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Ritu Waroda
Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat, Madhya Pradesh, India

JS Bisen
Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat, Madhya Pradesh, India

Corresponding Author:
Ritu Waroda
Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat, Madhya Pradesh, India

Response of phosphorus levels and bio-inoculants on growth, yield and quality of lentil (*Lens culinaris* L.)

Ritu Waroda and JS Bisen

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Abstract
A field experiment was conducted during the *Rabi* season of 2021-22 to find out the effect of phosphorus and biofertilizers on the growth and yield attributes of lentil crops. The experiment was laid down in factorial RBD at Instructional Farm of the Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat (M.P.). The experiment consisted of four phosphorus levels (0, 25, 45 and 65 kg P_2O_5/ha) and seed inoculation with *Rhizobium* and inoculation with PSB (Phosphate solubilizing bacteria) while, compare with without inoculation. The results showed at the maximum crop growth stage that the number of branches/plant, the number of pods/plant, the number of seeds/ pod, test weight, seed and straw yields increased significantly up to P_2O_5/ha and the results were found at par with the treatment 45 kg P_2O_5/ha. Among biofertilizers treatments, seed inoculation with Rhizobium produced a significantly number of branches/plant, number of pods/plant, number of seeds/ pod, test weight, seed and straw yields than other treatments. It proved beneficial for the highest seed yield of lentils under the Balaghat region condition of combined application of 65 kg P_2O_5/ha + *Rhizobium* produced significantly higher grain yield.

Keywords: Lentil, phosphorus, biofertilizers, *Rhizobium*, PSB, pods, test weight

Introduction
Lentil (*Lens culinaris* L.) is an ancient and early domesticated legume that continues to play an important role in human and animal diet, and modern agriculture. It is the fourth most important legume crop after bean (*Phaseolus vulgaris* L.), pea (*Pisum sativum*) and chickpea (*Cicer arietinum*); with an area of 4.17 m ha and production of 4.41 m tons in 2011 (FAO, 2013) [2]. Lentil is an important source of protein, fibre, minerals, vitamins, antioxidant compounds and macronutrients, micronutrients and trace elements. Dietary deficiencies in mineral elements can have significant negative impacts, such as learning disabilities in children, increased morbidity and mortality etc. Nutrient deficiencies mainly result from their low concentrations in most of the plant foods and thus in the daily diet. Hence, there has been an interest in increasing the mineral concentrations of various pulse crops. With these intentions, breeding strategies have been devised for increasing nutrient density in foods and are being assessed to develop sustainable and long-term solutions.

The yield level of lentils is generally low because it is a less cared crop and is mostly grown in poor soil without manures and fertilizers. Regular depletion of nutrient resources of soil has led to emergence of several nutrient deficiencies in many crops including lentil. Lentil needs less nitrogen as it can absorb atmospheric nitrogen through *rhizobial* symbiosis.

Phosphorus is one of the most needed elements for pulse production. Phosphorus has a significant effect on pulse crop yields as it enhances nodulation which helps to fix more nitrogen from air through their root nodules. Phosphorus, although not required in large quantities, is critical to lentil yield because of its multiple effects on nutrition.

In India, the low yield of lentil may be attributed to many reasons such as lack of quality seeds, optimum seed rate, using local varieties as planting material, inappropriate sowing time, lack of judicious fertilizer application and lack of biofertilizers use (Gowda *et al*., 1982) [4]. Given the above discussion, the present study was undertaken to determine the effect of different levels of phosphorus fertilizer and different levels of biofertilizers and their interaction effect on the yield

and yield components of lentils.

Bio-fertilizers, a component of integrated nutrient management and are considered to be cost-effective, eco-friendly and renewable source of non-bulky, low cost plant nutrient supplementing fertilizers in sustainable agriculture system in India. Therefore, the role of bio-fertilizers assumes a special significance in present context of the very high costs of chemical fertilizers. The seed of pulses are inoculated with Rhizobium and Phosphorus solubilizes with an objective of increasing their number in the rhizosphere and substantial increase in the N and P availability for the plant growth.

Materials and Methods

The experiment was carried out at the Agronomy Instructional Farm of Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat (M.P.) during Rabi season 2021-22.

The experiment was conducted in randomize complete block design having a Factorial concept with three replications. Different rates of phosphorus combined application with biofertilizers were allocated to the plots as per treatments. The treatments were four rates of phosphorus *viz.*, P_0- 0 kg /ha, P_1- 25 kg/ha, P_2- 45 kg/ha and P_3- 65 kg/ha, while three biofertilizers were tested are BF_1- no inoculation, BF_2- seed inoculation with Rhizobium and BF_3- seed inoculation with PSB. The gross and net plot size was 6 m x 3.5 m and 5 m x 3 m, respectively. The fertilizers grades were applied as per treatments. Whole dose of phosphorus (as per treatment) and K @ 25 kg K_2O/ ha was applied as basal dose at the time of sowing. Nitrogen @ 25 kg/ha was applied as basal during land preparation and remaining amount of nitrogen was top dressed 25 days after sowing.

