GROWTH AND YIELD RESPONSE OF LENTIL TO RHIZOBIUM STRAINS AND DIFFERENT NUTRIENTS MANAGEMENT

SOMAYA SIDDIQUE

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR DHAKA-1207

DECEMBER, 2020

GROWTH AND YIELD RESPONSE OF LENTIL TO RHIZOBIUM STRAINS AND DIFFERENT NUTRIENTS MANAGEMENT

By

SOMAYA SIDDIQUE

Reg. No. 18-09093

A Thesis

Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2020

Approved by:

Prof. Dr. Md. Fazlul Karim	**Prof. Dr. H. M. M. Tariq Hossain**
Supervisor	**Co-Supervisor**

Prof. Dr. Tuhin Suvra Roy

Chairman

Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "***GROWTH AND YIELD RESPONSE OF LENTIL TO RHIZOBIUM STRAINS AND DIFFERENT NUTRIENTS MANAGEMENT***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.) in AGRONOMY****, embodies the result of a piece of bona-fide research work carried out by* ***Somaya Siddique,*** *Registration no.* ***18-09093*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Place: Dhaka, Bangladesh

Prof. Dr. Md. Fazlul Karim
Department of Agronomy
Sher-e-Bangla Agricultural University,
Dhaka-1207

ACKNOWLEDGEMENTS

All praises to the Almighty Allah, the Great, the Gracious, Merciful and Supreme ruler of the universe Who enables me to complete this piece of work for the degree of Master of Science (M.S.) in the Department of Agronomy.

The author would like to express deepest sense of gratitude and respect to research supervisor, ***Prof. Dr. Md. Fazlul Karim****, Department of Agronomy, Sher- e-Bangla Agricultural University, for his kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, extending generous help and encouragement during the research work and also in preparation of the manuscript.*

The author sincerely expresses her deepest respect and boundless gratitude to her co-supervisor ***Prof. H. M. M. Tariq Hossain****, Department of Agronomy, for his helpful suggestion and valuable advice during the preparation of this manuscript.*

The author would like to express her deepest respect and boundless gratitude to all respected teachers of the Dept. of Agronomy, Sher-e-Bangla Agricultural University, for this valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and suggestions and encouragement to research work. The author would like to express her cordial thanks to the departmental and field staff for their active help during the experimental work.

The author feels proud to express her sincere appreciation and gratitude to Ministry of Science and Technology, The People's Republic of Bangladesh for providing her National Science and Technology (NST) fellowship.

At last but not the least, the author feels indebtedness to her beloved parents and husband whose sacrifice, inspiration, encouragement and continuous blessing paved the way to her higher education.

GROWTH AND YIELD RESPONSE OF LENTIL TO RHIZOBIUM STRAINS AND DIFFERENT NUTRIENTS MANAGEMENT

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, to study the effect of *Rhizobium* strains and different nutrient management on growth and yield response of lentil, during rabi season from November 2019 to March 2020. The experiment was consisted of two factors. Factor A: *Rhizobium* strains (2) ;1. R_1= BARI RLc-102 and 2. R_2= BARI RLc-104 and Factor B: Different nutrient management (6); F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 of Urea, TSP, MoP kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3= Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}). The experiment was laid out in split plot design with three replications. Growth and yield, and yield contributing parameters like plant height, branches $plant^{-1}$, thousand seed weight, seed yield, stover yield, biological yield were collected and compared for different treatments. Results revealed that between the *Rhizobium* strains, R_1 (BARI RL_C- 102) treated plot had numerically the maximum number of pod $plant^{-1}$ (50.73), seeds $pods^{-1}$ (1.95), 1000-seeds weight (22.39 g), seed yield (1884.1 kg ha^{-1}), stover yield (2128.3 kg ha^{-1}) and biological yield (4012.4 Kg ha^{-1}) of lentil. On the other hand, among different nutrient management, F_1 (recommended chemical fertilizer (N+P+K) dose) treated plot had numerically the maximum plant height (17.2, 34.715, 41.26, and 39.875 cm at 30, 70, 90 DAS and harvest respectively), branches $plant^{-1}$ (3.83, 7.85, 10.30,11.43 and 12.145 at 30, 50, 70, 90 DAS and harvest respectively), above ground dry weight $plant^{-1}$ (0.27, 0.92, 1.90, 4.92, and 6.48 g at 30, 50, 70, 90 DAS and harvest respectively), pods $plant^{-1}$ (64.56), 1000 seed weight (24.31 g), seed yield (2255.2 kg ha^{-1}), stover yield (2421.0 kg ha^{-1}) and biological yield (4676.2 kg ha^{-1}). In case of combined effect, (R_1= BARI RL_C-102, along with F_1= recommended dose of fertilizer) R_1F_1 treatment combination was found, superior in producing maximum pods $plant^{-1}$ (65.2), 1000 seed weight (24.33 g), seed yield (2220 kg ha^{-1}) stover yield (2575.33 kg ha^{-1}) and biological yield (4795.33 kg ha^{-1}). So *Rhizobium* strains (R_1) along with recommended fertilizer management application may improve the growth, yield and yield contributing characters of lentil.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENT (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
Co	Cobalt
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAE	Department of Agricultural Extension
DAS	Days after sowing
^0C	Degree Celsius
et al	And others
FAO	Food and Agriculture Organization
g	gram(s)
ha^{-1}	Per hectare
HI	Harvest Index
kg	Kilogram
Max	Maximum
mg	Milligram
Min	Minimum
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not significant
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource Development Institute
TSP	Triple Super Phosphate
UPOV	Union for the Protection of Plant Varieties
Wt.	Weight

CHAPTER I
INTRODUCTION

Lentil (*Lens culinaris*) belongs to the family Fabaceae. It is a nutritious food legume. It is one of the oldest annual grains legumes more consumed and cultivated in the world and mostly eaten as dhal. Lentil was originated from South Western Asia as early as 6000 B.C. Lentil is rich in protein and also contains high concentration of essential amino acid as isoleucine and lysine, as well as other nutrients like minerals and fiber, folate, vitamin B1 (Rozan *et al*., 2001). Lentil is also known as a "poor man's meat" because of its rich protein content. In South East Asia lentil is also equally liked by all socioeconomic groups (Bhatty, 1988).

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 *Rhizobium* bacteria in the field and due to which yield could be increased up to 2 ton ha^{-1} (Bisen *et al*., 1980). Small doses of N fertilizers applied to an annual pulse are beneficial if nodule initiation is delayed (Mahon and Child, 1979). 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 (Mclaren and Cameron, 1996; Ali *et al.*, 1997). 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.

Nutrition is essential for proper growth and high grain yield of lentil. Genotype of lentils may show a differential response to nutrients. Like mort annual legumes, lentil can provide a part of its own N requirement though synoptic N_2 fixation when the plants are inoculated. Sonulski and Buchan (1978) reported that Rhizobial inoculation alone is not enough for obtaining high yield of legumes because of poor nodulation & nitrogenase activity. They concluded that annual legumes may require a high level of plant N fertility to achieve maximum yield. Small doses of N fertilizers applied to an annual pulse are beneficial if nodulation initiation is delayed (Mohon and Child, 1979), In dry land cultivation 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), similarly application of fertilizer N increased dry bean 8 (*Phareolus vulgaris l.)* seed yield proportionally in southern Manitoba (Mc Andrew and Mills, 2000). Organic manures as a source of plant nutrients for cultivation of field crops has received worldwide attention due to rising costs, rapid nutrient loss and adverse environmental impacts from inorganic fertilizers. Cowdung has long been recognized as perhaps the most desirable animal manures because of its high nutrient & organic matter content for degraded soil which may lead to the increasing activity of beneficial soil organisms as well as the fertility status of soil by increasing the availability of nutrients for the plants from soil. Poultry manure as an organic fertilizer obtained from doping of birds. The use of poultry manure is being used for the increased production of various vegetables, pulses and others crops. Many reports have shown the significant increase in the production of lady finger, cucumber, maize, lentil after adding poultry manure in the fields (Farhad *et al*., 2009; Islam *et al*., 2014; Hadiuzamman *et al.,* 2015; Maqshoof *et al.,* 2015). Well rotted farmyard manure is a soil enriching product, produced from organic matter that helps to boost the nutrient levels and properties of the soil. Vermicompost stimulates to influence the microbial activity of soil, increase the availability of oxygen, maintains normal soil temperature, increase soil porosity & infiltration of water, improvers nutrient content & increase growth, yield & quality of the plant.

Different reviews suggested that there in a scope to improve growth and yield of lentil by using a good combination of *Rhizobium* strain and nutrient sources so present study was taken with above fact with the following objectives:

I. To study the effect of different *Rhizobium* strains on lentil.
II. To assess the influence of different nutrient sources on lentil.
III. To determine the combined effect of *Rhizobium* strain and different nutrient management on the growth & yield of lentil.

CHAPTER 2

REVIEW OF LITERATURE

An attempt was made in this section to collect and study the relevant information available in the country and abroad regarding the influence of biofertilizer, different nutrient sources on nodulation, growth and yield of lentil to gather knowledge helpful in conducting the present research work and subsequently writing up the results and discussion.

2.1. Effect of bio-fertilizers 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 a routine phenomena for most growers.

The application of biofertilizers, micronutrients and recommended dose of fertilizers 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) revealed that the Combination of 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 40kg P_2O_5 /ha 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 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) 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.

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.

Lentil is a legume and fulfils most of its N requirement through atmospheric N_2fixation with the symbiotic help of rhizobia living in its root nodules. Generally, the level of N_2 fixation in legumes depends on host genotypes, rhizobial strains, environment and their combineds. Lentil cultivars have shown genetic variability in their ability to symbiotically fix N_2 therefore genotypes with high N_2 fixation and high seed yield are desirable for sustainable agriculture.

Several researches carried out to assess the source of nitrogen (N_2 fixation, soil and fertilizer), N assimilation, partitioning and mobilization in rainfed lentil at various growth stages using 15N isotopic dilution. Nitrogen for developing pods can be supplied from soil, atmospheric N_2, and from the mobilization of existing N in plant tissues. The relative importance of these sources depends on several factors including plant species, genotype, drought stress, plant and soil N status, and N_2 fixation ability. Grain legumes respond most strongly to inoculation when they are introduced into new areas where soils lack appropriate rhizobia (Van Kessel and Hartley, 2000). There is presumably a yield advantage to crop inoculation in soils with inadequate inorganic N supply. However, the yield response to inoculation was highly variable and affected by inherent field variability, and by differences in environmental and edaphic conditions.

Effective indigenous strains of *Rhizobium leguminosarum biovarviciae* are lacking in most prairie soils, and therefore inoculation is essential to ensure adequate nodulation and N fixation for maximum yields (Bremer *et al*., 1980). When chickpea (*Cicer arietinum*) and lentil were introduced to North America, both crops responded strongly to inoculation. In subsequent years, and as the resident population of effective rhizobia in soils increased, N_2 fixation remained significant but responses to further inoculation diminished (Bremer *et al*., 1989). Mengel (1994) concluded that nitrogenase activity is a flexible process that adjusts to the N demand of the host. The amount of N_2 fixed becomes much more dependent on the demand of N by the host than on the intrinsic capacity of the rhizobia to fix N.

2.2. Effect of chemical fertilizers on nodulation, growth & yield

Nutrition is essential for proper growth and high grain yield of lentil. Genotype of lentils may show a differential response to nutrients. Like most annual legumes, lentil can provide a part of its own N requirement through symbiotic N_2 fixation when the plants are inoculated with Rhizobium strains.

Sosulski and Buchan (1978) reported that Rhizobial inoculation alone is not enough for obtaining high yield 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. Small doses of N fertilizers applied to an annual pulse are beneficial if nodulation initiation is delayed (Mohon and child, 1979), In dry land cultivation of 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), similarly application of fertilizer N increased dry bean 8 (*Phareolus vulgaris* l.) seed yield proportionally in southern Manitoba (Mc Andrew and Mills, 2000). Phosphorus plays a major role in many plant processes, including storing and transfer of energy, stimulation of root growth, flowering, fruiting, seed formation, nodule development and N_2 fixation (McLasen and Camenon, 1996; Ali *et al*,. 1997), Phosphorus application on legume can also increase leaf area, yield of top, roots and grain, nitrogen concentration in tops and grain; number and weight of nodules on roots and increased acetylene reduction rate of the nodules (Jossep *et al.*, 1999, Yahiya *et al*, 1995) Potassium (K) is becoming increasingly important for pulse crops. Pulse crops showed yield benefit from potassium application. Improved potassium supply also enhances biological nitrogen fixation & protein content of pulse grains (Srinivasarao *et al.*, 2003).

Malik *et al.* (2003) carried out a field experiment on bean in Pakistan 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 bean cv. NM-98. Although plant population was not affected significantly, various growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted in the maximum seed yield (1,113 kg ha^{-1}). Protein content (25.6%) was maximum in plots treated with 50 kg N + 75 kg P ha^{-1}, followed by 25.1% protein content in plots treated at 25 kg N + 75 kg P ha^{-1}. The highest net income (Rs. 21,375) was obtained by applying 25 kg N + 75 kg P ha^{-1}.

Srinivas and Shaik (2002) conducted field experiment during the kharif seasons to study the effects of N (0, 20, 40 and 60 kg ha^{-1}) and P (0, 25, 50 and 75 kg ha^{-1}) along with seed inoculation with *Rhizobium* culture on the growth and yield components of greengram. Plant height generally increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} followed by decrease with further increase in N. Number of seeds pod^{-1}, 1000-seed weight, seed and haulm yields generally increased. Seed inoculation with *Rhizobium* resulted in higher values for the parameters measured relative to the control. The combined effects between N and P were not significant for the number of pods $plant^{-1}$, pod length, seed and haulm yield.

Patel *et al.* (2003) conducted a field experiment in Gujrat, India during the summer seasons of 1995 to 1998 on sandy loam soils to determine the suitable sowing date, and nitrogen and phosphorus requirements of summer lentil (cv. GM3). Treatments comprised: all the 27 combinations of three sowing dates: 15 February, 1 March and 15 March; three nitrogen rates:

10, 20 and 30 kg N ha^{-1}; and three phosphorus rates: 20, 40 and 60 P ha^{-1}. Results indicated that sowing lentil on 1 March recorded significantly higher grain yields, 37 and 16% higher than those of early (15 February) or late-sown crops (15 March), respectively. Application of 10 kg N ha^{-1} recorded significantly higher grain yield over the control. Treatment with 40 kg P ha^{-1} produced 15 and 18% higher grain yields than treatments with 20 and 60 kg P ha^{-1}, respectively. The highest net return of Rs. 18,240 ha^{-1} was recorded from lentil sown on 1 March and treated with 20 kg N ha^{-1} and 40 kg P ha^{-1}.

Sharma *et al.* (2001) carried out a field experiment on mungbean cv. Pusa Baisakhi which was fertilized with various levels of nitrogen (0, 10 and 20 kg N ha^{-1}) and phosphorus (0, 30 and 60 kg $P_2O_5 ha^{-1}$) under mid-hill conditions in Himachal Pradesh, India during the kharif seasons of 1998 and 1999. The highest levels of N and P_2O_5 applications resulted in the average maximum test weight, biological and grain yields, harvest index and seed protein content.

Ashraf *et al.* (2003) conducted a field experiment at Faisalabad in Pakistan to observe the effects of seed inoculation of a biofertilizer and NPK application on the performance lentil cv. NM-98. The treatments consisted of the seed inoculation of *Rhizobium* phaseoli singly or in combination with 20:50:0, 40:50:0 or 50:50:50 NPK kg ha^{-1} (urea), P (single super phosphate) and K (potassium sulphate) were applied during sowing. The tallest plants (69.9 cm) were obtained with seed inoculation + 50:50:0 kg NPK ha^{-1}. Seed inoculation + 50:50:0 or 50:50:50 kg ha^{-1} resulted in the highest number of pods $plant^{-1}$ (29.0, 56.0, 63.9 and 32.6, respectively) and seed yield (1,053, 1,066, 1,075 and 1,072 kg ha^{-1}). Harvest index was the highest with seed inoculation in combination with NPK and 40:50:0 (25.23), 50:50:0 (24.70) or 50:50:50 (27.5). Seed inoculation along with NPK at 30:50:0 kg ha^{-1} was optimum for the production of high seed yield by lentil cv. NM-98.

Sangakhara (2003) carried out a field experiment in Sri Lanka in 1999 to determine the impact of effective microorganisms (EM) on N dynamics in a cereal (maize cv. Ruwan)-legume (mungbean) cropping system, using 15N labeled maize or mungbean residues. EM increased the 15N concentrations of maize at the V8 growth stage indicating better use of applied nutrients from organic matter. The uptake of 15N was greater from mungbean residues rather than from maize. EM also increased biological N fixation. The synergistic effects of EM in organic systems were evident from this field study.

Panda *et al.* (2003) conducted field experiments in West Bengal, India to evaluate the effects of NK application on the productivity of yambean (*Pachyrhizus erosus*)-pigeonpea (*Cajanus cajan*) intercropping system and its residual effect on the succeeding mungbean (*Vigna radiata).* Marketable tuber yield of yambean increased linearly with increasing NK levels, with the highest being recorded with NK at 80 kg ha^{-1} applied in 2 splits (22.9 t ha^{-1}) closely followed by 100 kg NK ha^{-1} applied in 2 splits (22.4 t ha^{-1}). For pigeonpea, the maximum grain (14.38 q ha^{-1}),stick (8.08 q ha^{-1}) and bhusa yield (9.96 q ha^{-1}) were recorded with 80 kg NK ha^{-1} applied in 2 splits. The highest level of NK (100 kg ha^{-1}) applied in 3 splits to yambean-pigeonpea intercropping system registered the maximum grain yield of the succeeding mungbean (9.43 q ha^{-1}), which was 33% higher than the untreated control.

