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Effect of Biofertilizers and Phosphorus on Growth and Yield of Lentil (*Lens culinaris* L.)

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***Abstract:** Sixteen treatments comprising of four biofertilizer inoculations [Rhizobium, phosphate solubilizing bacteria (PSB), Rhizobium + PSB and no inoculation] and four phosphorus (0, 20, 40 & 60 kg P_20_5/ha) levels were evaluated at Palampur to study the interaction of biofertilizers and phosphorus on growth and yield of lentil. Dual inoculation of Rhizobium and PSB resulted in taller plants, higher dry matter, nodules/plant, pods/plant, seeds/pod, 100-seed weight and seed and straw yield. Among phosphorus levels, significantly taller plants and higher number of primary branches/plant, seeds/pod and 100-seed weight were recorded at 40 kg P_2O_5/ha. The number of pods/plant and yield were highest at 60 kg P_2O_5/ha. The interaction between inoculation and phosphorus was significant for yield contributing characters and yield. The highest number of primary branches/plant (6.7), seeds/plant (1.8) and seed yield (924 kg/ha) was recorded under dual inoculation of biofertilizers + 60 kg P_2O_5/ha.*

***Keywords:** Lentil, growth, phosphorus, PSB, Rhizobium, yield*

Introduction

Lentil (*Lens culinaris* L.) is an important winter pulse crop grown in Indian sub-continent. In Himachal Pradesh, it is the second most important *rabi* pulse crop after chickpea with an area of 872 ha and productivity of 456 kg/ha, lower than the national average (Anonymous 2008). Lentil like other pulse crops is given secondary importance as far as its growing environment is concerned. It is grown on marginal lands with low fertility and receives sub-optimal fertilizer application. Though, it shows good response to phosphorus application (Chaubey *et al.* 1990; Muhammad *et al.* 2002). *Rhizobium* and phosphate solubilizing bacteria are known to benefit the crop by increasing the availability of soil nitrogen and phosphorus (El Sayed 1999). Considering the above said facts, the present investigation was carried out to evaluate the effect of biofertilizers and phosphorus levels on growth, yield attributes and yield of lentil under mid hill condition of Himachal Pradesh.

A field experiment was conducted during winter 2002-03 at the Research Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32^o6¢ N latitude, 76^o3¢ E longitude and 1290.8 m altitude).

Palampur falls under mid hill sub-humid zone of the state and is endowed with mild summers and cool winters with high rainfall during monsoon. The soil of experimental site was silty clay loam in texture and acidic in reaction (pH 5.5). It was low in available nitrogen (193.4 kg/ha) and medium in phosphorus (14.2 kg/ha) and potassium (224.5 kg/ha). There were 16 treatments comprising of four levels each of phosphorus (0, 20, 40 & 60 kg P_20_5/ha) and biofertilizers [*Rhizobium*, PSB, *Rhizobium* + PSB and control (no inoculation)] in randomized block design with three replications. Lentil cv 'HPL-5' was sown with inter-row spacing of 30 cm during early December 2003. Nitrogen at 10 kg/ha was applied through urea whereas phosphorus was applied as per treatment through single super phosphate as basal application. The seeds of lentil were inoculated with *Rhizobium* and PSB cultures as per treatment before sowing. Other package of practices was followed as per recommendations of the university.

Dual inoculation of *Rhizobium* and phosphate solubilizing bacteria (PSB) significantly increased plant height over their sole application and control at 90 days after sowing (DAS) and at harvest (Table 1). However, increase in plant dry matter was significant under dual inoculation of *Rhizobium* and PSB at all the growth stages. *Rhizobium* and PSB inoculation had statistically equal plant height and dry matter. Seed inoculation with *Rhizobium* alone and in combination with PSB significantly increased nodules/plant over no inoculation at 90 days after sowing. However, nodule number/plant was not significantly influenced at 120 DAS due to inoculation. Plant height increased with increasing level of phosphorus up to 40 kg P_2O_5/ha. Application of 20 kg P_2O_5/ha and control (P_0) had similar plant height at 90 and 120 DAS while at harvest, former had taller plants than the latter. Plant dry matter accumulation increased with an increase in phosphorus level up to 60 kg P_2O_5/ha at 90 and 120 DAS. However, at harvest 60 kg P_2O_5/ha could not significantly increase plant dry matter accumulation over 40 kg P_2O_5/ha. At the harvest, 20 kg P_2O_5/ha and control produced similar dry matter. Nodules/plant increased with increasing level of phosphorus up to 60 kg P_2O_5/ha at 90 DAS, while it was up to 40 kg P_2O_5/ha at 120 DAS. The better growth due to biofertilizers and phosphorus may be due to better availability of nutrients during the crop growth period. Similar findings were also reported by Roy and Rahaman (1992), Haque and Khan (2012) and Krishnareddy and Ahlawat (1996). Biofertilizer x phosphorus interaction was not significant for any of the growth characters.

