International Journal of Environment and Climate Change

Volume 13, Issue 9, Page 1053-1058, 2023; Article no.IJECC.101751
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Influence of Biofertilizers and Phosphorus on Yield and Economics of Lentil (*Lens culinaris* Medik)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i92327

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101751

Original Research Article

Received: 02/05/2023
Accepted: 04/07/2023
Published: 13/07/2023

ABSTRACT

The Experiment was conduct in Crop Research Farm in Department of Agronomy, SHUATS, Prayagraj during *Rabi* season of 2022 on Lentil crop. The treatment consisted of three levels of Biofertilizer *Rhizobium*, PSB and *Rhizobium* + PSB and three levels of Phosphorus (30, 40 and 50 kg/ha) and control. The experiment was layout in Randomized Block Design (RBD) with 10 treatment and replicated thrice. The soil in the experimental area was sandy loam with pH (8.0), EC (0.56 dS/m), Organic Carbon (0.62%), Available N (225 kg/ha), Available P (38.2 kg/ha), and Available K (240.7 kg/ha). The results revealed that the treatment-9 [*Rhizobium* + PSB + phosphorus (50 kg/ha)] produces higher seed yield (2018.04 kg/ha), gross return (110992.56 INR/ha), net return (80852.56 INR/ha) and benefit cost ratio (2.46).

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Keywords: Lentil; biofertilizer; phosphorus; yield and economics.

1. INTRODUCTION

"Lentils are small, lens-shaped legumes that are widely cultivated and consumed around the world. They have been a staple food in many cuisines for centuries and are known for their nutritional value and versatility in cooking. Lentils belong to the family Fabaceae and are scientifically known as *Lens culinaris*. It contains carbohydrates, mainly starches (55-65%); proteins, including essential amino acids (24-28%) and fat (1-4%). These are rich source of protein in vegetarian diet which contains around 20-30% protein which is nearly 2.0-2.5 times higher than that in the cereals. lentil is rich in proteins and contains high concentrations of essential amino acids like isoleucine and lysine, as well as other nutrients like dietary fiber, folate, vitamin B1, and minerals" [1,2]. Lentils are valued for their culinary versatility and can be used in a variety of dishes. They are commonly used in soups, stews, salads, curries, and side dishes. Lentils have a mild, earthy flavor that pairs well with various herbs, spices, and vegetables, allowing them to complement a wide range of flavors and cuisines [3].

In Uttar Pradesh (1026 kg/ha) productivity of lentil crop. The National yield average was (1032 kg/ha). The lowest yield was observed in the state of Assam (712 kg/ha), Jharkhand (882 kg/ha) [16].

Biofertilizers are microbial-based products that contain beneficial microorganisms such as bacteria, fungi, or algae. These microorganisms play a vital role in enhancing soil fertility, nutrient availability, and plant growth. Several studies have examined the influence of biofertilizers on lentil cultivation, and their results have shown positive effects. Crop productivity and nutrient use efficiency are increased when biofertilizers are used in conjunction with chemical fertilizers, organic manures, and crop wastes [4]. "One key group of biofertilizers used in lentil cultivation is *Rhizobium* inoculants. *Rhizobium* are nitrogen-fixing bacteria that form a symbiotic relationship with leguminous plants like lentils. They colonize the root nodules and convert atmospheric nitrogen into a form that can be readily utilized by the plant. *Rhizobium* inoculation can significantly increase nitrogen availability, leading to improved growth, yield, and nitrogen use efficiency in lentils" [5,6]. In addition to *Rhizobium* inoculation, other biofertilizers like phosphate-solubilizing bacteria (PSB) can also enhance lentil growth. PSB have the ability to solubilize bound phosphorus in the soil, making it more accessible to plants. Phosphorus is an essential nutrient for lentils, and its availability can limit growth and yield. By improving phosphorus uptake, PSB can enhance lentil productivity. "Bio-fertilizers contains living micro-organisms, it augments the biochemical processes in soil and pathogen control. Production of the lentil enhanced by optimum use of nutrients" [7, 8].

