EFFECT OF NITROGEN, PHOSPHORUS AND BIO-FERTILIZER ON YIELD AND SEED QUALITY OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN, PHOSPHORUS AND BIO-FERTILIZER ON YIELD AND SEED QUALITY OF LENTIL"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **B.M. ALAMGIR KABIR**, Registration No. **12-04902** 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.

June, 2018
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Dedicated to My Beloved Parents

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EFFECT OF NITROGEN, PHOSPHORUS AND BIO-FERTILIZER ON YIELD AND SEED QUALITY OF LENTIL

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2017 to March 2018 to examine the effect of nitrogen, phosphorus and bio-fertilizer on yield and seed quality of lentil. The treatment consisted of two factors *viz*. (1) Factor A: two biofertilizer levels; (i) B_0 = 0 (Control; without Bio-fertilizer) and (ii) B_1 = Bio-fertilizer (50 gm per 2.5 kg of seeds) and (2) Factor B: six nitrogen and phosphorus levels; D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P and D_5 = 50% higher N+P. The experiment was conducted in randomized complete block design (factorial) with three replications. A significant variation among the treatments was found while biofertilizer application and different levels of N+P fertilizers applied in different combinations. The highest number of pods plant^{-1} (69.23), number of seeds pod^{-1} (2.12), 1000 seed weight (21.20 g) and seed yield (2576.60 kg ha^{-1}) were obtained from the treatment combination of B_1D_3 where the lowest was from B_0D_0. Considering seed quality parameters, all the parameters were significantly affected by combined effect of biofertilizer and N+P treatments except percent seed germination and root length. However, the highest percent (%) seed germination (97.00%), root length (2.95 cm), shoot length (6.52 cm) and seed vigor index (635.39) was obtained from the treatment combination of B_1D_3. Considering results of the experiment, application of biofertilizer, along with NPK fertilizer is best producing greater yield and better quality of lentil seed.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Lentil *(Lens culinaris* L. Medik) is one of the most important pulse crops grown in Bangladesh. It belongs to family fabaceae. In Bangladesh, it is popularly known as masur. The lentil crop covers 33.33 per cent of the total area of pulses in the country (BBS, 2016). Total production of lentil in Bangladesh, during 2014-2015 was 228568 tons from an area of 180574 hectare with an average yield of 1.2657 ton ha^{-1} (BBS, 2016). It occupies a unique position in the world of agriculture by virtue of its high protein content and capacity of fixing atmospheric nitrogen. In developing countries like Bangladesh, pulse constitutes the major concentrate source of dietary protein. 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 bhushi is highly protein concentrated feed to cattle, horse and sheep etc. (Tomar *et al*., 2000a). Lentil being a legume crop can fix atmospheric nitrogen through root nodules by *Rhizobium* bacteria, which may reduce the pressure of nitrogenous fertilizer application to the crop. It is evident that pulse included cropping pattern helped to increase the organic matter in the soil (Islam, 1988).

Average grain yield of lentil is low in our country. One of the main reasons for this problem is the inappropriate use or distribution of fertilizer (Azad, and Gill, 1989). Lack of nutrient management is the main reason for low yield of crop. Nitrogen is critical element for increasing the quality of food crops. Nitrogen deficiency can be occurred frequently in everywhere therefore these elements should be comprised as a fertilizer. Nitrogen application of suitable amount in legumes increased pod number, seed number and seed weight (Hashemi-Dezfuli *et al*., 1999). Verma and Kalra (1983) reported that lentil have good response to nitrogen fertilizer applied at the rate of 20 kg per hectare. Depending on the species, stage of growth and organ of plant, the amount of nitrogen required for optimum plant growth is between two to five percent of dry weight (Khaladberin and Slamzadeh, 2006).

Phosphorus is an important macro elements for growth of legumes. It has important role in the formation of root nodules and this has an important role in nitrogen fixation (Sepetoglu, 2002). In vegetative growth stage, phosphorus is needed between 0.3 to 0.5 percent dry weights of plant. Phosphorus deficiency reduces the number of flowers and delayed flowers formation (Khaladberin and Slamzadeh, 2006). Adding phosphate to the soil increased yield of legumes. Studies have shown that nitrogen fertilizer application rate of 20 to 25 kg ha^{-1} of as a starter is necessary to achieve maximum plant growth. Using of 50 - 60 kg P/ha increased yield of legume significantly (Oguz, 2004). Numbers of filled pods are main components of seed yield that are influenced by the amount of fertilizer placed. Application of 20 - 80 kg P/ha in combination with 40 kg N/ha increased the number of filled pod of lentil (Ahmadpour *et al*., 1994).

Omer (2009) reported that lentil is good choice in crop rotations as it produced 130.44 nodules per plant which improve soil health by adding nitrogen and organic matter for following crops. Lentil crop requires nitrogen for their growth and development approximately 85% of nitrogen necessity of lentil is fulfilled with the help of atmospheric nitrogen fixation during symbiotic relationship of lentil roots with microorganism Rhizobium bacteria in the field and due to which yield could be increased up to 2 ton ha^{-1} (Bisen *et al*., 1980).

Hossain and Suman (2005) carried out an experiment to evaluate the effect of *Rhizobium* and different levels of urea (N) on growth, yield and N-uptake of lentil. Among the treatments *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

Rhizobium treatment that was statistically similar to that of 100% N and *Rhizobium* with the corresponding yields of 1533 and 1458 kg/ha, respectively. The inoculation of *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 *Rhizobium* and N-uptake by shoot (53.87 kg/ha) was recorded for the treatment 100% N. Therefore, inoculation of *Rhizobium* may be a good practice to achieve higher seed yield of lentil.

Furthermore, for having maximum growth and yield of lentil, it is necessary to find out the best combination of nitrogen, phosphorous and biofertilizer. Very little information is available about the influence of nitrogen, phosphorous and biofertilizer on nodulation, growth, yield and seed quality of lentil. Thus, the present study was carried out following the objectives:

1. To observe the influence of biofertilizers on growth, yield and seed quality of lentil,
2. To determine suitable nitrogenous and phosphetic fertilizer management for maximum yield and seed quality of lentil,
3. To asses interaction of biofertilizer, nitrogenous and phosphetic fertilizer on the yield and seed quality of lentil.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made in this section to collect and study the relevant information available in the home and abroad regarding the influence of Bio-fertilizer, nitrogen and phosphorous on growth, yield and seed quality of lentil to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion.

2.1 Effect of bio-fertilizer on growth and yield

Gyaneshwar *et al*. (2002) stated that bio-fertilizers are gaining importance as they are eco-friendly, 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. Bio-fertilizers 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.

Singh *et al.* (2007) reported that the application of bio-fertilizers, 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.

Dhingra *et al*. (1988) observed 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 gave yield equivalent to 40 kg P_2O_5 /ha without Rhizobium.

Gupta and Sharma (1992) reported 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) conducted an experiment with 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 bio-fertilizer saved 50% N, P (10 kg N, 25 kg P_2O_5). It also saved the financial resource as well as FYM.

Sharma and Sharma (2004) concluded 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) conducted 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 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.

Effect of nitrogen on growth and yield

Like most annual legumes, lentil can provide a part of its own N requirement through symbiotic N_2 fixation when the plants are inoculated. Sosulski and Buchan (1978) reported that rhizobial inoculation alone is not enough for obtaining high yields of legumes because of poor nodulation and nitrogenase activity. They concluded that annual legumes may require a high level of plant N fertility to achieve maximum yield. Indigenous populations of *Rhizobia* for legumes may be present in prairie soils, but these indigenous populations may be ineffective for inducing $_{N2}$ fixation under semiarid environments (Kucey and Hyne

1989). Small doses of N fertilizers applied to an annual pulse are beneficial if nodule initiation is delayed (Mahon and Child, 1979). In dry pea, N application at 20 to 60 kg ha^{-1} increased seed yield by an average of 9% in one quarter of 58 trials conducted in Alberta (McKenzie *et al.*, 2001).

When spring soil NO_3-N (0 to 30 cm depth) was less than 20 kg N ha^{-1}, the use of fertilizer N increased pea yield by an average of 11% in one-third of the trials. Similarly, application of fertilizer N increased dry bean 8 (Phaseolus vulgaris L.) seed yield proportionally in southern Manitoba (McAndrew and Mills, 2000).

Most producers in Western Canada inoculate the seed or the soil with a rhizobia strain and provide little or no fertilizer N to their lentil crops. Due to the lag period between rhizobial root colonization infection and the onset of nodule functioning, the young lentil plants may require a small dose of additional N (i.e., starter- N) from external sources to achieve vigorous vegetative growth and establish N_2-fixing symbiosis.

Effect of phosphorus on growth and yield

Phosphorus plays a major role in many plant processes, including storing and transfer of energy; stimulation of root growth, flowering, fruiting and seed formation; nodule development and N_2 fixation (Cameron *et al.*, 1996; Ali *et al.*, 1997).

Phosphorus application on legumes can also increase leaf area, yield of tops, roots and grain; nitrogen concentration in tops and grain; number and weight of nodules on roots; and increased acetylene reduction rate of the nodules (Ali *et al*., 1981).

Nodule number, volume, and dry weight can be increased by treating P deficient soils with fertilizer P. However, Bremer *et al.* (1989) found that P application increased dry matter and grain yield but did not affect N_2 fixation indicating that the legume host was more responsive to P application than the *Rhizobia.*

Saskatchewan soils generally test low to medium in available phosphorus (Rossi and Henry, 1980), a nutrient required in relatively large amounts by pulse crops. Total P in Saskatchewan soils ranges from about 400 to 2200 kg ha^{-1} in the top 15 cm of soil, but only a very small amount of the total P is available to the crop during a growing season (Saskatchewan Ministry of Agriculture, 2006).

Although crops can sometimes be grown for a few years without adding P fertilizer, yields sooner or later begin to decline. Phosphorous is relatively immobile (moves very little) in the soil. Most crops recover only 10 to 30% of the P in fertilizer the first year following application (Havlin *et al.,* 2005).

Recovery varies widely depending on soil type and conditions, the crop grown and application method. However, Saskatchewan research has shown 9 that the newly formed soil P reaction products are more plant available than the native soil P minerals and crops can continue to recover fertilizer P for several years after application (Saskatchewan Ministry of Agriculture, 2006).

Granular monoammonium phosphate (MAP) (12-51-0 or 11-55-0) is the most common P fertilizer used in Saskatchewan (Saskatchewan Ministry of Agriculture, 2006). Lentils are sensitive to high rates of P fertilizer placed directly in the seed rows. Research conducted over a three year period indicated that increasing rates of seed-placed MAP (11-55-0) resulted in reduced stands of lentil but high yield per plant as compared to side-banded P application (McVicar *et al.,* 2010).

Lentil has a relatively high requirement for phosphorus to promote development of its extensive root systems and vigorous seedlings; and may benefit from improved frost, disease, and drought tolerance because of P application (McVicar *et al.,* 2010). Bremer *et al.* (1989) reported that P response is more prevalent in the Black soils, which had the most favorable growing conditions and lowest available soil P levels, than in Brown or Dark Brown soils of Saskatchewan.

Rasool and Singh (2016) conducted an experiment of sixteen treatments comprising of four biofertilizer inoculations [*Rhizobium*, phosphate solubilizing bacteria (PSB), *Rhizobium* + PSB and no inoculation] and four phosphorus (0, 20, 40 and 60 kg P_20_5 ha^{-1}) levels to study the interaction of biofertilizers and phosphorus on growth and yield of lentil. The result of the experiment revealed that, maximum seed yield (794 kg ha^{-1}) was found from 60 kg P_2O_5 ha^{-1} and minimum seed yield (492 kg ha^{-1}) was found from 0 kg P_2O_5 ha^{-1}.

Datta *et al.* (2013) carried out an experiment to study the effect of variety and level of phosphorus fertilizer on the yield and yield components of lentil at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during October 2009 to March 2010. Three lentil varieties viz. Binamasur-2, Binamasur-3 and BARI Masur-4 and four levels of phosphorus viz. 0 kg P ha^{-1} (P_0), 15 kg P ha^{-1} (P15), 30 kg P ha^{-1} (P30) and 45 kg P ha^{-1} (P45) were used in this experiment. They reported that, the highest seed yield (1222 kg ha^{-1}) was observed in P45 treatment, which was statistically similar with P_{30} treatment (1211 kg ha^{-1}) and the lowest seed yield (893 kg ha^{-1}) was observed in P_0 treatment.

Choubey *et al.* (2013) conducted an experiment during Rabi season on a silty loam soil. The treatment consisted of 4 phosphorus levels (Control 20, 40 and 60 kg ha^{-1}) and 3 sulphur levels (Control 20 and 40 Kg ha^{-1}) were laid-out in Randomized Block Design with 4 replications. They found that, he highest grain yield (21.03 q ha^{-1}) was recorded from 60 kg P ha^{-1} and the lowest grain yield (16.40 q ha^{-1}) was recorded from 0 kg P ha^{-1}.

Niri *et al*. (2010) conducted an experiment to study the effect of different levels of nitrogen and phosphorus fertilizer on grain yield and protein content of lentil in dry conditions a factorial experiment based on randomized complete block with three replications. The treatments consist of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 40 and 60 kg ha^{-1}). The results revealed that, the maximum seed yield (1466.50 kg ha^{-1}) was recorded from 40 kg P ha^{-1} and the minimum seed yield (1027.90 kg ha^{-1}) was recorded from 0 kg P ha^{-1}.

Zeidan (2007) carried out two field experiments during the two winter seasons of 2003/ 2004 and 2004/2005 at the Experimental Farm of the National Research Centre at Nubariato study the effect of organic manure at 0, 10 and 20 m^3/ fed. and four phosphorus levels of 0, 30, 45 and 60 Kg P_2O_5/fed on growth, yield and quality of lentil grown in sandy soil. Results indicated that, the highest seed yield $plant^{-1}$ (50.8 g) was recorded from 60 kg P fed^{-1} and the lowest seed yield $plant^{-1}$ (25.70 g) was recorded from control treatment (no phosphorous). The highest seed yield fed^{-1} (3.04 ardab) was recorded from 60 kg P fed^{-1} and the lowest seed yield fed^{-1} (2.10 ardab) was recorded from control treatment (no phosphorous).

