover yields, compared to uninoculated controls. The highest seed yield was recorded for the treatment *Azotobacter+Rhizobium* that was statistically similar to that of 100% N and Rhizobium with the corresponding yields of 1533 and 1458 kg/ha, respectively. The dual inoculation of Azotobacter and 5 Rhizobium significantly influenced all the crop characters including N contents, N uptake by seed and shoot as well as protein content of seed. The highest N-uptake by seed (78.61 kg/ha) was recorded for the treatment *Azotobacter+Rhizobium* and N-uptake by shoot (53.87 kg/ha) was recorded for the treatment 100% N. The performances of Azotobacter or Rhizobium alone were not as good as *Azotobacter+Rhizobium* in most cases. Therefore, inoculation of both Azotobacter and Rhizobium together may be a good practice to achieve higher seed yield of lentil.

Kumar and Uppar (2007) conducted a field experiment to evaluate the effects of organic manures, biofertilizers, micronutrients and plant growth regulators on the seed yield and quality of mothbean. RDF + FYM @ 10 t/ha recorded the highest values for the different seed yield and quality attributes of mothbean.

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.

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.

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.

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 B_2 (2 kg B ha^{-1}) and the lowest was found from B_0 (control) treatment. The highest soil pH and organic matter was recorded from B_2 (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.

Sumdanee (2010) conducted a study on the effect of Boron and Molybdenum on the growth and yield of mungbean. The variety BARI mung-6 was used as test crop. The experiment consists of two factors: Factor A: Boron (4 levels); 0 (B_0), 1.0 (B_1), 1.5 (B_2) and 2.0 (B_3) kg B ha^{-1} and Factor B: Molybdenum (4 levels); 0 (Mo_0), 1.0 (Mo_1), 1.5 (Mo_2) and 60 (Mo_3) kg Mo ha^{-1}. The experiment was conducted following split plot design with three replications. The result revealed that treatment B_3 (2 kg B ha^{-1}) showed the highest plant height (47.22 cm), dry matter plant^{-1} (16.68 g), number of pods plant^{-1} (30.36), pod length (8.97cm), seed yield (1.53 t ha^{-1}) and stover yield (1.78 t ha^{-1}), but B_2 (2 kg B ha^{-1}) showed the highest 1000-seed weight (44.28 g). On the other hand, B_o (0 kg B ha^{-1}) showed the lowest plant height (44.10cm), dry matter plant-1 (13.44 g), number of pods plant^{-1} (22.07), pod length (7.02 cm.), seeds pod^{-1} (7.91), 1000 seed weight (41.62 g), seed yield (1.18 t ha^{-1}) and stover yield (1.53 t ha^{-1}). The result also revealed that Mo_3 (2 kg Mo ha^{-1}) showed the highest plant height (44.06 cm), dry matter plant^{-1} (16.59 g), number of pods plant^{-1} (29.51), pod length (8.92 cm), 1000-seed weight (44.69 g), seed yield (1.60 t ha^{-1}) and stover yield (1.85 t ha^{-1}) but Mo_2 (2 kg Mo ha^{-1}) showed the highest seeds plant^{-1} (10.89). On the other hand, Mo_0 (0 kg Mo ha^{-1}) showed the lowest plant height (44.67cm), dry matter plant^{-1} (14.17g), number of pods plant^{-1} (24.14), pod length (7.05cm), seeds per pod (8.29), 1000-seed weight (40.31 g), seed yield (1.17 t ha^{-1}) and stover yield (4.5 t ha-1). The interaction of B_3Mo_3 (2 kg B ha^{-1} x 2 kg Mo ha^{-1}) showed the highest plant height (47.44 cm), dry matter plant^{-1} (17.75 g), number of pods plant^{-1} (33.07), pod length (9.35 cm), 1000-seed weight (45.49 g), and stover yield (1.97 tha^{-1}) but B_3Mo_2 (2 kg B ha^{-1} x1.5 kg Mo ha^{-1}) showed the highest seeds per pod (12.32) and seed yield (1.74 t ha^{-1}). On the other hand, B_0Mo_o (0 kg B ha^{-1} x 0 kg Mo ha^{-1}) showed the lowest plant height (40.21 cm), dry matter plant^{-1} (12.58 g), number of pods plant^{-1} (18.40), pod length (5.77 cm), seeds per pod (7.43), 1000 seed weight (38.05 g), seed yield (0.99 t ha^{-1}) and stover yield (1.37t ha^{-1}). It may be concluded that boron and molybdenum had a significant influence on the growth and yield of mungbean and 1.5 kg B and 1.5 kg Mo per hectare can be the optimum dose for higher yield of mungbean.

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 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.

Sultana (2018) conducted a field experiment on influence of foliar application of zinc and boron on the growth and yield of lentil. 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 plant1 (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).

Ali *et al.* (2017) conducted a field experiment on effect of phosphorus and zinc on yield of lentil and found that the application of zinc at 9 kg ha^{-1} produced more pods $plant^{-1}$ (117) and grain yield (1846 kg ha^{-1}). Statistically similar results were found in plots received 9 and 12 kg Zn ha^{-1} regarding thousand grain weights (30.6 g and 29.4 g) and seeds recovery percentage (68 %). The above all experimental results concluded that zinc should be used at the rates of 9 kg ha^{-1} for the growth and yield of lentil.

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%), Zn2 (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.

2.4 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 (27,009/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 N24 P20 K30 S15 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 Zn1.0B1.5 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 N20 P16 K30 S10 kg/ha were used. The treatments were arranged *viz*. T_1= Zn_0B_0; T_2= Zn_0B0.5; T_3= Zn0B1.0; T_4= Zn0B1.5; T_5= Zn_1.0B_0;

T_6= Zn1.0B0.5; T_7= Zn1.0B1.0; T_8= Zn1.0B1.5; T_9= Zn2.0B0; T_{10}= Zn2.0B0.5; T_{11}= Zn_2.0B1.0; T_{12}= Zn_2.0B1.5; T_{13}= Zn3.0B0; T_{14}= Zn3.0B0.5; T_{15}= Zn_3.0B1.0 and T_{16}= Zn_3.0B1.5. The experiment was laid out in RCBD with three replications. Results showed that the combination of $Zn_{3.}$0B1.5 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 literatures, it very well may be inferred that zinc assumes a huge part for higher lentil production and furthermore other pulse crop. Likewise, boron is additionally significant plant supplement for effective pulse production particularly for lentil.

CHAPTER III
MATERIALS AND METHODS

A field experiment was accomplished at the Agronomy Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during the period from November, 2019 to March, 2020 to observe the influence of biofertilizer and different levels of boron + zinc on growth and yield of lentil. This chapter contains a brief description of location of the experimental site, climatic condition and soil, materials used for the experiment, treatment and design of the experiment, production methodology, intercultural operations, data collection procedure and statistical analysis etc., which are presented as following headings:

3.1 Experimental sites

The experiment was conducted at the Agronomy Farm, Sher-e-Bangla Agricultural University Farm, Dhaka, during the period from November, 2019 to March, 2020 to study the influence of biofertilizer and different levels of B + Zn on growth and yield of lentil. The location of the site is $23^0 74'$ N latitude and $90^0 35'$ E longitudes with an elevation of 8.2 meter from sea level in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28). For better understanding about the experimental site, it has been shown in the map of AEZ of Bangladesh in Appendix-I.

3.2 Climate

The experimental site was located in the sub-tropical monsoon climatic zone, characterized by heavy rainfall during the months from April to September (*Kharif* season) and scanty of rainfall during the rest of the year (*Rabi* season). In addition, under the sub-tropical climatic, which is individualized by high temperature, high humidity and heavy precipitation with seasonal unexpected winds and relatively long in Kharif season (April- September) and sufficient sunlight with moderately low temperature, intensity of humidity and short-day period of during Rabi season (October-March). The information of weather regarding the atmospheric temperature, relative humidity, rainfall, sunshine hours and soil temperature persuaded at the experimental site during the whole period of observation (Appendix II).

3.3 Soil

The experimental soil belongs to the Modhupur Tract under AEZ No. 28 (UNDP-FAO, 1988). The land which selected was medium and the soil series was Tejgaon. The soil characteristics of the experimental plot were analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and the experiment field primarily had a P^H of 6.5. The physical and chemical properties of the soil have been presented in Appendix-III.

3.4 Planting materials

One high yielding varieties of lentil designated as 'BARI Masur-6,' developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was used in the experiment as a planting material. This varieties bear good phenotypic characters; such as deep green leaf, no tendril in front of leaf, bushy type 24 plant, 35-40 cm height, white color flower and seed size is larger than local seed, deep brown color, duration of 105-110 days and seed yield of 2200-2300 kg ha^{-1}

3.5 Treatments of the experiment

Twelve treatment combinations included in the study were as follows:

Treatments:

Factor A. Biofertilizer (Two levels)- Main plot

B_0 = Control (Without Biofertilizer)

B_1 = Biofertilizer

Factor B. B + Zn (6 levels)- Sub-plot

F_0 = Control (without B+Zn),

F_1 = (B+Zn) @ 50% of their recommended dose

F_2 = (B+Zn) @75% of their recommended dose

F_3 = (B+Zn) @ their recommended dose

F_4 = (B+Zn) @ 125% of their recommended dose

F_5 = (B+Zn) @ 150% of their recommended dose

There were on the whole 12 treatment combinations named as B_0F_0, B_0F_1, B_0F_2, B_0F_3, B_0F_4, B_0F_5, B_1F_0, B_1F_1, B_1F_2, B_1F_3, B_1F_4, B_1F_5.

N.B. All the recommended dose of fertilizers except B and Zn were applied as basal. B and Zn were applied per treatment. Recommended dose of the fertilizers has presented in section 3.8.