Hayat *et al*. (2004) conducted a field experiment during kharif 2000 in Rawalpindi, Pakistan to find out the effect of N and Rhizobium sp. inoculation on the yield, N uptake and economics of mungbean (cultivars NM 92 and NCM 209). The treatments were: control; 500 g *Rhizobium* inoculum, 30, 60 and 90 kg N $ha^{-1}$and inoculum combined with N at 30, 60 and 90 kg ha^{-1}. N content was higher in nodules of NM 92 than NCM 209. The highest N content in nodules (2.80%) was obtained with inoculation + 30 kg N ha^{-1}. NCM 209 had higher N shoot content (2.13%) than NM 92 (1.87%). The highest shoot N content was obtained with inoculation + 30 kg N ha^{-1}. The highest soil N content was obtained with inoculation + 90 kg N ha^{-1}. NCM 209 produced higher yield than NM 92. The maximum economic yield for NM 92 and NCM 209 (768 and 910 kg ha^{-1}, respectively) was obtained with inoculation + 90 kg N ha^{-1}. The maximum biological yield (4,889 kg ha^{-1}) was obtained in NCM 209 with inoculation + 30 kg N ha^{-1}. NCM 209 showed higher biological yield than NM 92. The highest harvest index of 18.45% was obtained with inoculation + 30 kg N ha^{-1}. The maximum net income (Rs. 18,329 and Rs. 13,003 ha^{-1}) in NCM 209 and NM 92 was obtained with inoculation alone and inoculation + 30 kg N ha^{-1}, respectively.

The highest benefit: cost ratio was obtained in NCM 209 with the inoculation treatment alone.

A field experiment was laid out by Oad and Buriro (2005) to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of lentil cv. AEM 96 in Tandojam, Pakistan during the spring season of 2004. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.3 cm, germination of 90.5%, satisfactory plant population of 162, prolonged days taken to maturity of 55.5, long pods of 5.02 cm, seed weight per plant of 10.5 g, seed index of 3.52 g and the highest seed yield of 1,205 kg ha^{-1}. There was no significant change in the crop parameters beyond this level.

Rana and Choudhary (2006) conducted a field experiment during 2000 and 2001 in New Delhi, India to evaluate the relative moisture utilization by maize grown as sole crop or in maize-lentil intercropping system. Total grain production in terms of maize equivalent was higher in maize (75 cm) + two rows of lentil. Total N uptake and water use efficiency were also highest in maize (75 cm) + two rows of lentil. All parameters increased with increasing concentration of N up to 120 kg ha^{-1}.

Tickoo *et al.* (2006) carried out a field experiment in Delhi, India during the kharif season of 2000 with mungbean cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1}. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t ha^{-1}, respectively) compared to cv. Pusa 105. Differences in the values of the parameters examined. NP rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both crops.

Sultana *et al.* (2009) conducted a field experiment during the period from March 2007 to June 2007 at Sher-e-Bangla Agricultural University, Dhaka with nitrogen and weed management in mungbean where nitrogen (0, 20 kg ha^{-1} at vegetative, 20 kg N ha^{-1} at vegetative and flowering) and weeding (no weeding, one weeding at vegetative, two weeding at vegetative and flowering) was done. Result showed that application of 20 kg N ha basal showed significantly higher values of all growth parameters like number of leaflet (24.3 at 20 DAS and 24.3 at 40

DAS), leaf area (23.3 cm^2 at 20 DAS and 102.2 cm^2 at 40 DAS), Leaf dry weight (0.30, 6.99 and 10.61 g at 10, 17 and 24 DAS, respectively) and shoot dry weight (2.76 and 4.69 g at 17 and 24 DAS, respectively). This treatment also produced significantly more number of branches (1.67), pods $plant^{-1}$ (17.8) and seed yield (1,982 kg ha^{-1}).

Yaqub *et al.* (2010) carried out pattern based experiment at Pakistan to evaluate the induction of short-duration (maturity period, 55-70 days) mungbean [*Vigna radiata* (L.) Wilczek] as a grain legume in the pre-rice niche of the rice-wheat annual double cropping system and found that induction of a short-duration grain legume in the rice-wheat system appears to be more attractive as it offers short- term additional benefits to farmers and is equally beneficial in sustaining the productivity of rice-wheat system over time. The mungbean crop (grown without mineral N fertilizer) produced 1,166 kg ha^{-1} of grain in addition to 4,461 kg ha^{-1}ofthe manure biomass (containing 52 kg N ha^{-1}) that was ploughed under before planting rice with urea-N applied in the range of 0-160 kg N ha^{-1}. Averaged across urea-N treatments, manuring significantly increased the number of tillers $plant^{-1}$ (11% increases), rice grain yield (6% increase), grain N content (4% increase) and grain N uptake (9% increase). Significant residual effects of manuring were observed on the subsequent wheat crop showing higher grain yield (21% increases), grain N uptake (29% increase) and straw yield (15% increase). The results suggested the feasibility of including mungbean in the pre-rice niche to improve the productivity of the annual rice-wheat double cropping system.

Kayani *et al.* (2010) conducted experiment to investigate the impact of legume on the oncoming wheat crop. Lentil was planted during kharif 2007. The wheat variety Inqalab-91 was sown before and after the lentil plantation during Rabi 2006-07 and 2007. Twelve different treatments were applied having different doses of N and P but Farm Yard Manure (FYM) remained constant. Six parameters were selected to investigate the potential effects of the legume viz., soil physico-chemical properties, plant height, spike length, number of grains $spike^{-1}$, 1000 grains weight and yield $plot^{-1}$. The results showed significant increase in plant height, spike length, number of grains/spike, 1000-grains weight and yield/plot after cropping lentil. The yield was obtained at an increase of 26.90% after lentil application. Based on results, cereal legume crop rotation is highly recommended.

A field experiment was conducted by Mohammad *et al.* (2010) to study the effect of crop residues and tillage practices on BNF, WUE and yield of mungbean (*Vigna radiata* (L.) Wilczek) under semi-arid rainfed conditions at the Livestock Research Station, Surezai, Peshawar in North West Frontier Province (NWFP) of Pakistan. The experiment comprised of two tillage i) conventional tillage (T1) and ii) no-tillage (T0) and two residues ii) wheat crop residues retained (+) and iii) wheat crop residues removed (-) treatments. Basal doses of N @ 20: P @ 60 kg ha^{-1} was applied to mungbean at sowing time in the form of urea and single super phosphate respectively. Labeled urea having 5% N-15 atom excess was applied @20 kg N ha^{-1} as aqueous solution in micro plots ($1m^2$) in each treatment plot to assess BNF by mungbean. Similarly, maize and sorghum were grown as reference crops and were fertilized with N-15 labeled urea as aqueous solution having 1% N-15 atom excess @ 90 kg N ha^{-1}. The results obtained showed that mungbean yield (grain/straw) and WUE were improved in no-tillage treatment as compared to tillage treatment. Maximum mungbean grain yield (1224 kg ha^{-1}) and WUE (6.61 kg ha^{-1} mm^{-1}) were obtained in no-tillage (+ residues) treatment. The N concentration in mungbean straw and grain was not significantly influenced by tillage or crop residue treatments. The amount of fertilizer-N taken up by straw and grain of mungbean was higher under no-tillage with residues-retained treatment but the differences were not significant. The major proportion of N (60.03 to 76.51%) was derived by mungbean crop from atmospheric N-2 fixation, the remaining (19.6 to 35.91%) was taken up from the soil and a small proportion (3.89 to 5.89%) was derived from the applied fertilizer in different treatments. The maximum amount of N fixed by mungbean (82.59 kg ha^{-1}) was derived in no-tillage with wheat residue-retained treatment. By using sorghum as reference crop, the biological nitrogen fixed by mungbean ranged from 37.00 to 82.59 kg $ha-^{1}$ whereas with maize as a reference crop, it ranged from 34.74 to 70.78 kg ha^{-1} under different treatments. In comparison, non-fixing (reference) crops of sorghum and maize derived upto 16.6 and 15.5% of their nitrogen from the labeled fertilizer, respectively. These results suggested that crop productivity, BNF and WUE in the rainfed environment can be improved with minimum tillage and crop residues retention.

Field study was carried by out by Sangakkara *et al.* (2011) for testing the impact of fertilizer K on root development, seed yields, harvest indices, and N-use efficiencies of maize and mungbean, two popular smallholder crops over major and minor seasons. Application of 120 kg K ha^{-1} optimized all parameters of maize in the major wet season, whereas the requirement was 80 kg K ha^{-1} in the minor season. Optimal growth yields and N-use efficiencies of mungbean was with 80 kg K ha^{-1}in both seasons. Information regarding rates of fertilizer K that optimized N use and yield of maize and mungbean during each of the two tropical monsoonal seasons of South Asia is presented.

2.3 Combined effect of *Rhizobium* strains and chemical fertilizers

Lentil (*Lens culinaris* L.) occupies the top position in terms of popularity and has been placed second in respect of area and production in Bangladesh (BBS, 2012).It is cultivated during rabi season under rainfed condition. About 80% of total lentil in the country is grown in greater Faridpur, Kustia, Jessore, Rajshahi and Pabna districts of Bangladesh . The yield of lentil is very poor (928kg ha-^{1}). There is a great possibility to increase its production by exploiting better colonization of their root and rhizosphere through *Rhizobium*, which can also reduce the use of nitrogenous fertilizer as well as protect environment. But there is still lacking of sufficient, effective and resistant *Rhizobium* strains in soil. Moreover, degradation of *Rhizobium* occurs regularly. So, collection and screening of new *Rhizobium* strains and their sub-culturing and testing are necessary. For this reason, few indigenous *Rhizobium* strains were collected from different AEZs of Bangladesh and were screened, tested at research stations. Their efficiency in crop production is needed to be tested at farmers level. Response of inoculation depends on soil type, cultivars and effectiveness of *Rhizobium* strains and its competitive ability with native *Rhizobium* (Khanam *et al.,* 1993). Khanam *et al.,* (1999) found 46% higher seed yield in lentil at Meherpur, 30% higher at Faridpur and 33% higher at Jessore districts of Bangladesh due to *Rhizobium* inoculum. They also observed that inoculated plant with chemical fertilizers gave 72%, 59% and 75% higher yield over farmers' practice at Meherpur, Faridpur and Jessore districts of Bangladesh, respectively.

2.4 Effect of different nutrient sources on nodulation, growth & yield

Organic manures as a source of plant nutrients for cultivation of field crops has received worldwide attention due to rising costs, rapid nutrient loss and adverse environmental impacts from inorganic fertilizers. Cow dung has long been recognized as perhaps the most desirable animal manures because of its high nutrient & organic matter content of degraded soil which may lead to the increasing activity of beneficial soil organisms as well as the fertility status of soil by increasing the availability of nutrients for the plants from soil. Cowdung significantly increased the growth & yield of plants (Gudugi, 2013; Akande *et al.,* 2006; Mehedi *et al.*, 2011), This study therefore sought to evaluate the effects of cow dung on growth of leaf biomass, yield of stein & its effect on the fertility status of post harvest soil in the ecological condition of Bangladesh Agricultural University.

Poultry manure as an organic fertilizer obtained from doping of birds. The use of poultry manure is being used for the increased production of various vegetables, pulses & others crops. Many reports have shown the significant increase in the production of lady finges, cucumber, maize, and lentil after, adding poultry manure in the fields (Farhad *et al.,* 2009; Islam *et al.*, 2014; Hadiuzamman *et al.,* 2015), In these study effect of poultry manure obtained from birds fed with probiotic supplemented feed in comparison to poultry manure obtained from birds fed with feed supplemented with antibiotic was studied on the growth & production of lentil (Lens culinaris) the results of this study clearly shown that efficacy of poultry manure on soil fertility, plant growth & yield pen hector as compassed to negative control.

Well rotted farmyard manure is a soil enriching product, produced from organic matter that helps to boost the nutrient levels and properties of the soil. Application of animal manures can contribute substantial amounts of N, P, K and other nutrients in crop production however, they are often inefficiently used due to poor storage & application methods (Fageria, 2009) Application on of manure results long term improvement in crop production & quality of soil; while release of nutrients is a slow mechanism Barzegan *et al.,* (2002) advocated that organic amendments such an FYM improves physical properties of soil. FYM significantly increase crop yield & need quality. This phenomenon helps in greeted accumulation of seed ingredients in pulse crops e.g. calcium carbonators & improved metabolism leading to increase protein content in pulse crop (Channabasanagowda *et al.*, 2008, and Roy and Singh, 2006)

Vermicompost stimulates to influence the microbial activity of soil, increase the availability of oxygen, maintains normal soil temperature, increase soil porosity & infiltration of water, improvers nutient content & increase growth, yield & quality of the plant . Vermicompost in a nourishing organic fertilizer having high amount of humus, nitrogen-2-3% phosphorus 1.55-2.55% potassium- 1.85-2.25% micronutrients, more beneficial soil microbes like "Nitrogen Fixing bacteria" & mycorrhizal fungi. Vermicompost has been scientifically proved as miracle plant growth enhancer (Chaoui *et al.*, 2003).According to several researches it is reported that worm's vermicast contains 7.37% N, 19.58% phosphorous as P_2O_5 Remarkable growth obtained in vermicompost- treated plants due to improved soil health and the physio-chemical properties of soil enhanced (Singh *et al.* 2011) Microbial activity is stimulated by vermicompost. Annual application of adequate amounts of some vermicompost led to significant increase in soil enzyme activities such as urease, phospho mono esterase phospho di esterase & arylsulphatase. Vermicompost has beneficial effects on plant growth & yield.

2.5 Combined effect of *Rhizobium* strains and different nutrient sources

The indiscriminate use of chemical fertilizers without organic manures is known to degrade physio-chemical as well as biological properties of the soil i.e. soil environment and soil health. On the other hand, the use of different type of organics improves soil properties; its health and fertilizer use efficiency, mitigates short supply of micro nutrients, stimulates the proliferation of diverse group of soil microorganisms and improves the ecological balance of rhizosphere. Farmyard manure is well known as a store house of plant nutrients. Poultry manure is a good source of nutrients and each tonne of deep litter contain 29.40 kg nitrogen, 20.41 kg phosphorus and 20.41 kg potassium together with 6.8 kg magnesium, 6.8 kg sodium and 24.21 kg calcium (Channabasavanna *et al.,* 2009). Vermicompost being a rich source of macro and micronutrients and vitamins, plant growth regulators and beneficial micro-flora appeared to be the best organic source in maintaining soil fertility on sustainable basis towards an eco-friendly environment (Edward *et al*., 2004). Vermicompost application to different field crops has been known to reduce the requirement of chemical fertilizers without any reduction in crop yield

(Giraddi, 2000). Similarly, FYM, poultry manure and farm-compost etc. are known for being the storehouse of plant nutrients with great variation in their nutrient contents and their release pattern after decomposition. Looking to the poor fertility condition of the intensively cropped lands where lentil is generally grown, addition of organics is important for securing sustainable yield potential.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2016 to March 2020. Detailed of the experimental materials and methods followed in the present study were presented in this chapter. The experiment was conducted to study the influence of biofertilizer, nitrogen and phosphorous on nodulation, growth and yield of lentil.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where flood plain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as „islands‟ surrounded by floodplain (Anon., 1988b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.1.3 Soil

Soil pH ranged from 5.6-6.5 and had organic matter 1.10-1.99%. The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource Development Institute (SRDI), Dhaka. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- III.

3.1.4 Climate

This area characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March) as it is sub-tropical climate. Weather information regarding temperature, relative humidity and rainfall prevailed at the experimental site during the study period were presented in Appendix IV.

3.2 Details of the experiment

3.2.1 Treatments

The experiment consisted of 2 factors

Factors A: *Rhizobium* strains (2)

(a) R_1= BARI RLc-102

(b) R_2= BARI RLc-104

Factors B: Different nutrient management (6)

(a) F_0= Control (no fertilizer management)

(b) F_1= Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1})

(c) F_2= Recommended dose of cowdung (5 t ha^{-1})

(d) F_3= Recommended dose of poultry litter (1.5 t ha^{-1})

(e) F_4= Recommended dose of farm yard manure (10 t ha^{-1})

(f) F_5= Recommended dose of vermicompost (1.75 t ha^{-1})

Treatment Combination:

R_1F_0, R_1F_1, R_1F_2, R_1F_3, R_1F_4, R_1F_5, R_2F_0, R_2F_1, R_2F_2, R_2F_3, R_2F_4, R_2F_5

3.2.2 Experimental design and layout:

The experiment was laid out in a split plot design with three replications. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was $4 \times 1.2 m^2$. The distances between plot to plot and replication to replication were 0.50 m and 1.0 m respectively. The layout of the experimental field was presented in Appendix II.

3.3 Crop/Planting Material

BARI Masur-7 was used as plant material.

3.3.1 Description of Crop: BARI Masur-7

Lentil variety that is BARI Masur-7 was used as experimental material. BARI Masur-7 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur. The line was selected on the basis of yield, disease tolerant, early ripening etc. The variety is cultivated in all kind of soil but randy loam roil is better. It is also cultivated as rely crop. Plant height of the variety is 32-38 cm. The leaves turn straw color during maturity seed color is deep brown & cotyledons are bright orange. It has a 1000 seed weight is 23-25g. The duration of this crop is 110-115 days. Its yield is 1800-2300 kg/ha.

3.4 Crop management

3.4.1 Seed collection

Seeds of BARI Masur-7 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.4.2 Seed sowing

Seeds were sowed in the field on 15 November, 2019. The field was labeled properly and was divided into 36 plots. The seeds of BARI Mosur-7 were sowed 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 15 November, 2019.

3.4.3 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.

3.4.4 Layout and preparation of experimental land

A pre- sowing irrigation was given on November 8, 2019. 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 15, 2019 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.4.5 Fertilizer application

The recommended chemical fertilizer dose was 44, 100, and 40 Kg ha^{-1} of Urea, TSP, MOP respectively. According to the treatments all the fertilizers were applied as basal dose (Biofertilizer strains applied in main plot and different nutrient sources applied in sub-plot) and mixed with soil thoroughly at the time of final land preparation after making specific plot.

3.4.6 Intercultural operations

3.4.6.1 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.

3.4.6.2 Weeding

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

3.4.6.3 Application of irrigation water

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

3.4.6.4 Drainage

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

3.4.6.5 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.

3.4.7 Harvesting and post-harvest operation

Maturity of crop was determined when 80-90% of the pods become straw color. The harvesting of BARI Mosur-7 were done up to 1 March, 2020. Ten pre-selected 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 for recording seed and straw yield data. The seeds were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally seed and straw yields $plot^{-1}$ were determined and converted to kg ha^{-1}.

3.5 Recording of data

Emergence of plants were counted from starting to a constant number of plants $m\text{-}^2$ area of each plot. Experimental data were determined from 15 days of growth duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of plants at different specific dates from the inner rows leaving border rows and harvest area for grain. The following data were recorded during the experimentation.