Zafar *et al.* (2003) conducted a field experiment to evaluate the growth and yield response of lentil to phosphorus. The experiment was laid out in a randomized complete block design with four replications. Treatments included in this study were: Control, 25, 50 and 75 kg P_2O_5 ha^{-1} at sowing. The result revealed that, there was a highly significant effect of rate of different phosphorus application on the seed yield. However, highest seed yield ha^{-1} was recorded with the application of 75 kg P_2O_5 ha^{-1}.

Hussain *et al.* (2003) conducted an experiment to observed the effect of different P rates (0, 25, 50 and 75 kg ha^{-1}) on the chemico-qualitative parameters of lentil cultivars Masoor local, Masoor-85 and Masoor-93 were studied under field conditions in Faisalabad, Pakistan on a sandy- clay loam soil for two years. The seed protein concentration was significantly higher (25.36%) in Masur-93 than Masur-85 (23.24%) and Masur-local (23.07%) whereas the seed contents of P, K, Ca, Mg, and phytic acid and cooking quality were similar in all cultivars. By contrast, 50 kg P_2O_5 ha^{-1} significantly improved the cooking quality, seed P and phytic acid content compared to the control.

Harmsen and Mahmood (2004) conducted an experiment to see the response of lentil to different levels of phosphorus fertilizer (0, 15, 30, 45 and 60 kg P< sub>2</ sub >0< sub>5</ sub> ha^{-1}) was measured at three sites: Haripur (LI), Baffa (L2) and Pharana (L3), in the Hazara division of NWFP-Pakistan during the Rabi season of 2004-05. Phosphate treatments yielded significantly more than the control. The response to phosphate fertilizer was linear. Higher doses of P< sub>2</ sub>O< sub>5</ sub> (45 & 60 kg P< sub>2</ sub>0< sub>5</ sub> ha^{-1}) significantly induced early flowering but delayed maturity, which might be due to enhanced nitrogen's activity of intact root nodules and balancing effect of Phosphorus on the lentil physiological processes and uptake of other nutrients. The maximum mean yield of 1092 kg ha^{-1} was recorded with the 60 kg P< sub>2</ sub> 0₅ ha^{-1} treatment producing 8.8 kg grain yield kg^{-1} of NPK fertilizer with a return of Rs. 9.0 for each invested rupee in fertilizer. The response to the application of phosphorus fertilizer was greatest in soil with a low available phosphorus status.

Tomar *et al.* (2000b) conducted a field experiment to study the effect of seed rate, moisture regime and phosphorous levels on mungbean. They found that absolute growth rate, relative growth rate; net assimilation rate and dry matter at all the growth stages and crop growth rate at 65 days recorded significantly higher with application of phosphorous at 60 kg P_2O_5 ha^{-1} as compared to the other levels of phosphorous.

Interaction effect of nitrogen and phosphorus

Mahboob and Asghar (2002) studies the effect of seed inoculation at different NPK level on the yield and yield components of lentil at the agronomic research station, Farooqabad in Pakistan during the year of 2000 and 2001. They reported that various yield components like 1000 grain weight were affected significantly with 50-50-0 NPK kg ha^{-1} application.

Karle and Pawar (1998) examined the effect of varying levels of N and p fertilizers on lentil. They reported that lentil production higher seed yield with the application of 35 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different N level on lentil at the agronomic research station. Farooqabad in pakistan. They reported that seed inoculat in+ 40-80-30 NPK kg ha^{-1} exhibits superior performance in respect of seed yield (1670 kg ha^{-1}).

Rajender *et al.* (2003) investigated the effects of N (10, 20, 40, and 50 kg ha^{-1}) and P_2O_5 (20, 40, 60 and 80 kg ha^{-1}) fertilizer rates on lentil. Grain yield increased with increasing N rates up to 40 kg ha^{-1}. Further increase in N did not affect yield.

Sarkar and Banik (1991) made a field experiment to study the response of green gram to nitrogen, phosphorous and molybdenum. They reported that application of N and P improved plant productivity and enhanced the plant height, branch number, dry weight, pods plant and grain yield of green gram significantly. Growth parameters were recorded as better response for increased productivity.

They also reported that response to N and P_2O_5 was recorded up to 45 and 60 kg ha^{-1} respectively for better yield.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of lentil. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P_2O_5 ha^{-1} resulted in the maximum plant height (37.52 cm), number of branches plant (12.32), pods $plant^{-1}$ (86.34), seed yield (1112.96 kg ha^{-1}) and harvest index (41.88%). They also observed that number of flowers $plant^{-1}$ was found to be significantly higher by varying levels of nitrogen and phosphorus and pod length was significantly affected by both nitrogen and phosphorus application.

Patel *et al.* (1992) conducted a field trial to evaluate the response of mungbean to sulphur fertilizaton under different levels of nitrogen and phosphorus. Greengram cv. Gujrarat 2 and K 851 were given 10 kg N + 20 kg P_2O_5 ha^{-1} or triple these rates and 0, 10, 20 or 30 kg sulphur ha^{-1} as gypsum. Seed yield was 1.20 and 1.24 t ha^{-1} in Gujrarat 2 and K 851, respectively and was increased with the increase of fertilizer up to 20 kg N + 40 kg P_2O_5 ha^{-1}.

Yakadri *et al.* (2002) studied the effect of nitrogen (20, 40 and 60 kg ha^{-1}) and phosphorus (40 and 60 kg ha^{-1}) on crop growth and yield of greengram (cv.ML-267). Application of nitrogen at 20 kg $ha^{-1}$and phosphorus at 60 kg ha^{-1} resulted in the significant increase in leaf area ratios indicating better partitioning of leaf dry matter.

A field experiment was conducted by Sarkar and Banik (1991) to evaluate the effect of varying rates of N on mungbean. Results revealed that application of 10 kg N ha^{-1} resulted in the appreciable improvement in different yield attributes along with number of pods plant^{-1}, 1000 seed weight over the control (no application). Application of N along with P significantly increased the seed yield of mungbean. The higher yield was found with the application of N and P_2O_5 up to 10 and 60 kg ha^{-1}, respectively. However, the maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_2O_5 ha^{-1}.

Srinivas *et al.* (2002) examined the effect of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and phosphorus (0, 25, 50 and 75 kg ha^{-1}) on the growth and yield of mungbean. They observed that the number of pods plant^{-1} was increased with the increasing rates of N up to 40 kgha^{-1} followed by a decrease with further increase in N. Pod length was increased with the increasing rates of N up to 40 kg ha^{-1}which was followed by a decrease with further increase. 1000 seed weight was generally increased with increasing rates of P along with increasing rates of N up to 40 kg ha^{-1} which was than followed by a decrease with further increase in N.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on the yield and yield components of mungbean at the Agronomic Research Station, Farooqabad in Pakistan during the year of 2000 and 2001. They revealed that various yield components like 1000 grain weight were affected significantly with fertilizer (50 - 50 - 0 NPK kg ha^{-1}) application. They also revealed that seed inoculation + 5050-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Yein *et al.* (1981) conducted field trials in Assam, India, and applied N and P fertilizers to study their relative contributions towards increasing the seed yield of mungbean. Their studies showed that N along with P fertilizers increased the seed yield. They observed that 10 kg N in combination with 20 kg P_2O_5 ha^{-1} resulted in significant increases in the seed yield.

Arya and Kalra (1988) reported that application of N at the rate of 50 kg ha^{-1} along with P_2O_5 (50 kg ha^{-1}) increased mungbean yield. Results from field experiments conducted by Mahadkar and Saraf (1988) during summer season showed that the application of N with P and K at 20 :2 :5 kg ha^{-1} gave higher seed yield.

Ardesna *et al.* (1993) conducted a field experiment on clay soil during the rainy season of 1990 to study the response of mungbean to nitrogen, phosphorus and Rhizobium inoculation. They observed that seed yield increased with the application of nitrogen fertilizer up to 20 kg N ha^{-1} in combination with phosphorus fertilizer up to 40 kg P2O5 and inoculation with *Rhizobium.*

Yadav *et al.* (1994) conducted a field experiment on sandy loam soil during the kharif (monsoon) season of 1986 at Hisar, Hariana, India, with mungbean cv. k 851. Treatments 0, 50 or 100% of the recommended N and P fertilizers (20 kg N as Urea and 40 kg P_2O_5 ha^{-1} as single super phosphate) were tested. They found that mungbean receiving the recommended dose gave the highest seed yield.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported that mungbean produced higher yield with the combination application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India. Mungbean was grown using farmers' practices (no fertilizer) or using different combinations of fertilizer application (10 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 to N ha^{-1} with farmers' practices, while the highest yield was obtained by the fertilizer application (0.77 t ha^{-1}).

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N rate did not affect yield.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM - 98 to seed inoculation and different levels of fertilizer (0 - 0, 15 - 30, 30 - 60 and 45 - 90 kg N- P_2O_5 ha^{-1}) under field conditions. Results showed that the application of fertilizer significantly increased the seed yield and the maximum seed yield was obtained when 30 N ha^{-1} was applied.

Azad and Gill (1989) set up a experiment where lentils cv.L9-12 were given 0 to 40 kg P_2O_5 ha^{-1} + 12.5 kg N ha^{-1} or soils low in available P and organic matter in Rabi (winter) season and found that seed yield increased with increasing P rate from cv. of 285 kg ha^{-1} without applied P to 758 kg with 40 kg P_2O_5. They got the greatest response of P in soil with lowest available P contents.

Kumar *et al.* (1993) have described the effect of P and N on growth and grain yield of lentil. They found that all the growth attributes were significantly F increased by 20 kg N and 50 kg P_2O_5. Yield, yield attributes and quality of lentil also exhibited the same trend, although N application did not significantly increased seed yield.

Amanullah (2004) conducted an experiment during 2000-01 in Pesbawar, Pakistan to investigate the effect of various levels of N (0 and 20 kg ha^{-1} and P (0, 30, 60 and 90 kg ha^{-1}) on the growth and yield components of lentil cultivars masur-85, Masur-93 and Manshera-89 under rainfed conditions. P application had significantly affected the number of pods $plant^{-1}$, 1000-seed weight and dry matter yield. Lower number of pods $plant^{-1}$ (81), seeds pod (1.5), 1000-seed weight (14.2 g) and grain yield (550 kg ha^{-1}) were recorded without P application. P applied at 60 kg ha^{-1} resulted in the highest number of pods $plant^{-1}$ (84), number pod^{-1} (1.6), 1000-seed weight (14.8 g), dry matter yield (2875 kg ha^{-1}) and grain yield (595 kg ha^{-1}) but had no significant effect on nodule numbers.

Patel and Patel (1999) found that 20 kg N + 40 kg P_2O_5 ha^{-1} gave the highest seed yield (1.74t ha^{-1}) which was not significantly different from foliar application of urea (1.5%) + DAP (0.5%) at 30 and 40 days after sowing (1.67 t ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the farm of, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2017 to March 2018. Detailed of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to study the effect of nitrogen, phosphorus and bio-fertilizer on yield and seed quality of lentil.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Research Farm, Dhaka-1207, Bangladesh. It is located at 90°22′ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28 (Appendix I).

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September). Details of weather data in respect of temperature (^{0}C), rainfall (mm) and relative humidity (%) for the study period was collected from Bangladesh Meteorological Department, Agargoan, Dhaka-1207 (Appendix II).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was silty clay loam in texture with pH 5.6. The physical and chemical characteristics of the soil have been presented in Appendix III.

3.4 Details of the experiment

3.4.1 Treatments

The experiment consisted of 2 factors:

Factor A: Bio-fertilizer (2)

1. B_0 = 0 (Without Bio-fertilizer)
2. B_1 = Bio-fertilizer (50 g per 2.5 kg of seeds)

Factor B: Rates of Nitrogen (N) + Phosphorus (P) (6)

1. D_0 = Control (without N+P)
2. D_1 = 50% less N+P
3. D_2 = 25% less N+P
4. D_3 = Recommended doses of N+P
5. D_4 = 25% higher N+P
6. D_5 = 50% higher N+P

The nitrogenous (N) and phosphate (P) fertilizers were applied in the form of urea and triple super phosphate (TSP). The rate of the urea and TSP, and other fertilizers has been presented in section 3.6.4.

Treatment combinations

B_0D_0, B_0D_1, B_0D_2, B_0D_3, B_0D_4, B_0D_5, B_1D_0, B_1D_1, B_1D_2, B_1D_3, B_1D_4, B_1D_5.

3.4.2 Experimental design and layout

The experiment was laid out in RCBD (factorial) with three replications. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 3.0×2.0 m^2. The distances between plot to plot and replication to replication were 0.50 m and 1.0 m, respectively.

3.5 Crop/Planting material

BARI Mosur-6 was used as planting material.

3.5.1 Description of crop: BARI Mosur-6

BARI Mosur-6 was developed by Pulses Research Centre, Ishurdi, Pabna. BARI Mosur-6 is a semi erect and medium standdard and bushy cultivar. Seed color is deep brown and cotyledons are bright orange. It has a 1000 seed weight of 19.84 g.

3.6 Sowing and crop management

3.6.1 Seed collection

Seeds of BARI Mosur-6 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.6.2 Collection and preparation of initial soil sample

The soil sample of the experimental field was collected before fertilizer application. The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.6.3 Preparation of experimental land

A pre- sowing irrigation was given on November 22, 2017. After that the land was open with the help of a tractor drawn disc harrow, then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on November 30, 2017 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.6.4 Fertilizer application

The recommended chemical fertilizer dose was 50, 100, 55 and 1 kg ha^{-1} of Urea, TSP, MOP and Boric acid respectively. All the fertilizers according to the treatment were applied thoroughly at the time of final land preparation.