3.6 Design and layout of the experiment

The two factors experiment was laid out in split plot design with three replications. An area of 20 m × 10 m was divided into three equal blocks. Each of the blocks was divided into 2 main plots. Each of the main plots was divided into six sub plots (as mention in the Figure 1). Biofertilizer was placed as main plot treatment and B + Zn was considered in the sub-plot treatments. The treatment combinations were allocated at random with three replications. There were 36-unit plots altogether in the experiment. The size of each unit plot was 2.1 m × 1.8 m. The distance maintained between plot to plot and replication to replication were 0.25 cm and 0.75 cm, respectively.

3.7 Land preparation

The experiment field was first disc-ploughed and harrowed. Final land preparation was made by a tiller followed by leveling with scrapper. Clods were broken and weeds were removed from the field to obtain desirable tilth. The basal doses of manures and fertilizers were added and mixed into the soil during final land preparation. Then the experimental area was layout as per design. Irrigation channels were made around each plot.

3.8 Application of manures and fertilizers

Fertilizers were applied following the recommendation of BARI (2011), which has been presented in the following Table. Manures and fertilizer such as Urea, TSP, M_OP, H_3BO_4 and $ZnSO_4$ were used as source for N, P, K, B, and Zn, respectively. Zinc and Boron fertilizer were applied to each plot as per treatment while among other fertilizer were used as per recommended dose in those plots during final land preparation. The fertilizers were incorporated into soil by spading.

Table 1. Manures and fertilizer dose

SL No.	Manures/ fertilizers	Recommended dose/ha.
1	Cow dung	1 t
2	Urea	50 kg
3	TSP	90 kg
4	MoP	55 kg
5	Gypsum	50 kg
6	Boron	1.5 kg
7	Zinc	3.0 kg
8	Biofertilizer	0.5 kg

Source: BARI (2011)

3.9 Seed sowing

Seeds were air-dried before sowing since water soaked to facilitate germination. The Seeds of lentil were sown on 2 November 2019. The seeds were treated with Bavistin before sowing the seeds to control the seed born disease. Seeds were sown in well-prepared plot by maintaining row to row distance of 30 cm and plant to plant distance within the rows 5 cm (approximately).

3.10 Intercultural operations

3.10.1 Thinning

The optimum plant population was maintained by thinning out the excess plant. Seeds were germinated four days after sowing (DAS). Thinning was done at 15 days after sowing (DAS) to maintain 5 cm distance between plant to plant to obtain proper plant population in each plot.

3.10.2 Weeding

The crop was infested with some weeds during the early stages of crop establishment. The crop was weeded twice; first weeding was done at 15 DAS and second weeding was done at 30 DAS.

3.10. 3 Application of irrigation water

For better growth and development of crop, three irrigations were given to the field. First irrigation was done at 15 DAS and second and final irrigation were done at 45 DAS and 65 DAS, respectively.

3.10.4 Drainage

Drainage channels between the plots were properly prepared to easy and quick drained out of excess water.

3.10.5 Plant protection measures

At seedling stage, fungal disease was observed in the field and some plants were died. For prevention from disease, Bavistin was sprayed. At vegetative stage, aphid (*Aphis craccivora*) attacked the young plants and at latter stage of growth, pod borer (*Maruca testulalis*) attacked the plant. For aphid control, Ripcord 2 ml water and for pod borer Dimacron 50 EC at the rate of 3 ml was sprayed, respectively.

3.10.6 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with tag for recording data of plant characters. The data of plant characters were recorded from 25 days of sowing to till harvest at 20 days interval. Yield and yield contributing parameters were recorded from the central part of the plots. A brief outline of the data recording on morpho-physiological and yield contributing characters are given below.

3.11 Harvesting and threshing

Crop was harvested when 90% (approximately) of the pods became brown to black in color. Five plants from each plot avoiding central 1 m^2 area were collected and tagged properly from which yield attributes data were recorded. For taking yield data, the matured crops were harvested from the central 1 m^2 area of each plot and tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.12 Drying and weighing

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

3.13 Data collection

The following growth, yield attributes and yield data were recorded from the experiment-

a. Plant height (cm) (at 25, 45, 65, 85 DAS and at harvest)

b. Branches $plant^{-1}$ (no.) (at 25, 45, 65, 85 DAS and at harvest)

c. Dry weight $plant^{-1}$ (g) (at 25, 45, 65, 85 DAS and at harvest)

d. Pods $plant^{-1}$ (no.)

e. Seeds pod^{-1} (no.)

f. 1000-seed weight (g)

g. Grain yield (kg ha^{-1})

h. Stover yield (kg ha^{-1})

i. Biological yield (kg ha^{-1})

j. Harvest index (%)

3.13.1 Plant height

The height of pre-selected 5 plants from each plot was measured from ground level (stem base) to the tip of the plant at dates. Mean plant height was calculated and expressed in cm. Plant height data were taken at 25, 45, 65, 85 DAS and at harvest.

3.13.2 Branches plant^{-1}

The number of branches of 5 randomly pre-selected plants from each plot were counted and recorded at each date. Average value of five plants was recorded as branches plant^{-1}. These data were recorded at 25, 45, 65, 85 DAS and at harvest.

3.13.3 Dry weight plant^{-1}

Randomly selected 5 plants from each plot excluding the harvest area were uprooted and oven dried and weighed. The average value was recorded in g plant^{-1}. Dry weight data were recorded 25, 45, 65, 85 DAS and at harvest.

3.13.4 Pods plant^{-1}

Total number of pods were collected from 5 randomly selected plants and then averaged to express in number of pods plant^{-1}.

3.13.5 Seeds pod^{-1}

The number of seeds in each pod was recorded from randomly selected 20 pods at the harvest time. The average number of seeds from the 20 pods was expressed as number of seeds pod^{-1}.

3.13.6 Weight of 1000-seeds (g)

One thousand (1000) seeds were counted from the harvested 1 m^2 area in each plot and weighed with a digital electric balance. The 1000-seed weight was recorded in gram.

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

After threshing, cleaning and drying of total seeds from harvested area (1 m^2) was weighted and was converted to kg ha^{-1}.

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

After separation of seeds from plant the straw and shell from harvested area was sun dried and then weight was recorded and converted into kg ha^{-1}.

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

The summation of seed yield and above ground stover yield was the biological yield.

Biological yield = Grain yield + Stover yield.

3.13.10 Harvest index (%)

It is the ratio of economic yield (grain yield) to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.14 Statistical analysis

The data obtained for different parameters were analyzed following computerized package program MSTAT- C for analysis of variation. The treatment means were adjusted by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

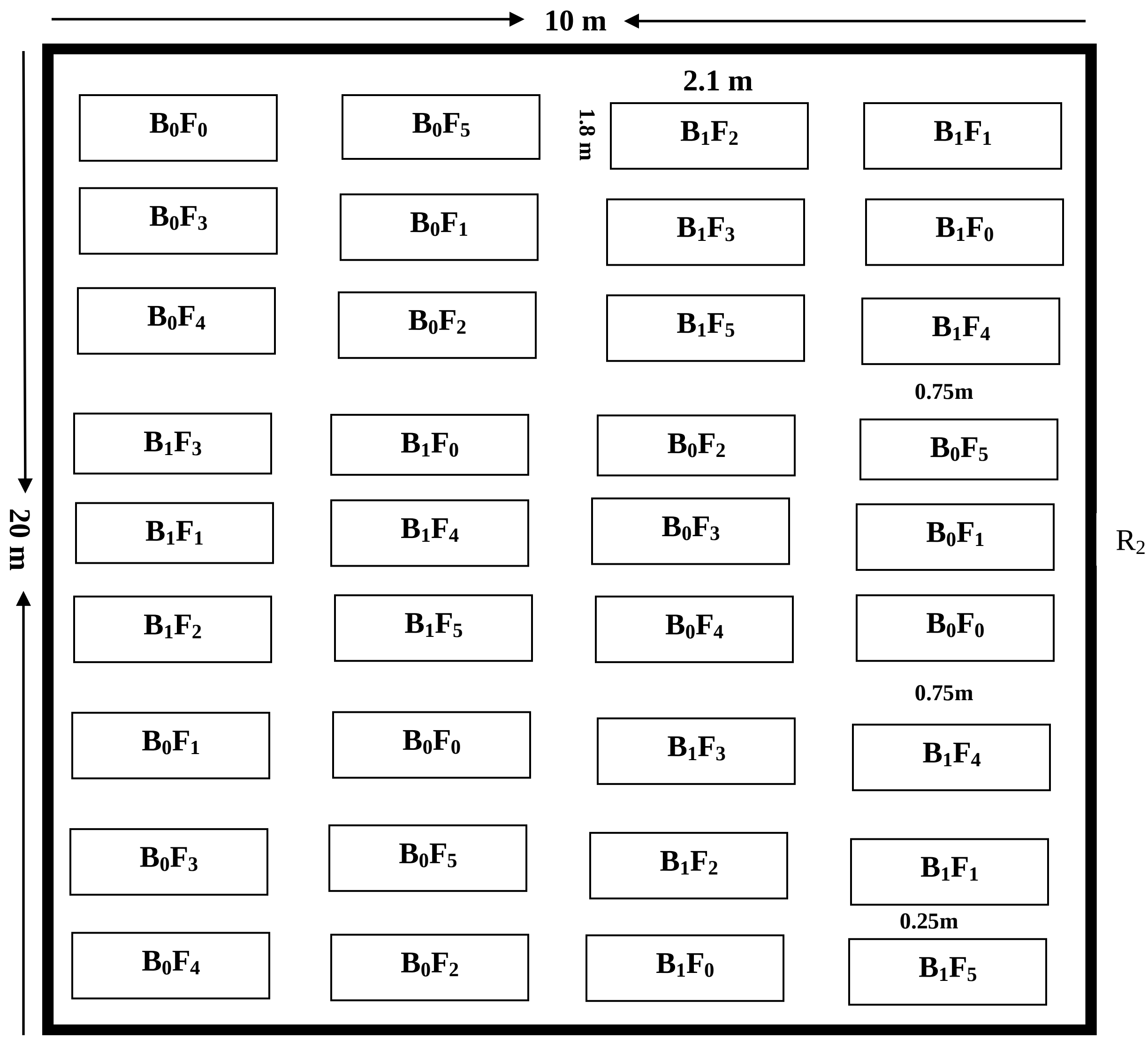


Figure 1. Layout of the experiment (Split plot)