A. Crop growth characters

I. Plant height (at 30, 50, 70, 90 DAS and at harvest)
II. Branchs plant^{-1} (at 30, 50, 70 DAS and at harvest)
III. Nodule count (at 50, 60, 70 and 80 DAS)
IV. Above ground dry weight plant^{-1} (at 30, 50, 70 ,90 DAS and at harvest)

B. Yield and other crop characters

I. Pods plant^{-1} (no.)
II. Thousand seed weight (g)
III. Seed yield (kg ha^{-1})
IV. Stover yield (kg ha^{-1})
V. Biological yield (kg ha^{-1})
VI. Harvest index (%)

3.5.1 Detailed procedures of recording data

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

A. Crop growth characters

3.5.2 Plant height

The height of 10 randomly selected plants from each plots for every treatments of all three replication was taken carefully at harvest and after 30, 50, 70, 90 days of sowing of the seeds of BARI Mosur-7. Plant height was measured from the above ground portion of the plants.

3.5.3 Branch plant^{-1}

The branches plant^{-1} were counted carefully from 10 randomly selected plant from each plot for every treatments of all three replications when it became 30, 50 and 70 days after sowing and at harvest.

3.5.4 Nodule count

The nodule plant^{-1} were counted carefully from 10 randomly selected plant from each plot for every treatments of all three replications when it became 50, 60, 70, 80 days after sowing. Then it was averaged.

3.5.5 Above ground dry weight plant^{-1} (kg ha^{-1})

10 randomly selected plant from each plot were harvest after 30, 50, 70, 90 days of sowing. Then the plants were dried properly and individual plant weight was taken to make them average for each treatment.

B. Yield and other crop characters

3.5.6 Pods plant^{-1}

The pods of ten pre selected plants were collected from each plot at the time of harvest and then counted total number and then averaged them to get pods plant^{-1}.

3.5.7 Thousands seed weight (g)

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

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

Grains of 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 of the grains.

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

Stover of central 1 m^2 area in each plot was sun dried and weighed. Then the weight was converted in kg ha^{-1}.

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

Biological yield was calculated by adding the grain yield and stover yield.

Biological yield = grain yield + Stover yield.

3.5.11 Harvest index (%)

Harvest index was calculated on d by basis with the help of following formula.

Harvest index (HI %) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100$

Here, Biological yield = Grain yield + stover yield

3.6 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 data analysis software and the mean differences were adjudged by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

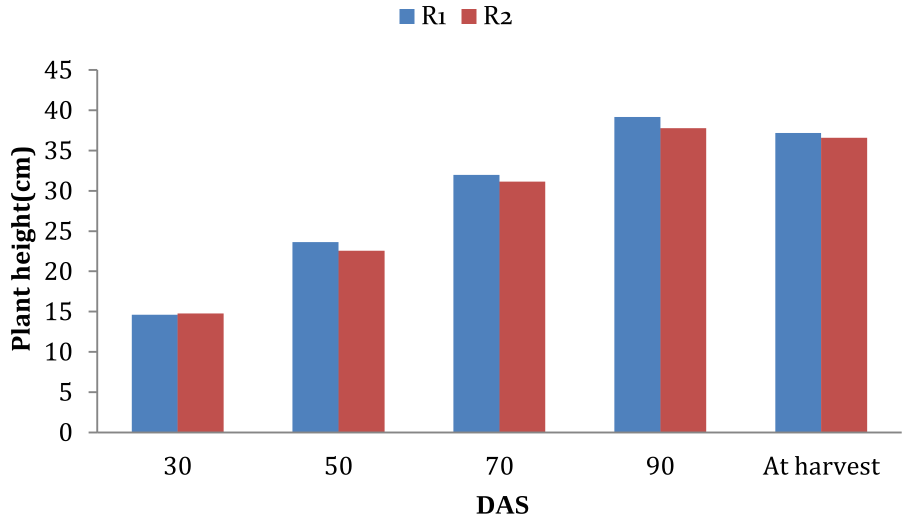
RESULTS AND DISCUSSION

The data on different growth, yield contributing characters and yield were recorded to find out the suitable Bio-Fertilizer and nutrient management on Lentil. The results have been presented and discussed and possible explanation have been given under the following headings:

4.1. Plant height

4.1.1 Effect of *Rhizobium* strains

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. From this experiment, result revealed that there was no significant effect of *Rhizobium* strains on plant height (Fig. 1 and Appendix V). From the experiment result revealed that numerically the maximum plant height (14.778 cm) was observed in R_2 (BARI RL_C-104) treatment at 30 DAS, at 50, 70, 90 DAS and harvest, respectively numerically the maximum plant height (23.62, 31.958, 39.155, and 37.185 cm) was observed from R_1 (BARI RL_C-102) treatment. Whereas numerically the minimum plant height (14.59 cm) was observed from R_1 (BARI RL_C-102) treatment at 30 DAS, at 50, 70, 90 DAS and harvest, respectively numerically the minimum plant height (22.565, 31.157, 37.798 and 36.578 cm) was observed from R_2 (BARI RL_C-104) treatment. 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. Dhingra *et al* . (1988) reported that the combination of *Rhizobium* and 20 kg P_2O_5 /ha gave yield equivalent to 40kg P_2O_5 /ha without *Rhizobium*. Sharma and Sharma (2004) also found similar result which supported the present finding.



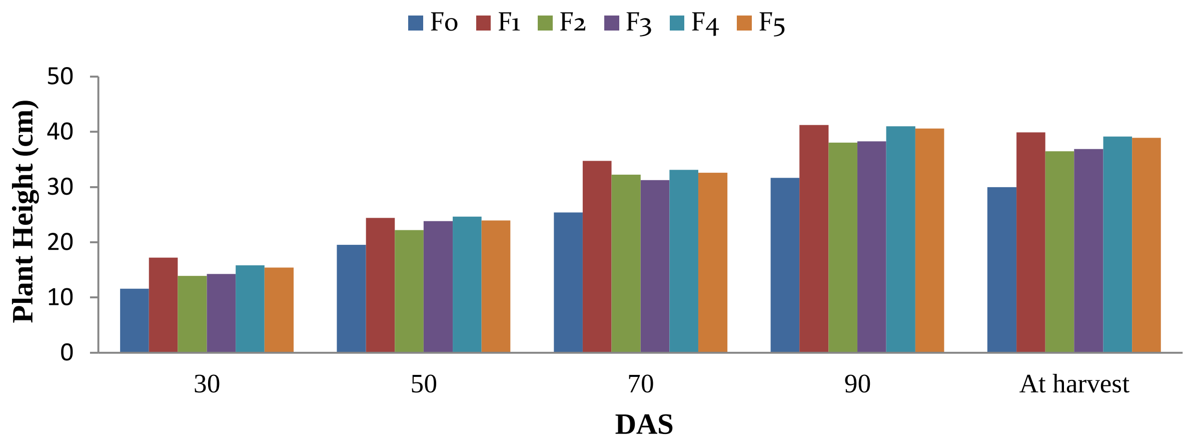
] 102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.1. Effect of *Rhizobium* strains on plant height (cm) at different DAS (LSD$_{0.05}$ =NS at different DAS).

4.1.2 Effect of different nutrient management

Different Nutrient Management showed significant variation on plant height at different days after showing (Fig 2 and Appendix V). From the experiment result revealed that numerically the maximum plant height (17.2 cm) was observer in F_1 treatment. At 50 DAS numerically the maximum plant height (24.645 cm) was observer in F_5 treatment which was statistically similar with F_3(23.85 cm) treatment, followed by F_4 treatment (24.645 cm) and F_1 (24.39 cm), at 70, 90 DAS and harvest respectively numerically the maximum plant height (34.715, 41.26, and 39.875 cm) was observed in F_1 treatment which was statistically similar with F_4 treatment (33.125, 41.0 and 39.145 cm at 70, 90 DAS and harvest respectively): and with F_5 treatment (32.60, 40.605, and 38.93 at 70, 90 DAS and harvest respectively). Whereas numerically the minimum plant height (11.555, 19.505, 25.405, 31.650 and 29.98 cm at 30, 50 70, 90 DAS and harvest respectively) was observed in F_0 treatment .Srinivas and Shaik (2002) conducted field experiment during the kharif seasons to study the effects of N (0, 20, 40 and 60 kg ha^{-1}) and P (0, 25, 50 and 75 kg ha^{-1}) along with seed inoculation with Rhizobium culture on the growth and yield components of greengram. Plant height generally increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} followed by decrease with further increase in

N. Oad and Buriro (2005) reported that the 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.3 cm. Kayani *et al.* (2010)also found similar result which supported the present finding.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.2. Effect of different nutrients management on plant height (cm) at different DAS ($LSD_{(0.05)}$ =1.1661, 1.4750, 2.3322, 2.5070 and 2.2261 at 30, 50 ,70, 90 DAS and harvest respectively).

4.1.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined of *Rhizobium* strains and different nutrient management showed significant variation on plant height at different days after showing (Table 1). Result exhibited that the numerically the maximum plant height (17.380, 26.850, 35.50, 42.12, and 40.60 cm at 30, 50 70, 90 DAS and harvest respectively) was observed in R_1F_1 treatment combination. Which was statistically similar with R_2F_1, R_2F_4 and R_2F_5 treatment combination at 30 DAS; with R_1F_4 treatment combination at 50 DAS ; with R_2F_1, R_2F_4, R_1F_2, R_2F_4, R_1F_5 and R_2F_5 treatment combination at 70 DAS ; with R_1F_4, R_1F_5, R_2F_4, R_2F_1, R_2F_5 and R_1F_3 treatment combination at 90 DAS; and at harvest all other treatments was statistically similar except R_1F_0, R_1F_2, R_2F_0, R_2F_2 and R_2F_3 treatment combination. Whereas the numerically the minimum plant height

(11.10 and 19.21 cm at 30 and 50 DAS) was observed in R_1F_0 treatment combination which was statistically similar with of R_2F_0 (12.01 and 19.8 cm) treatment combination at 30 and 50 DAS), and at 70, 90 DAS and harvest respectively numerically the minimum plant height (25.31, 30.85, and 29.9 cm) was observed in R_2F_0 treatment combination which was statistically similar with B_1F_0 treatment combination at 70, 90 DAS and harvest respectively.

Table 1: Combined effect of *Rhizobium* strains and different nutrient management on plant height (cm) at different DAS

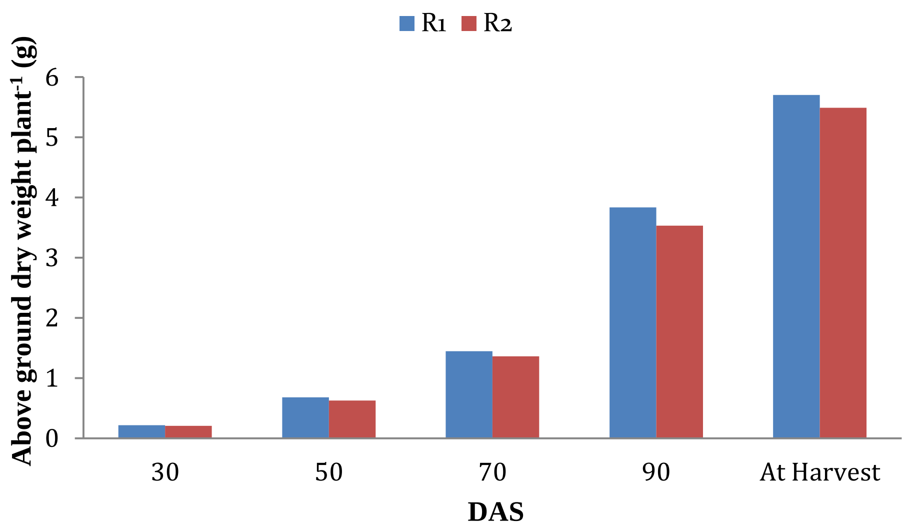
Treatments Combinations	Plant height (cm) at different DAS				
	30	50	70	90	At harvest
R_1F_0	11.100h	19.210e	25.500c	32.450e	30.010d
R_1F_1	17.380a	26.850a	35.500a	42.120a	40.600a
R_1F_2	14.520c-f	22.400cd	32.890ab	38.450b-d	36.750b
R_1F_3	14.000ef	24.450bc	31.660b	39.300a-d	37.710ab
R_1F_4	15.530b-e	24.800ab	33.450ab	41.600ab	39.190ab
R_1F_5	15.010c-e	24.010b-d	32.750ab	41.010a-c	38.850ab
R_2F_0	12.010gh	19.800e	25.310c	30.850e	29.950d
R_2F_1	17.020ab	21.930d	33.930ab	40.400a-d	39.150ab
R_2F_2	13.250fg	22.010d	31.600b	37.650cd	36.250b
R_2F_3	14.450d-f	23.250b-d	30.850b	37.290d	36.010c
R_2F_4	16.110a-c	24.490b	32.800ab	40.400a-d	39.100ab
R_2F_5	15.830a-d	23.910b-d	32.450ab	40.200a-d	39.010ab
$LSD_{(0.05)}$	1.6491	2.0860	3.2982	3.5455	3.1482
CV(%)	6.59	5.30	6.14	5.41	5.01

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

4.2 Above ground dry weight plant^{-1} (g)

4.2.1 Effect of *Rhizobium* strains

Above ground dry weight plant^{-1} of lentil was significantly influenced by *Rhizobium* strains during all growth period of plant (Fig 3 and Appendix VI). Result revealed that numerically the maximum above ground dry weight plant^{-1} (0.2150, 0.6783, 1.4433, 3.8367 and 5.7017 g at 30, 50, 70, 90 DAS and harvest respectively) was observed in R_1 treatment. Whereas numerically minimum above ground dry weight plant^{-1} (0.2033, 0.6283, 1.3583, 3.5317, and 5.4883g at 30, 50, 70, 90 DAS and harvest respectively) was observed R_2 treatment.

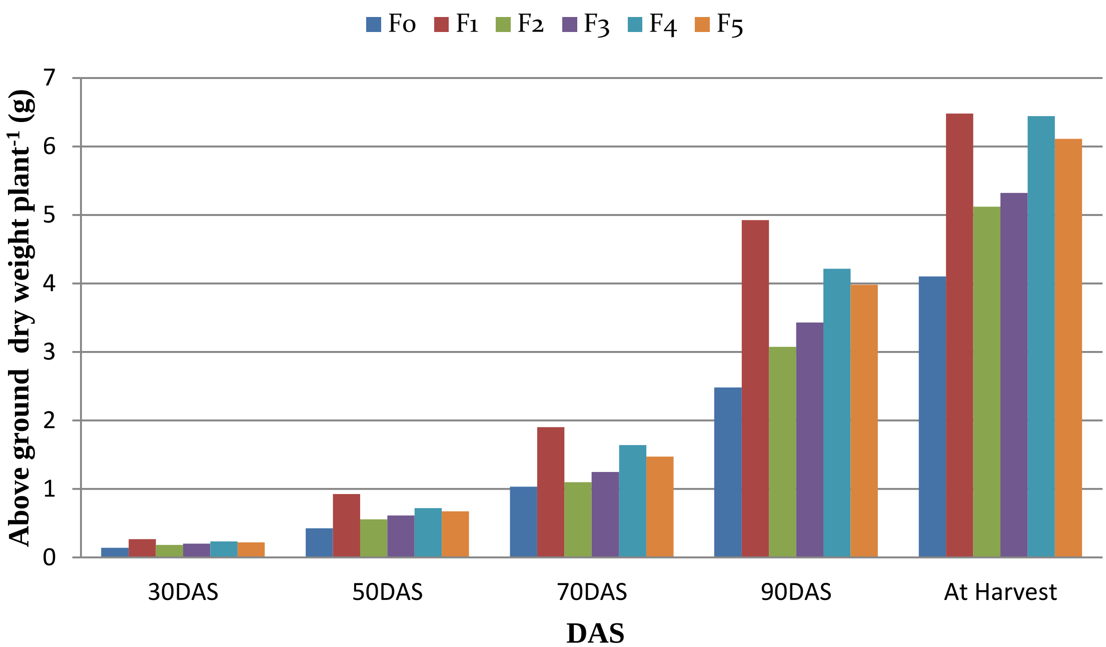


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig. 3. Effect of *Rhizobium* strains on above ground dry weight plant^{-1} of lentil at different DAS ($LSD_{(0.05)}$ =0.0110, 0.0395, 0.0828, 0.2401 and 0.1800 at 30,50, 70,90DAS and harvest respectively).

4.2.2 Effect of different nutrient management

Above ground dry weight plant^{-1} of lentil was significantly influenced by different nutrient management during all growth period of plant (Fig 4 and Appendix VI). Result revealed that numerically the maximum above ground dry weight plant^{-1} (0.27, 0.925, 1.905, 4.925, and 6.48 g at 30, 50, 70, 90 DAS and harvest respectively) was observed F_1 treatment which was statistically similar with F_4 (6.440 g) treatment during harvest. Whereas numerically the minimum above ground dry weight plant^{-1} (0.14, 0.425,1.035, 2.48, and 4.1 g at 30, 50, 70, 90DAS and harvest respectively) was observed in F_0 treatment which was statistically similar with F_2 (1.1 g) treatment at 70 DAS.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig. 4. Effect of different nutrient management on above ground dry weight $plant^{-1}$ of lentil at different DAS ($LSD_{(0.05)}$=0.0161, 0.0449, 0.0880, 0.2531and 0.2995 at 30, 50, 70, 90 DAS and harvest respectively).

4.2.3 Combined effect of *Rhizobium* strains and different nutrient management

Above ground dry weight $plant^{-1}$ of lentil was significantly influenced by combined of *Rhizobium* strains and different nutrient management (Table 2). Result revealed that numerically the maximum above ground dry weight $plant^{-1}$ (0.280, 0.960, 1.97, 5.18 and 6.88 g at 30, 50, 70, 90 DAS and harvest respectively) was found in R_1F_1 treatment combination which was statistically similar with the R_2F_1 treatment combination at 30DAS. Whereas numerically the minimum above ground dry weight $plant^{-1}$ (0.13, 0.4, 1.02, 2.45, and 4.05 g at 30, 50, 70, 90DAS and harvest respectively) was found from the treatment combination of

R_2F_0 which was statistically similar with R_1F_0 treatment combination; with treatment combination R_2F_2 followed by B_2F_3 at 70 DAS.