3.6.5 Sowing of seed

Seeds were sown in the field on 30 November, 2017. The field was labeled properly and was divided into 36 plots. The seeds of BARI Mosur-6 were sown by hand in 30 cm apart from lines with continuous spacing at about 3 cm depth at the rate of 40 g $plot^{-1}$ on 30 November, 2017.

3.7 Intercultural operations

3.7.1 Thinning

The plots were thinned out on 15 days after sowing to maintain a uniform plant stand which facilitates proper aeration and light for optimum growth and development of the crops.

3.7.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done, first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.7.3 Irrigation

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two irrigation were given 3 days before weeding.

3.7.4 Drainage

Drainage channel were properly prepared to easy and quick drained out of excess water.

3.7.5 Plant protection measures

The crop was infested by insects and diseases, those were effectively and timely controlled by applying recommended insecticides and fungicides. Malathion 18 ml/L and Ripcord 20ml/L uses as protection measure.

3.8 Harvesting and post-harvest operation

Maturity of crop was determined when 80-90% of the pods become straw color. The harvesting of BARI Mosur-6 were done up to 5 March, 2018. Five pre-elected plants per plot were harvested from which different yield attributing data were collected and 1 m^2 area from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain yields $plot^{-1}$ was determined and converted to kg ha^{-1}.

3.9 Recording of data

Ten plants from each plot were marked from the inner rows and all the growth characters, data were collected from that plants. At maturity stage, five sample plants were collected randomly from each plot avoiding border rows and central 1 m^2 area. The yield attributes data were collected from these five plants. For taking yield data, plants of central 1 m^2 area were harvested.

3.9.1 Crop growth characters

1. Plant height (at 30, 60 and 90 DAS)
2. Branches $plant^{-1}$ (at 30, 60 and 90 DAS)

3.9.2 Yield contributing characters and yield

1. Number of pods $plant^{-1}$
2. Number of seeds pod^{-1}
3. 1000 seed weight (g)
4. Grain yield (kg ha^{-1})

3.9.3 Seed quality parameters

After obtaining grain yield from the field, quality of seeds were tested in Laboratory and data on following parameters were collected:

1. Percent seed germination
2. Root length (cm)
3. Shoot length (cm)
4. Seed vigor index

3.10 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

3.10.1 Crop growth characters

Plant height

The height of 10 randomly selected plants from each plot were taken carefully at 30, 60 and 90 DAS. Plant height was measured from the above ground portion of the plants and expressed in centimeter (cm).

Number of branches $plant^{-1}$

Number of branches $plant^{-1}$ was counted carefully from 10 randomly selected plants from each plot and averaged them to get branches $plant^{-1}$. It was done at 30, 60 and 90 days after sowing.

3.10.2 Yield contributing parameters and yield

Number of pods plant^{-1}

The pods of five randomly collected plants in each plot were counted and then averaged them to get pods plant^{-1}.

Number of seeds pod^{-1}

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

Thousands seed weight

Thousand seeds from of each plot were collected and their weight were taken by digital electric balance in gram (g).

Grain yield

Total grains of central 1 m^2 area in each plot was weighed and then converted into kg ha^{-1}. The grain weight was taken at 12% moisture content.

3.10.3 Seed quality test

Percent seed germination

The number of sprouted and germinated seeds was counted daily commencing. Germination was recorded at 24 hrs interval and continued up to 10th. More than 2 mm long plumule and radicle was considered as germinated seed.

The germination was calculated using the following formula:

$$\text{Germination (\%)} = \frac{Total\ number\ of\ germinated\ seeds}{Total\ seed\ placed\ for\ germination} \times 100$$

Root length (cm)

The Root length of five seedlings from each sample was recorded finally at 10 DAS. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

Shoot length (cm)

The shoot length of five seedlings from each sample was measured finally at 10 DAS. Measurement was done using the unit centimeter (cm) by a meter scale.

Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

VI = RL+SL×GP,

Where

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.11 Statistical analysis

The data obtained for different parameters were analyzed statistically. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was carried out to find the effect of nitrogen, phosphorus and bio-fertilizer on yield and seed quality of lentil. The effect of different nitrogen, phosphorus and bio-fertilizer and their interaction on growth yield contributing characters and yield and also seed quality have been presented and discussed in this chapter under the following heads.

4.1 Growth parameters

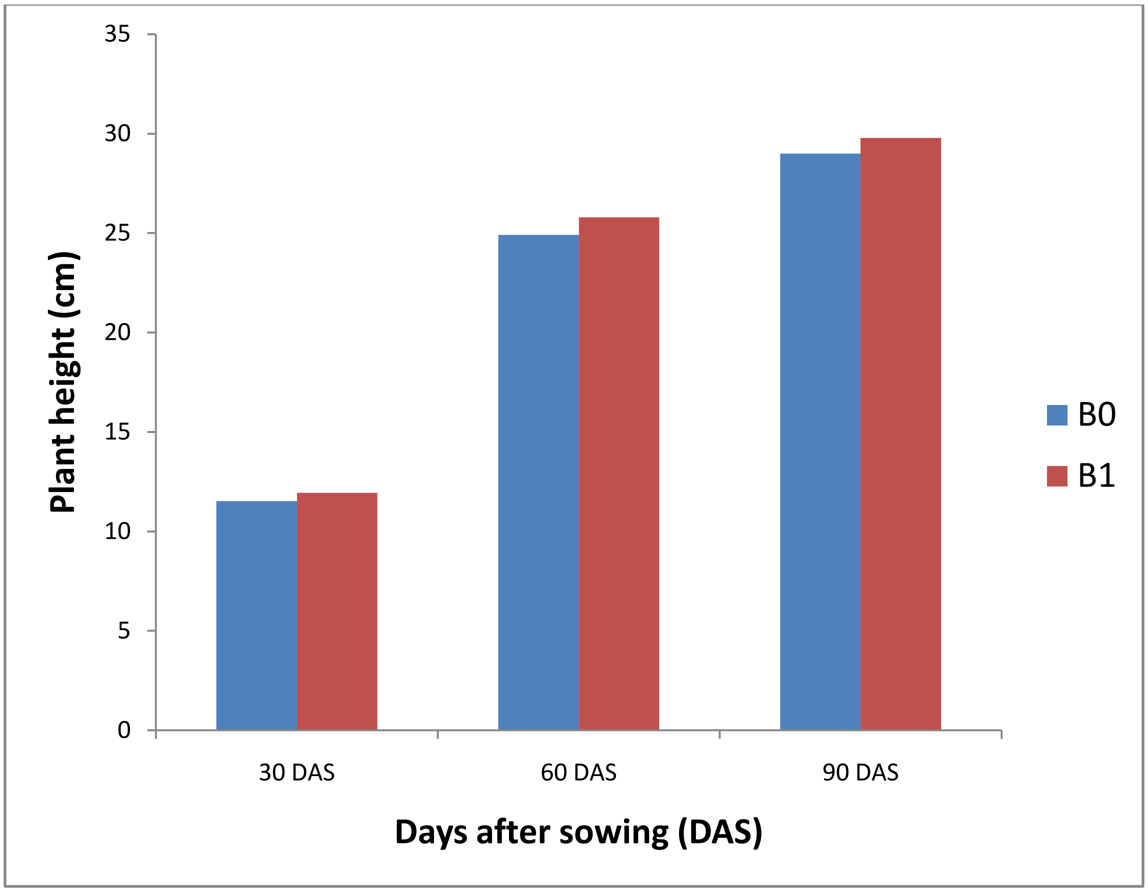
4.1.1 Plant height

Effect of bio-fertilizer

There was no significant variation on plant height of lentil at different growth stages influenced by different biofertilizer treatment (Fig. 1 and Appendix V). The figure revealed that irrespective of biofertilizer application, plant height increased gradually with the advances of plant growth stages. However, the higheer plant height (11.94, 25.79 and 29.78 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment B_1 (Bio-fertilizer; 50 gm per 2.5 kg of seeds) and the lower plant height (11.52, 24.91 and 29.00 cm at 30, 60 and 90 DAS, respectively) was obtained from the control treatment B_0 (without bio-fertilizer).

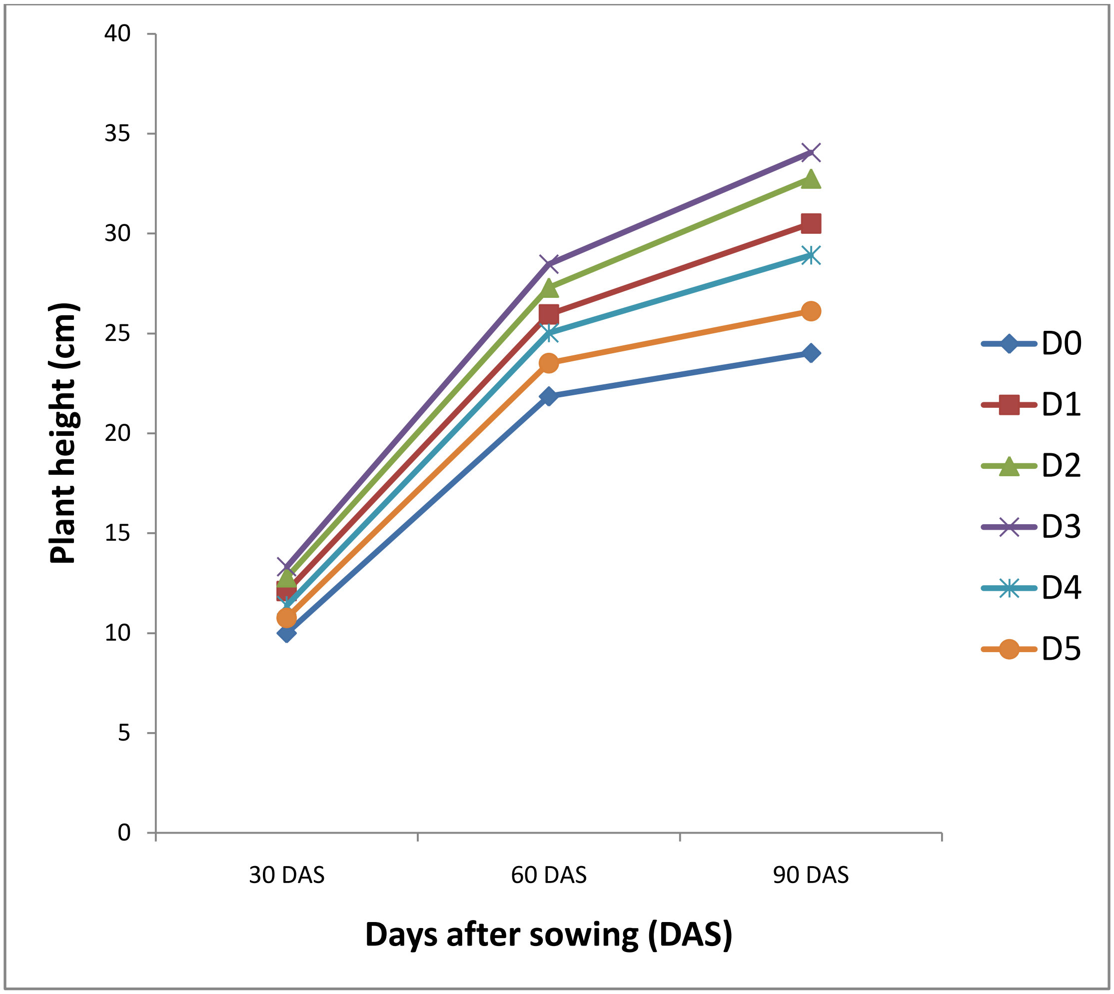
Effect of N+P

Plant height of lentil at different growth stages was significantly influenced by different N+P treatments except at 30 DAS (Fig. 2 and Appendix V). It can be inferred from the result that plant height showed an increasing trend with the increases of growth stages of plant and the growth continued up to 90 DAS irrespective of N+P fertilizer level. The rate of growth was much higher from 30 DAS to 60 DAS, after that the rate of increase becomes slow and it continued up to 90 DAS. However, the highest plant height (13.32, 28.46 and 34.05 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment D_3 (Recommended doses of N+P) which was statistically identical with D_2 (25% less of recommended N+P) at 60 DAS. The lowest plant height (10.00, 21.85 and 24.02 cm at 30, 60 and 90 DAS, respectively) was obtained from the control treatment D_0 (without N+P) which was significantly different from all other treatments.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 1. Effect of biofertilizer on plant height at different growth stages of lentil ($LSD_{0.05}$ = NS at 30, 60 and 90 DAS)



Here, D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 2. Effect on N+P on plant height at different growth stages of lentil ($LSD_{0.05}$ = NS, 1.12 and 1.05 at 30, 60 and 90 DAS respectively)

Combined effect of bio-fertilizer and N+P

Significant variation was observed on plant height of lentil at different growth stages except 30 DAS influenced by combined effect of bio-fertilizer and N+P (Table 1 and Appendix V). It was observed that the highest plant height (13.36, 28.55 and 34.23 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of B_1D_3 which was statistically similar with the treatment combination of B_0D_3 and B_0D_2 at 60 and 90 DAS. The lowest plant height (9.58, 21.14 and 23.92 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of B_0D_0 which was statistically similar with the treatment combination of B_0D_5 and B_1D_0 at 90 DAS.