B_o = Control (without biofertilizer)
B_1 = Biofertilizer

F_0 = Control (without B+Zn)
F_1 = B+Zn @ 50% of their recommended dose
F_2 = B+Zn @ 75% of t5heir recommended dose
F_3 = B+Zn @ their recommended dose
F_4 = B+Zn @ 125% of their recommended dose and
F_5 = B+Zn @ 150% of their recommended dose

CHAPTER IV

RESULTS AND DISCUSSION

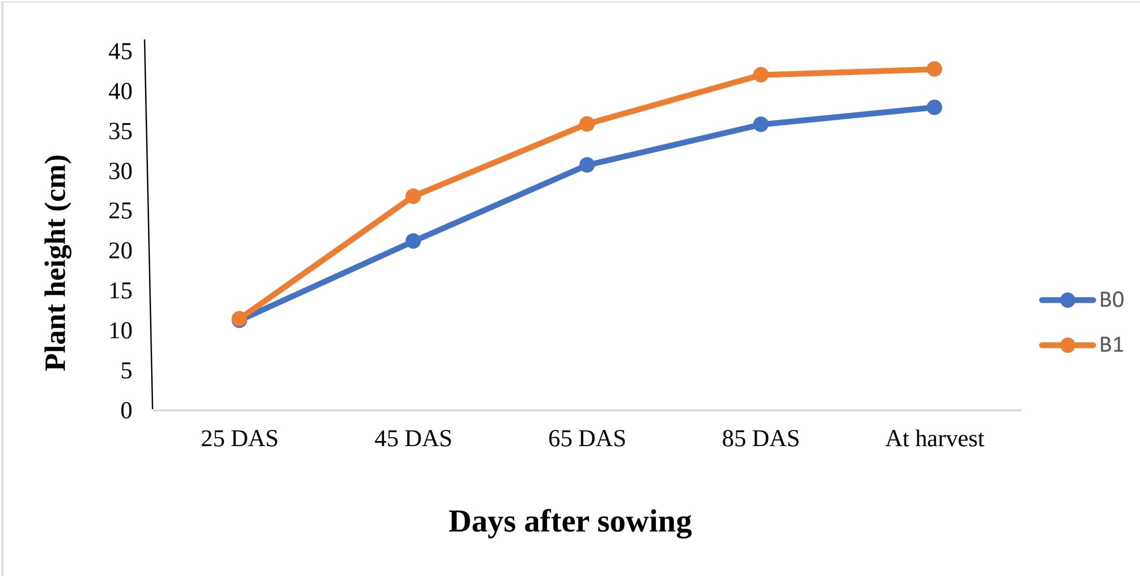
The experiment was conducted to evaluate influence of biofertilizer and different levels of boron+zinc on growth and yield of lentil. The parameters studied were plant height, number of branches plant^{-1}, dry weight plant^{-1}, numbers of seeds pod^{-1}, pods plant^{-1}, shelling percent, thousand seed weight, grain yield, stover yield, biological yield and harvest index (%). The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix IV-VIII. The findings of the experiment have been presented and discussed, and possible interpretations have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of biofertilizer

A statistically significant variation was observed for plant height of lentil due to application of biofertilizer at 45, 65, 85 DAS and at harvest (Figure 2 and appendix IV). Plant height showed an increasing trend with the advances of growth stages, irrespective of biofertilizer treatment. The maximum plant height was recorded from B_1 (biofertilizer) (26.84 cm, 35.90 cm, 42.06 cm and 42.79 cm, respectively at 45, 65, 85 DAS and at harvest) and the lowest from B_0 (control) treatment (21.21 cm, 30.75 cm, 35.85 cm and 37.98 cm, respectively for 45, 65, 85 DAS and at harvest). Plant height recorded for other sampling date (25 DAS) showed non-significant difference due to biofertilizer application.

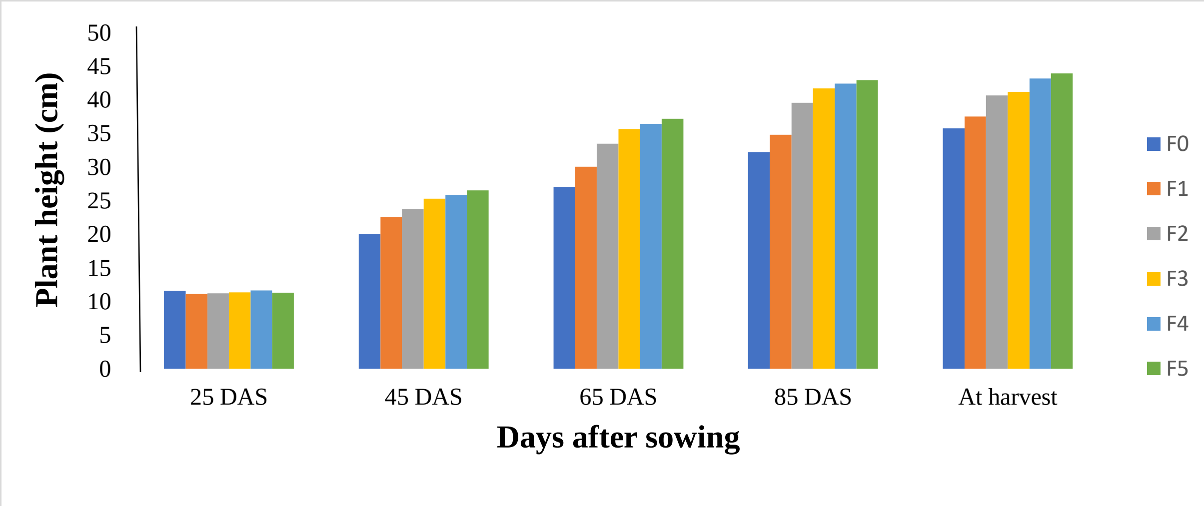


Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer

Figure 2. Effect of biofertilizer application on plant height of lentil at different days after sowing (LSD $_{0.05}$ = NS, 0.62, 1.75, 3.39, 2.67 at 25, 45, 65, 85 and at harvest, respectively)

4.1.1.2 Effect of boron + zinc

Effect of different level of boron + zinc on plant height was observed at 25, 45, 65, 85 DAS and at harvest. Among these, statistically significant variation was recorded at 25, 45, 65, 85 DAS and at harvest (Figure 3 and appendix IV). The maximum plant height of 43.94 cm was found at F_5 which was statistically similar with F_3 (43.21 cm) and F_2 (41.21 cm). On the other hand, minimum plant height of 35.79 cm was obtained at F_0 level of boron + zinc application. Plant height recorded for other sampling date (25 DAS) showed non-significant difference due to boron + zinc level.



F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

Figure 3. Effect of B + Zn application on plant height of lentil at different days after sowing (LSD $_{0.05}$ = NS, 1 .36, 1.71, 2.32, 3.53 at 25, 45, 65, 85 and at harvest, respectively)

4.1.1.3 Interaction effect of biofertilizer and boron + zinc

Interaction effect of biofertilizer and boron + zinc showed statistically significant differences for plant height at 45, 65, 85 DAS and at harvest (Table 1 and appendix IV). The tallest plant (29.15 cm) was recorded from B_1F_5 and the shortest plant (18.03 cm) was recorded from B_0F_0 at 45 DAS. At 65 DAS, the tallest plant (39.27 cm) was recorded from B_1F_5 interaction and the shortest plant (24.17 cm) was recorded from B_0F_0 interaction. The tallest plant (46.16 cm) was recorded from B_1F_5 and the shortest (29.35cm) was found from B_0F_0 interaction at 85 DAS. The tallest plant (46.70 cm) was recorded from B_1F_5 and the shortest (34.41cm) was found from B_0F_0 interaction at harvest. Plant height recorded for other sampling date (25 DAS) showed non-significant difference due to application of biofertilizer and boron and zinc level. At 25 DAS, the tallest plant height (11.89 cm) was recorded from B_1F_0 (biofertilizer × control) and the shortest plant (11.04 cm) was recorded from BoF$_2$ (Control × B+Zn at 75% of recommended dose) interaction.