Table 2: Combined effect of *Rhizobium* strains and different nutrient management on above ground dry weight plant^{-1} of lentil at different DAS

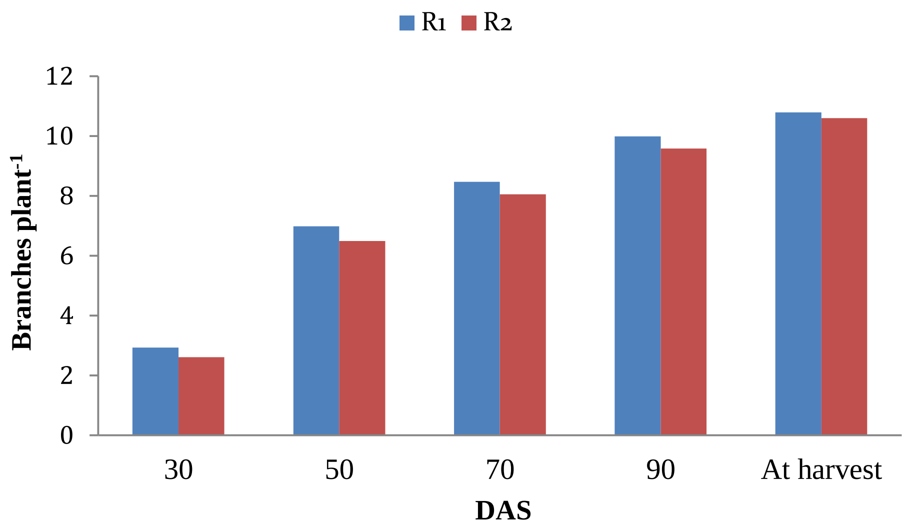
Treatments Combinations	Above ground dry weight plant^{-1} at different DAS				
	30	50	70	90	At Harvest
R_1F_0	0.1500h	0.4500i	1.0500f	2.5100f	4.1500f
R_1F_1	0.2800a	0.9600a	1.9700a	5.1800a	6.8800a
R_1F_2	0.1900fg	0.5800gh	1.1100f	3.1900e	5.1400e
R_1F_3	0.2100d-f	0.6300e-g	1.3600e	3.8000d	5.5800d
R_1F_4	0.2400bc	0.7500c	1.6700c	4.3300bc	6.3300bc
R_1F_5	0.2200c-e	0.7000cd	1.5000d	4.0100cd	6.1300bc
R_2F_0	0.1300h	0.4000i	1.0200f	2.4500f	4.0500f
R_2F_1	0.2600ab	0.8900b	1.8400b	4.6700b	6.0800c
R_2F_2	0.1800g	0.5400h	1.0900f	2.9600e	5.1000e
R_2F_3	0.2000e-g	0.6000f-h	1.1400f	3.0600e	5.0600e
R_2F_4	0.2300cd	0.6900c-e	1.6100cd	4.1000cd	6.5500ab
R_2F_5	0.2200c-e	0.6500d-f	1.4500e	3.9500cd	6.0900c
$LSD_{(0.05)}$	0.0227	0.0635	0.1244	0.3579	0.4235
CV(%)	6.38	5.71	5.21	5.70	4.44

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

4.3 Branches plant^{-1} (No.)

4.3.1 Effect of *Rhizobium* strains

Statistically significant variation was observed at 30, 50, 70, 90 DAS in the branches plant^{-1} of lentil due to application of different Bio-Fertilizers (Fig 5 and Appendix VII). At harvest non-significant effect was observed. From the experiment result showed that numerically the maximum branches plant^{-1} (2.9267, 6.9767, 8.4639, 9.9817 and 10.791 at 30, 50, 70, 90 DAS and harvest respectively) was observed in R_1 treatment. Whereas, numerically the minimum branches plant^{-1} (2.61, 6.4833, 8.05, 9.583, and 10.592 at 30, 50, 70, 90 DAS and harvest respectively) was observed in R_2 treatment.

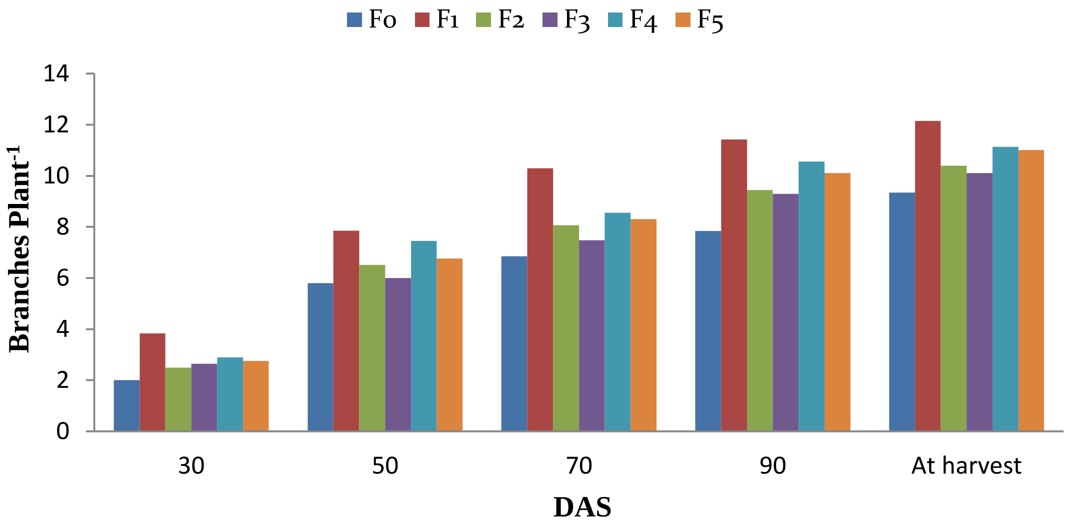


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.5. Effect of *Rhizobium* strains on no. of branches plant^{-1} at different DAS ($LSD_{(0.05)}$=0.207, 0.4554, 0.402, 0.395 and NS at 30, 50 70, 90DAS and harvest respectively).

4.3.2 Effect of different nutrient management

Statistically significant variation was observed in the branches plant^{-1} of lentil due to application of different nutrient management (Fig 6 and Appendix VII). From the experiment result showed that numerically the maximum branches plant^{-1} (3.83, 7.85, 10.30, 11.43 and 12.145 at 30, 50, 70, 90 DAS and harvest, respectively) was observed in F_1 treatment. Whereas numerically the minimum branches plant^{-1} (2, 5.8, 6.85, 7.845 and 9.35 at 30, 50, 70, 90 DAS and harvest respectively) was observed in F_0 treatment which was statistically similar with F_3 (branches number 6) treatment at 50 DAS.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.6. Effect of different fertilizer management on number of branches plant^{-1} at different DAS ($LSD_{(0.05)}$= 0.2057, 0.3295, 0.4404, 0.5640 and 0.6174 at 30, 50 70, 90 DAS and harvest respectively)

4.3.3 Combined effect of *Rhizobium* strains and different nutrient management

Statistically significant variation was found in the branches plant^{-1}of lentil due to combined effect of *Rhizobium* strains and different nutrient management (Table 3). Result revealed that numerically the maximum branches plant^{-1} (4.0, 8.20, 10.80, 11.80 and 12.40 at 30, 50, 70, 90 DAS and harvest respectively) was found in R_1F_1 treatment combination which was statistically similar with the treatment combination of R_1F_4 at 50 DAS; with R_2F_1 treatment combination at 90 DAS and harvest respectively. Whereas numerically the minimum branches plant^{-1} (2.0) was observed in R_2F_0 treatment combination which was statistically similar with R_1F_0 treatment combination at 30 DAS, at 50 DAS numerically the minimum branches plant^{-1}

(5.50) was observed in R_2F_3 treatment combination which was statistically similar with R_2F_0 and R_1F_0 treatment combination. Numerically the minimum branches plant^{-1} (6.8, 7.80 and 9.20 at 70, 90 DAS and harvest respectively) was found in R_2F_0 treatment combination which was statistically similar with the treatment combination of R_1F_0 treatment combination.

Table 3: Combined effect of *Rhizobium* strains and different nutrient management on number of branches plant^{-1} at different DAS

Treatments Combinations	No. of branches plant^{-1} at different DAS				
	30	50	70	90	At harvest
R_1F_0	2.0000g	5.8000gh	6.900hi	7.890g	9.500fg
R_1F_1	4.0000a	8.2000a	10.800a	11.800a	12.400a
R_1F_2	2.6600e	6.8300de	8.330cde	9.700d-f	10.500c-e
R_1F_3	2.7900de	6.5000ef	7.453gh	9.500ef	10.200d-f
R_1F_4	3.1100c	7.8000ab	8.800c	10.800bc	11.133bc
R_1F_5	3.0000cd	6.7300de	8.500cd	10.200c-e	11.010cd
R_2F_0	2.0000g	5.8000gh	6.800i	7.800g	9.200g
R_2F_1	3.6600b	7.5000bc	9.800b	11.060ab	11.890ab
R_2F_2	2.3300f	6.2000fg	7.800e-g	9.200f	10.300c-f
R_2F_3	2.5000ef	5.5000h	7.500fg	9.100f	10.010e-g
R_2F_4	2.6700e	7.1000cd	8.300c-e	10.330b-d	11.130bc
R_2F_5	2.5000ef	6.8000de	8.100d-f	10.010c-e	11.020b-d
$LSD_{(0.05)}$	0.2909	0.4659	0.6228	0.7977	0.8731
CV(%)	6.17	4.06	4.43	4.79	4.79

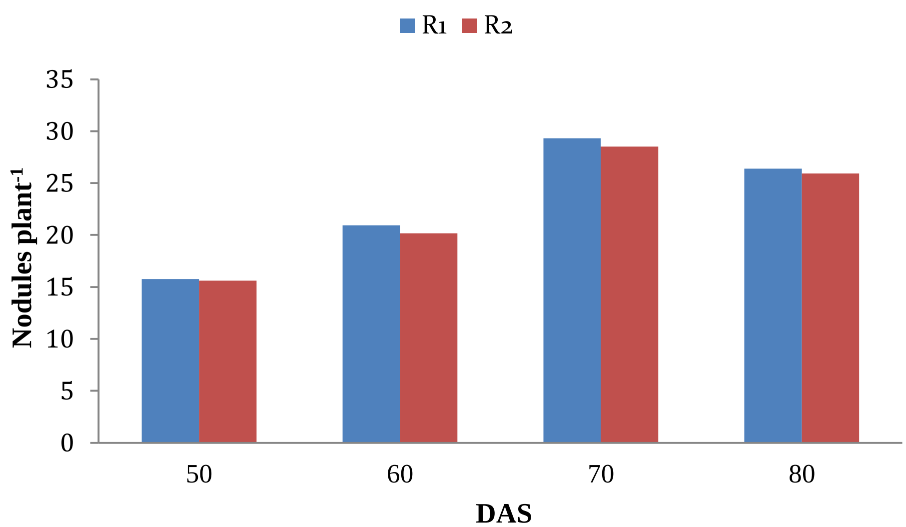
R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

4.4 Nodules plant^{-1} (No.)

4.4.1 Effect of *Rhizobium* strains

Non significant effect of *Rhizobium* strains was observed on nodules plant^{-1} of lentil plant (Fig 7 and Appendix VIII). From the experiment result revealed that numerically the maximum nodules plant^{-1} (15.763, 20.947, 29.322, and 26.375 at 50, 60, 70 and 80 DAS) was found in

R_1 treatment .Whereas numerically the minimum nodules plant^{-1} (15.622, 20.178, 28.513 and 25.935 at 50, 60, 70 and 80DAS) was found in R_2 treatment. Lentil is a legume and fulfils most of its N requirement through atmospheric N_2 fixation with the symbiotic help of rhizobia living in its root nodules. Generally, the level of N_2 fixation in legumes depends on host genotypes, rhizobial strains, environment and their combinations. Lentil cultivars have shown genetic variability in their ability to symbiotically fix N_2 (Rennie and Dubetz, 1986), therefore genotypes with high N_2 fixation and high seed yield are desirable for sustainable agriculture.

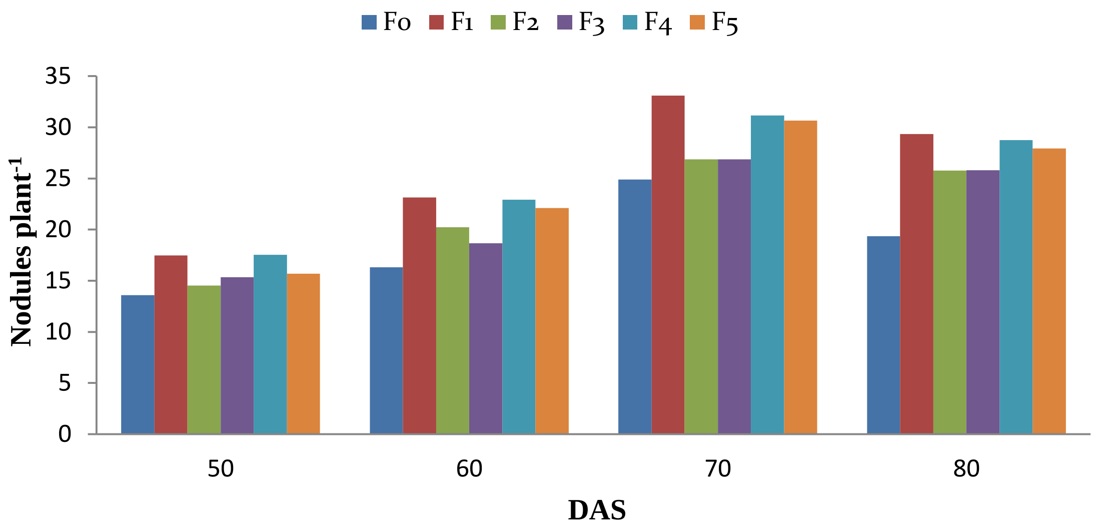


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.7. Effect of bio-fertilizers on number of nodules plant^{-1} at different DAS (LSD$_{(0.05)}$=NS, 0.7171, NS and NS at 50, 60, 70 and 80 DAS respectively)

4.4.2 Effect of different nutrient management

The nodules plant^{-1} of lentil was significantly differed due to the application of different nutrient management (Fig 8 and Appendix VIII). From the experiment result revealed that numerically the maximum nodules plant^{-1} (17.53)) was found in F_4 treatment at 50 DAS which was statistically similar with F_1 (17.47) treatment. At 60, 70 and 80 DAS numerically the maximum nodules plant^{-1} (23.130, 33.085, and 29.335) was found in F_1 treatment statistically similar result also found with F_4 (22.93 and 28.735) treatment at 60 and 80DAS and F_5 (22.105 and 27.93) treatment at 60 and 80DAS. Whereas numerically the minimum nodules plant^{-1}(13.575, 16.325 , 24.88, and 19.36 at 50, 60, 70 and 80 DAS respectively) was observed in F_0 treatment. McLasen and Camenon 1996; Ali *et al*,. 1997) found similar result which supported the present study.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.8. Effect of different nutrient management on number of nodules plant^{-1} at different DAS ($LSD_{(0.05)}$=1.2535, 1.0883, 1.8722, 1.8722 at 50, 60, 70 and 80 DAS respectively)

4.4.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined of *Rhizobium* strains and different nutrient management showed significant effect on number of nodules plant^{-1} of lentil (Table 4). From the experiment result revealed that numerically the maximum nodules plant^{-1} (17.86) was observed in R_1F_1 treatment combination which was statistically similar with R_1F_4, R_2F_1, and R_2F_4 treatment combination at 50 DAS. At 60 DAS numerically the maximum nodules plant^{-1} (23.66) was observed in R_1F_4 treatment combination which was statistically similar with R_1F_1, R_2F_1, R_1F_5, and R_2F_4 treatment combination at 60 DAS. At 70 and 80 DAS numerically the maximum nodules plant^{-1} (33.14 and 29.66) was observed in R_1F_1 treatment combination which was statistically similar with

R_2F_1, R_1F_4, R_1F_5, and R_2F_4 treatment combination at 70 DAS; and with R_2F_1, R_2F_4, R_1F_4, R_2F_5 and R_1F_5 treatment combination. Whereas numerically the minimum nodules plant^{-1} (13.500) was observed in R_1F_0 treatment combination which was statistically similar with R_2F_0, R_2F_2, R_1F_2 and R_1F_3 treatment combination at 50 DAS. At 60, 70 and 80 DAS numerically the minimum nodules plant^{-1} (15.880, 24.43, and 19.06) was found B_2F_0 treatment combination which was statistically similar with R_1F_0 treatment combination at 60 DAS; with R_1F_0, R_2F_2 and R_2F_3 treatment combination at 70 DAS; and with R_1F_0 treatment combination at 80 DAS. Sharma and Sharma (2004) reported that the 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, 1000-seed weight and seed yield. Effective indigenous strains of *Rhizobium leguminosarum biovar viciae* lacking in most prairie soils, and therefore inoculation is essential to ensure adequate nodulation and N fixation for maximum yields (Bremer *et al*., 1989).