Table 1. Plant height of lentil as influenced by bio-fertilizer and N+P the interaction and combination at different growth stages

Treatments	Plant height (cm) at		
	30 DAS	60 DAS	90 DAS
B_0D_0	9.58	21.14 g	23.92 g
B_0D_1	11.73	25.44 d	30.32 cd
B_0D_2	12.72	26.96 bc	32.40 b
B_0D_3	13.28	28.37 a	33.86 a
B_0D_4	11.33	24.88 de	28.72 ef
B_0D_5	10.47	22.68 f	24.78 g
B_1D_0	10.42	22.55 f	24.12 g
B_1D_1	12.48	26.48 c	30.67 c
B_1D_2	12.88	27.64 ab	33.12 ab
B_1D_3	13.36	28.55 a	34.23 a
B_1D_4	11.42	25.16 de	29.10 de
B_1D_5	11.07	24.33 e	27.44 f
$LSD_{0.05}$	NS	1.005	1.332
CV(%)	6.12	8.37	10.26

B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

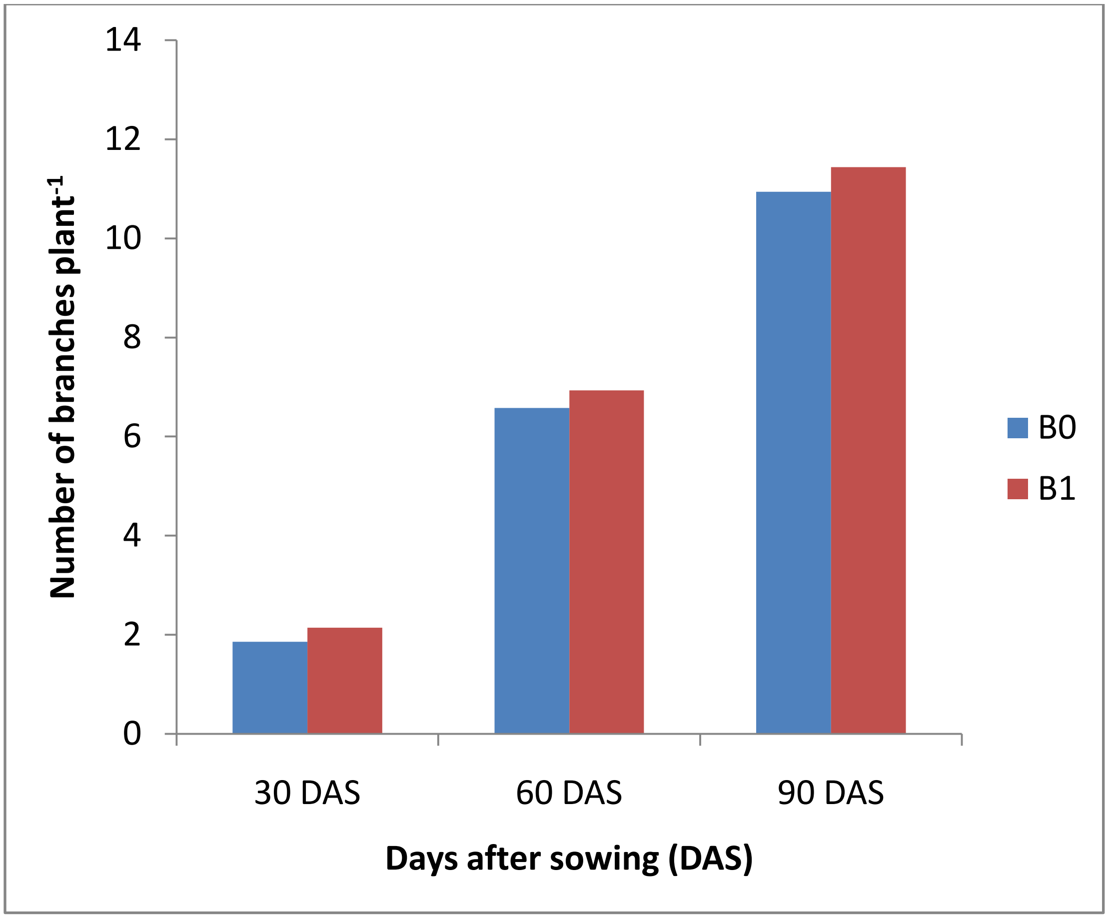
4.1.2 Number of branches plant^{-1}

Effect of bio-fertilizer

Number of branches plant^{-1} was not affected significantly due to different biofertilizer treatment at different growth stages of lentil (Fig. 3 and Appendix VI). However, the higher number of branches plant^{-1} (2.14, 6.93 and 10.94 at 30, 60 and 90 DAS, respectively) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and the lower number of branches plant^{-1} (1.86, 6.58 and 10.94 at 30, 60 and 90 DAS, respectively) was obtained from the control treatment B_0 (without bio-fertilizer).

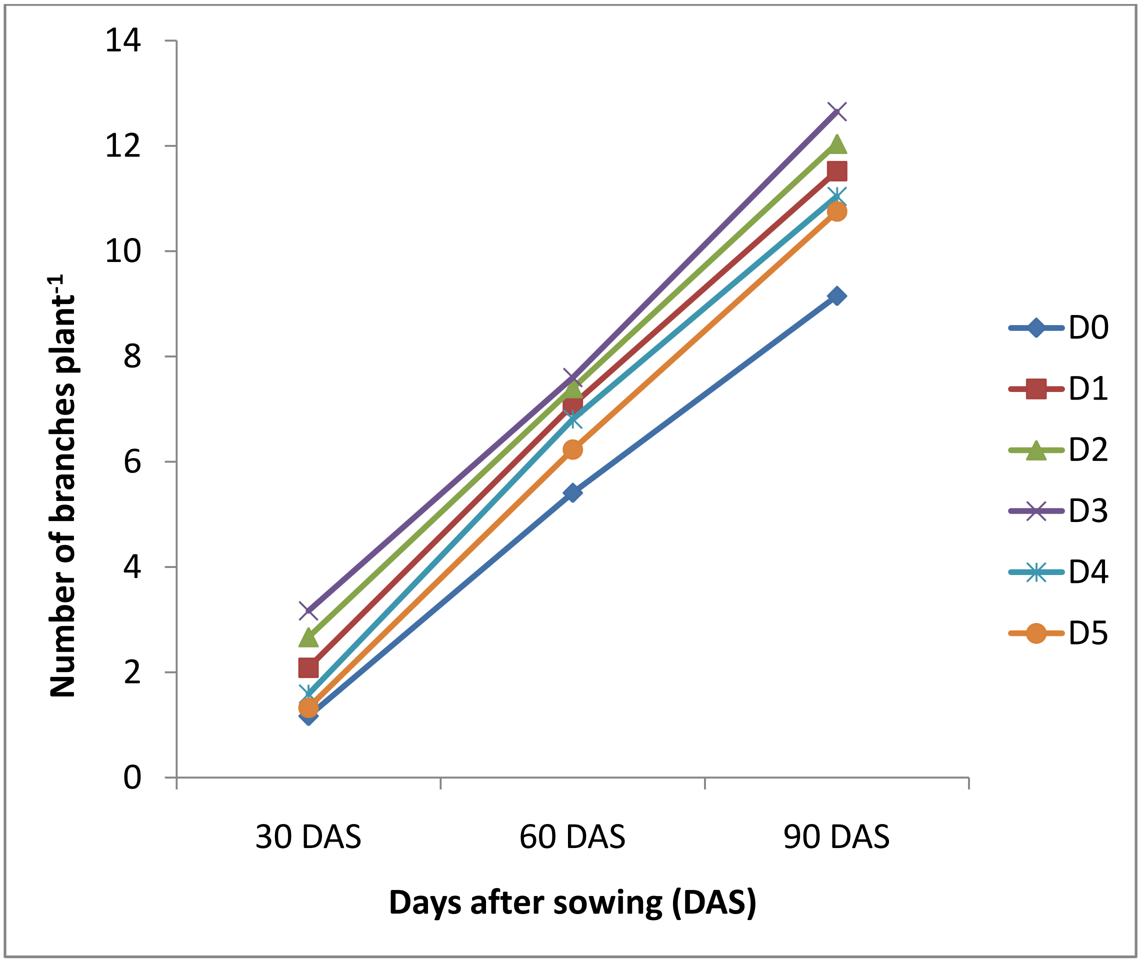
Effect of N+P

Remarkable variation was observed on number of branches plant^{-1} due to different levels N+P treatments in lentil (Fig. 4 and Appendix VI). The result revealed that number of branches plant^{-1} increased sharply with the advancement of growth stages, irrespective of different level of N+P fertilizations. The rate of increase was same throughout the growth period up to 90 DAS. It was observed that the highest number of branches plant^{-1} (3.17, 7.60 and 12.65 at 30, 60 and 90 DAS, respectively) was obtained from the treatment D_3 (Recommended doses of N+P) which was statistically similar with D_2 (25% less of recommended N+P) at 60 and 90 DAS. The lowest number of branches plant^{-1} (1.17, 5.41 and 9.15 at 30, 60 and 90 DAS, respectively) was obtained from the control treatment D_0 (without N+P) which was significantly different from all other treatments. Similar result was also observed by Malik *et al.* (2003) which supported the present study that number of branches plant^{-1} increased with the increased level of fertilizers.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 3. Effect of biofertilizer on number of branches plant^{-1} at different growth stages of lentil ($LSD_{0.05}$ = NS at 30, 60 and 90 DAS)



Here, D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 4. Effect on N+P level on number of branches plant^{-1} at different growth stages of lentil ($LSD_{0.05}$ = 0.344, 0.247 and 0.611 at 30, 60 and 90 DAS respectively)

Combined effect of bio-fertilizer and N+P

Significant variation was observed on number of branches plant^{-1} at different growth stages except 30 and 60 DAS due to combined effect of bio-fertilizer and N+P (Table 2 and Appendix VI). The highest number of branches plant^{-1} (3.33, 7.67 and 12.82 at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of B_1D_3 which was significantly different from all other treatment combinations followed by B_1D_2 and B_0D_2. The lowest number of branches plant^{-1} (1.00, 4.87 and 8.38 at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of B_0D_0 which was significantly different from all other treatment combinations.

Table 2. Number of branches plant^{-1} as influenced by the interaction bio-fertilizer and N+P in lentil at different days after sowing.

Treatments	Number of branches plant^{-1} at		
	30 DAS	60 DAS	90 DAS
B_0D_0	1.00	4.87	8.38 i
B_0D_1	1.67	6.92	11.36 de
B_0D_2	2.67	7.33	11.85 c
B_0D_3	3.00	7.52	12.47 b
B_0D_4	1.50	6.72	10.94 fg
B_0D_5	1.33	6.12	10.63 g
B_1D_0	1.33	5.95	9.92 h
B_1D_1	2.50	7.24	11.67 cd
B_1D_2	2.67	7.46	12.22 b
B_1D_3	3.33	7.67	12.82 a
B_1D_4	1.67	6.90	11.13 ef
B_1D_5	1.33	6.33	10.86 fg
$LSD_{0.05}$	NS	NS	0.336
CV(%)	4.29	7.66	9.34

B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

4.2 Yield contributing parameters and yield

4.2.1 Number of pods plant^{-1}

Effect of bio-fertilizer

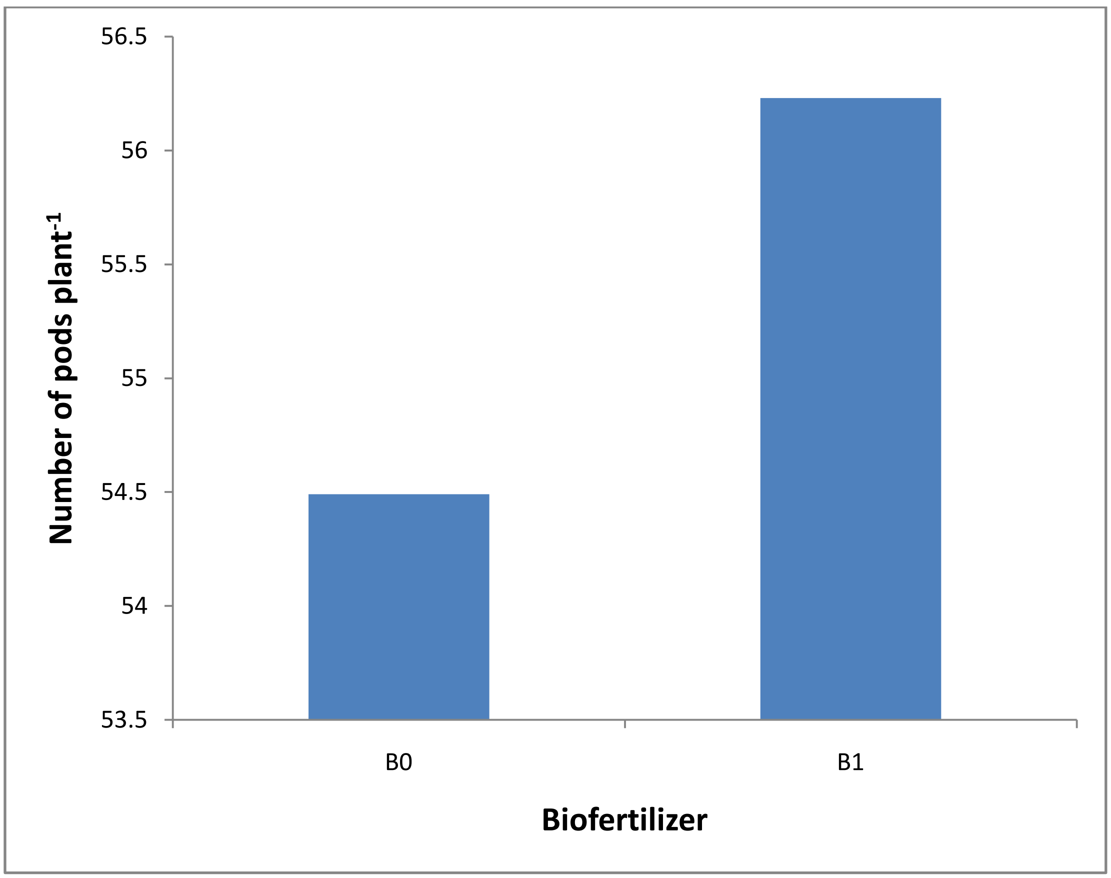
Remarkable variation was observed on number of pods plant^{-1} influenced by different biofertilizer treatment (Fig. 5 and Appendix VII). The higher number of pods plant^{-1} (56.23) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds). The lower number of pods plant^{-1} (54.49) was obtained from the control treatment B_0 (without bio-fertilizer). This indicates biofertilizer (B_1) increased the production of pods plant^{-1} by 3.19% over without biofertilizer (B_0) treatment in lentil.