Table 2. Interaction effect of biofertilizer and B + Zn application on plant height of lentil at different days after sowing

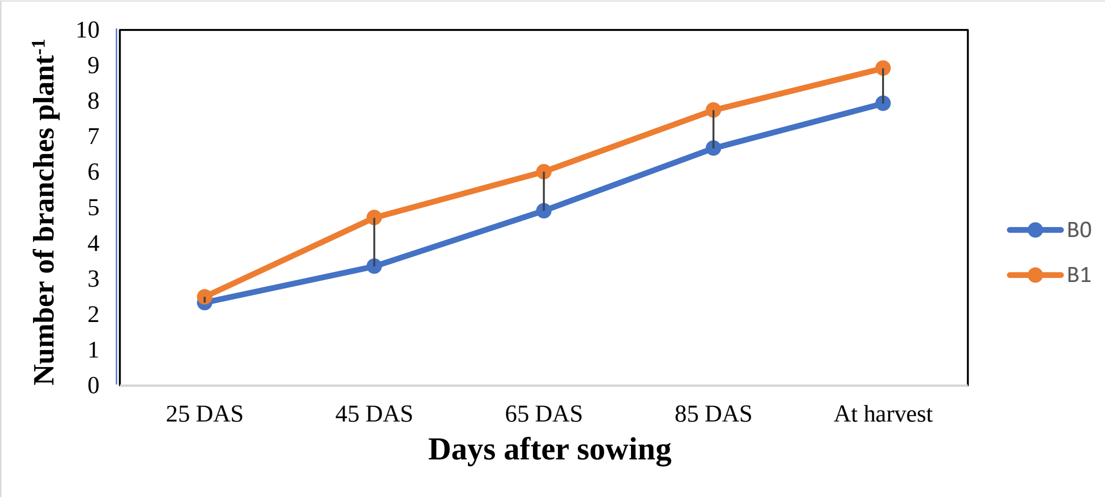
Interaction (Biofertilizer x B + Zn)	Plant height (cm) at				
	25 DAS	45 DAS	65 DAS	85 DAS	At harvest
B_0F_0	11.33	18.03 g	24.17 g	29.35 f	34.41 f
B_0F_1	11.13	19.35 fg	27.50 f	32.09 ef	35.37 ef
B_0F_2	11.04	20.43 ef	30.12 de	36.21 d	37.47 d-f
B_0F_3	11.48	22.28 de	33.07 c	38.48 cd	39.01 c-f
B_0F_4	11.70	23.29 d	34.46 bc	39.23 b-d	40.45 cd
B_0F_5	11.05	23.93 d	35.18 bc	39.75 bc	41.18 b-d
B_1F_0	11.89	22.12 de	29.98 ef	35.18 de	37.18 d-f
B_1F_1	11.16	25.86 c	32.60 cd	37.53 cd	39.65 c-e
B_1F_2	11.44	27.16 bc	36.89 ab	42.94 ab	43.86 a-c
B_1F_3	11.27	28.35 ab	38.27 a	44.92 a	43.42 a-c
B_1F_4	11.58	28.45 ab	38.42 a	45.68 a	45.98 ab
B_1F_5	11.56	29.15 a	39.27 a	46.16 a	46.70 a
LSD $_{(0.05)}$	**NS**	**1.92**	**2.41**	**3.28**	**5.00**
CV (%)	**9.65**	**4.71**	**4.26**	**4.95**	**7.28**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.1.2 Number of branches plant^{-1}

4.1.2.1 Effect of biofertilizer

Effect of biofertilizer on number of branches plant^{-1} was observed at 25, 45, 65, 85 DAS and at harvest (Figure 4 and Appendix V). Among these, statistically significant variation was recorded at 25, 45, 65, 85 DAS and at harvest. The maximum number of branches plant^{-1} of (2.49, 4.72, 6.01, 7.74 and 8.92) were found in B_1 at 25, 45, 65, 85 DAS and at harvest, respectively. On the other hand, minimum number of branches plant^{-1} of (2.33, 3.35, 4.91, 6.67 and 7.93) were obtained from B_0 (no biofertilizer application) at 25, 45, 65, 85 DAS and at harvest, respectively.

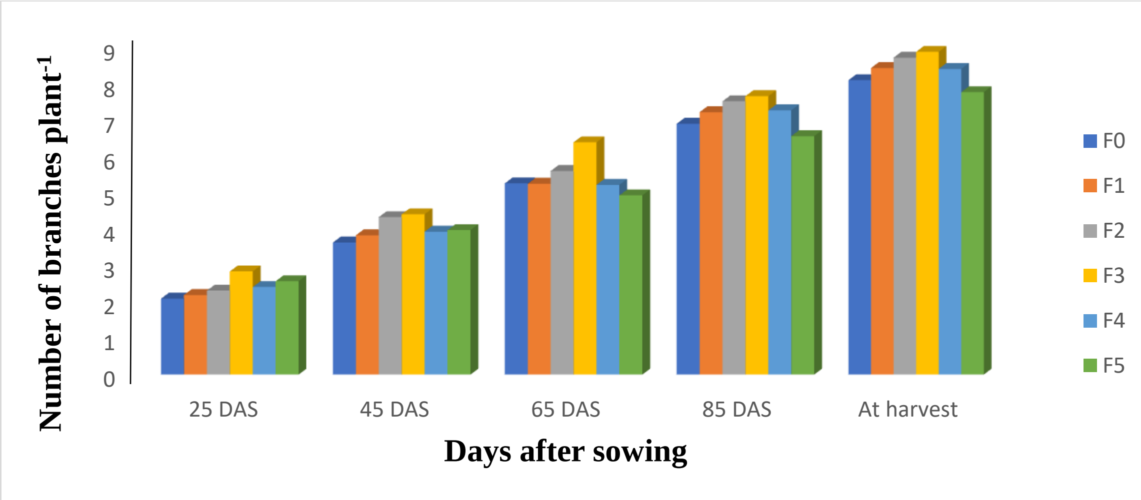


Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer

Figure 4. Effect of biofertilizer application on number of branches plant^{-1} of lentil at different days after sowing (LSD $_{0.05}$ = 0.19, 0.79, 0.34, 0.62, 0.30 at 25, 45, 65, 85 and at harvest, respectively)

4.1.2.2 Effect of boron + zinc

A statistically significant variation was observed for number of branches plant^{-1} of lentil due to application of different level of boron + zinc at 25, 45, 60, 75 DAS and at harvest (Figure 5 and Appendix V). Number of branches plant^{-1} showed an increasing trend with the increases rate of boron + zinc for all the sampling dates up to F_3 (B+Zn at recommended dose) dose after that the value of branch number plant^{-1} reduced slightly. This may perhaps the dry up of older branches and later stage of growth. However, F_3 (B+Zn at recommended dose) showed the maximum number of branches plant^{-1} at 25, 45, 65, 85 DAS and at harvest (2.85, 4.43, 6.41, 7.29 and 8.90, respectively).



F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

Figure 5. Effect of B + Zn application on number of branches plant^{-1} of lentil at different days after sowing (LSD $_{0.05}$ = 0.14, 0.29, 0.55, 0.61, 0.71 at 25, 45, 65, 85 and at harvest, respectively)

4.1.2.3 Interaction effect of biofertilizer and boron + zinc

Interaction effect of biofertilizer and boron + zinc showed statistically significant differences for number of branches plant^{-1} at 25, 45, 65 and 85 DAS (Table 3 and Appendix V). At 25 DAS, the maximum number of branches plant^{-1} (3.15) was recorded from B_1F_3 (biofertilizer× B+Zn at recommended doze) and the minimum (2.20) was recorded from BoF0 (control) interaction. The maximum (5.17) was recorded from B_1F_3 and the minimum (3.20) was recorded from B_0F_0 at 45 DAS. At 65 DAS, the maximum (6.75) was recorded from B_1F_3 interaction and the minimum (4.44) was recorded from B_0F_0 interaction. The maximum (8.12) was recorded from B_1F_3 and the minimum (6.12) was found from B_0F_0 interaction at 75 DAS. The maximum (9.48) was recorded from B_1F_3 and the minimum (7.30) was found from B_0F_0 interaction at harvest.

Table 3. Interaction effect of biofertilizer and B+Zn application on number of branches plant^{-1} of lentil at different days after sowing

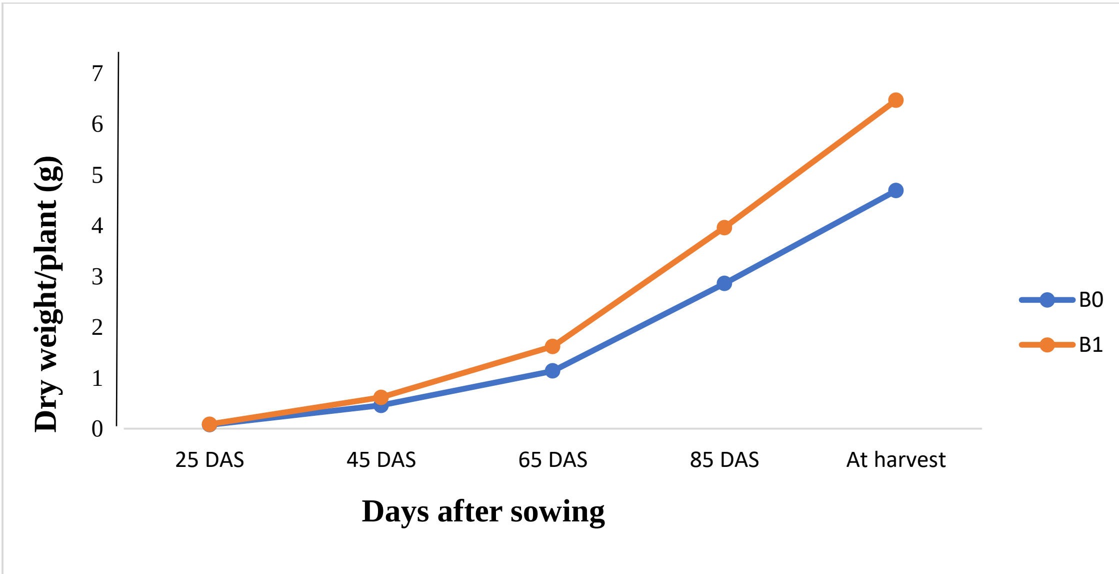
Interaction (Biofertilizer x B + Zn)	Number of branches plant^{-1} at				
	25 DAS	45 DAS	65 DAS	85 DAS	At harvest
B_0F_0	2.20 de	3.20 cd	4.44 de	6.12 f	7.30 d
B_0F_1	2.27 d	3.45 bc	5.04 cd	6.79 c-f	8.12 b-d
B_0F_2	2.03 ef	3.90 b	5.55 bc	7.05 b-e	8.44 bc
B_0F_3	2.56 c	3.70 b	6.07 ab	7.25 a-d	8.33 bc
B_0F_4	1.98 f	2.88 e	4.39 de	6.65 d-f	7.45 cd
B_0F_5	2.98 ab	3.00 d	4.02 e	6.21 ef	7.98 b-d
B_1F_0	2.00 ef	4.10 b	6.12 ab	7.72 a-c	8.94 ab
B_1F_1	2.13 d-f	4.25 b	5.50 bc	7.70 a-c	8.99 ab
B_1F_2	2.62 c	4.81 a	5.69 bc	8.03 a	9.05 ab
B_1F_3	3.15 a	5.17 a	6.75 a	8.12 a	9.48 a
B_1F_4	2.86 b	5.02 a	6.10 ab	7.94 ab	8.96 ab
B_1F_5	2.19 d-f	4.98 a	5.88 b	6.95 c-f	8.13 b-d
LSD $_{(0.05)}$	**0.21**	**0.41**	**0.78**	**0.87**	**1.01**
CV %	**5.14**	**6.01**	**8.49**	**7.11**	**7.09**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.1.3 Dry weight plant^{-1}