Table 4: Combined effect of *Rhizobium* strains and different nutrient management on number of nodules plant^{-1} at different DAS

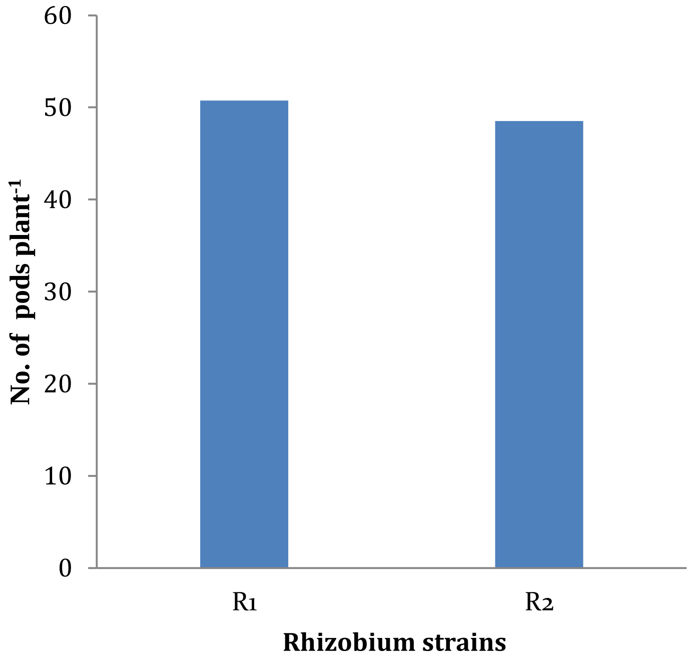
Treatments Combinations	No. of nodules plant^{-1} at different DAS			
	50	60	70	80
R_1F_0	13.500d	16.770f	25.330de	19.660e
R_1F_1	17.860a	23.600a	33.140a	29.660a
R_1F_2	14.630cd	20.550cd	27.110d	26.000cd
R_1F_3	15.200cd	18.880e	27.660cd	26.600b-d
R_1F_4	17.860a	23.660a	31.440ab	28.670a-c
R_1F_5	15.530bc	22.220ab	31.250ab	27.660a-d
R_2F_0	13.650d	15.880f	24.430e	19.060e
R_2F_1	17.080ab	22.660ab	33.030a	29.010ab
R_2F_2	14.440cd	19.880de	26.620de	25.520d
R_2F_3	15.500bc	18.460e	26.060de	25.020d
R_2F_4	17.200ab	22.200ab	30.880ab	28.800a-c
R_2F_5	15.860bc	21.990bc	30.060bc	28.200a-c
$LSD_{(0.05)}$	1.7727	1.5392	2.6477	2.6477
CV(%)	6.63	4.39	5.38	5.94

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

4.5 Pods plant^{-1} (No.)

4.5.1 Effect of *Rhizobium* strains

Rhizobium strains exhibit significant effect on pods plant^{-1} of lentil (Fig 9 and Appendix IX). Result showed that numerically the maximum number of pod plant^{-1} (50.733) was observed in R_1 treatment. Whereas numerically the minimum number of pod plant^{-1} (48.534) was observed in R_2 treatment. Sharma and Sharma (2004) reported that 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. It was found similar result which supported the present study.

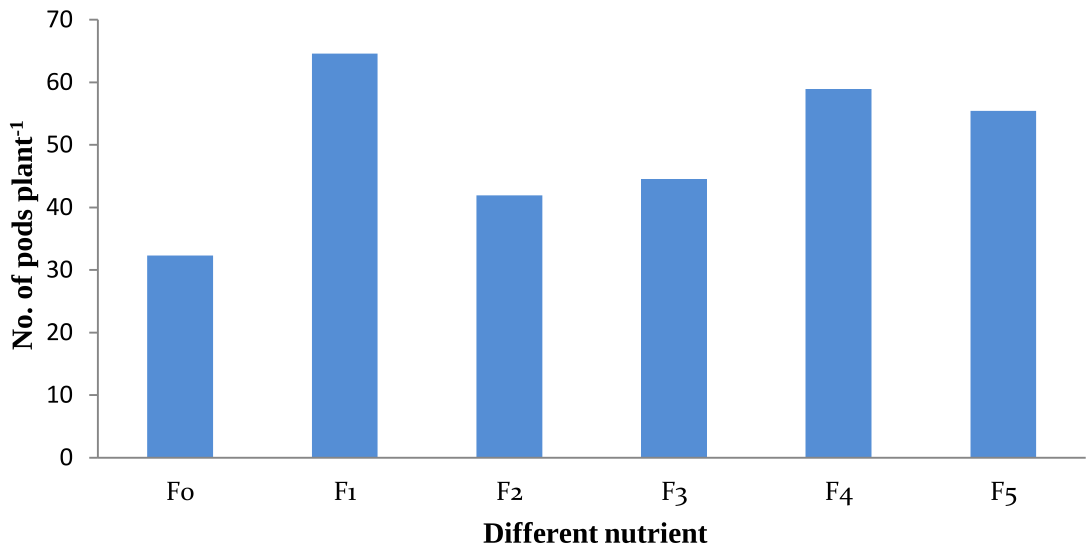


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.9. Effect of *Rhizobium* strains on number of pods plant^{-1} (LSD$_{(0.05)}$= 2.0423)

4.5.2 Effect of different nutrient management

Different Nutrient Management showed significant difference in respect of pods plant^{-1}of lentil (Fig 10 and Appendix IX). Among the different nutrient management numerically the maximum number of pod plant^{-1} (64.565) was observed in F_1 treatment .Whereas numerically the minimum number of pod plant^{-1} (48.534) was observed in F_0 treatment. Sonulski and Buchan (1978) also found similar result which supported the present finding.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.10. Effect of different nutrient management on number of pods plant^{-1} ($LSD_{(0.05)}$=2.9157)

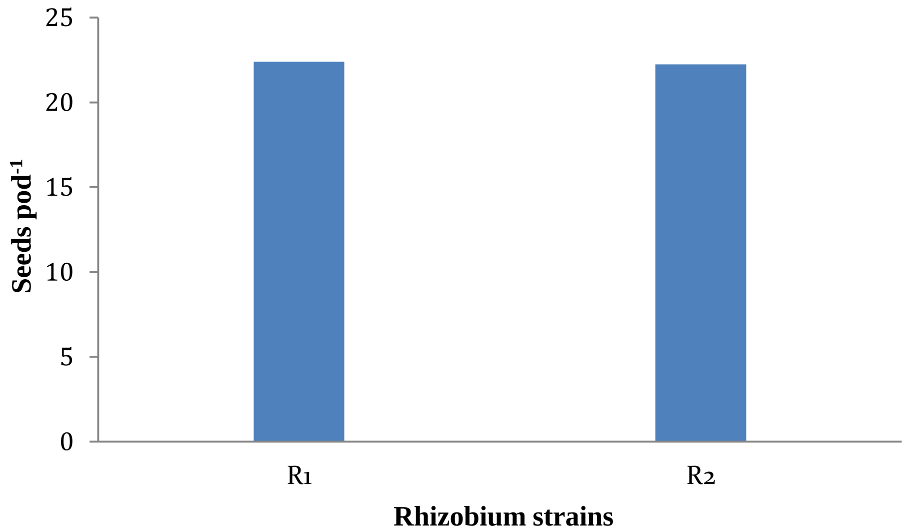
4.5.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of different *Rhizobium* strains and nutrient management showed significant difference in respect of pods plant^{-1} of lentil (Table 5). Among the treatment combinations numerically the maximum number of pod plant^{-1} (65.20) was observed in B_1F_1 treatment combination which was statistically similar with R_2F_1 treatment combination. On the contrary, numerically the minimum number of pod plant^{-1} (30.31) was observed in R_2F_0 treatment combination Which was also statistically similar with R_1F_0 treatment combination

4.6 Seeds pods^{-1} (No.)

4.6.1 Effect of *Rhizobium* strains

Seeds pod^{-1}of lentil was significantly varied due to application of bio-fertilizer (Fig 11 and Appendix IX). Result showed that numerically the maximum number of seeds pods^{-1} (1.9511) was observed in R_1 treatment. Whereas minimum number of seeds pods^{-1} (1.8617) was observed R_2 treatment .

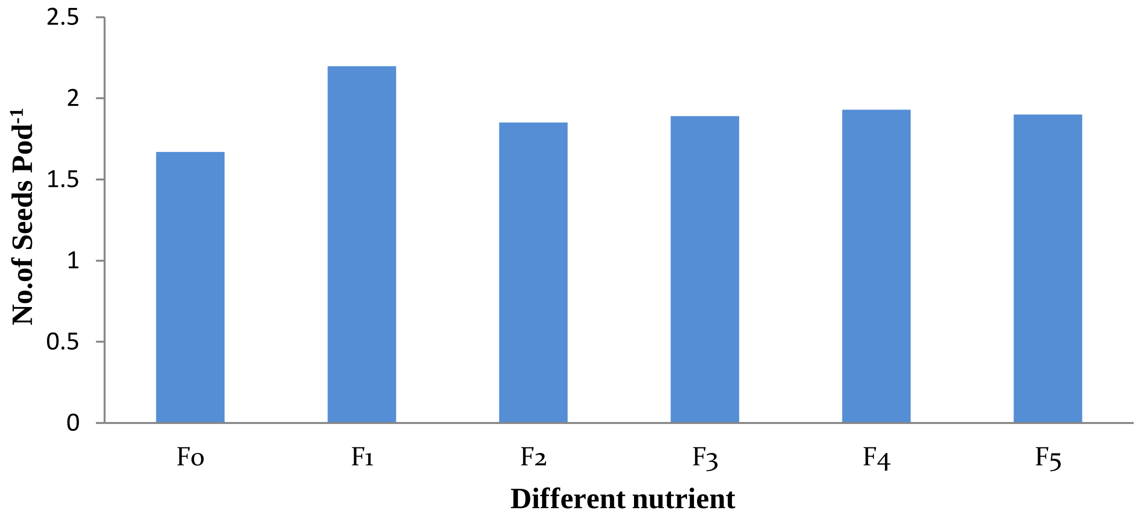


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.11. Effect of *Rhizobium* strains on number of seeds pod^{-1} (LSD$_{(0.05)}$=0.0423).

4.6.2 Effect of different nutrient management

Different nutrient management showed significant difference in respect of seeds pod^{-1}of lentil (Fig 12 and Appendix IX). Among the different nutrient management numerically the maximum number of seeds pod^{-1} (2.1983) was observed in F_1 treatment. Whereas numerically the minimum number of Seeds pod^{-1} (1.6700) was observed in F_0 treatment. Srinivas and Shaik (2002) reported that in case of greengram, increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} followed by decrease with further increase in N. Number of seeds pod^{-1}, 1000-seed weight, seed and haulm yields generally increased.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.12. Effect of different nutrient management on number of seeds pod^{-1} ($LSD_{(0.05)}$=0.1235).

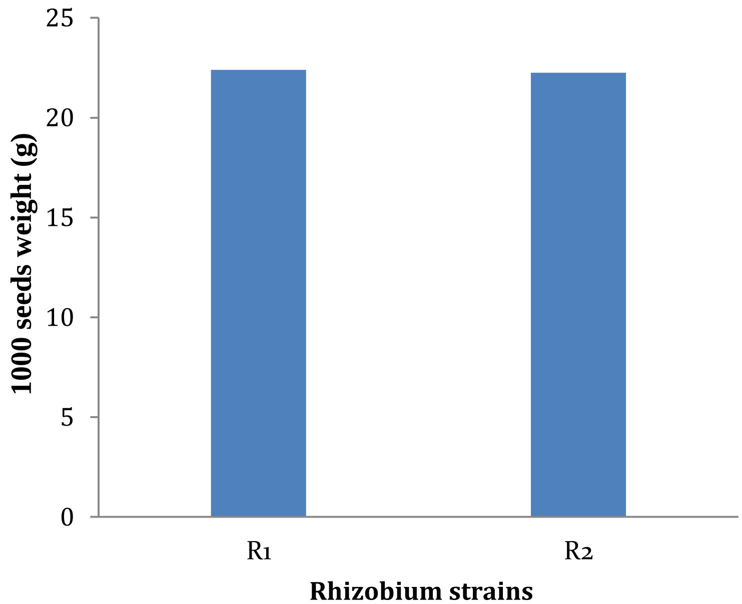
4.6.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of *Rhizobium* strains and different nutrient management showed significant difference in respect of seeds pod^{-1} of lentil (Table 5). Among the treatment combinations numerically maximum seeds pod^{-1} (2.3967) was observed in R_1F_1 treatment combination. On the contrary, numerically minimum seeds pod^{-1} (1.670) was observed in R_1F_0 treatment combination which statistically similar with the treatment combination of R_2F_0 followed by R_2F_2 treatment combination.

4.7 1000-seed weight (g)

4.7.1 Effect of *Rhizobium* strains

Rhizobium strains showed non significant effect on 1000-seed weight (g) of lentil (Fig 13 and Appendix IX). From the experiment result showed that numerically the maximum 1000-seeds weight (22.395 g) was observed in R_1 treatment. Whereas numerically the minimum 1000-seeds weight (22.248 g) was observed in R_2 treatment.

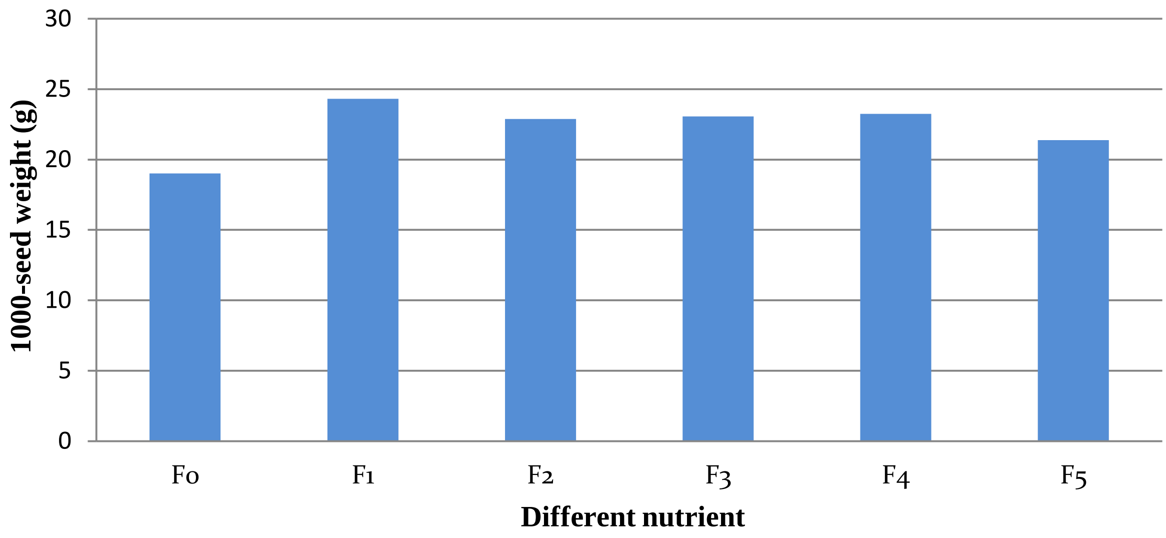


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.13. Effect of *Rhizobium* strains on 1000-seed weight ($LSD_{(0.05)}$= NS)

4.7.2 Effect of different nutrient management

Different nutrient management showed significant difference in respect of 1000-seed weight (g) of lentil (Fig 14 and Appendix IX). Among the different nutrient management numerically the maximum 1000-seed weight (24.310 g) was observed in F_1 treatment which was statistically similar with F_4 (23.25 g) treatment followed by F_3(23.075 g) treatment. Whereas numerically the minimum 1000-seed weight (19.025 g) was observed from the treatment of F_0.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.14. Effect of different nutrient management on 1000-seed weight of lentil ($LSD_{(0.05)}$=1.2438).

4.7.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of *Rhizobium* strains and different nutrient management showed significant difference in respect of 1000-seed weight of lentil (Table 5). From the experiment result showed that numerically the maximum 1000-seeds weight was (24.93 g) observed in R_1F_1 treatment combination which was statistically similar with the treatment combinations of R_2F_1 followed by R_1F_4 and R_2F_4 treatment combination. Whereas numerically the minimum 1000-seeds weight (19.04 g) was observed in R_1F_0 treatment combination which showed similarity with R_2F_0 treatment combination.

Table 5: Combined effect of *Rhizobium* strains and different nutrient management on the yield contributing characteristics of lentil

Treatments Combinations	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	1000-grain weight (g)
R_1F_0	34.330e	1.6700d	19.040e
R_1F_1	65.200a	2.3967a	24.930a
R_1F_2	42.450d	1.9200bc	22.990bc
R_1F_3	45.350d	1.8900bc	23.050bc
R_1F_4	59.060b	1.9300bc	23.290a-c
R_1F_5	58.010b	1.9000bc	21.070d
R_2F_0	30.310e	1.6700d	19.010e
R_2F_1	63.930a	2.0000b	23.690ab
R_2F_2	41.450d	1.7800cd	22.780b-d
R_2F_3	43.750d	1.8900bc	23.100bc
R_2F_4	58.900b	1.9300bc	23.210a-c
R_2F_5	52.867c	1.9000bc	21.700cd
$LSD_{(0.05)}$	4.1234	0.1746	1.7590
CV(%)	4.88	5.38	4.63

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5 , K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

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

4.8.1 Effect of *Rhizobium* Strains

Rhizobium strains showed non significant effect on seed yield of lentil (Fig 15 and Appendix X). The experiment result showed that numerically the maximum seed yield (1884.1 kg ha^{-1}) was observed in R_1 treatment. Whereas minimum seed yield (1826.3 kg ha^{-1}) was observed in R_2 treatment.

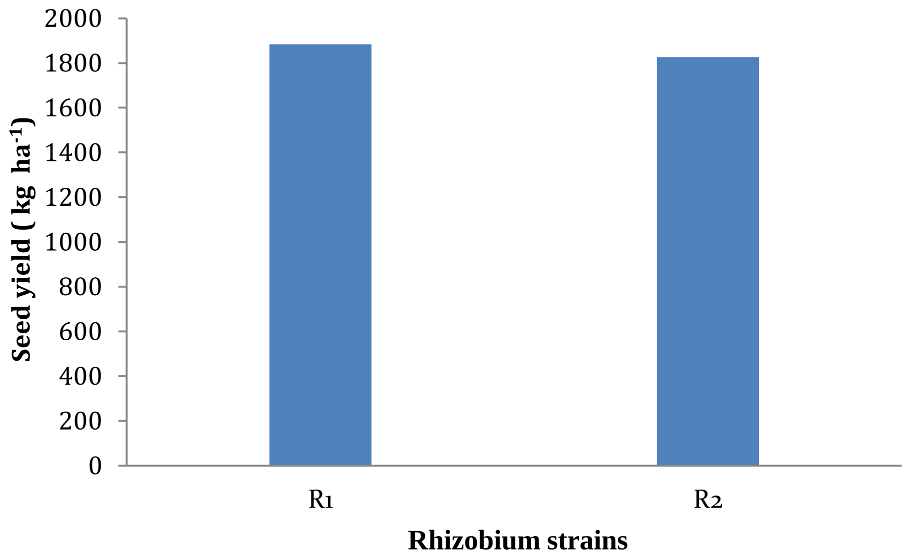
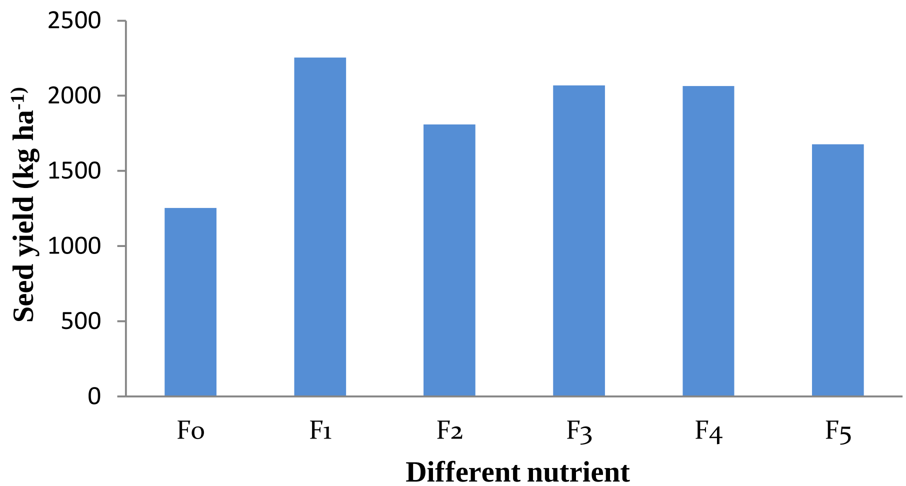


Fig.15. Effect of *Rhizobium* strains on seed yield ($LSD_{(0.05)}$= NS).