"Phosphorus plays a significant role in the successful introduction and cultivation of lentils. Lentils, like other legumes, have a symbiotic relationship with nitrogen-fixing bacteria called rhizobia. These bacteria form nodules on the roots of lentil plants and convert atmospheric nitrogen into a form that the plants can use for growth. However, phosphorus is essential for the proper functioning of these nitrogen-fixing bacteria and for the overall growth and development of lentil plants" [9]. Phosphorus is required for the development of root hairs and the formation of nodules, which house the nitrogen-fixing bacteria. Insufficient phosphorus can limit nodulation and, subsequently, nitrogen fixation, leading to reduced plant growth and yield. Insufficient phosphorus can lead to reduced flower formation, pod set, and seed production. Moreover, phosphorus influences seed quality attributes, including protein content and composition, which are important for lentil's nutritional value and marketability [10].

2. MATERIALS AND METHODS

This experiment was laid out during the *Rabi* season of 2022 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The crop research farm is situated at 25^0 39" 42" N latitude, 81^0 67" 56" E longitude and at an altitude of 98 m above mean sea level. The experiment was laid out in Randomized Block Design Which consisting of ten treatments T_1 – (*Rhizobium*) + (Phosphorus 30 kg/ha), T_2 – (*Rhizobium*) + (Phosphorus 40 kg/ha), T_3 – (*Rhizobium*) + (Phosphorus 50 kg/ha), T_4 - (PSB) + (Phosphorus 30 kg/ha), T_5 -(PSB) + (Phosphorus 40 kg/ha), T_6 - (PSB + (Phosphorus 50 kg/ha), T_7 - (*Rhizobium* + PSB) + (Phosphorus 30 kg/ha), T_8 - (*Rhizobium* + PSB) + (Phosphorus 40 kg/ha), T_9 -(*Rhizobium* + PSB)

+ (Phosphorus 50 kg/ha), T_{10} - Control (RDF 20-40-20).The soil in the experimental area was sandy loam with pH (8.0), Organic Carbon (0.42%), Available N (180.58 kg/ha), Available P (15.54 kg/ha) and Available K (198.67 kg/ha). Seeds are sown at a spacing of 30×10 cm to a seed rate of 50 kg/ha. The recommended dose of nitrogen (20 kg/ha), phosphorus (40 kg/ha) and potassium (20 kg/ha) in the form of urea, SSP, Muriate of Potash respectively. Seeds were treated with the respective *Rhizobium* sp. and PSB inoculants by following the standard procedure and sown on 13th Dec. 2022 with seed rate of 50 kg/ha at spacing 30 cm x 10 cm. Biofertilizer and phosphorus were applied as per the treatments. Nitrogen, phosphorus and potash was applied as basal at the time of sowing. One hand weeding was done manually with *Khurpi* at 25 DAS followed by second manual weeding was done at 45 DAS. This was done to control grass as well as broad leaf weeds. Two irrigation was applied to field. Data recorded on different aspects of crop, *viz.,* yield attributes were subjected to statistically analysis by analysis of variance method [11] and economic data analysis mathematical methods.

3. RESULTS AND DISCUSSION

3.1 Seed Yield (kg/ha)

The data revealed that Treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] was recorded significantly maximum Seed yield (2018.04 kg/ha) which was superior over all other treatments. Significant increase in seed yield might be due to the Dual inoculation of *Rhizobium* can increase seed yield in pulse crop up to 10 to 15% while PSB increase availability of insoluble phosphorous into soil. Results were similar to Singh et al. [12]. “Further Significant and higher seed yield was with application of phosphatic fertilizer therefore provided balance nutrition to the crop which resulted in higher seed yield of lentil. Phosphorus also increased the photosynthesis and translocation of assimilates to different plant parts for enhanced growth and yield attributing characters of the crop as observed in number of pods per plant and number of seeds per pod. In the later stage, the excess assimilates stored in the leaves was translocated towards sink development which ultimately contributed to higher seed yield”. Choubey et al., [13].

3.2 Stover Yield (kg/ha)

The data revealed that Treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] was recorded significantly maximum Stover yield (3530.60 kg/ha) which was superior over all other treatments. Significant increase in stover yield with Dual inoculation of *Rhizobium*, PSB increase in nitrogen availability in soil leads to increase in content of nitrogen in seed and increase in P availability through solubilization of insoluble native P and production of plant growth promoting substances. Results were similar to Singh et al. [10]. “Further higher stover yield was with application of phosphorus might have contributed for better growth of plant as expressed in terms of plant height, number of nodules/plants, dry weight, which improved nutrient uptake, resulted increased in stover yield”. [17] Similar findings were reported by Choubey et al. [13] and Kumar et al. [14].

3.3 Harvest Index (%)

At harvest, maximum harvest index (36.39 %) was recorded in Treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] though there was no significant difference among the treatments.