4.1.3.1 Effect of biofertilizer

Significant variation was observed when considering dry weight plant^{-1} by application of biofertilizer at different days after sowing (DAS) under the present study (Figure 6 and Appendix VI). The result showed an in increasing trend with the increase of growth stages and the highest increase was recorded with at harvest stage, irrespective of biofertilizer treatments. The rate of increase was much slower in the early stage of growth up to 65 DAS that later stage. This may be due to the higher number of branches plant^{-1}, higher plant height and formation of pods in later stage. B_1 treatment showed the highest dry weight plant^{-1} and that was 0.09, 0.62, 1.62, 3.96 and 6.47 g at 25, 45, 65, 85 DAS and at harvest, respectively. Control treatment gave the lowest dry weight plant^{-1} which was 0.08, 0.46, 1.14, 2.86 and 4.69 g at 25, 45, 65, 85 DAS and at harvest, respectively.

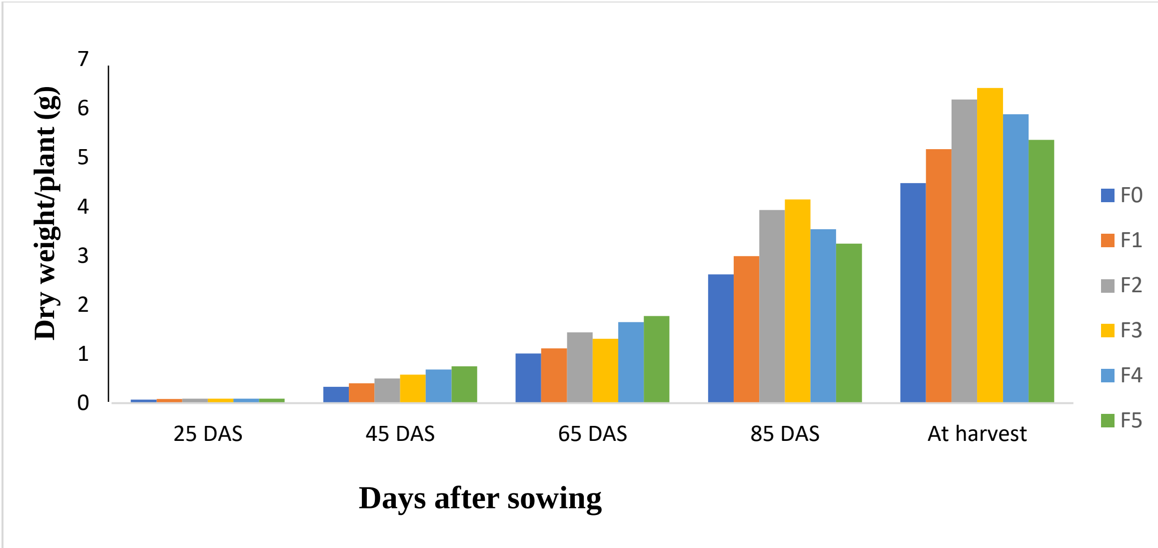


Here, Bo = Control (without biofertilizer), B_1 = Biofertilizer

Figure 6. Effect of biofertilizer application on dry weight of lentil at different days after sowing (LSD $_{0.05}$ = 0.03, 0.06, 0.10, 0.65, 0.87 at 25, 45, 65, 85 and at harvest, respectively)

4.1.3.2 Effect of boron + zinc

Boron + zinc fertilizer application significantly increased dry weight plant^{-1} of lentil which has been presented in Figure 7 and Appendix VI and it was marked that the highest dry weight plant^{-1} (0.09, 0.75 and 1.77 g) at 25, 45 and 65 DAS, respectively) at F_5 treatments and but the highest dry weight plant^{-1} 4.15 and 6.42 at 85 DAS and at harvest, respectively was achieved with F_3 treatment where the lowest were (0.07, 0.33, 1.01, 2.62 and 4.48 g at 25, 45, 65, 85 DAS and at harvest, respectively) was recorded from the control treatment.



F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

Figure 7. Effect of B + Zn application on dry weight of lentil at days after sowing (LSD $_{0.05}$ = 0.01, 0.07, 0.20, 0.72, 0.62 at 25, 45, 65, 85 and at harvest, respectively)

4.1.3.3 Interaction effect of biofertilizer and boron + zinc

Results obtained with the present experiment for dry weight plant^{-1} presented in Table 4 which showed that the combination of biofertilizer and boron + zinc levels had significant effect at different growth stages of lentil. Biofertilizer interaction with boron + zinc (B_1F_5) provided the highest dry weight plant^{-1} (0.09, 0.88 and 2.19 g at 25. 45 and 65 DAS, respectively). Biofertilizer interact with boron + zinc (B_1F_3) provided the highest dry weight plant^{-1} (4.93 and 7.18 g at 85 DAS and at harvest, respectively) and control treatment (B_0F_0) showed the lowest dry weight at 25, 45, 65, 85 DAS and at harvest (0.06, 0.28, 0.96, 2.33 and 3.45 g, respectively).

Table 4. Interaction effect of biofertilizer and B + Zn application on dry weight of lentil at different days after sowing (DAS)

Interaction (Biofertilizer x B + Zn)	Dry weight at (g) at				
	25 DAS	45 DAS	65 DAS	85 DAS	At harvest
B_0F_0	0.06 b	0.28 f	0.96 e	2.33 f	3.45 h
B_0F_1	0.08 ab	0.36 ef	1.02 e	2.62 ef	4.18 gh
B_0F_2	0.09 a	0.43 de	1.12 de	3.30 c-f	5.51 d-f
B_0F_3	0.09 a	0.50 cd	1.18 c-e	3.37 c-e	5.67 c-e
B_0F_4	0.09 a	0.58 bc	1.23 c-e	2.85 d-f	5.00 e-g
B_0F_5	0.09 a	0.63 b	1.35 cd	2.73 d-f	4.36 f-h
B_1F_0	0.08 ab	0.38 ef	1.05 e	2.92 d-f	5.52 d-f
B_1F_1	0.09 a	0.45 de	1.19 c-e	3.37 c-f	6.16 b-d
B_1F_2	0.09 a	0.58 bc	1.77 b	4.57 ab	6.85 ab
B_1F_3	0.09 a	0.67 b	1.45 c	4.93 a	7.18 a
B_1F_4	0.09 a	0.78 a	2.08 a	4.23 a-c	6.77 a-c
B_1F_5	0.09 a	0.88 a	2.19 a	3.78 b-d	6.37 a-d
LSD $_{(0.05)}$	**0.02**	**0.11**	**0.29**	**1.02**	**0.88**
CV %	**13.62**	**11.80**	**12.45**	**17.68**	**9.24**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.2 Yield attributes

The response of yield attributes considered as number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight of lentil.

4.2.1 Pods plant^{-1}

4.2.1.1 Effect of biofertilizer

Number of pods plant^{-1} is one of the most important yield contributing characters in lentil. The number of pods plant^{-1} was significantly affected by different levels of biofertilizer (Table 5 and Appendix VII). The results obtained from the present experiment showed that the number of pods plant^{-1} increased with the application of biofertilizer over control (without biofertilizer). The highest number of pods plant^{-1} (58.32) was recorded at B_1. The lowest number of pods plant^{-1} (51.12) was recorded from no biofertilizer application (control).

4.2.1.2 Effect of boron + zinc

Significant variations were clearly evident in case of number of pods plant^{-1} with different boron + zinc levels (Table 5 and Appendix VII). Increase dose of boron + zinc levels up to recommended dose showed gradual increase of number of pods plant^{-1} after that the number of pods plant^{-1} reduced slightly. However, the highest number of pods plant^{-1} (60.90) resulted from F_3 (recommended B+Zn) and the lowest (47.19) was obtained from control treatment (no B+Zn) level.

4.2.1.3 Interaction effect of biofertilizer and boron + zinc

Pods plant^{-1} is an important yield contributing character which has a great effect on final yield. The combination of B_1 and F_3 supported plant to maximum production and pods plant^{-1} which could positively influenced the higher dry matter production. It was observed that under the present study, biofertilizer, boron and zinc showed significant effect on pods plant^{-1} (Table 6 and Appendix VII). The highest number of pods plant^{-1} (140.70) produced with B_1 and F_3 (B_1F_3). The lowest number of pods plant^{-1} (58.44) was given by the control combination (B_0F_0).

4.2.2 Seeds pod^{-1}

4.2.2.1 Effect of biofertilizer

Number of seeds pod^{-1} is one of the most important yield contributing characters of lentil. The number of seeds pod^{-1} was significantly affected by different levels of biofertilizers (Table 5 and Appendix VII). The results showed that biofertilizer increase seeds pod^{-1} over control (without biofertilizer) treatment that was 14.29% higher. The highest number of seeds pod^{-1} (1.52) was recorded at B_1. The lowest number of seeds pod^{-1} (1.33) was recorded from no biofertilizer application (control).