4.8.2 Effect of different nutrient management

Different nutrient management showed significant difference in respect of seed yield of lentil (Fig 16 and Appendix X). Among the different nutrient management numerically the maximum seed yield (2255.2 kg ha^{-1}) was observed in F_1 treatment. Whereas numerically the minimum seed yield (1254.5 kg ha^{-1}) was observedin F_0 treatment. .Ashraf *et al.* (2003), Sharma *et al.* (2001),and Ashraf *et al.* (2003) also found similar result which supported the present study.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.16. Effect of different nutrient managementon seed yield of lentil ($LSD_{(0.05)}$=155.48

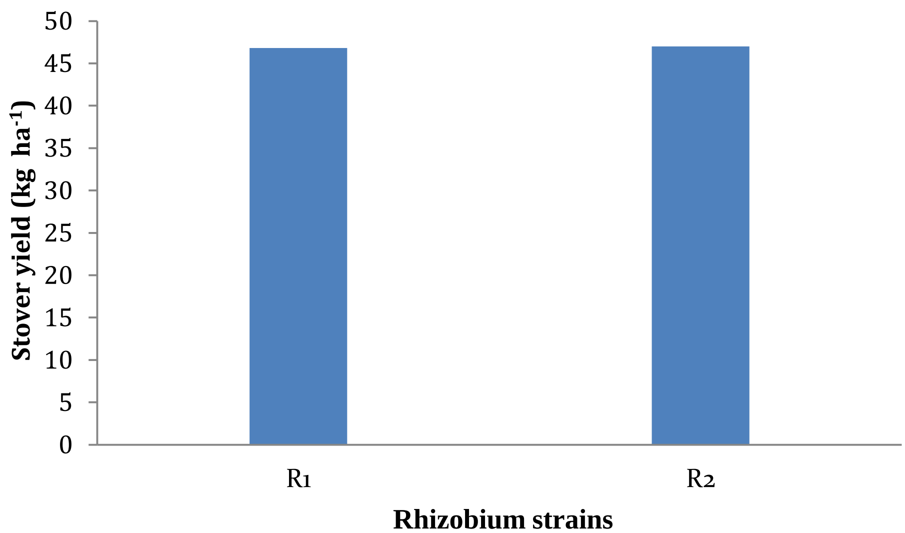
4.8.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of *Rhizobium* strains and different nutrient management showed significant difference in respect of seed yield of lentil (Table 6). From the experiment result showed that numerically the maximum seed yield (2320 kg ha^{-1}) was observed in R_1F_1 treatment combination which was statistically similar with R_2F_1 treatment combination. Whereas numerically the minimum seed yield (1220 kg ha^{-1}) was observed in R_2F_0 treatment combination which showed statistic similarity with R_1F_0 treatment combination. Kumar and Uppar (2007) reported that the effects of organic manures, biofertilizers, micronutrients and plant growth regulators on the seed yield and quality of moth bean. RDF + FYM @ 10 t/ha recorded the highest values for the different seed yield and quality attributes of mothbean. 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.

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

4.9.1 Effect of *Rhizobium* strains

Rhizobium strains showed non significant effect on stover yield of lentil (Fig 17 and Appendix X). Numerically the maximum stover yield (2128.3 kg ha^{-1}) was observed in R_1 treatment. Whereas numerically the minimum stover yield (2049.7 Kg ha^{-1}) was observed in R_2 treatment.

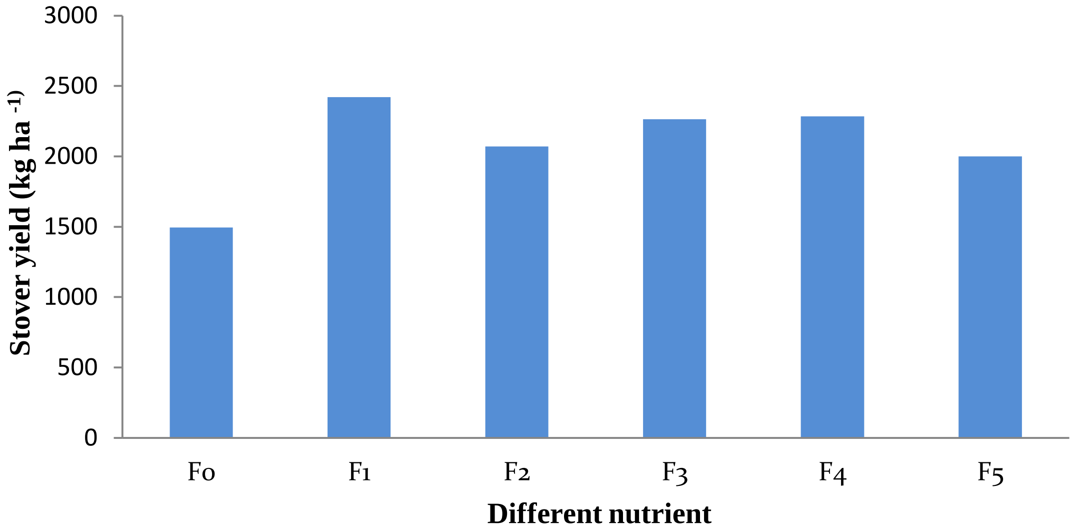


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.17. Effect of *Rhizobium* strains on stover yield of lentil (LSD$_{(0.05)}$= NS).

4.9.2 Effect of different nutrient management

Different Nutrient Management showed significant difference in respect of stover yield of lentil (Fig 18 and Appendix X). Among the different nutrient management numerically the maximum stover yield (2421.0 kg ha^{-1}) was observed in F_1 treatment .Whereas numerically the minimum stover yield (1494.2 kg ha^{-1}) was observed in F_0 treatment.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.18. Effect of different nutrient management on stover yield of lentil ($LSD_{(0.05)}$=111.58).

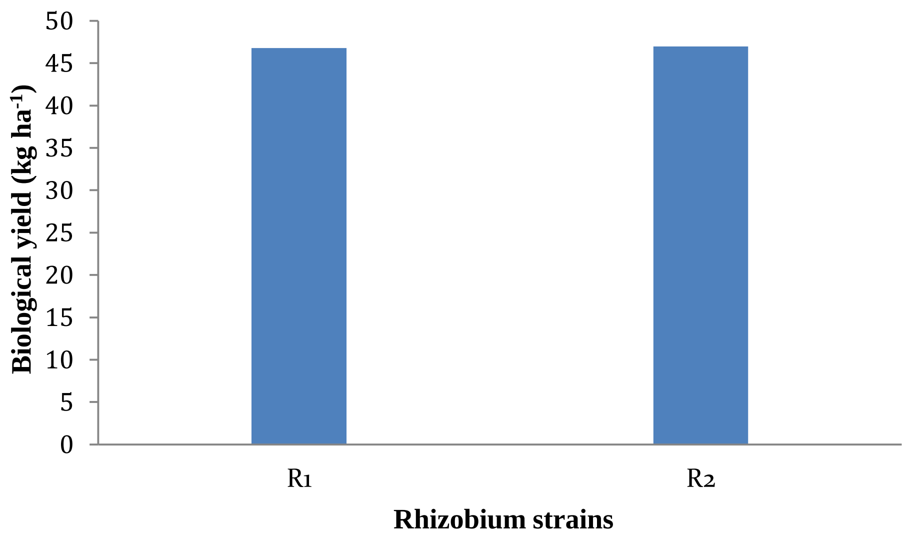
4.9.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of *Rhizobium* strains and different nutrient management showed significant difference in respect of stover yield of lentil (Table 6). From the experiment result showed that numerically the maximum stover yield (2475.3 kg ha^{-1}) was observed in R_1F_1 treatment combination which was statistically similar with the treatment combinations of R_2F_1 followed by B_1F_4 treatment combination. Whereas numerically the minimum stover yield (1437.3 kg ha^{-1}) was observed in R_2F_0 treatment combination which showed statistic similarity with B_1F_0 treatment combination.

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

4.10.1 Effect of *Rhizobium* strains

The biological yield refers to the total dry matter accumulation of a plant system. From this experiment result exhibited that *Rhizobium* strains showed non significant effect on biological yield of lentil (Fig 19 and Appendix X). From the experiment result showed that numerically the maximum biological yield (4012.4 Kg ha^{-1}) was observed from R_1 treatment. Whereas numerically the minimum biological yield (3876.0 Kg ha^{-1}) was observed from R_2 treatment.

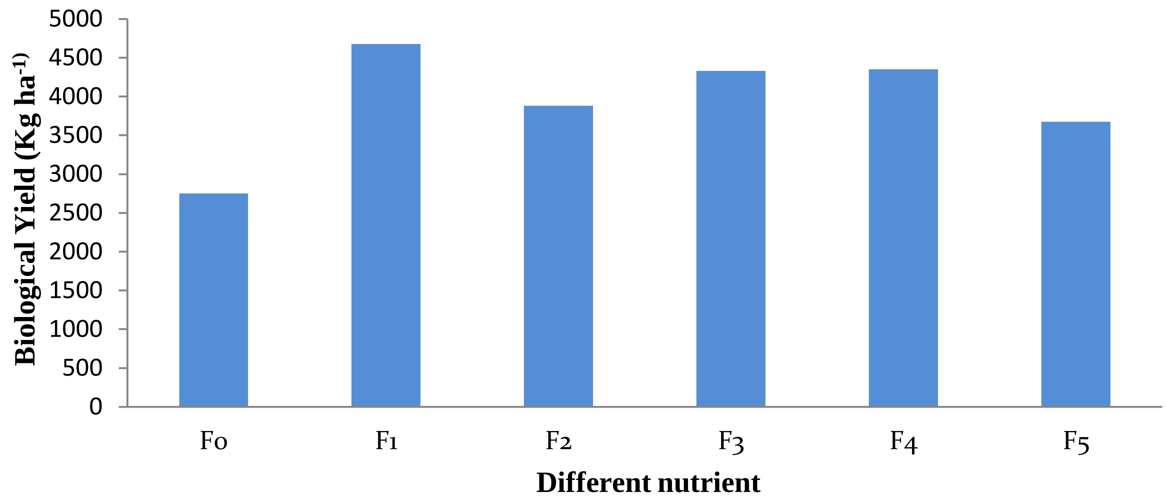


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.19.Effect of *Rhizobium* strains on biological yield of lentil (LSD$_{(0.05)}$= NS).

4.10.2 Effect of different nutrient management

Different Nutrient Management showed significant difference in respect of biological yield of lentil (Fig 20 and Appendix X) . Among the different nutrient management numerically the maximum biological yield (4676.2 kg ha^{-1}) was observed in F_1 treatment. Whereas numerically the minimum biological yield (2748.7 kg ha^{-1}) was observed in F_0 treatment Sharma *et al.* (2001) also found similar result which supported the present finding.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.20. Effect of different nutrient management on biological yield of lentil ($LSD_{(0.05)}$=286.69).

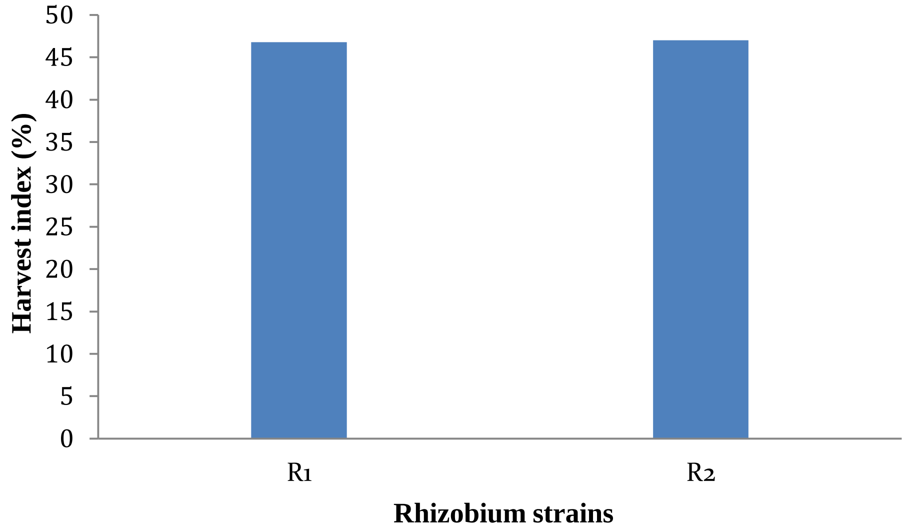
4.10.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined effect of *Rhizobium* strains and different nutrient management showed significant difference in respect of biological yield of lentil (Table 6). From the experiment result showed that numerically the maximum biological yield (4795.3 kg ha^{-1}) was observed in R_1F_1 treatment combination which showed statistic similarity with the treatment combinations of B_2F_1. Whereas numerically the minimum biological yield (2657.3 kg ha^{-1}) was observed from treatment combination of R_2F_0 which showed statistic similarity with the treatment combination of R_1F_0.

4.11 Harvest index (%)

4.11.1 Effect of *Rhizobium* strains

Harvest index of lentil was not significantly influenced by *Rhizobium* strains (Fig 21 and Appendix X) . From the experiment result showed that numerically the maximum and harvest index (46.988) was observed in R_2 treatment whereas numerically the minimum harvest index (46.795 %) was observed in R_1 treatment

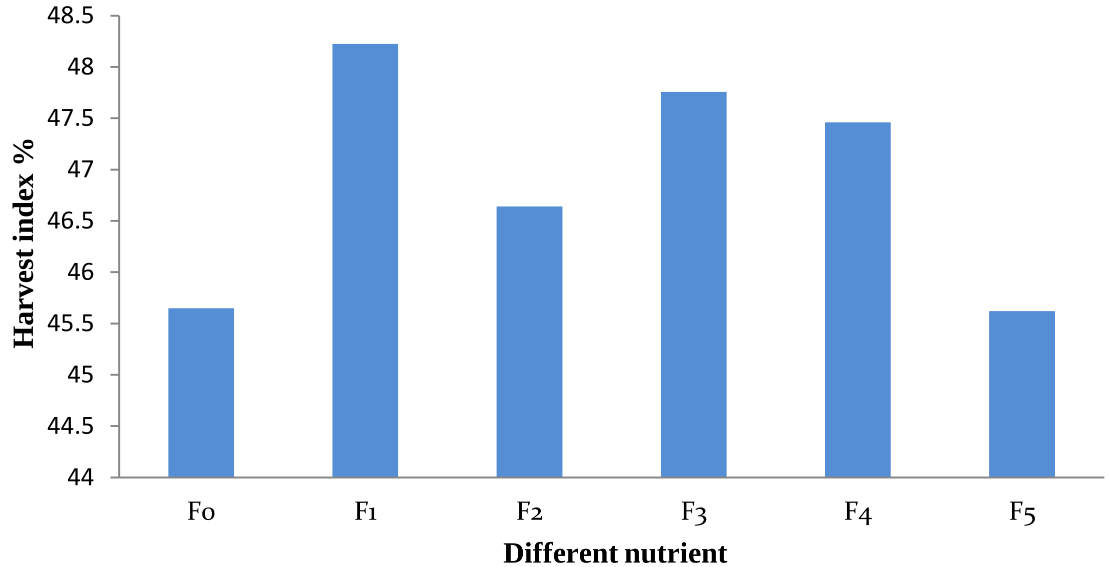


R_1:*Rhizobium* strain (BARI RLc-102), R_2: *Rhizobium* strain (BARI RLc-104)

Fig.21. Effect of *Rhizobium* strains on harvest index of lentil ($LSD_{(0.05)}$= NS).

4.11.2 Effect of different nutrient management

Different Nutrient Management showed significant difference in respect of harvest index of lentil (Fig 22 and Appendix X). Among the different nutrient management numerically the maximum harvest index (48.225 %) was observed in F_1 treatment .which was statistically similar with F_4 (47.755) treatment followed by F_3 (47.460) and F_2 (45.62 %) treatment. Whereas numerically the minimum harvest index (45.62) was observed in F_5 treatment. which was statistically similar with F_0 (45.65%) treatment. Hayat *et al*. (2004) and Ashraf *et al.* (2003) also found similar result which supported the present finding.



F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Fig.22. Effect of different nutrient managementon harvest index of lentil (LSD$_{(0.05)}$=2.4583)

4.11.3 Combined effect of *Rhizobium* strains and different nutrient management

Combined of *Rhizobium* strains and different nutrient management showed non significant effect on harvest index of lentil (Table 6). The result showed that numerically the maximum harvest index (48.38 %) was observed in R_1F_1 treatment combination. Whereas numerically minimum harvest index (45.39%) was observed in R_1F_0 treatment combination.