“Significant increase in harvest index with inoculation of *Rhizobium* may be increase due to the stimulatory effect in cell division, cell elongation and background of cell structure and also higher dose of vermicompost may be responsible for increased leaf area and chlorophyll content causing higher photosynthesis and assimilation, metabolic activities responsible for overall reproductive phase and ultimately increased the of harvest index”. Kaushik et al. [15].

4. ECONOMICS

In Table 2 data pertaining to economics of growing as influenced by biofertilizer and Phosphorus on Lentil has been exhibited. The common and variable cost of production has been given in table.

4.1 Cost of Production (INR/ha)

Cost of production (30140.00 INR/ha) was found to be highest in treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] as compared to other treatment.

Table 1. Effect of Biofertilizers and Phosphorus on yield attributes and yield of Lentil

S.No.	Treatment combination	Seed Yield (kg/ha)	Stover Yield (kg/ha)	Harvest Index (%)
1.	*Rhizobium* + Phosphorus 30 kg/ha	1150.56	2505.80	31.31
2.	*Rhizobium* + Phosphorus 40 kg/ha	1304.34	2540.20	33.93
3.	*Rhizobium* + Phosphorus 50 kg/ha	1439.03	2574.60	35.92
4.	PSB + Phosphorus 30 kg/ha	1458.15	2731.00	34.77
5.	PSB + Phosphorus 40 kg/ha	1498.94	2813.40	34.86
6.	PSB + Phosphorus 50 kg/ha	1649.16	3046.00	35.13
7.	*Rhizobium* + PSB + Phosphorus 30 kg/ha	1718.97	3083.40	35.75
8.	*Rhizobium* + PSB + Phosphorus 40 kg/ha	1796.59	3364.40	34.89
9.	*Rhizobium* + PSB + Phosphorus 50 kg/ha	2018.04	3530.60	36.39
10.	Control (NPK 20-40-20 kg/ha)	1132.16	2156.40	34.35
F-test		S	S	NS
SEm(±)		103.30	123.28	2.00
CD (p=0.05)		306.88	366.23	-

Table 2. Effect of biofertilizers and phosphorus on economics of lentil

S.No.	Treatment combination	Cost cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
1.	*Rhizobium* + Phosphorus 30 kg/ha	36045	75810.20	39765.20	1.10
2.	*Rhizobium* + Phosphorus 40 kg/ha	36562	84439.88	47877.88	1.31
3.	*Rhizobium* + Phosphorus 50 kg/ha	37080	92019.83	54939.83	1.48
4.	PSB + Phosphorus 30 kg/ha	36165	93853.25	57688.25	1.60
5.	PSB + Phosphorus 40 kg/ha	36682	96509.07	59827.07	1.63
6.	PSB + Phosphorus 50 kg/ha	37200	105933.98	68733.98	1.85
7.	*Rhizobium* + PSB + Phosphorus 30 kg/ha	36105	109960.53	73855.53	2.05
8.	*Rhizobium* + PSB + Phosphorus 40 kg/ha	36622	115634.82	79012.82	2.16
9.	*Rhizobium* + PSB + Phosphorus 50 kg/ha	37140	128645.57	91505.57	2.46
10.	Control (NPK 20-40-20 kg/ha)	34380	73051.30	38671.30	1.12

4.2 Gross Return (INR/ha)

Gross return (110992.56 INR/ha) was found to be highest in treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] as compared to other treatment.

4.3 Net Return (INR/ha)

Net return (80852.56 INR/ha) was found to be highest in treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] as compared to other treatment.

4.4 B: C Ratio

Benefit Cost Ratio (2.46) was found to be highest in treatment 9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)] as compared to other treatment.

"The statistically higher Benefit cost ratio was with the application of treatment-9 [*Rhizobium* + PSB + Phosphorus (50 kg/ha)], due to the nitrogen and phosphorus provides conclusive condition to the soil with the synergistic effect of Nitrogen and Phosphorus resulting better benefit cost ratio". [17] These results are supported by the findings of Kaushik et al., [15] in lentil.

5. CONCLUSION

Based on the above findings it can be concluded that lentil with the application of *Rhizobium* + PSB along with the application of Phosphorus 50 kg/ha (Treatment 9) recorded highest seed yield, stover yield, harvest index and economics.

ACKNOWLEDGEMENT

The authors are thankful to Dr. Rajesh Singh Associate Professor, Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology And sciences, (U.P) India for providing necessary facilities to undertaken the studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101751