Effect of N+P

Significant variation was remarked on number of pod plant^{-1} as influenced due to different N+P treatments in lentil (Fig. 6 and Appendix VII). The figure indicates the of pods plant^{-1} increased gradually with the increases of N+P level and the highest increase was recorded with D_3 treatment, after that the production of pods plant^{-1} reduced gradually up to the highest dose of N+P fertilizer (D_5). The highest number of pods plant^{-1} (67.56) was obtained from the treatment D_3 (Recommended doses of N+P) which was significantly different from all other treatments followed by D_2 (25% less of recommended N+P). The lowest number of pods plant^{-1} (43.16) was obtained from the control treatment D_0 (without N+P) which was also significantly different from all other treatments followed by D_5 (50% higher of recommended N+P). The result obtained from the present study was similar with the findings of Sarkar and Banik (1991) who reported that N+P fertilizer dose increased the pods plant^{-1}.

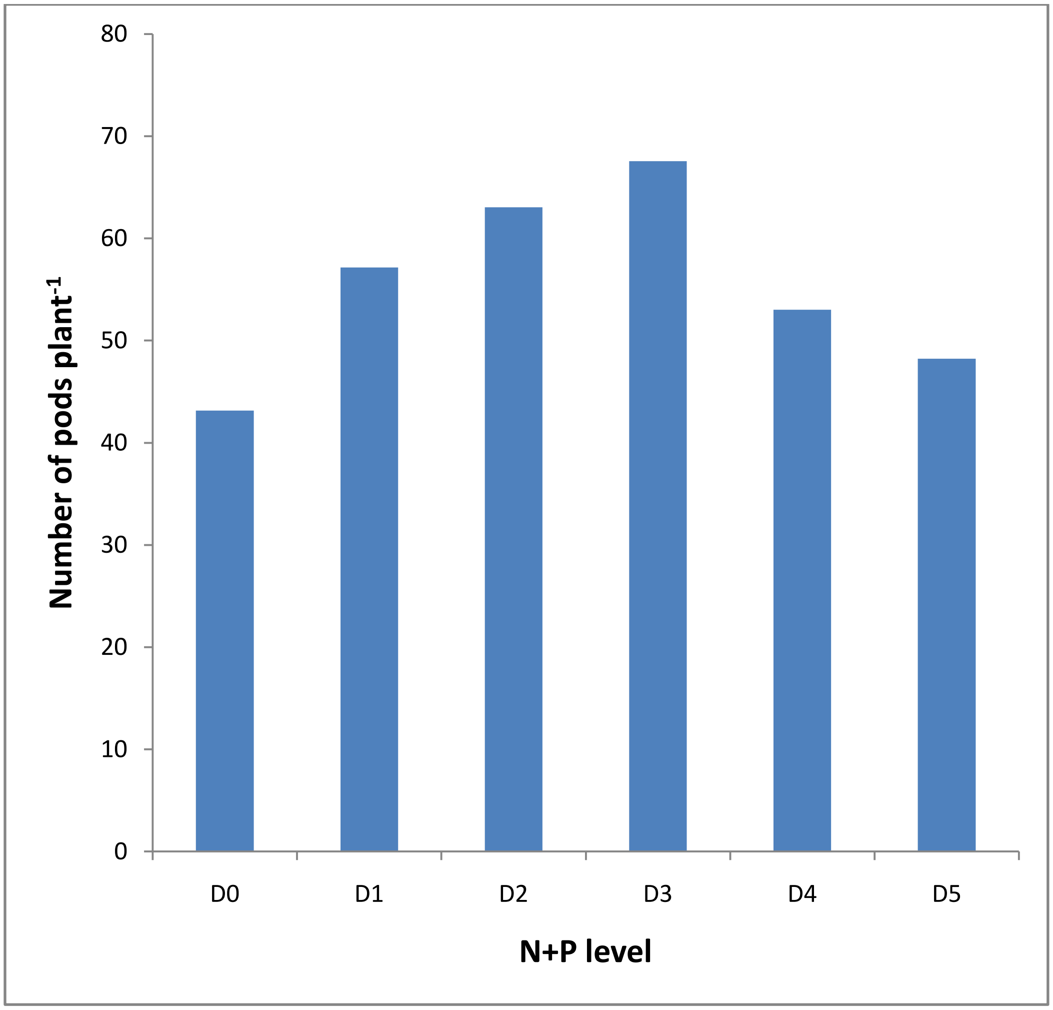
Combined effect of bio-fertilizer and N+P

Significant influence was found on number of pods plant^{-1} due to combined effect of bio-fertilizer and N+P in lentil (Table 3 and Appendix VII). The highest number of pods plant^{-1} (69.23) was obtained from the treatment combination of B_1D_3 which was statistically similar with the treatment combination of B_1D_2 and B_0D_3 (65.88 and 64.36 respectively). The lowest number of pods plant^{-1} (40.38) was obtained from the treatment combination of B_0D_0 which was significantly different from all other treatment combinations.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 5. Effect of biofertilizer on number of pods plant^{-1} of lentil ($LSD_{0.05}$ = 1.24)



D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 6. Effect of N+P level on number of pods plant^{-1} of lentil ($LSD_{0.05}$ = 2.52)

4.2.2 Number of seeds pod^{-1}

Effect of bio-fertilizer

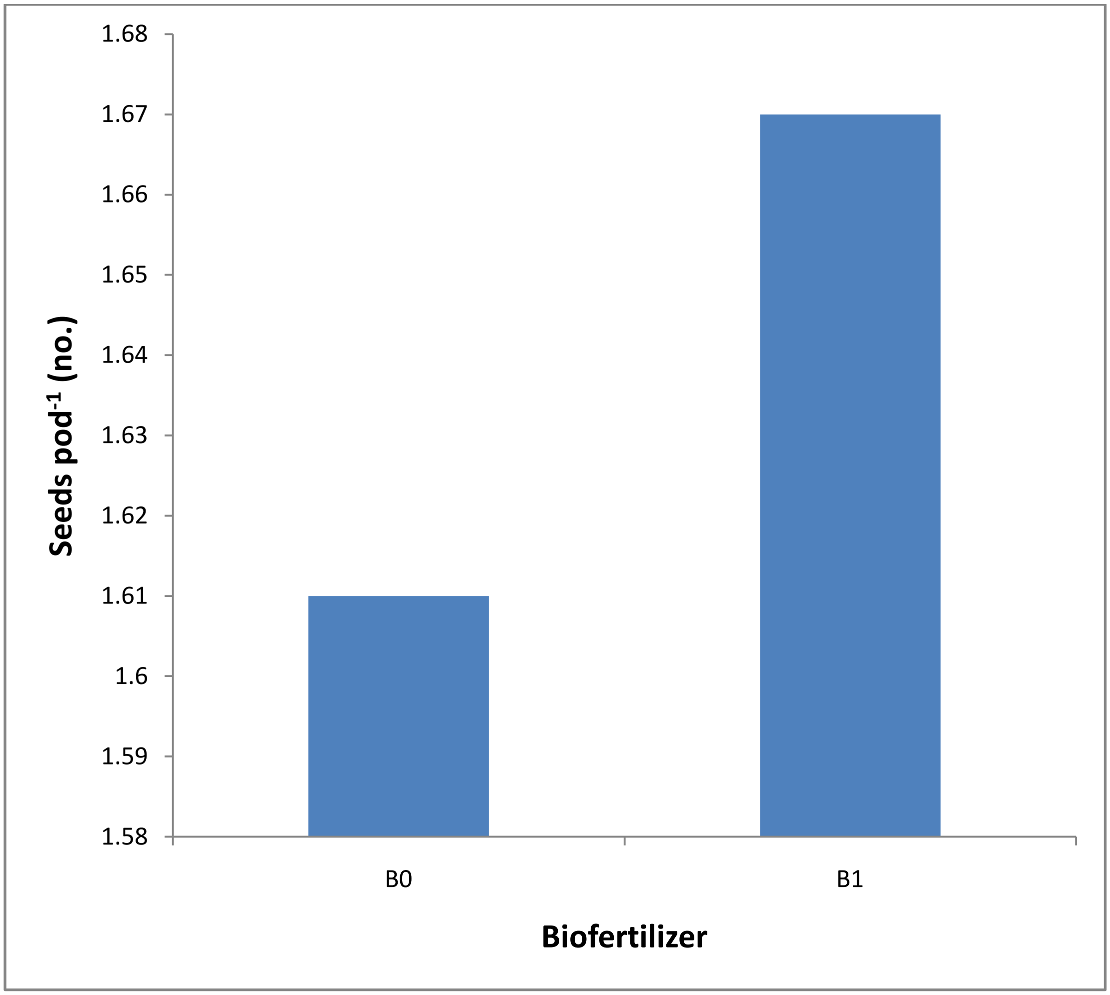
Number of seeds pod^{-1} was not significant with the application of different biofertilizer treatment in lentil (Fig. 7 and Appendix VII). However, The highest number of seeds pod^{-1} (1.67) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and the lowest number of seeds pod^{-1} (1.61) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

Variation on number of seeds pod^{-1} was found non-significant due to different N+P treatments in lentil (Table 8 and Appendix VII). Data on number of seeds pod^{-1} due to different levels of N+P have been presented in Figure 8. The data indicates that number of seeds pod^{-1} increased gradually with increased N+P levels and the highest increase was found with D_3 level, after that seeds pod^{-1} reduced gradually with the higher dose. The highest number of seeds pod^{-1} (2.07) was obtained from the treatment D_3 (Recommended doses of N+P) which was statistically similar with D_2 (25% less of recommended N+P). The lowest number of seeds pod^{-1} (1.25) was obtained from the control treatment D_0 (without N+P) which was significantly different from all other treatments.

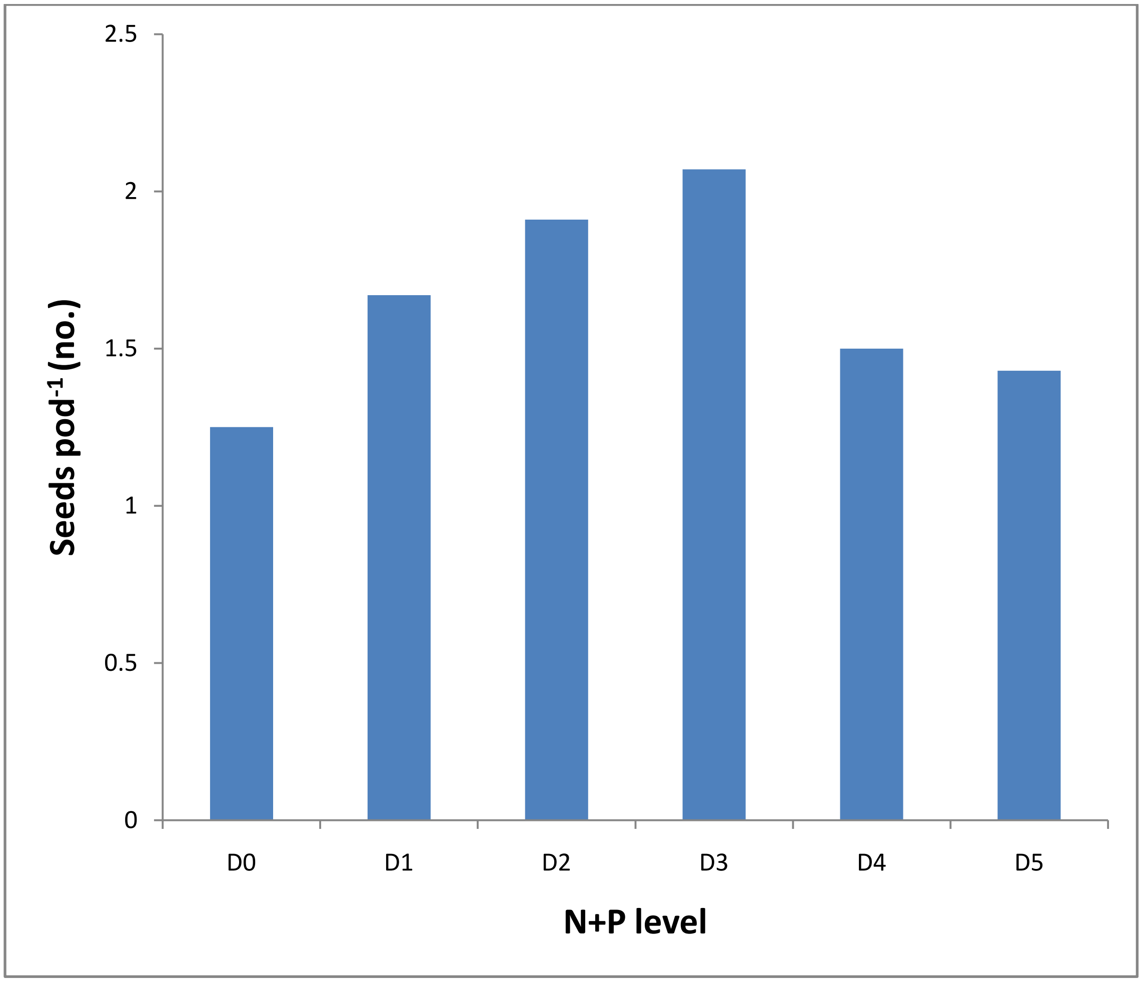
Combined effect of bio-fertilizer and N+P

The recorded data on number of seeds pod^{-1} was significant affected by combined effect of bio-fertilizer and N+P levels in lentil (Table 3 and Appendix VII). The highest number of seeds pod^{-1} (2.12) was obtained from the treatment combination of B_1D_3 which was statistically similar with the treatment combination of B_0D_3 (2.02). The lowest number of seeds pod^{-1} (1.18) was obtained from the treatment combination of B_0D_0 which was statistically similar with the treatment combination of B_1D_0.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 7. Effect of biofertilizer on number of seeds pod^{-1} of lentil ($LSD_{0.05}$ = NS)



Here, D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 8. Effect of different levels of N+P on number of seeds pod^{-1} of lentil ($LSD_{0.05}$ = 0.18)

4.2.3 Weight of 1000 seeds

Effect of bio-fertilizer

Remarkable variation was not found on 1000 seed weight of lentil due to different biofertilizer treatment (Fig. 9 and Appendix VII). However, the higher 1000 seed weight (20.33 g) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and the lower 1000 seed weight (20.13 g) was obtained from the control treatment B_0 (without bio-fertilizer).