4.2.2.2 Effect of boron + zinc

Significant variations were clearly evident in case of number of seeds pod^{-1} with different boron + zinc levels (Table 5 and Appendix VII). Seeds pod^{-1} increased gradually with the increase of boron+ zinc rate up to F_3 treatment after that it reduced. The highest number of seeds pod^{-1} (1.56) recorded from F_3 and the lowest (1.33) was obtained from control treatment at F_0. Further increase in phosphorus level could not increase number of seeds pod^{-1}. Similar result was found by Saxena *et al.* (2010) and they observed that seed yield of lentil was positively correlated with number of pods plant^{-1} which was close agreement with the result.

4.2.2.3 Interaction effect of biofertilizer and boron + zinc

Number of seeds pod^{-1} is also an important yield contributing character which has a great effect on final yield. It was observed that treatment combination of biofertilizer and boron + zinc had significant effect on number of seeds pod^{-1} under the present study (Table 6 and Appendix VII). The combination of B_1 with F_3 (B_1F_3) supported plant to produce maximum number of seeds pod^{-1} (1.65) where the lowest one (1.25) was achieved with control treatment (B_0F_0). The results from all other treatments showed significantly different results compared to highest and lowest value regarding number of seeds pod^{-1}.

4.2.3 Shelling percent

4.2.3.1 Effect of biofertilizer

The shelling percent was significantly affected by different levels of biofertilizer (Table 5 and Appendix VII). Biofertilizer treated plot showed significantly the highest shelling percent than biofertilizer untreated plot. The highest value of shelling percent (74.63) was recorded at B_1. The lowest shelling percent (70.91) was recorded from no biofertilizer application (control).

4.2.3.2 Effect of boron + zinc

Significant variations were clearly evident in case of shelling percent with different boron + zinc levels (Table 5 and Appendix VII). The result revealed that F_3 (B+Zn at recommended dose) treatment was superior in producing highest shelling percent in lentil than higher and lower dose of boron + zinc dose. Numerically, the highest shelling percent (76.88) resulted from F_3 and the lowest (70.69) was obtained from F_1 treatment.

4.2.3.3 Interaction effect of biofertilizer and boron + zinc

It was observed that under the present study, biofertilizer and boron + zinc interaction showed significant effect on shelling percent (Table 6 and Appendix VII). The highest shelling percent (80.32) produced with B_1 and F_3 (B_1F_3). The lowest shelling percent (65.07) was given by the control combination (B_0F_0).

Table 5. The effect of biofertilizer and B + Zn application on yield attributes of lentil

Treatment (Biofertilizer)	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Shelling percentage (%)	1000 seed weight (g)
B_0	51.12 b	1.33 b	70.91 b	20.77 b
B_1	58.32 a	1.52 a	74.63 a	22.51 a
LSD $_{(0.05)}$	**3.75**	**0.04**	**3.30**	**1.36**
CV %	**9.65**	**5.48**	**4.39**	**10.23**
Treatment (B + Zn fertilizer)				
F_0	47.19 d	1.33 c	70.02 a-c	19.03 c
F_1	51.13 cd	1.35 bc	69.05 c	20.09 bc
F_2	58.33 ab	1.49 ab	72.13 a-c	23.19 a
F_3	60.90 a	1.56 a	76.88 a	23.76 a
F_4	56.98 ab	1.42 bc	75.60 ab	22.10 ab
F_5	53.80 bc	1.41 bc	72.95 a-c	21.69 ab
LSD $_{(0.05)}$	**4.93**	**0.13**	**5.83**	**2.17**
CV %	**7.48**	**7.96**	**6.66**	**8.35**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.2.4 1000 seed weight (g)

4.2.4.1 Effect of biofertilizer

Different levels of biofertilizer had significant effect on 1000 seed weight of lentil (Table 5 and Appendix VII). It can be inferred from the data that application of biofertilizer increased 1000-seed weight 8.38% over biofertilizer untreated treatment. However, biofertilizer applied plot (B_1) gave the highest weight (22.51 g) that of lowest (20.77 g) from B_0.

4.2.4.2 Effect of boron + zinc

The results obtained from boron + zinc levels treatment had significant effect on 1000-seed weight in lentil (Table 5 and Appendix VII). The result revealed that in general, application of boron + zinc significantly increased 1000-seed weight at different level over control. However, recommended doze (F_3) gave the highest 1000-seed weight (23.76 g) whereas control treatment (F_0) gave the lowest (19.03 g) 1000-seed weight. The result also revealed that among the boron + zinc dose except (F_1) gave statistically similar result in respect of 1000-seed weight.

4.2.4.3 Interaction effect of biofertilizer and boron + zinc

The 1000 seed weight is an important yield contributing character which has a great effect on final yield. It was observed that treatment combination of biofertilizer and boron + zinc had significant effect on 1000- seed weight under the present study (Table 6 and Appendix VII). The combination of B_1 with F_3 (B_1F_3) supported plant to produce maximum 1000-seed weight (24.21 g) where the lowest one (18.11 g) was achieved with control treatment (B_0F_0).

Table 6. The interaction effect of different levels of biofertilizer and B + Zn on yield contributing characters of lentil

Interaction (Biofertilizer x B + Zn)	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Shelling percentage (%)	1000 seed weight (g)
B_0F_0	45.07 e	1.25 d	65.07 d	18.11 e
B_0F_1	47.67 de	1.26 d	71.71 b-d	19.13 e
B_0F_2	54.23 b-d	1.40 b-d	70.23 b-d	22.51 a-d
B_0F_3	57.40 a-c	1.47 a-c	70.13 b-d	23.310a-c
B_0F_4	52.70 cd	1.32 cd	70.89 b-d	20.69 c-e
B_0F_5	49.67 de	1.31 cd	77.45 ab	20.88 b-e
B_1F_0	49.31 de	1.42 b-d	74.98 ab	19.95 de
B_1F_1	54.60 b-d	1.45 bc	66.40 cd	21.05 b-e
B_1F_2	62.43 a	1.58 ab	74.03 a-c	23.87 ab
B_1F_3	64.40 a	1.65 a	75.77 ab	24.21 a
B_1F_4	61.27 ab	1.52 ab	80.32 a	23.52 a-c
B_1F_5	57.93 a-c	1.51 ab	76.32 ab	22.51 a-d
LSD $_{(0.05)}$	**6.97**	**0.19**	**8.25**	**3.07**
CV %	**7.48**	**7.96**	**6.66**	**8.35**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.3 Yield parameters

4.3.1 Seed yield

4.3.1.1 Effect of biofertilizer

Significant variation was found in seed yield of lentil due to biofertilizer treatment (Table 7 and Appendix VIII). Biofertilizer applied plot produced the highest grain yield (2211.40 kg ha^{-1}) which was significantly different from non-treated plot. On the other hand, B_0 gave the lowest seed yield (1993.00 kg ha^{-1}). The result indicated that application of biofertilizer increase seed yield by 11.32% in lentil.

4.3.1.2 Effect of boron + zinc

Significant variations due to boron + zinc management were found in respect of seed yield (Table 7 and Appendix VIII). It was found that F_3 (recommended dose of B+Zn) gave the highest seed yield (2451.81 kg ha^{-1}) which was significantly different from all other treatments. On the other hand, F_0 (No fertilizer) gave the lowest seed yield (1706.71 kg ha^{-1}) which was significantly different from other treatments.

4.3.1.3 Interaction effect of biofertilizer and boron + zinc

Interaction of biofertilizer and boron + zinc management showed significant influence on seed yield of lentil (Table 8 and Appendix VIII). It was found that, B_1F_3 (biofertilizer with recommended of B+Zn) gave the highest seed yield (2552.83 kg ha^{-1}) and it was statistically similar with B_1F_2 (biofertilizer with B+Zn at 75% of recommended dose) (2460.81 kg ha^{-1}) and B_1F_4 (biofertilizer with B+Zn at 125% of recommended dose) (2384.30 kg ha^{-1}). On the contrary, it was noted that, B_0F_0 (control) gave the lowest seed yield (1621.40 kg ha^{-1}) which was statistically similar with B_0F_1 (control with B+Zn at 50% of recommended dose) (1774.10 kg ha^{-1}).

Table 7. The effect of different levels of biofertilizer and B + Zn on yield of lentil

Treatment (Biofertilizer)	**Seed yield (kg ha^{-1})**	**Stover yield (kg ha^{-1})**	**Biological yield (kg ha^{-1})**	**Harvest index (%)**
B_0	1993.00 b	4005.74 a	5998.70 b	32.09 b
B_1	2211.40 a	4105.33 a	6366.70 a	34.59 a
LSD $_{(0.05)}$	**190.38**	**162.84**	**356.04**	**1.65**
CV %	**6.34**	**4.84**	**4.67**	**4.19**
Treatment (B + Zn fertilizer)				
F_0	1706.71 e	3867.71 d	5574.42 d	30.60 d
F_1	1843.19 d	3992.29 c	5835.48 cd	31.57 cd
F_2	2350.20 a	4191.57 b	6541.79 ab	35.91 ab
F_3	2451.81 a	4279.23 a	6731.04 a	36.41 a
F_4	2215.55 b	3965.78 cd	6331.33 a-c	34.94 ab
F_5	2045.74 c	4036.65 bc	6082.39 b-d	33.60 bc
LSD $_{(0.05)}$	**128.24**	**99.02**	**510.17**	**2.70**
CV %	**5.08**	**5.76**	**6.85**	**6.63**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer
F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

4.3.2 Stover yield

4.3.2.1 Effect of biofertilizer

Stover yield was found to no significant due to biofertilizer treatments (Table 7 and Appendix VIII). From the study, it was revealed that, B_1 (biofertilizer) produced the highest stover yield (4105.33 kg ha^{-1}). B_0 gave the lowest stover yield (4005.74 kg ha^{-1}).