Table 6: Combined effect of *Rhizobium* strains and different nutrient management on the yield characteristics of lentil

Treatments Combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
R_1F_0	1289.0f	1551.0e	2840.0e	45.390
R_1F_1	2320.0a	2475.3a	4795.3a	48.380
R_1F_2	1825.0c-e	2125.0cd	3950.0cd	46.200
R_1F_3	2085.3b	2290.0b	4375.3b	47.660
R_1F_4	2091.7b	2320.3ab	4412.0ab	47.400
R_1F_5	1693.3e	2008.3d	3701.7d	45.740
R_2F_0	1220.0f	1437.3e	2657.3e	45.910
R_2F_1	2190.3ab	2366.7ab	4557.0ab	48.070
R_2F_2	1795.0e	2017.7d	3812.7d	47.080
R_2F_3	2052.7bc	2236.7bc	4289.3bc	47.850
R_2F_4	2038.0b-d	2250.0bc	4288.0bc	47.520
R_2F_5	1661.7e	1989.7d	3651.3d	45.500
$LSD_{(0.05)}$	219.88	157.79	405.44	NS
CV(%)	6.96	4.43	6.04	4.35

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2019 to March 2020, to investigate the effect of *Rhizobium* strains and different nutrients management on growth and yield response of lentil. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors, and conducted following split plot design with three replications. Factor A: *Rhizobium* strains (2); R_1= BARI RLc-102 and R_2= BARI RLc-104 and Factor B: Different nutrient management (6) ; F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5 , K_2O kgha^{-1}) , F_2= Recommended dose of cowdung (5 t ha^{-1}), F_3= Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).The total numbers of unit plots were 36. The size of unit plot was $4\times1.2m^2$. The distances between plot to plot and replication to replication were 0.50 m and 1.0 m respectively. According to the treatments all the fertilizers were applied as basal dose (*Rhizobium* strains applied in main plot and different nutrient sources applied in sub-plot) and mixed with soil thoroughly at the time of final land preparation after making specific plot. Data on different growth and yield parameters like plant height, no. of branch plant^{-1}, nodule number, above ground dry weight plant^{-1},pods plant^{-1}, 1000 seed weight, grain yield, stover yield, biological yield and harvest index were recorded for comparing different treatments to find out the suitable biofertilizer (i.z *Rhizobium* strains) and proper nutrient sources for the highest yield of lentil.

In case of *Rhizobium* strains result revealed significant variation was observed in some of the specific parameters of lentil. Numerically the maximum plant height (14.778 cm) was observed in R_2 treatment at 30 DAS, whereas at 50, 70, 90 DAS and harvest, respectively numerically the maximum plant height (23.62, 31.958, 39.155, and 37.185 cm) was observed in R_1 (BARI RL_C-102) treatment, the highest above ground dry weight plant^{-1} (0.2150, 0.6783, 1.4433, 3.8367 and 5.7017 g at 30, 50, 70, 90 DAS and harvest respectively), branches plant^{-1} (2.9267, 6.9767, 8.4639, 9.9817 and 10.791 at 30, 50, 70, 90 DAS and harvest respectively), nodules plant^{-1} (15.763, 20.947, 29.322, and 26.375 at 50, 60, 70 and 80 DAS), number of pod plant^{-1} (50.733), number of seeds pods^{-1} (1.9511), 1000-seeds weight (22.395 g), seed yield (1884.1 kg ha^{-1}), stover yield (2128.3 kg ha^{-1}) and biological yield (4012.4 Kg ha^{-1}) were observed in R_1 treatment, and numerically the maximum and harvest index (46.988) was observed in R_2 treatment. Whereas numerically the minimum plant height (14.59 cm) was observed from R_1 (BARI RL_C-102) treatment at 30 DAS, at 50, 70, 90 DAS and harvest respectively numerically the minimum plant height (22.565, 31.157, 37.798 and 36.578cm) was observed from R_2 (BARI RL_C-104) treatment, numerically the minimum above ground dry weight plant^{-1} (0.2033, 0.6283, 1.3583, 3.5317, and 5.4883g at 30, 50, 70, 90 DAS and harvest respectively), branches plant^{-1} (2.61, 6.4833, 8.05, 9.583, and 10.592 at 30, 50, 70, 90 DAS and harvest respectively), nodules plant^{-1} (15.622, 20.178, 28.513 and 25.935 at 50, 60, 70 and 80DAS),number of pod plant^{-1} (48.534), number of seeds pods^{-1} (1.8617), 1000- seeds weight (22.248 g), seed yield (1826.3 kg ha^{-1}), stover yield (2049.7 Kg ha^{-1}) and biological yield (3876.0 Kg ha^{-1}) were observed in R_2 treatment, whereas numerically the minimum harvest index (46.795 %) was observed in R_1 treatment.

Different growth parameter alongwith yield and yield contributing parameters were significantly influenced by different nutrient management. From the experiment, result revealed that numerically the maximum plant height (17.2 cm) was observer in F_1 treatment. At 50DAS numerically the maximum plant height (24.645 cm) was observer in F_5 treatment, at 70, 90 DAS and harvest respectively numerically the maximum plant height (34.715, 41.26, and 39.875 cm) was observed in F_1 treatment, numerically the maximum above ground dry weight plant^{-1} (0.27, 0.925, 1.905, 4.925, and 6.48 g at 30, 50, 70, 90 DAS and harvest respectively), branches plant^{-1} (3.83, 7.85, 10.30, 11.43 and 12.145 at 30, 50, 70, 90 DAS and harvest respectively) was observed in F_1 treatment. Numerically the maximum nodules plant^{-1} (17.53) was found in F_4 treatment at 50 DAS. At 60, 70 and 80 DAS numerically the maximum nodules plant^{-1} (23.130, 33.085, and 29.335) was found in F_1 treatment. Among the different nutrient management numerically the maximum number of pod plant^{-1} (64.565) ,number of Seeds pod^{-1} (2.1983), 1000-seed weight (24.310 g), seed yield (2255.2 kg ha^{-1}), stover yield (2421.0 kg ha^{-1}), biological yield (4676.2 Kg ha^{-1}) and harvest index (48.225 %) were observed in F_1 treatment. Whereas numerically the minimum plant height (11.555, 19.505, 25.405, 31.650 and 29.98 cm at 30, 50 70, 90 DAS and harvest respectively), above ground dry weight plant^{-1} (0.14, 0.425,1.035, 2.48, and 4.1 g at 30, 50, 70, 90DAS and harvest respectively), branches plant^{-1} (2, 5.8, 6.85, 7.845 and 9.35 at 30, 50, 70, 90 DAS and harvest respectively), nodules plant^{-1}(13.575, 16.325 , 24.88, and 19.36 at 50, 60, 70 and 80 DAS respectively), number of pod plant^{-1} (48.534), number of seeds pod^{-1} (1.6700) seed yield (1254.5 kg ha^{-1}), stover yield (1494.2 kg ha^{-1}), biological yield (2748.7 kg ha^{-1}) were observed in F_0 treatment., Whereas numerically the minimum harvest index (45.62) was observed in F_5 treatment.

Different growth yield and yield contributing parameters were significantly influenced by the combined application of *Rhizobium* strains and different nutrients management. Result exhibited that the numerically the maximum plant height (17.380, 26.850, 35.50, 42.12, and 40.60 cm at 30, 50 70, 90 DAS and harvest respectively), above ground dry weight plant^{-1} (0.280, 0.960, 1.97, 5.18 and 6.88 g at 30, 50, 70, 90 DAS and harvest respectively), branches plant^{-1} (4.0, 8.20, 10.80, 11.80 and 12.40 at 30, 50, 70, 90 DAS and harvest respectively), nodules plant^{-1} (17.86) was observed in R_1F_1 treatment combination at 50 DAS, at 60 DAS numerically the maximum nodules plant^{-1} (23.66) was observed in R_1F_4 treatment combination and at 70 and 80 DAS numerically the maximum nodules plant^{-1} (33.14 and 29.66) was observed in R_1F_1 treatment combination. Among the treatment combinations numerically the maximum number of pod plant^{-1} (65.20), number of seeds pod^{-1} (2.3967), 1000-seeds weight (24.93 g), seed yield (2320 kg ha^{-1}), stover yield (2475.3 kg ha^{-1}), biological yield (4795.3 kg ha^{-1}) and harvest index (48.38 %) were observed in R_1F_1 treatment combination. Whereas numerically the minimum plant height (11.10 and 19.21 cm at 30 and 50 DAS) was observed in R_1F_0 treatment combination, and at 70, 90 DAS and harvest respectively numerically the minimum plant height (25.31, 30.85, and 29.9 cm) was observed in R_2F_0 treatment combination. Among the treatment combinations numerically the minimum above ground dry weight plant^{-1} (0.13, 0.4, 1.02, 2.45, and 4.05 g at 30, 50, 70, 90 DAS and harvest respectively), branches plant^{-1} (6.8, 7.80 and 9.20 at 70, 90 DAS and harvest respectively) were found in R_2F_0 treatment combination, numerically the minimum nodules plant^{-1} (13.500) was observed in R_1F_0 treatment combination at 50 DAS. At 60, 70 and 80 DAS numerically the minimum nodules plant^{-1} (15.880, 24.43, and 19.06) was found R_2F_0 treatment combination. Among the treatment combinations, numerically the minimum number of pod plant^{-1} (30.31) was observed in R_2F_0 treatment combination, numerically the minimum seeds pod^{-1} (1.670) and 1000-seeds weight (19.04 g) were observed in R_1F_0 treatment combination. Numerically the minimum seed yield (1220 kg ha^{-1}), stover yield (1437.3 kg ha^{-1}), biological yield (2657.3 kg ha^{-1}) were observed in R_2F_0 treatment combination and numerically minimum harvest index (45.39%) was observed in R_1F_0 treatment combination.

Conclusion

From the above findings it can be concluded that, some of the specific characteristics (such as above ground dry weight $plant^{-1}$, branches $plant^{-1}$, nodules number at 60 DAS, seeds pod^{-1}, and seeds $plant^{-1}$) of lentil showed the best performance due to application of *Rhizobium* strains (R_1=BARI RLc-102). Again, from different nutrient management, (F_1= Recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}) showed the best performance regarding most of the growth, yield and yield contributing characteristics. In case of combined effect, *Rhizobium* strains (R_1= BARI RLc-102) along with recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}) (F_1) gave the best result in producing maximum number of pod $plant^{-1}$ (65.20), seeds pod^{-1} (2.3967) and 1000-seeds weight (24.93 g. which ultimately influences seed yield . The highest seed yield 2320 kg ha^{-1} was obtained from R_1F_1 treatment combination (R_1= BARI RLc-102 along with F_1= recommended dose of fertilizers (44, 100, 40 N, P_2O_5, K_2O kg ha^{-1}). So, this treatment combination (R_1F_1) can be treated as the best treatment combination under the present study.

Recommendations

The following preliminary recommendations are proposed here under:

1. Before making final conclusion, further trials with the same treatment combinations on different locations of Bangladesh would be useful. However, further investigation is necessary for the other soil types under different AEZ in Bangladesh.

REFERENCES

Akande, M. O., Oluwatoyinbo, F. I., Kayode, C. O. and Olowokere, F. A. (2006). Response of maize (Zea mays) and okra (Abelmoschusesculentus) intercrop relayed with cowpea (*Vigna unguiculata*) to different levels of cow dung amended phosphate rock. *World J. Agric. Sci.* **2**: 119.

Ali, W., Zada, K., Shah, P., Haider, A., Ayaz, S. and Malik, S. (1997). Correlation and regression analysis of agronomic parameters with grain yield of wheat. *Sarhad J. Agric*. **8**(4): 329-332.

Anonymous. (1988 a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (2004). Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

Ashraf, M., Mueen, M. and Warrick, N. H. (2003). Production efficiency of mungbean (*Vigna radiata* L.) as affected by seed inoculation and NPK application. *Intl. J. Agric. Biol.* **5**(2): 179-180.

Bangladesh Bureau of Statistics (BBS). 2012. Statistical Yearbook of Bangladesh. 32nd Edition. Bangladesh Bureau of (BBS) Statistics. Ministry of Planning, Govt. People's Republic of Bangladesh. p. 133.

Barzegar, A.R., Yousefi, A. and Daryashenas, A. (2002). The effect of addition of different amounts and types of organic materials on soil physical properties and yield of wheat. *Plant Soil.* **247**: 295–301.

Bhatty, R. S. (1988). Composition and quality of lentil (Lens culinaris Medik): a review. *Can. Inst. Food Sci. Technol. J*. **21**: 144-160.

Bisen, C. R., Tamar, J. S., Hivamunthy, R. B. and Kashayap, M. L. (1980). Response of lentil Rhizobium inoculation and fertilization under different moisture regimes. *Mysore J. Agric. Sci.* **14**: 483-6.

Bremer, E., Van Kessel, C. and Karamanos, R. (1989). Inoculant, phosphorus and nitrogen responses of lentil. *Can. J. Plant Sci*. **69**: 691-701.

Channabasanagowda, N. K., Patil, B., Patil, B. N., Awaknavar J. S., Ninganur, B. T. and Hunje, R. (2008). Effect of organic manures on growth, seed yield and quality of wheat. *Karnataka J. Agric. Sci.* **21**(3): 366-368.

Channabasavanna, A. S., Shivakumar, N. and Biradar, D. P. (2009). Productivity, profitability, resource use efficiency and sustainability of rice (*Oryza sativa* l.) as influenced by poultry manure and npk levels. **43**: 299-302.

Chaoui, H. I, Zibilske L. M. and Ohno, S. (2003). Efects of earthworms cast andcompost on soil microbial activity and plant nutrient availability. *Soil. Biol. Biochem.* **35**: 295–302.

Edward, C. A., Dominguez, J. and Anancon, N. Q .(2004). The influence of vermicompost on plant and pest incidence. In :Shakin SH and Mikhail W & A (eds) soil zoology for sustainable development in the 21st century. Self-publisher Cairo, Egypt. pp. 397-420.

Fageria, N. K. (2009). Nitrogen. In: The Use of Nutrients in Crop Plants. CRC Press, Taylor& Francis Group, Boca Raton, FL. pp. 31-90.

Farhad, W., Saleem, M. F., Cheema, M. A. and Hammad, H. M. (2009). Effect of poultry manure levels on the productivity ofspring maize (Zea mays). *J. Ani. Plant Sci.* **19**(3): 122-125.

Ginaddi, R. S. (2007). Vermi technologies (in kannada).University of Agricultural Sciences, Dharwadi. pp. 62.

Gomez, M. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. Pp. 97–129, 207–215.

Gudugi, I. A. S. 2013. Effect of cowdung and variety on the growth and yield of okra (*Abelmoschus esculentus* L.). *Eur. J. Exp.Biol.* **3**: 495–498.

Gyaneshwar, P., Kumar, G. N., Paresh, L. T. and Pole, P.S. (2002) Role of soil microorganisms in improving ‘P’ nutrients of plants. Plant and Soil. **245**:83 - 93.

Hadiuzamman, M., Mia, S., Ahmed, S., Abuyusuf , M. and Biswas, P. (2015). Effect of biochar, poultry litter, cow dungand vermin composting on yield of lentil. *Bangladesh J.Sci. Res.* **12**(2): 141-144.

Hakeem, S. A., Prasad, V. M. and Prasad, F. M. (2007). Effect of Rhizobium and organic manureon soil properties and yield of blackgram. *Ann. Plant & Soil Res.* **9**: 93-94.

Hayat, R., Ali , S. and Khan, F. S. (2004). Effect of nitrogen and Rhizobium inoculation on yield, N-uptake and economics of mungbean. *Intl. J. Agric. Biol.* **6**(3): 547-551.

Hussain, M. S., Rahman, M. M., Harun-ur-rashid, M., Farid, A. T. M., Quyyum, M. A., Ahamed, M., Alam, M. S. and Salahuddin, K. M. (2006). KrishiProjuktiHatboy (Handbook on Agro-tecnology), 4th edition, Bangladesh Aricultural Researh Institute, Gazipur 1701. pp. 123-142.

Islam, M., Hossain, N., Alamgir, M. and Kibria, M. G. (2014).Comparative effects of biogas plant residues, poultrymanure and inorganic fertilizer on growth and yield ofladies finger. *IOSR J. Agric. Vet. Sci.* **7**(1): 29-33.

Joseph, J. A., Hale, B. S., Denisova, N. A., Bielinski, D., Martin, A., McEwen , J J., and Bickford, P. C. Reversals of Age-Related Declines in Neuronal Signal Transduction, Cognitive, and Motor Behavioral Deficits with Blueberry, Spinach, or Strawberry Dietary Supplementation. *J. Neurosci.* **19**(18):8114–8121.

Kayani, A. K., Qureshi, S., Kayani, W. K., Qureshi, R., Waheed, A., Arshad, M.,Gulfraz, M. and Laghari, M. K. (2010). Assessment of wheat yield potential after cropping mungbean (*Vigna radiata* (l.) Wilczek). *Pakistan J. Bot.* **42**(3): 1535-1541.

Khanam, D., Bhuiyan, M. A. H., Rahman., M. H. H. and Hossain, A. K. M. (1999). On-farm experience of the application and adoption of biological nitrogen fixation technologyi n Bangladesh. *Bangladesh J. Agril. Res.* **24**(2): 375-382.

Khanam, D., Rahman, M. H. H., Bhuiyan, M. A. H., Hossain, A. K. M., and Rahman, A. F. M. (1993). Effect of rhizobial inoculation and chemical fertilizer on the growth and yield of lentil at Two Agroecological zones of Bangladesh. *Bangladesh J. Agril.Res.* **18**(2): 196-200.

Kumar, S. H. A. and Uppar, D.S. (2007). Influence of integrated nutrient management on seed yield and quality of mothbean [*Vigna aconitifolia* (Jacq.) Marchel]. *Karnataka J. Agril. Sci.***20** (2): 394-396.

Mahon, J. D. and Child, J. J. (1979). Growth response of inoculated peas(Pisumsativum) to combined nitrogen. *Canadian J. Bot*. **57**: 1687-1693.

Malik, M. A., Saleem, M. F., Ali, A. and Mahmood, I. (2003). Effect of nitrogenand phosphorus application on growth, yield and quality of mungbean(*Vigna radiata* L.). *Pakistan J. Agril. Sci.* **40**(3/4): 133-136.

McAndrew, D. W. and Mills, K. (2000). Nitrogen fertilizer in dry bean in Manitoba. In Proc. Third Pulse Crop Research Workshop. Winnipeg, MB. Nov. 19–21. pp. 72-75.

McKenzie, R. H., Middleton, A. B., Solberg, E. D., Demulder, J., Flore, N., Clayton, G. W. and Bremer, E. (2001). Response of pea to rhizobia inoculation and starter nitrogen in Alberta. *Can. J. Plant Sci.* **81**: 637–643.