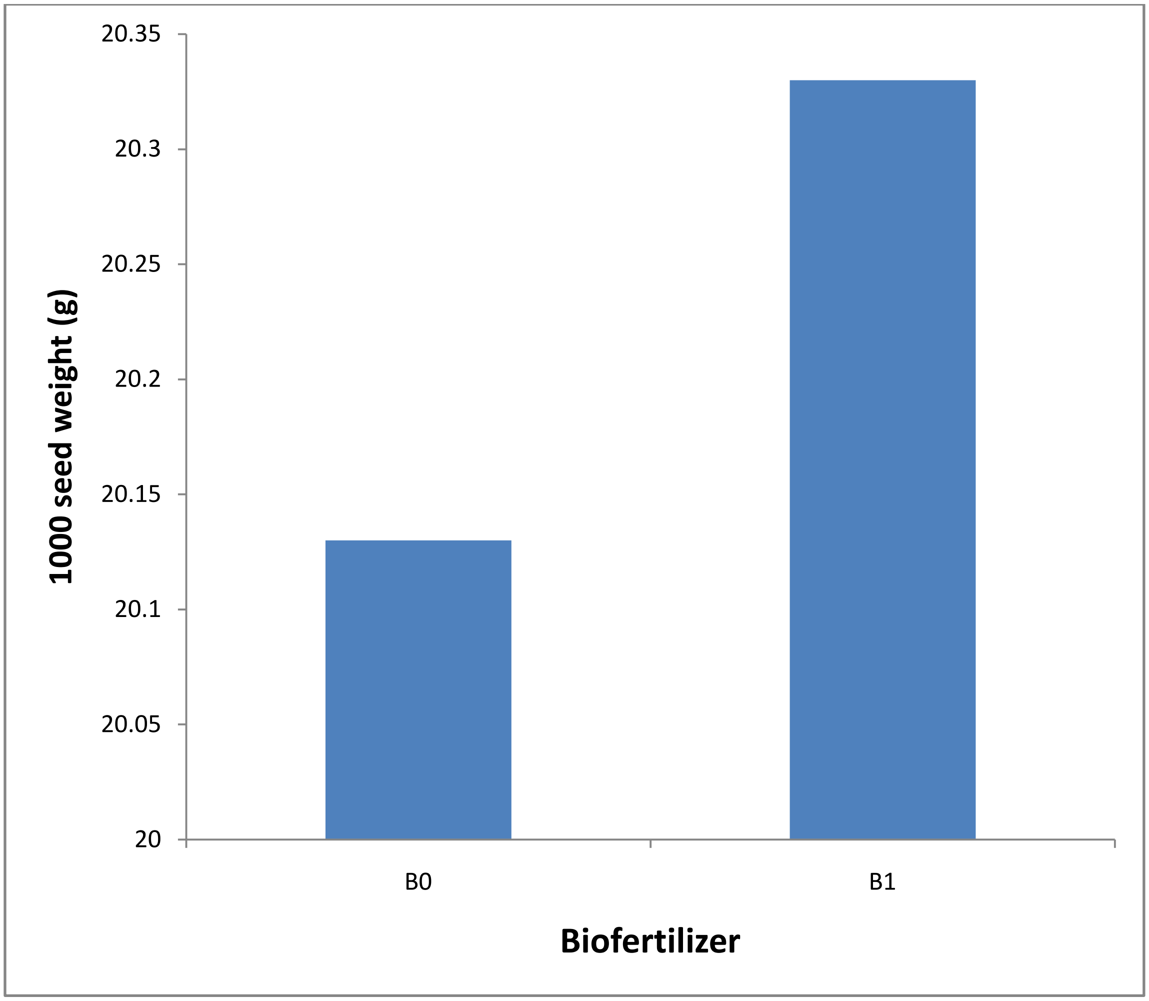
Effect of N+P

Significant influence was noted on 1000 seed weight of lentil due to different N+P level treatments (Fig. 10 and Appendix VII). The figure showed a gradual increase in trend with the increases of higher doses. The highest 1000 seed weight was found with D_3 treatment after that it was reduced markedly with the further higher doses. The highest 1000 seed weight (21.14 g) was obtained from the treatment D_3 (Recommended doses of N+P) which was statistically similar with D_2 (25% less of recommended N+P). The lowest 1000 seed weight (19.30 g) was obtained from the control treatment D_0 (without N+P) which was significantly different from all other treatments followed by D_4 (25% higher of recommended N+P) and D_5 (50% higher of recommended N+P). The result obtained from the present study was similar with the findings of Sarkar and Banik (1991) and Srinivas *et al.* (2002) who reported that higher doses of N+P increased the highest of 1000 seeds.

Combined effect of bio-fertilizer and N+P level

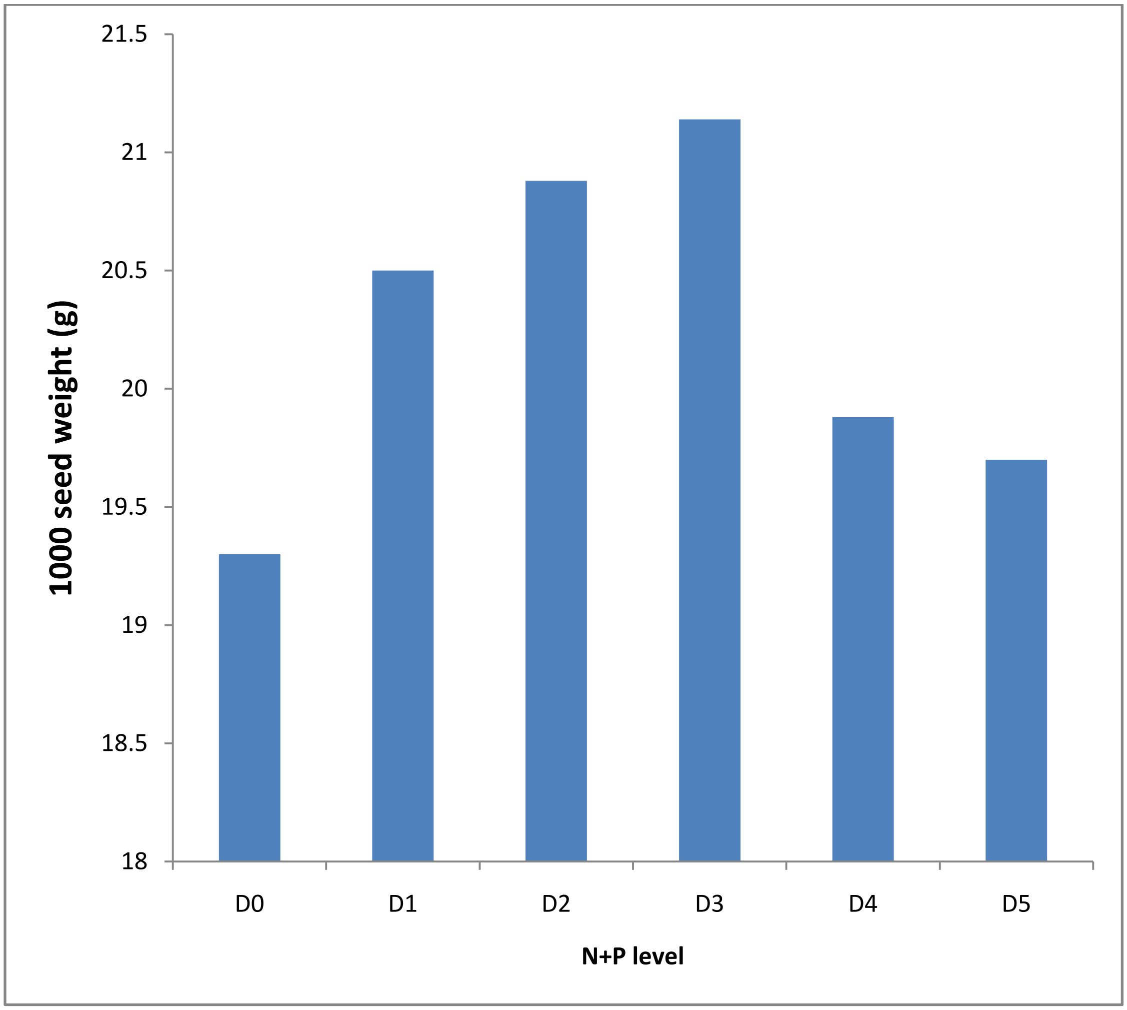
Significant variation was observedd on 1000 seed weight of lentil due to combined effect of bio-fertilizer and N+P levels (Table 3 and Appendix VII). The highest 1000 seed weight (21.20 g) was obtained from the treatment combination of B_1D_3 which was statistically similar with the treatment combination of B_0D_3, B_0D_2 and B_1D_2 (21.07, 20.83 and 20.92 g respectively). The lowest 1000 seed weight (19.00

g) was obtained from the treatment combination of B_0D_0 which was significantly different from all other treatment combinations.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 9. Effect of biofertilizer on 1000 seed weight of lentil ($LSD_{0.05}$ = NS)



Here, D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 10. Effect of N+P level on 1000 seed weight of lentil ($LSD_{0.05}$ = 0.29)

4.2.4 Seed yield

Effect of bio-fertilizer

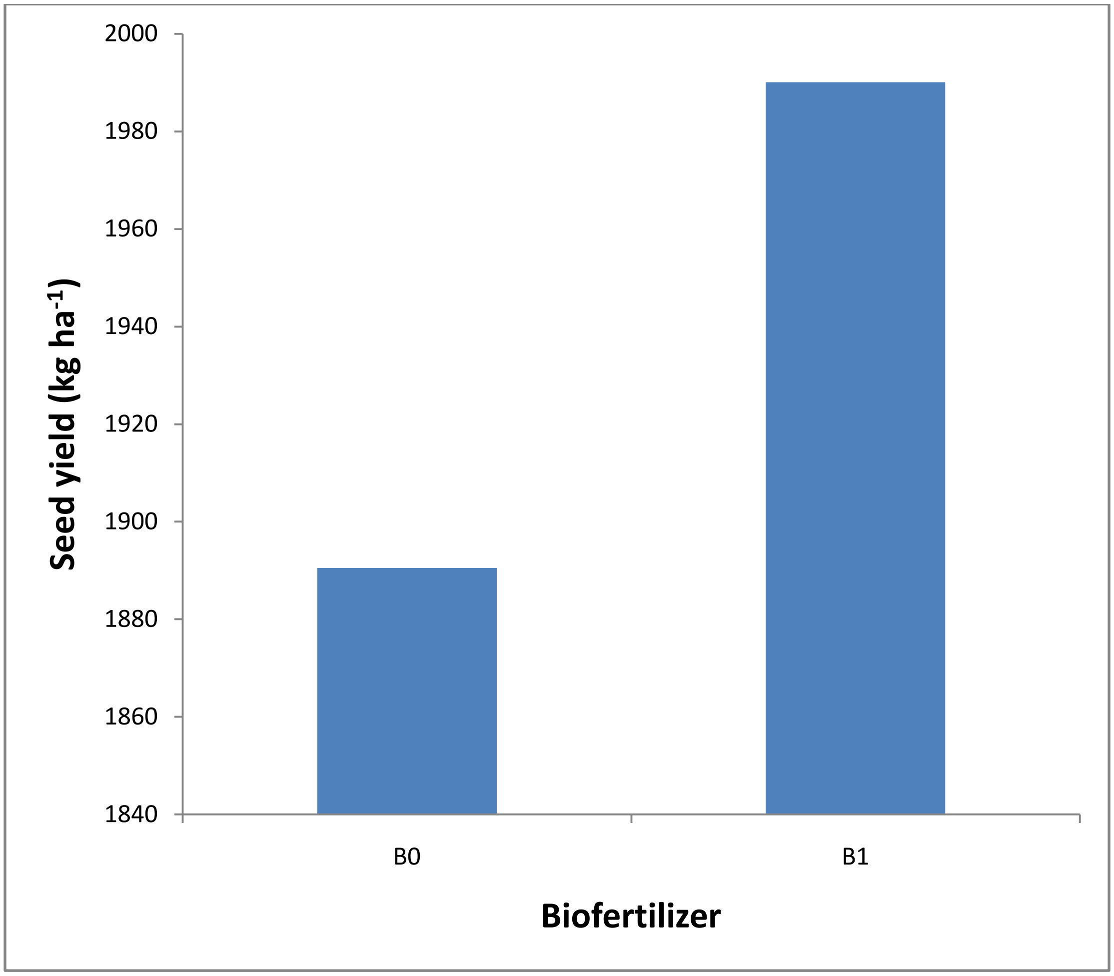
Seed yield of lentil was found significant with the application of different biofertilizer treatment (Fig. 11 and Appendix VII). The figure revealed that B_1 (Bio-fertilizer) showed the superiority by producing 5.27% higher yield over B_0 (without bio-fertilizer). However, the higher seed yield (1990.10 kg ha^{-1}) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) where the lower seed yield (1890.53 kg ha^{-1}) was obtained from the control treatment B_0 (without bio-fertilizer). Similar result was also observed by Dhingra *et al*.(1988) and Sharma and Sharma (2004) who reported that biofertilizer increased seed yield of lentil than without biofertilization.