All the other agronomic practices were applied uniformly to all the treatments. The seeds were sown continuously manually in the row by *kudali* and covered with soil with the seed rate used was 40 kg/ha. Seeds were properly covered with the soil to obtain uniform germination; plant stand and avoid sun's harmful rays. The un-inoculated seeds were sown first to avoid the risk of contamination followed by treatment-wise inoculated seeds in each plot.

Results and Discussion

The result shows growth and yield attributing characters as well as seed yield of lentil crop that number of branches/plant, number of pods/plant, number of seeds/ pod, test weight, seed and Stover yields was influenced significantly due to different concentrations of phosphorus and biofertilizers.

Effect of phosphorus on growth and yield of lentil

Data regarding the number of branches per plant are reported in (Table 1). Statistical analysis of the data revealed that the maximum number of branches per plant (7.87) was recorded in plots treated with the application of phosphorus @ 65 kg/ha (P_3) while, the lowest values was observed in plot that received no phosphorus.

The growth and development of plants depends on the initiation of tissues and organ primordial and on the differentiation and expansion of cells. Several metabolic activities or reactions are associated with this phenomenon which involves the uptake of nutrients from soil, the synthesis of metabolites and the transport of substances within the plant body. Adequate moisture, nutrients, space and light play an important role.

The increase in growth parameters of lentil came through better nodulation and extensive root development by application of optimum level of phosphorus, which resulted in healthy crop growth with the increase in soil nutrients and higher photosynthetic area (leaf area). The phosphorus supply also augments nitrogen supply at critical stages like flowering and pod development through symbiotically fixed nitrogen which results in better vegetative growth as well as pod development. These results corroborate the findings of Sarkar *et al*. (1995) [11], Saraf *et al.* (1997) [10] and Mukherjee and Rai (2000) [7].

Phosphorus application increased the number of branches. Phosphorus creates a more favourable situation for symbiosis in the plants, in terms of supply of photosynthates to bacteria and rhizobia which are known to supply the host plants with fixed nitrogen. Similar results were also reported by Sahu *et al*., (2002) [12] in lentil crops.

Application of a higher dose of phosphorus recorded higher seed and Stover yield over rest of the treatment tested. The increasing seed and Stover yield of increasing level of phosphorus might be due to increased plant height, number of branches/ plant and fresh and dry weight of plant observed in this treatment. Similar finding was also reported by Abraham and Lal (2003) [1], Yadav *et al.* (2007) [15].

Application of phosphorus also enhances nodulation in the lentil probably because it stimulates the rhizobia on one hand and enhances plant growth on the other as it is evident from plant height, number of branches and root nodules. Increased vigour and growth with phosphorus application led to better development of yield attributes. Nayar and Singh (1985) [9] suggested that increase in the number of seeds and pods by phosphorus application had been due to efficient translocation of photosynthates into the reproductive parts and retention of higher percentage of flowers formed. The capacity of plant to produce economic yield depends not only on the size of photosynthetic system, its efficiency and length of the time for which it is active but also on translocation of photosynthates into economic sink. The final builds up is the cumulative function of yield components.

Effect of biofertilizers on growth and yield of lentil

Data regarding number of branches per plant are reported in (Table 1). Statistical analysis of the data revealed that seeds inoculated with *Rhizobium* gave maximum number of branches per plant value of and 6.87.

Biofertilizers of *Rhizobium*, a root nodule bacterium has the ability to fix atmospheric nitrogen in symbiotic association with legumes. Normally, they enter the root hairs, multiply there and form nodules. The amount of nitrogen fixed varies with the *Rhizobium* strain, the plant species and environmental conditions. Because of nitrogen fixation, legumes are self-dependent on their nitrogen requirement and play a significant role in maintaining the nitrogen balance of the soil. Legumes are also helpful in improving the physical condition of the soil.

Growth characteristics of lentil increased with the *Rhizobium* inoculation as compared to without inoculation as well as PSB. *Rhizobium* application in the form of seed inoculation has ensured adequate nodulation and N_2 fixation for maximum growth. According to Ram *et al*., (2002) inoculation with *Rhizobium* and *Azotobacterial* increased the nutrient availability to plant. The result of present study is in close conformity with the finding of Singh *et al.*, (1984) [13].