4.3.2.2 Effect of boron + zinc

Significant variation due to different management of boron + zinc was found in respect of stover yield (Table 7 and Appendix VIII). Application of different doses boron + zinc, F_3 treatment gave the highest stover yield (4279.23 kg ha^{-1}) which was significantly different from all other treatments. On the contrary, F_0 (No fertilizer) gave the lowest stover yield (3867.71 kg ha^{-1}) it was statistically different from other treatments. Treatments F_1 and F_4 gave statistically similar stover yield.

4.3.2.3 Interaction effect of biofertilizer and boron + zinc

Interaction of biofertilizer and boron + zinc management showed significant differences for stover yield (Table 8 and Appendix VIII). Combination of B_1F_3 (biofertilizer with recommended of B+Zn) gave the highest stover yield (4328.11 kg ha^{-1}) and it was statistically similar with all the interactions except B_1F_4 and B_0F_0. On the contrary, B_0F_0 (no biofertilizer + no B+Zn fertilizer) gave the lowest stover production (3765.42 kg ha^{-1}) which was followed by B_0F_1, B_0F_2, B_0F_4, B_0F_5, B_1F_0, B_1F_1, B_1F_4 and B_1F_5.

4.3.3 Biological yield

4.3.3.1 Effect of biofertilizer

Biological yield was found significant in respect of biofertilizer (Table 7 and Appendix VIII). The results revealed that B_1 (biofertilizer) produced the highest biological yield (6366.70 kg ha^{-1}). B_0 gave the lowest biological yield (5998.70 kg ha^{-1}).

4.3.3.2 Effect of boron + zinc

Significant variation in biological yield of lentil was found in case of different management of boron + zinc (Table 7 and Appendix VIII). It was found that, F_3 (recommended of B+Zn) gave the highest biological yield (6731.04 kg ha^{-1}) which was significantly similar with F_2 and F_4 (6541.79 and 6331.33 kg ha^{-1}, respectively). The lowest biological yield (5574.42 kg ha^{-1}) was obtained from control treatment and it was statistically similar with F_1 (5835.48 kg ha^{-1}). The higher biological yield with higher rate of boron + zinc application might be due to cause of higher vegetative growth with higher boron + zinc application.

4.3.3.3 Interaction effect of biofertilizer and boron + zinc

Combination of biofertilizer and boron + zinc management showed significant influence on biological yield of lentil (Table 8 and Appendix VIII). The highest biological yield (6880.94 kg ha^{-1}) was achieved by B_1F_3 (biofertilizer with recommended of B+Zn) and it was statistically similar with B_1F_2, B_1F_4, B_1F_5, B_0F_2 and B_0F_3 (6724.14, 6624.90, 6279.99, 6359.44 and 6581.13 kg ha^{-1}, respectively)). Combination of B_0F_0 (no biofertilizer + no fertilizer) gave the lowest biological yield (5386.87 kg ha^{-1}) which was statistically similar with B_0F_1, B_0F_4, B_0F_5, B_1F_0 and B_1F_1 (6037.76, 5884.78, 5761.96 and 5928.48 kg ha^{-1}, respectively).

4.3.4 Harvest index (%)

4.3.4.1 Effect of biofertilizer

Harvest index is an important measurement of yield performance. The harvest index was found significant between the biofertilizer treatments in lentil (Table 7 and Appendix VIII). The highest harvest index (34.59 %) was recorded for B_1. The lowest harvest index (32.09 %) was recorded from B_0.

4.3.4.2 Effect of boron + zinc

There were significant variations observed for harvest index due to different boron + zinc management in lentil (Table 7 and Appendix VIII). Among the B+Zn treatments, F_3 (recommended of B+Zn) gave the highest harvest index (36.41 %) which was followed by F_2 and F_4 (35.91 and 34.94%, respectively). The lowest harvest index (30.60 %) was obtained from F_0 (No fertilizer) which was followed by F_1 treatment. Saxena *et al.* (2010) and Tomar *et al.* (2000) observed that harvest index increased significantly with increased F_3 application up to a certain level/ limit which support the present findings.

4.3.4.3 Interaction effect of biofertilizer and boron + zinc

Interaction of biofertilizer, boron and zinc management may be important determining factor for harvest index. Biofertilizer and boron + zinc management showed significant differences for harvest index (Table 8 and Appendix VIII). The highest harvest index (37.10 %) was obtained from B_1F_3 (biofertilizer with recommended of B+Zn) combination. The lowest harvest index (30.10 %) was given by B_0F_0 (no biofertilizer + no B+Zn fertilizer) which was statistically similar with $B_0F_{1,}$ B_0F_4, B_0F_5, B_1F_0 and B_1F_1 (30.89, 33.90, 32.72, 31.10 and 32.26%, respectively).

Table 8. Interaction effect of biofertilizer and B + Zn application on yield and harvest index of lentil

Interaction (Biofertilizer x B + Zn)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
B_0F_0	1621.40 g	3765.42 c	5386.87 e	30.10 e
B_0F_1	1774.10 fg	3968.62 a-c	5742.47 de	30.89 de
B_0F_2	2239.66 bc	4119.81 a-c	6359.44 a-d	35.22 a-c
B_0F_3	2350.78 a-c	4230.35 ab	6581.13 a-c	35.72 a-c
B_0F_4	2046.80 de	3990.96 a-c	6037.76 b-e	33.90 a-d
B_0F_5	1925.50 d-f	3959.28 a-c	5884.78 c-e	32.72 b-e
B_1F_0	1792.00 e-g	3969.99 a-c	5762.00 de	31.10 de
B_1F_1	1912.53 ef	4015.95 a-c	5928.48 c-e	32.26 c-e
B_1F_2	2460.81 ab	4263.33 ab	6724.14 ab	36.60 ab
B_1F_3	2552.83 a	4328.11 a	6880.94 a	37.10 a
B_1F_4	2384.30 ab	3940.60 bc	6624.90 a-c	35.99 a-c
B_1F_5	2166.00 cd	4114.02 a-c	6279.99 a-d	34.49 a-d
LSD (0.05)	**173.69**	**373.65**	**721.48**	**3.81**
CV %	**5.08**	**5.76**	**6.85**	**6.63**

Here, B_o = Control (without biofertilizer), B_1 = Biofertilizer

F_0 = Control (without B+Zn), F_1 = B+Zn at 50% of recommended dose, F_2 = B+Zn at 75% of recommended dose, F_3 = B+Zn at recommended dose, F_4 = B+Zn at 125% of recommended dose and F_5 = B+Zn at 150% of recommended dose

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 different levels of boron and Zinc on growth and yield of lentil. The experiment comprised of two factors; Factor A- Two levels of biofertilizers viz. i) B_0 = without biofertilizer, ii) B_1 = biofertilizer and Factor B- six levels of B + Zn, viz. i) F_0 = without B + Zn, ii) F_1 = B+Zn at 50% of their recommended dose, iii) F_2 = B+Zn at 75% of their recommended dose, iv) F_3 = B+Zn at their recommended dose, v) F_4 = B+Zn at 125% of their recommended dose and vi) F_5 = B+Zn at 150% of their recommended dose. The experiment was set up in spilt plot design under factorial arrangement with three replications. There were 12 treatment combinations. Data were collected on plant height, branches plant^{-1}, oven dry weight plant^{-1}, pods plant^{-1}, seed pod^{-1}, 1000 seed weight (g), seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}), and harvest index (%) parameters and analyzed statistically.

Plant height (cm), branches plant^{-1} and dry weight plant^{-1} (g) as influenced by biofertilizer was the highest with B_1 (biofertilizer) and the highest results were 42.79 cm, 8.92 and 6.47 g, respectively at the time of harvest. Fertilizer managements (B+Zn) showed the highest plant height (43.94 cm), branches plant^{-1} (8.90) at harvest, dry weight plant^{-1} (6.42 g) with F_3 (Recommended of B+Zn). Control treatment with F_0 showed the lowest results on growth parameters. Significant effect was also observed on plant height (cm), number of branches plant^{-1} and oven dry weight plant^{-1} by the combined effect of biofertilizer and boron + zinc. The highest values were 46.70 cm, 7.48 and 7.18 g, respectively which was achieved by B_IF_3 (biofertilizer with Recommended of B+Zn) but interaction of B_1F_2 showed similar result in some extent, while B_0F_0 (control) showed the lowest values (34.41 cm, 7.90 and 3.45 g, respectively).

Pods plant^{-1}, number of seeds pod^{-1}, shelling percent and 1000- seed weight (g) was significantly influenced by biofertilizer and boron + zinc individually and/or their interaction. The B_1 (biofertilizer) showed the highest number of seeds pod^{-1} (1.52), pods plant^{-1} (58.32), shelling (74.63%) and 1000 seed weight (37.46 g). Application of B+Zn at recommended (F_3) showed the highest seeds pod^{-1} (1.56), pods plant^{-1} (60.90), 1000 seed weight (23.76 g) and shelling (76.88%) were in F_3 statistically at per result was observed in F_2. Treatment combined of B_1F_3 (biofertilizer with B+Zn at recommended) represented the highest number of seeds pod^{-1} (1.65), pods plant^{-1} (64.40) shelling percent (80.32%) and 1000 seed weight (24.21 g) and but interaction of B_1F_2 showed statistically similar performance with B_1F_3. The lowest (1.25, 45.07, 65.07% and 18.11 g, respectively) from B_0F_0 (Control).