McLaren, R. G. and Cameron, K. C. (1996). Soil science: sustainable production and environmental protection. Auckland [N.Z.] : Oxford University Press. pp.304.

Mehedi, T. A., Siddique, M. A. and Shahid, S. B. 2012. Effect of urea and cow dung on growth and yield of carrot. *J. Bangladesh. Agril. Univ*. **10**: 9–13.

Mengel, K. (1994). Symbiotic dinitrogen fixation: its dependance on plant nutrition and its ecophysiological impact. *Zeitschrift für Pflanzenernährung und Bodenkunde*. **157**: 233- 241.

Mohammad, W. , Shah , S. A. , Shehzadi , S. and Haroon. (2014). Effect of Conservation Agriculture Practices on Oat Fodder Yield, Water Use Efficiency, and Microbial Biomass C and N in Rainfed Dry Area of North- West Pakistan. J. Agr. Sci. Tech. **16**: 1033-1042.

Oad, F. C. and Buriro, U. A. (2005). Influence of different NPK levels on the growth and yield of mungbean. *Indus J. Plant Sci.* **4**(4): 474-478.

Omer, F. A. (2009). Efficiency of nitrogen-fixing nodules developed on roots of broad bean, chickpea and lentil plants grow in pots. *J. Duhok Univ. Agri. Vet. Sci.* **12**(2): 169-174.

Panda, P. K., Sen, H., Mukherjee, A., and Satapathy, M. R. (2003). Studies on the effect of NK fertilization on the performance of yambean-pigeonpea intercropping system and its residual effect on the succeeding mung. *Legume Res.* **26**(4): 235-241.

Patel, J. J., Mevada, K. D. and Chotaliya, R. L. (2003). Response of summer mungbean to date of sowing and level of fertilizers. *Indian J. Pulses. Res*. **16**(2): 122-124.

Patel, M.P., Richhariya, G.P., Sharma, R.D. and Namdeo, K.N. (2012) Effect of fertility levelson growth, yield and quality of soybean(Glycine max.) genotypes. *Crop Research*. **44**(1&2): 68-70.

Rajput, R. L. and Kushwah, S. S (2005). Integrated weed management in soybean on farmers field. *Indian. J. Agron.* 50 (3): 225-227.

Rana, K. S. and Choudhary, R. S. (2006). Productivity, nitrogen uptake and water use in maize (Zea mays L.) + mungbean intercropping system as affected by nitrogen levels under rainfed conditions. *Crop Res. Hisar.* **32**(3): 306-308.

Rozan P., Kuo Y. H and Lambein F. (2001). Amino acids in seeds and seedlings of the genus Lens. *Phytochemistry*. **58**: 281-289.

Sangakkara, R., Amarasekera, P. and Stamp, P. (2011). Growth, yields, and nitrogen-use efficiency of maize (Zea mays L.) and mungbean (*Vigna radiata* L. Wilczek) as affected by potassium fertilizer in Tropical South Asia. *Communications in Soil Sci. and Plant Analysis.* **42**(7): 832-843.

Sharma, S., Daramwal, N. S., Sharma. C. R. and Upadhyay, R. G. (2001). Influence of various doses of nitrogen and phosphorus on protein content,yield and its attributes of mungbean [*Vigna radiata* (L.) Wilczek]. *Res. Crops*. **2**(2): 108-111.

Sharma, B.C. and Sharma, S.C. (2004). Integrated nutrient management in lentil. *Adv. Pl. Sci.* **17**(1): 195-197.

Sosulski, F. and Buchan, J.A. (1978). Effects of Rhizobium and nitrogen fertilizer on nitrogen fixation and growth of field peas. *Canadian J. Plant Sci.* **58**: 553–556.

Srinivas, M. and Shaik, M. (2002). Effect of Rhizobium inoculation and differentlevels of nitrogen and phosphorus on yield and economics of greengram(Vignaradiata L. Wil.). *Crop Res*. **24**(3): 463-466.

Srinivasarao, C., Massod, A., Ganeshamurthy, A. N. and Singh, K. K. (2003). Potassium requirements of pulse crops. *Better Crops. Intl.* 17(1): 8-11.

Sultana, S., J. Ullah, F. Karim and Asaduzzaman. (2009). Response of mungbean to integrated nitrogen and weed management . *American Eurasian J. Agron.* **2**(2): 104-108.

Tickoo, J. L., Chandra, N., Gangaiah, B. and Dikshit, H. K. (2006). Performance of mungbean (*Vigna radiata*) varieties at different row spacing and nitrogen-phosphorus fertilizer levels. *Indian J. Agril. Sci*. **76**(9): 564-565.

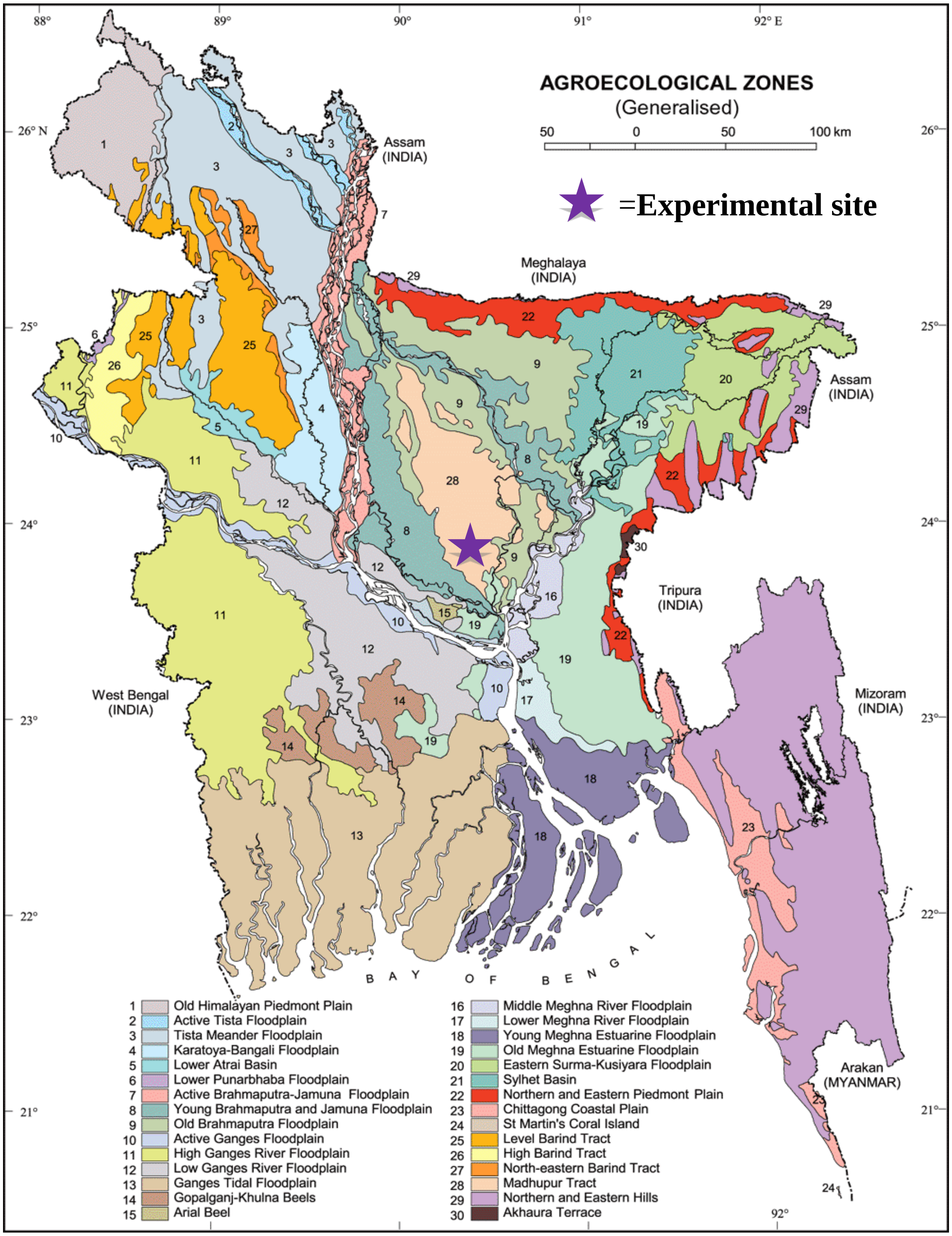
Van Kessel, C. and Hartley, C. (2000). Agricultural management of grain legumes: has it led to an increase in nitrogen fixation? Field Crops Res. **65**: 165-181.

Yahiya M, Samiullah, and Fatma, A. (1995). Influence of phosphorus on nitrogen fixation in chickpea cultivars. *J. Plant Nut.* **18**:719-727.

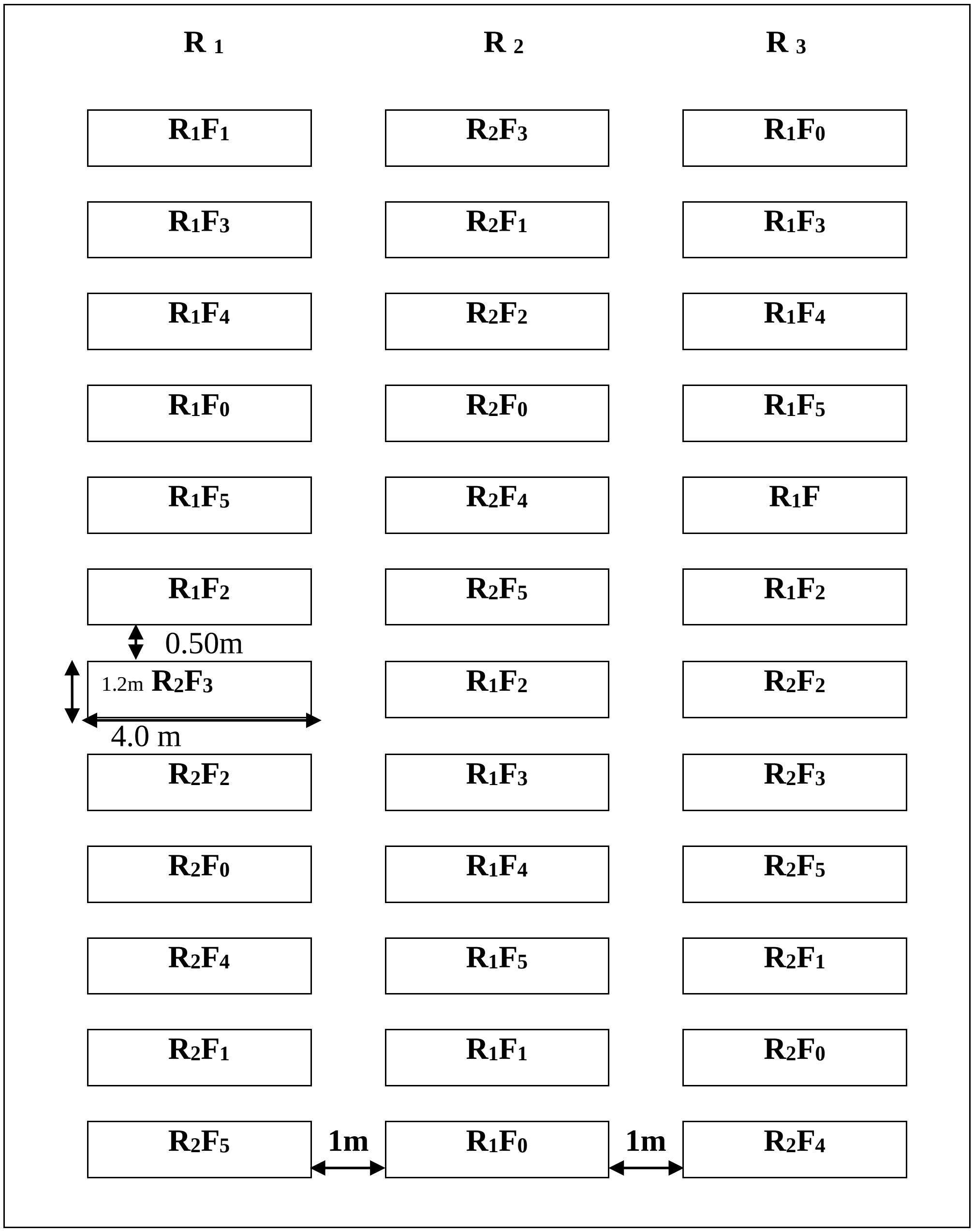
Yaqub, M., Mahmood, T., Akhtar, M., Iqbal, M. M. and Ali, S. (2010). Induction of mungbean [*Vigna radiata* (L.) Wilczek] as a grain legume in the annual rice-wheat double cropping system. *Pakistan J. Bot.* **42**(5): 3125-3135.

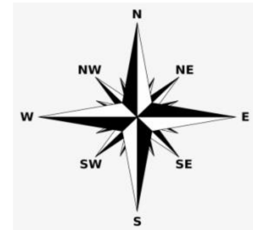
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Layout of the experimental field





LEGEND

R_1= BARI RLc-102, R_2= BARI RLc-104, F_0= Control (no fertilizer management), F_1=Recommended dose of fertilizers (44, 100, 40 N, P_2O_5 , K_2O kg ha^{-1}), F_2= Recommended dose of cowdung (5 t ha^{-1}),F_3 =Recommended dose of poultry litter (1.5 t ha^{-1}), F_4= Recommended dose of farm yard manure (10 t ha^{-1}), and F_5= Recommended dose of vermicompost (1.75 t ha^{-1}).

Appendix III. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow 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 characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Monthly meteorological information during the period from November, 2019 to March, 2020.

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix V. Analysis of variance of the data on plant height of Lentil as influenced combined effect of Rhizobium strains and different nutrient management

Source of variation	**df**	**Mean square of plant height at different days after sowing**				
		30	**50**	**70**	**90**	**At harvest**
Replication	2	1.3125	2.2500	5.2500	6.3333	1.7500
Bio-Fertilizers (A)	1	0.3192 ^{NS}	10.0172 ^{NS}	5.7840 ^{NS}	16.5649 ^{NS}	3.3124 ^{NS}
Error	2	0.5625	0.7500	2.2500	2.3333	5.0833
Different Nutrient management (B)	5	22.5626*	22.8935*	62.3173*	78.5549*	79.2690*
A× B	5	1.0707*	5.8724*	0.4433*	0.3754*	0.9215*
Error	20	0.9375	1.5000	3.7500	4.3333	3.4167

*Significant at 5% level of probability

^{NS}: Non-significant

Appendix VI. Analysis of variance of the data on dry matter weight plant^{-1}of Lentil as influenced by combined effect of *Rhizobium* strains and different nutrient management

Source of variation	df	Mean square of above ground dry weight plant^{-1} at different days after sowing				
		30	50	70	90	At harvest
Replication	2	0.00026	0.00142	0.00333	0.04270	0.09593
Bio-Fertilizers (A)	1	0.00122*	0.02250*	0.06502*	0.83723*	0.40960*
Error	2	0.00006	0.00076	0.00333	0.02803	0.01576
Different Nutrient management (B)	5	0.01185*	0.16924*	0.67677*	4.55361*	5.15850*
A× B	5	0.00009*	0.00030*	0.00880*	0.10877*	0.20968*
Error	20	0.00018	0.00139	0.00533	0.04417	0.06184

*Significant at 5% level of probability
^{NS}: Non-significant

Appendix VII. Analysis of variance of the data on branches plant^{-1}of Lentil as influenced by combined effect of *Rhizobium* strains and different nutrient management

Source of variation	df	Mean square of branches plant^{-1} at different days after sowing				
		30	50	70	90	At harvest
Replication	2	0.01750	0.08083	0.08688	0.35083	0.58861
Bio-Fertilizers (A)	1	0.90250*	2.19040*	1.54174*	1.42803*	0.35601 ^{NS}
Error	2	0.02083	0.10083	0.07854	0.07583	0.29694
Different Nutrient management (B)	5	2.18704*	3.86166*	8.26438*	9.03341*	5.56756*
A× B	5	0.04516*	0.27646*	0.20258*	0.08120*	0.05669*
Error	20	0.02917	0.07483	0.13371	0.21933	0.26278

*Significant at 5% level of probability
^{NS}: Non-significant

Appendix VIII. Analysis of variance of the data on nodules plant^{-1}of Lentil as influenced by combined effect of *Rhizobium* strains and different nutrient management

Source of variation	df	Mean square of nodules plant^{-1} at different days after sowing			
		50	60	70	80
Replication	2	1.5833	0.5833*	3.2500	3.2500
Bio-Fertilizers (A)	1	0.1806 ^{NS}	5.3130 *	5.8806 ^{NS}	1.7424 ^{NS}
Error	2	0.5833	0.2500	1.5833	1.5833
Different Nutrient management (B)	5	14.9722*	43.4822*	60.1959*	79.6398*
A× B	5	0.3543*	0.2830*	0.4294*	0.7969*
Error	20	1.0833	0.8167	2.4167	2.4167

*Significant at 5% level of probability
^{NS}: Non-significant

Appendix IX . Analysis of variance of the data on yield contributing characteristics of Lentil as influenced by combined effect of *Rhizobium* strains and different nutrient management

Source of variation	df	Mean square of		
		Pods plant^{-1}	Seeds pod^{-1}	1000-grain weight
Replication	2	9.694	0.00739	1.0000
Bio-Fertilizers (A)	1	43.516*	0.05921*	0.1936 ^{NS}
Error	2	2.028	0.00305	0.3333
Different Nutrient management (B)	5	874.366*	0.23394*	20.9346*
A× B	5	5.641*	0.03671*	0.5578*
Error	20	5.861	0.01179	1.0667

*Significant at 5% level of probability
^{NS}: Non-significant

Appendix X. Analysis of variance of the data on yield characteristics of Lentil as influenced by combined effect of biological strains and different nutrient management

Source of variation	**df**	**Mean square of**			
		Grain yield	**Stover yield**	**Biological yield**	**Harvest index**
Replication	2	23333	12767	70000	6.25000
Bio-Fertilizers (A)	1	30043^{NS}	55672^{NS}	167510^{NS}	0.33640^{NS}
Error	2	10000	4400	43333	2.08333
Different Nutrient management (B)	5	772908*	649604*	2827211*	7.28200*
A× B	5	2219*	2176*	6791*	0.30742^{NS}
Error	20	16667	8583	56667	4.16667

*Significant at 5% level of probability

^{NS}: Non-significant