Effect of N+P level

Variation on seed yield ha^{-1} was noted as significant due to different N+P level treatments (Fig. 12 and Appendix VII). The highest seed yield (2482.65 kg ha^{-1}) was obtained from the treatment D_3 (Recommended doses of N+P) which was significantly different from followed by D_2 (25% less of recommended N+P). The lowest seed yield (1437.15 kg ha^{-1}) was obtained from the control treatment D_0 (without N+P) which was also significantly different from all other treatments.

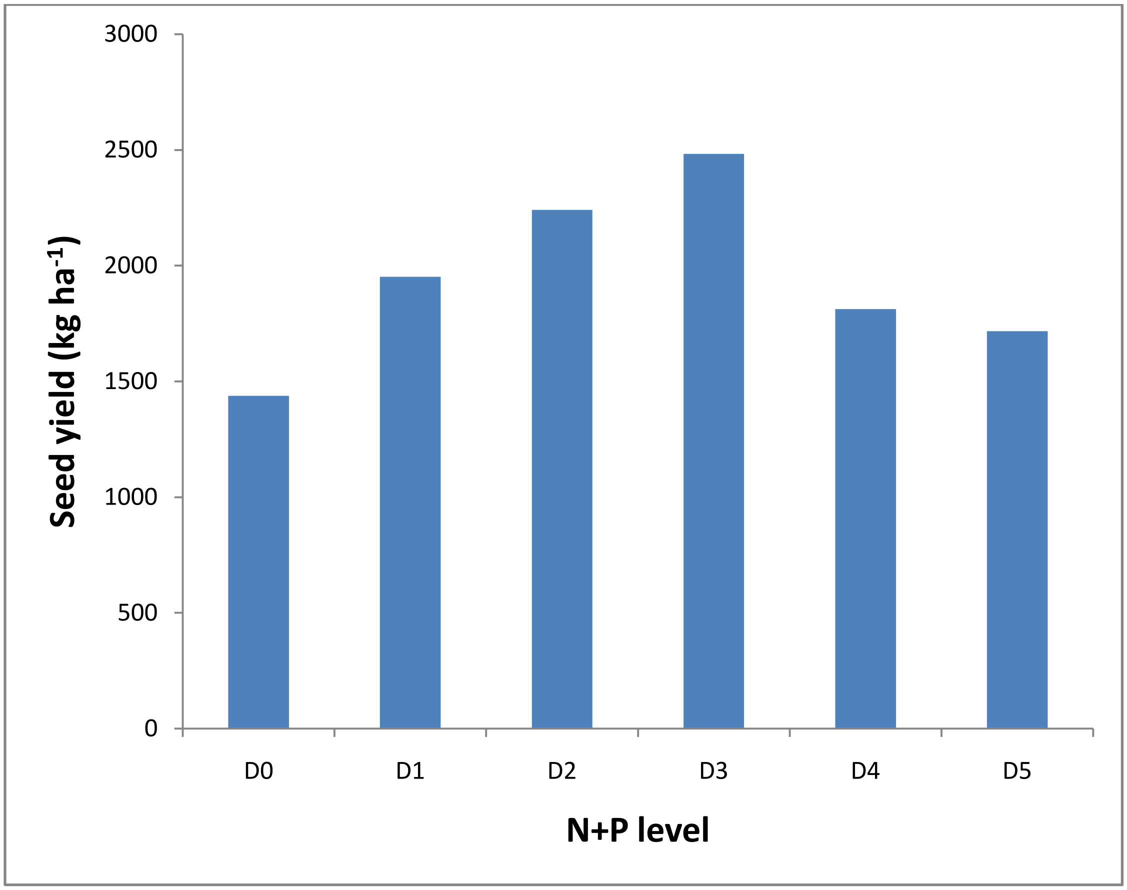
Combined effect of bio-fertilizer and N+P

The recorded data on seed yield was affected significantly by combined effect of bio-fertilizer and N+P level (Table 3 and Appendix VII). The highest seed yield (2576.60 kg ha^{-1}) was obtained from the treatment combination of B_1D_3 which was significantly different from all other treatment combinations followed by B_0D_3. The lowest seed yield (1360.40 kg ha^{-1}) was obtained from the treatment combination of B_0D_0 which was also significantly different from all other treatment combinations followed by B_1D_0.



Here, B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

Fig. 11. Effect of biofertilizer on seed yield of lentil ($LSD_{0.05}$ = 12.53)



Here, D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

Fig. 12. Effect of N+P level on seed yield of lentil ($LSD_{0.05}$ = 10.97)

Table 3. Yield contributing parameters and yield of lentil influenced by combined effect of biofertilizer and N+P level

Treatments	Yield contributing parameters and yield			
	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)	Seed yield (Kg ha^{-1})
B_0D_0	40.38 g	1.18 f	19.00 e	1360.40 l
B_0D_1	56.43 cd	1.65 c	20.33 c	1907.50 f
B_0D_2	61.74 bc	1.88 b	20.83 ab	2186.40 d
B_0D_3	65.88 ab	2.02 ab	21.07 a	2388.70 b
B_0D_4	52.77 de	1.48 de	19.81 d	1787.30 h
B_0D_5	49.76 ef	1.42 de	19.72 d	1712.90 i
B_1D_0	45.94 f	1.32 ef	19.60 d	1513.90 k
B_1D_1	57.89 cd	1.68 c	20.67 bc	1996.90 e
B_1D_2	64.36 ab	1.94 b	20.92 ab	2295.50 c
B_1D_3	69.23 a	2.12 a	21.20 a	2576.60 a
B_1D_4	53.26 de	1.52 cd	19.94 d	1837.00 g
B_1D_5	46.67 f	1.44 de	19.67 d	1720.70 j
$LSD_{0.05}$	5.121	0.16	0.3490	13.56
CV(%)	10.77	6.38	8.52	11.93

B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

4.3 Seed quality parameters

4.3.1 Percent (%) seed germination

Effect of bio-fertilizer

Different biofertilizer treatment had no significant influence on percent (%) seed germination (Table 4 and Appendix V). However, the higher percent (%) seed germination (93.94%) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and the lower percent (%) seed germination (93.39%) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

Significant variation was not found on percent (%) seed germination influenced by different N+P treatments (Table 4 and Appendix V). However, the highest percent (%) seed germination (96.84%) was obtained from the treatment D_3 (Recommended doses of N+P) and the lowest percent (%) seed germination (89.00%) was obtained from the control treatment D_0 (without N+P).

Combined effect of bio-fertilizer and N+P level

Significant variation was not found on percent (%) seed germination as influenced by combined effect of bio-fertilizer and N+P level (Table 4 and Appendix V). However, the highest percent (%) seed germination (97.00%) was obtained from the treatment combination of B_1D_3 and the lowest percent (%) seed germination (88.00%) was obtained from the treatment combination of B_0D_0.

4.3.2 Root length

Effect of bio-fertilizer

There was not significant variation on root length of lentil as influenced by different biofertilizer treatment (Table 4 and Appendix V). However, the higher root length (2.54 cm) was obtained from the treatment B_1 (Bio-fertilizer; 50 gm per 2.5 kg of seeds) and the lower root length (2.42 cm) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P level

Root length was not significantly influenced by different N+P treatments (Table 4 and Appendix V). However, the highest root length (2.94 cm) was obtained from the treatment D_3 (Recommended doses of N+P) and the lowest root length (1.99 cm) was obtained from the control treatment D_0 (without N+P).

Combined effect of bio-fertilizer and N+P level

Root length was not significantly influenced by combined effect of bio-fertilizer and N+P level (Table 4 and Appendix V). However, the highest root length (2.95 cm) was obtained from the treatment combination of B_1D_3 and the lowest root length (1.88 cm) was obtained from the treatment combination of B_0D_0.

4.3.3 Shoot length

Effect of bio-fertilizer

Shoot length was not significantly influenced by different biofertilizer treatment (Table 4 and Appendix V). However, the higher shoot length (5.56 cm) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and the lower shoot length (5.30 cm) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P level

There observed a significant variation on shoot length of lentil as influenced by different N+P level treatments (Table 4 and Appendix V). The highest shoot length (6.43 cm) was obtained from the treatment D_3 (Recommended doses of N+P) which was significantly different from all other treatments followed by D_2 (25% less of recommended N+P). The lowest shoot length (4.30 cm) was obtained from the control treatment D_0 (without N+P) which was also significantly different from all other treatments.

Combined effect of bio-fertilizer and N+P level

The recorded data on shoot length was significantly influenced by combined effect of bio-fertilizer and N+P level in lentil (Table 4 and Appendix V). The highest shoot length (6.52 cm) was obtained from the treatment combination of B_1D_3

which was statistically similar with the treatment combination of B_0D_3 and B_1D_2 (6.33 and 6.14 cm respectively). The lowest shoot length (4.00 cm) was obtained from the treatment combination of B_0D_0 which was significantly different from all other treatment.

4.3.4 Seed vigor index

Effect of bio-fertilizer

Significant variation was observed on seed vigor index of lentil as influenced by different biofertilizer treatment (Table 4 and Appendix V). The higher seed vigor index (526.88) was obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds). The lower seed vigor index (499.34) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P level

Different N+P treatments had significant influence on seed vigor index of lentil (Table 4 and Appendix V). The highest seed vigor index (625.12) was obtained from the treatment D_3 (Recommended doses of N+P) which was significantly different from all other treatments. The lowest seed vigor index (384.99) was obtained from the control treatment D_0 (without N+P) which was also significantly different from all other treatments.

Combined effect of bio-fertilizer and N+P level

Significant variation was remarked on seed vigor index as influenced by combined effect of bio-fertilizer and N+P level of lentil (Table 4 and Appendix V). Results revealed that the highest seed vigor index (635.39) was obtained from the treatment combination of B_1D_3 which was significantly different from all other treatment combinations. The lowest seed vigor index (353.88) was obtained from the treatment combination of B_0D_0 which was also significantly different from all other treatment combinations.

Table 4. Seed quality parameters of lentil influenced by bio-fertilizer, N+P level and their interaction

Treatments	Seed quality parameters			
	Seed germination (%)	Root length (cm)	Shoot length (cm)	Seed vigor index
Effect of bio-fertilizer				
B_0	93.39	2.42	5.30	499.34 b
B_1	93.94	2.54	5.56	526.88 a
$LSD_{0.05}$	NS	NS	NS	10.28
CV(%)	8.36	4.88	5.29	8.31
Effect of N+P level				
D_0	89.00	1.99	4.30 f	384.99 f
D_1	95.00	2.58	5.67 c	540.77 c
D_2	96.50	2.70	6.02 b	583.65 b
D_3	96.84	2.94	6.43 a	625.12 a
D_4	93.33	2.42	5.33 d	499.40 d
D_5	91.33	2.26	4.85 e	444.75 e
$LSD_{0.05}$	NS	NS	0.23	11.83
CV(%)	8.36	4.88	5.29	8.31
Combined effect of bio-fertilizer and N+P level				
B_0D_0	88.00	1.88	4.00 g	353.88 l
B_0D_1	94.67	2.55	5.61 c	533.65 f
B_0D_2	96.33	2.62	5.90 bc	570.97 d
B_0D_3	96.67	2.92	6.33 a	614.84 b
B_0D_4	93.33	2.36	5.17 de	484.88 h
B_0D_5	91.33	2.18	4.77 ef	437.82 j
B_1D_0	90.00	2.10	4.60 f	416.10 k
B_1D_1	95.33	2.60	5.72 c	547.89 e
B_1D_2	96.67	2.77	6.14 ab	596.32 c
B_1D_3	97.00	2.95	6.52 a	635.39 a
B_1D_4	93.33	2.47	5.48 cd	513.92 g
B_1D_5	91.33	2.33	4.92 ef	451.67 i
$LSD_{0.05}$	NS	NS	0.39	12.76
CV(%)	8.36	4.88	5.29	8.31

B_0 = Control (without bio-fertilizer), B_1 = Bio-fertilizer

D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P, D_5 = 50% higher N+P

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2017 to March 2018 to examine the effect of nitrogen, phosphorus and bio-fertilizer on yield and seed quality of lentil. The experiment consisted of two factors *viz*. (1) Factor A: two biofertilizer levels; (i) B_0 = 0 (Control; without Bio-fertilizer) and (ii) B_1 = Bio-fertilizer (50 g per 2.5 kg of seeds) and (2) Factor B: six nitrogen and phosphorus levels; D_0 = Control (without N+P), D_1 = 50% less N+P, D_2 = 25% less N+P, D_3 = Recommended doses of N+P, D_4 = 25% higher N+P and D_5 = 50% higher N+P. The experiment was conducted in Randomized Complete Block Design (factorial) with three replications. Data on different growth and yield parameters and also seed quality parameters were recorded. The collected data were statistically analyzed for assessment of the treatment effect. A significant variation among the treatments was found while Biofertilizer application and different levels of N+P fertilizers applied in different combinations.

Regarding biofertilozer effect, in terms of growth parameters, plant height and number of branches plant^{-1} was not significantly affected. However, the highest plant height (11.94, 25.79 and 29.78 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (2.14, 6.93 and 10.94 at 30, 60 and 90 DAS, respectively) were obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) whereas lowest plant height (11.52, 24.91 and 29.00 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (1.86, 6.58 and 10.94 at 30, 60 and 90 DAS, respectively) were obtained from the control treatment B_0 (without bio-fertilizer). Considering yield contributing parameters and yield, all the studied parameters were significantly affected by biofertilizer treatments except number of seeds pod^{-1} and 1000 seed weight. However, the highest number of pods plant^{-1}

(56.23), number of seeds pod^{-1} (1.67), 1000 seed weight (20.33 g) and seed yield (1990.10 kg ha^{-1}) were obtained from the treatment B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) whereas the lowest number of pods plant^{-1} (54.49), number of seeds pod^{-1} (1.61), 1000 seed weight (20.13 g) and seed yield (1890.53 kg ha^{-1}) were obtained from the control treatment B_0 (without bio-fertilizer). Considering seed quality parameters, non-significant influence was found on percent (%) seed germination, root length and shoot length but seed vigor index was significantly influenced by biofertilizer treatments. However, the highest percent (%) seed germination (93.94%), root length (2.54 cm), shoot length (5.56 cm) and seed vigor index (526.88) were obtained from the treatment B_1 (Bio-fertilizer; 50 gm per 2.5 kg of seeds) whereas the lowest percent (%) seed germination (93.39%), root length (2.42 cm), shoot length (5.30 cm) and seed vigor index (499.34) was obtained from the control treatment B_0 (without bio-fertilizer).