Seed yield, stover yield, biological yield and harvest index were significantly influenced by biofertilizer, B + Zn application and their interaction. Biofertilizer application showed the highest grain yield (2211.40 kg ha^{-1}), stover yield (4105.33 kg ha^{-1}), biological yield (6366.70 kg ha^{-1}) and harvest index (34.59%) and the lowest from B_0. Application of B+Zn at recommended (F_3) showed the highest seed yield (2451.81 kg ha^{-1}), stover yield (4279.23 kg ha^{-1}) and biological yield (6731.04 kg ha^{-1}) and harvest index (36.41 %). Likewise, F_2 treatment also showed similar performance with F_3. Control treatment, (no boron and Zinc application) showed the lowest values of yield parameters. Combined of B_1F_3 (biofertilizer with Application of B+Zn at recommended) showed the highest seed yield (2552.83 kg ha^{-1}), stover yield (4328.11 kg ha^{-1}), biological yield (6880.94 kg ha^{-1}) and harvest index (37.10%) but B_1F_2 combination showed similar performance in respect of B_1F_3. The lowest seed yield (1621.40 kg ha^{-1}), stover yield (3765.42 kg ha^{-1}) and biological yield (5386.87 kg ha^{-1}) and harvest index (30.10 %) were obtained by combination of B_0F_0 (Control). Therefore, the present experimental results suggest that lentil yield is improved with Biofertilizer and recommended dose or 75% of recommended dose of boron + zinc.

CONCLUSION

Considering the above result of this experiment, the following conclusion and recommendation can be drawn:

1. Application of biofertilizer performed best in producing yield attributes and yield of lentil.
2. Recommended dose or 75% of recommended dose of B+Zn gave best results for both vegetative growths, yield attributes and yield of lentil
3. Combination of biofertilizer and 75% of the recommended dose of B+Zn is suitable for lentil cultivation.

Recommendation

Considering the situation of the present experiment, further study might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances. The experiment was however, conducted in one season only and hence the results should be considered as a tentative. It is imperative that similar experiment should be carried out with more variables to reconfirm the recommendation.

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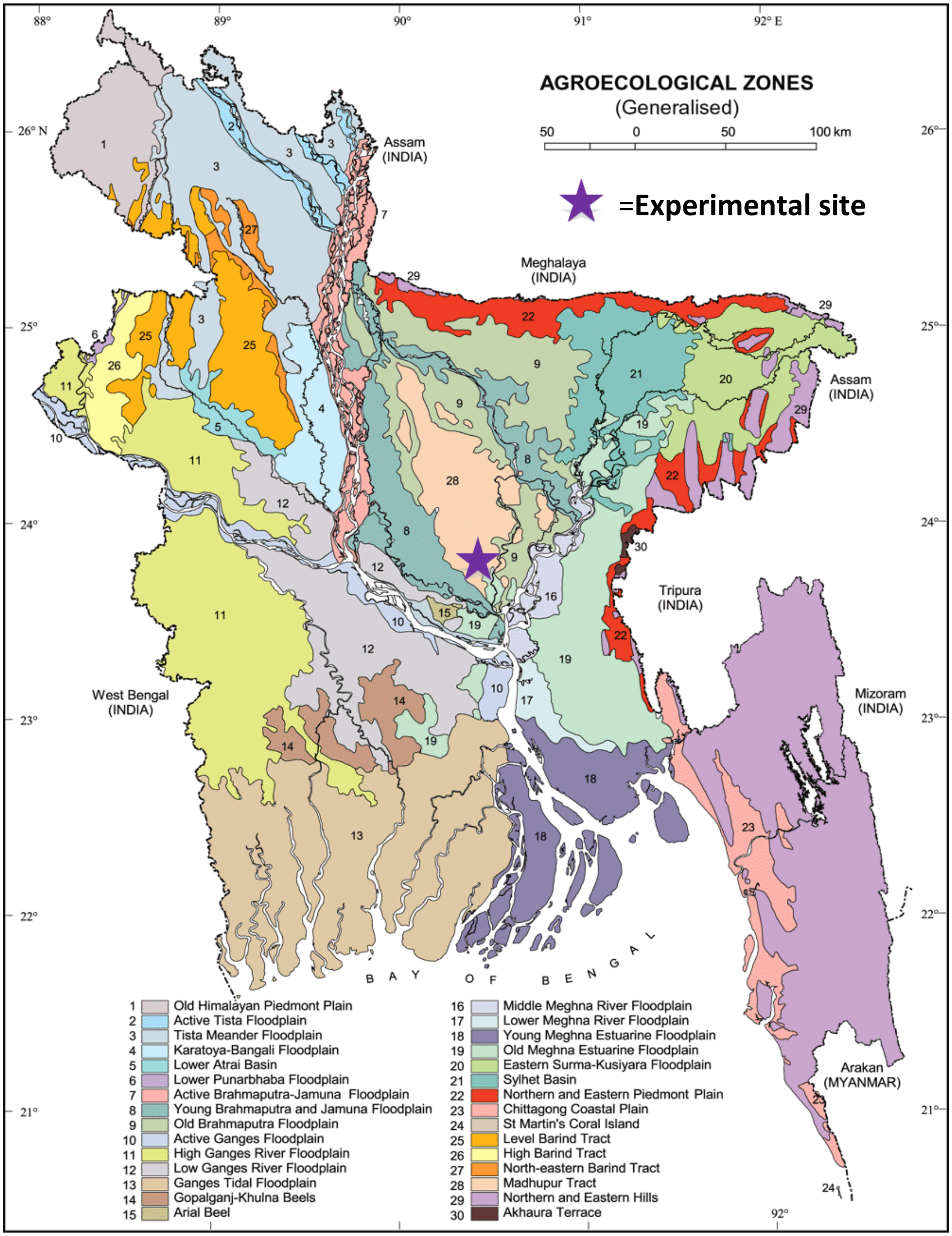
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2019 to March, 2020

Month	*Air temperature (^oC)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2019	25.8	16.0	78	00
December, 2019	22.4	13.5	74	00
January, 2020	25.2	12.8	69	00
February, 2020	27.3	16.9	66	39
March, 2020	31.7	19.2	57	23

* Monthly average,

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

Appendix III. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.5
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.071
Available P (ppm)	7.42
Exchangeable K (meq/100 g soil)	0.08

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix IV. Analysis of variance of effect of biofertilizer and (B+Zn) application on plant height of lentil

Sources of variation	Degrees of freedom	Plant height (cm) at different days after sowing				
		25 DAS	45 DAS	65 DAS	85 DAS	At harvest
Replication	2	71.98	27.28	41.25	225.69	299.927
Factor A	1	0.31^{NS}	285.27*	239.16*	347.82*	208.80*
Error	2	0.13	0.18	1.50	6.28	3.485
Factor B	5	0.24^{NS}	34.87*	96.21*	117.72*	60.88*
AB	5	0.16^{NS}	1.48^{NS}	1.68^{NS}	0.34^{NS}	2.44^{NS}
Error	20	0.20	1.28	2.01	3.71	8.63

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

Appendix V. Analysis of variance of effect of biofertilizer and (B+Zn) application on number of branches plant^{-1} of lentil

Sources of variation	Degrees of freedom	Number of branches plant^{-1} at different days after sowing				
		25 DAS	45 DAS	65 DAS	85 DAS	At harvest
Replication	2	1.39	18.46	30.56	64.51	82.83
Factor A	1	0.21^{NS}	16.81*	10.66*	10.20*	9.03*
Error	2	0.01	0.30	0.05	0.18	0.04
Factor B	5	0.45*	0.54*	1.56*	0.98*	1.01*
AB	5	0.60*	0.51*	0.83*	0.15^{NS}	0.21^{NS}
Error	20	0.01	0.05	0.21	0.26	0.35

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

Appendix VI. Analysis of variance of effect of biofertilizer and (B+Zn) application on dry weight plant^{-1} of lentil

Sources of variation	Degrees of freedom	Dry weight plant^{-1} at different days after sowing				
		25 DAS	45 DAS	65 DAS	85 DAS	At harvest
Replication	2	0.18	0.10	0.40	8.37	21.54
Factor A	1	0.16*	0.22*	2.05*	10.89*	27.15*
Error	2	0.001	0.002	0.005	0.20	0.35
Factor B	5	0.25*	0.15*	0.54*	1.98*	3.08*
AB	5	0.004^{NS}	0.005^{NS}	0.17*	0.21^{NS}	0.12^{NS}
Error	20	.001	0.004	0.02	0.36	0.26

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

Appendix VII. Analysis of variance of effect of biofertilizer and (B+Zn) application on yield contributing parameters of lentil

Sources of variation	Degrees of freedom	Yield contributing parameters			
		Number of seeds pod^{-1}	Number of pods $plant^{-1}$	Shelling (%)	1000 seed weight (g)
Replication	2	2.13	860.64	292.81	334.82
Factor A	1	0.38*	466.56*	124.76*	27.44*
Error	2	0.008	6.85	5.30	0.90
Factor B	5	0.04*	152.10*	56.09*	19.59*
AB	5	0.0009^{NS}	3.86^{NS}	53.90*	0.62^{NS}
Error	20	0.01	16.76	23.48	3.26

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

Appendix VIII. Analysis of variance of effect of biofertilizer and (B+Zn) application on yield contributing parameters of lentil

Sources of variation	Degrees of freedom	Yield parameters			
		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Replication	2	2269276	6685299	1.04	530.225
Factor A	1	429156^{NS}	89269^{NS}	1218794	20.22
Error	2	25870	21629	83247.9.6	2.00
Factor B	5	507865*	139486*	1142799*	33.37*
AB	5	7088^{NS}	12363^{NS}	25978.2^{NS}	0.21^{NS}
Error	20	10400	48128	179445	5.29

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

PLATES

Plate 1 (a). Field view during seedling stage

Plate 2 (a). Field view of the experimental field at seedling stage

Plate 2 (b). Field view of the experimental field at seedling stage

Plate 2 (c). Field view of the experimental field at maturation stage

Plate 3 (a). Plants view of the experimental field at pod maturation stage

Plate 3 (b). Plants view of the experimental field at pod maturation stage