The increase in yield attributes by biofertilizers *Rhizobium* inoculation might be due to better and vigorous improvement of growth parameters, root systems, nodules and higher relative leaf water content followed by inoculation with PSB. The increase in yields might have resulted due to improvement in

growth and yield attributing characters through better supply of nutrient as a result of *Rhizobium* inoculation. *Rhizobium* inoculation enhanced the development of more number of root nodules. These results are in accordance with the findings of Nagrajan and Balchander (2001) [8]. These results are line with those reported by Khandelwal *et al*. (2012) [5].

Table 1: Growth and yield response of phosphorus levels and biofertilizers to lentil

Treatment	Number of branches/ plant	Number of pods/plant	Number of seeds/ pod	Test weight (g)	Seed yield (q/ha)	Stover Yield (q/ha)
	Effect of nitrogen					
P_0	4.64	33.16	1.33	18.62	10.56	18.45
P_1	5.71	36.48	1.39	19.73	12.46	22.13
P_2	7.00	40.13	1.41	20.72	13.82	24.44
P_3	7.87	50.77	1.43	22.07	14.46	25.64
SEm±	0.05	0.16	0.004	0.04	0.08	0.05
CD	0.14	0.47	0.012	0.12	0.24	0.13
	Effect of varieties					
BF_1	5.43	35.71	1.35	19.39	12.08	21.48
BF_2	6.87	43.96	1.42	21.04	13.58	23.78
BF_3	6.62	40.74	1.40	20.43	12.81	22.74
SEm±	0.04	0.14	0.004	0.04	0.07	0.04
CD	0.12	0.41	0.011	0.10	0.21	0.11
	Interaction effect of nitrogen and varieties					
P_0BF_0	3.93	30.15	1.32	18.58	10.09	17.15
P_1BF_0	4.73	32.93	1.35	19.25	11.58	20.75
P_2BF_0	6.13	33.58	1.36	19.52	13.09	23.67
P_3BF_0	6.93	46.18	1.37	20.21	13.58	24.33
P_0BF_1	4.73	35.23	1.34	18.65	11.31	19.27
P_1BF_1	6.33	39.25	1.43	20.05	13.47	23.72
P_2BF_1	7.53	45.56	1.45	21.72	14.64	25.15
P_3BF_1	8.87	55.78	1.47	23.72	14.91	26.97
P_0BF_2	5.27	34.10	1.33	18.63	10.29	18.92
P_1BF_2	6.07	37.26	1.39	19.89	12.33	21.91
P_2BF_2	7.33	41.25	1.42	20.92	13.73	24.51
P_3BF_2	7.80	50.35	1.46	22.27	14.89	25.61
SEm±	0.08	0.28	0.007	0.07	0.14	0.08
CD	0.24	0.82	0.021	0.21	0.41	0.23

Interactive effect of phosphorus and biofertilizers on growth and yield of lentil

Statistical analysis of data revealed that interaction effect of phosphorus and biofertilizers significantly affected number of branches per plant was found significant. Similarly, in interaction the maximum number of branches per plant was recorded from plot receiving phosphorus @ 65 kg/ha (P_3) with combination of seed inoculation with *Rhizobium*, value of 8.87 while the minimum was recorded from the plot receiving 0 kg/ha phosphorus without seed inoculation with biofertilizers.

Critical examination of data of present study revealed that combined application of phosphorus along with *Rhizobium* and PSB inoculation positively affected the growth and, yield attributes and yield as well as nutrient content and uptake. According to result of this experiment, the highest levels of phosphorus (65 kg P_2O_5 /ha) with *Rhizobium* inoculation responded to the higher values. This is indicative of the synergistic effect of phosphorus x *Rhizobium* on the growth and yield of lentils. Grain and straw yield of lentils are cumulative effects of growth and yield attributes. Increased grain and straw yield by phosphorus x *Rhizobium* treatment might be due to better establishment of root system and functioning of root nodules. The beneficial effect of grain yield of lentils due to inoculation of *Rhizobium* and phosphorus fertilization have also confirmed by Tiwari and Mishra (2000) [14].

It has been reported that phosphorus plays a beneficial role in legume growth by promoting extensive root system and nodulation. The number of nodules as well as fresh and dry weight of plant have been enhanced due to inoculation of *Rhizobium* with optimum level of phosphorus. Similar results were also reported by Gajera *et al*. (2014) [3]. In the present study, applications of optimum dose of phosphorus and seed treated with *Rhizobium* sp. increased the yield. The inoculation of *Rhizobium* and nitrogen fixers enhanced various physiological activities culminating to higher biomass production and grain yield. Since, this is a non-hazardous way of fertilization of crop plants, it is very relevant to a developing country like India. This technique can solve the problem of high cost of fertilizers and help in saving the cost of inputs for the farmers (Lal *et al*., 1995) [6].

Conclusion

Based upon this experiment it is concluded that application of higher level of phosphorus @ 65 kg/ha combined application with seed inoculation *Rhizobium* recorded the maximum growth and grain yield of lentil.

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