Regarding N+P fertilizer effect, in terms of growth parameters, the highest plant height (13.32, 28.46 and 34.05 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (3.17, 7.60 and 12.65 at 30, 60 and 90 DAS, respectively) were obtained from the treatment D_3 (Recommended doses of N+P) whereas the lowest plant height (10.00, 21.85 and 24.02 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (1.17, 5.41 and 9.15 at 30, 60 and 90 DAS, respectively) were obtained from the control treatment D_0 (without N+P). Considering yield contributing parameters and yield, all the studied parameters were significantly affected by N+P fertilizer treatments. The highest number of pods plant^{-1} (67.56), number of seeds pod^{-1} (2.07), 1000 seed weight (21.14 g) and seed yield (2482.65 kg ha^{-1}) were obtained from the treatment D_3 (Recommended doses of N+P) where as the lowest number of pods plant^{-1} (43.16), number of seeds pod^{-1} (1.25), 1000 seed weight (19.30 g) and seed yield (1437.15 kg ha^{-1}) was obtained from the control treatment D_0 (without N+P). Considering seed quality parameters, N+P fertilizer treatments showed significant effect on shoot length and seed vigor index only but the highest percent (%) seed germination (96.84%), highest root length (2.94 cm), highest shoot length (6.43 cm) and highest seed vigor index (625.12) were also obtained from the treatment D_3 (Recommended doses of N+P) where lowest percent (%) seed germination (89.00%), root length (1.99 cm), shoot length (4.30 cm) and seed vigor index (384.99) was obtained from the control treatment D_0 (without N+P).

Regarding combined effect of biofertilizer and N+P fertilizer treatments, in terms of growth parameters, the highest plant height (13.36, 28.55 and 34.23 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (3.33, 7.67 and 12.82 at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of B_1D_3 where the lowest plant height (9.58, 21.14 and 23.92 cm at 30, 60 and 90 DAS, respectively) and number of branches plant^{-1} (1.00, 4.87 and 8.38 at 30, 60 and 90 DAS, respectively) were obtained from the treatment combination of B_0D_0. Considering yield contributing parameters and yield, all the studied parameters were significantly affected by combined effect of biofertilizer and N+P treatments. The highest number of pods plant^{-1} (69.23), number of seeds pod^{-1} (2.12), 1000 seed weight (21.20 g) and seed yield (2576.60 kg ha^{-1}) were obtained from the treatment combination of B_1D_3 where the lowest number of pods plant^{-1} (40.38), number of seeds pod^{-1} (1.18), 1000 seed weight (19.00 g) and seed yield (1360.40 kg ha^{-1}) were obtained from the treatment combination of B_0D_0. Considering seed quality parameters, all the parameters were significantly affected by combined effect of biofertilizer and N+P treatments except percent (%) seed germination and root length. However, the highest percent (%) seed germination (97.00%), root length (2.95 cm), shoot length (6.52 cm) and seed vigor index (635.39) was obtained from the treatment combination of B_1D_3 where lowest percent (%) seed germination (88.00%), root length (1.88 cm), shoot length (4.00 cm) and seed vigor index (353.88) was obtained from the treatment combination of B_0D_0.

Conclusion

From the above results, it can be concluded that application of biofertilizer and N+P treatment combinations is very much promising for higher lentil yield and better quality of seed. Comparing control treatment, the treatment combination of B_1 (Bio-fertilizer; 50 g per 2.5 kg of seeds) and D_3 (Recommended doses of N+P) showed better performance for lentil growth and yield and also seed quality. However, the bio-fertilizer, 50 g per 2.5 kg of seeds with recommended doses of N + P treatment combination was the best under the present study.

Recommendation

The present research work was carried out at the Sher-e-Bangla Agricultural University in one season only. Further trial of this work in different locations of the country is needed to justify the present results.

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APPENDICES

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

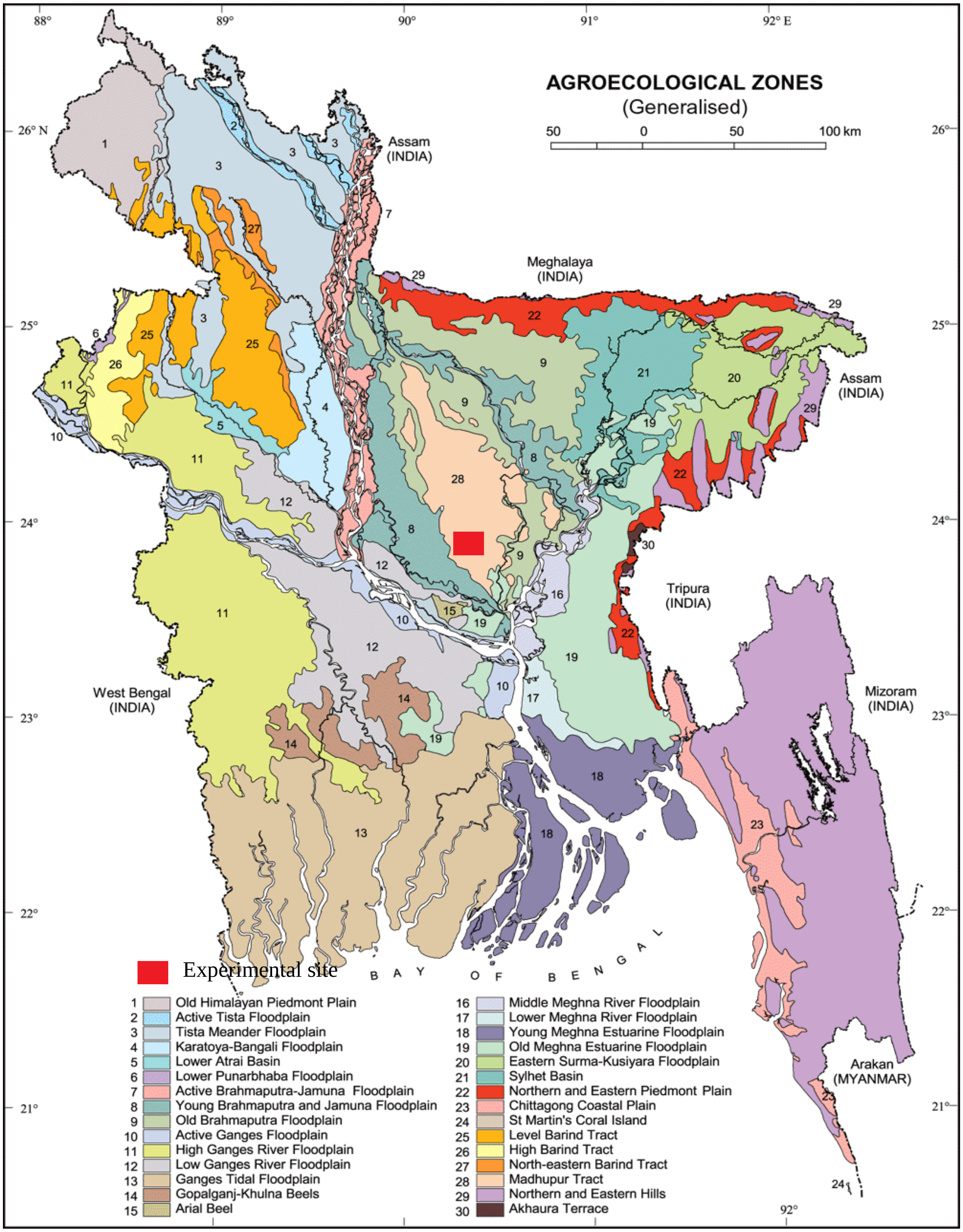

Fig. 13. Experimental site

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

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

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

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

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

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

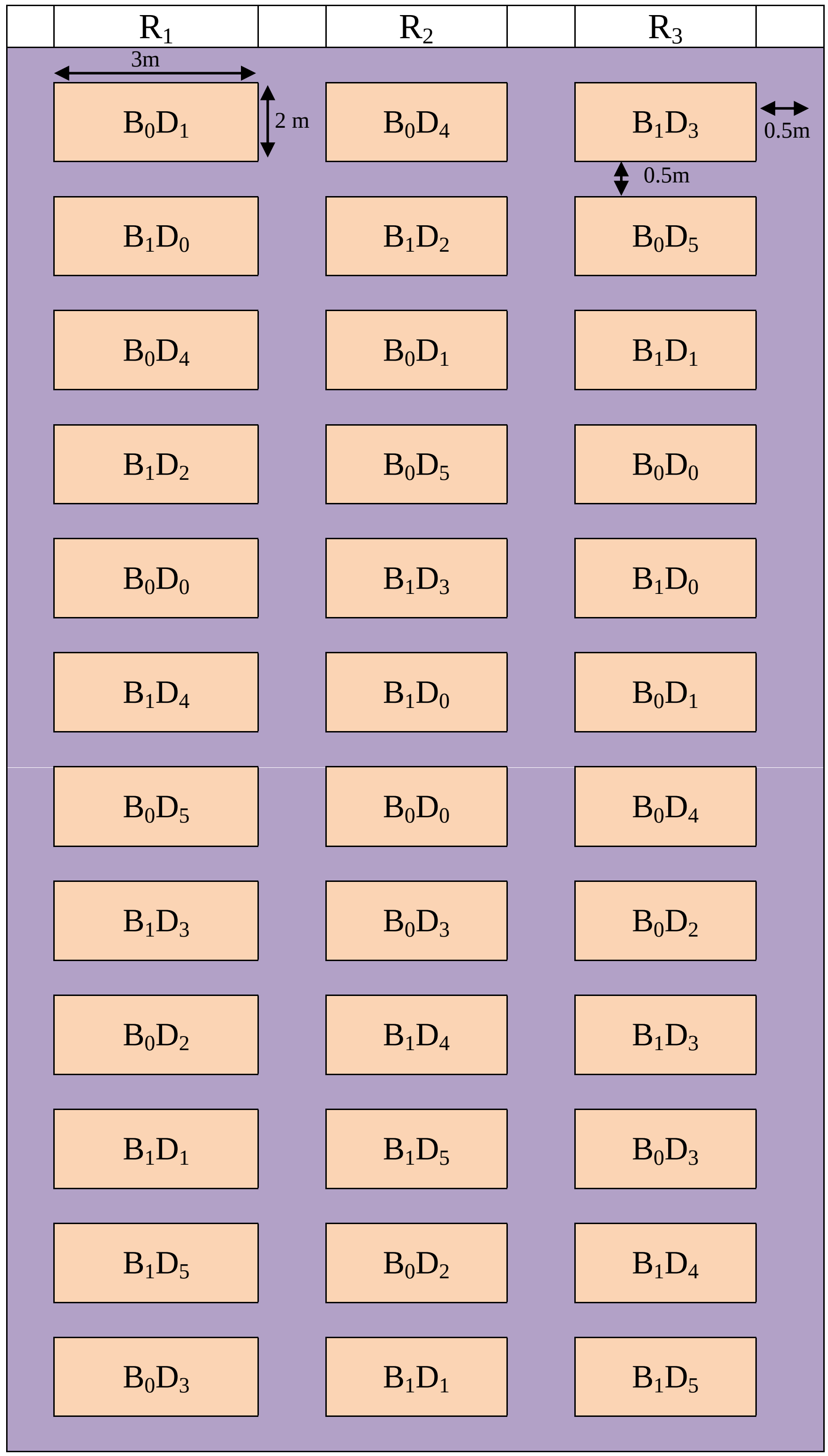

Fig. 14. Layout of the experimental plot

Appendix VI. Plant height of lentil as influenced by bio-fertilizer and N+P the interaction and combination at different growth stages

Sources of variation	Degrees of freedom	Mean square of plant height (cm) at		
		30 DAS	60 DAS	90 DAS
Replication	1	3.261	5.79	4.822
Factor A	1	NS	NS	NS
Factor B	5	NS	172.4*	158.083*
AB	5	NS	26.653*	42.263*
Error	11	2.079	3.513	4.361

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

Appendix VII. Number of branches plant^{-1} as influenced by the interaction bio-fertilizer and N+P in lentil at different days after sowing.

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1} at		
		30 DAS	60 DAS	90 DAS
Replication	1	0.522	1.321	1.052
Factor A	1	NS	NS	NS
Factor B	5	0.289	0.376	1.065
AB	5	NS	NS	0.178*
Error	11	0.074	0.104	0.274

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

Appendix VIII. Yield contributing parameters and yield of lentil influenced by combined effect of biofertilizer and N+P level

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters and yield			
		Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)	Seed yield (Kg ha^{-1})
Replication	1	2.311	0.132	1.711	35.665
Factor A	1	71.263*	NS	NS	5047.07*
Factor B	5	142.412*	0.538*	12.921*	8515.74*
AB	5	43.304*	0.411**	4.042*	178.072*
Error	11	2.152	0.236	1.227	21.305

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

Appendix IX. Seed quality parameters of lentil influenced by bio-fertilizer, N+P level and their interaction

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Seed germination (%)	Root length (cm)	Shoot length (cm)	Seed vigor index (%)
Replication	1	3.522	0.014	0.922	52.338
Factor A	1	NS	NS	NS	8871.364*
Factor B	5	NS	NS	5.314*	1352.436*
AB	5	178.293**	0.106*	0.241*	1483.116*
Error	11	21.307	0.044	0.327	48.671

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