Dual inoculation of *Rhizobium* and PSB significantly increased number of primary branches/plant and number of seeds/pod over no inoculation whereas *Rhizobium* and PSB inoculation remained at par with uninoculation (Table 2). 100-seed weight was not significantly increased by seed inoculation with biofertilizers either alone or in combination. However, the maximum seed weight was recorded with dual inoculation of biofertilizers. Biofertilizer inoculation individually as well as in combination significantly increased the biological yield. *Rhizobium* inoculation significantly increased seed yield by 11% over no inoculation. It may be due to increase in the availability of soil nitrogen to the plants for increased growth and development as *Rhizobium* present in root nodules fixes atmospheric nitrogen. Kantar *et al.* (1994) and Selim (1995) also reported similar results. Treatment with phosphate solubilizing bacteria also produced significantly higher seed and straw yield over no inoculation. PSB inoculation produced 7 and 9% higher seed yield than *Rhizobium* inoculation and uninoculation, respectively. PSB inoculation helps to release unavailable soil phosphorus and may increase the efficiency of applied phosphatic fertilizers. Similar results have also been reported by Gaur (1990). Dual inoculation of *Rhizobium* and PSB produced the highest seed and straw yield. Seed and straw yield was 29 and 17% higher with dual inoculation of biofertilizers over no inoculation, respectively. This may be due to increased availability of nitrogen and phosphorus to the plants which in turn results in enhanced absorption of nutrients. El Sayed (1999) also observed the similar effect.

Increasing level of phosphorus increased the number of primary branches/plant and seeds/pod up to 40 kg P_2O_5/ha (Table 2). P_{20} and P_0 had similar number of branches/plant. Seed weight also increased with increasing level of phosphorus up to 40 kg P_2O_5/ha. P_0 and P_{20} produced similar seed size. Increasing level of phosphorus increased biological yield up to 60 kg P_2O_5/ha. Application of phosphorus significantly increased seed and straw yield. The highest seed yield was recorded with 60 kg P_2O_5/ha. P_{60} resulted in 61, 57 and 11% higher seed yield over P_0, P_{20} and P_{40}, respectively. It may be due to the favourable effect of phosphorus on root development and root nodulation at initial stages and on yield components at later stages. The present results corroborate to the findings of Khare *et al.* (1988), Barua *et al.* (2011), Datta *et al.* (2013) and Mahmood *et al.* (2010).

The highest number of seeds/pod and number of branches/plant was recorded with dual inoculation of biofertilizers + 60 kg P_2O_5/ha. The interaction was non-significant however, maximum seed weight was with dual inoculation of biofertilizers + 40 kg P_2O_5/ha. Favourable effect of *Rhizobium* may be due to better availability of nitrogen to plants. These findings were in conformity with those of Maiti *et al.* (1988). This stimulating effect of PSB in yield attributes might be due to more availability of phosphorus to the plants and more synthesis of proteins, fats and carbohydrates. Phosphorus is known to take part in carbohydrate metabolism and it also acts as energy carrier derived from the metabolism which is stored as phosphate molecules for subsequent use in growth, development and production in plants. This may be due to better nutrition of the plants during reproductive period. Similar findings were also observed by Gwal *et al.* (1995). Dual inoculation of biofertilizers and 60 kg P_2O_5/ha significantly increased the biological yield. Seed inoculation with *Rhizobium* and PSB in combination with phosphorus at 60 kg P_2O_5/ha produced the highest seed and straw yield. These results are in conformity with those of Azad *et al.* (1991), Ali *et al.* (2004), Haque and Khan (2012) and Singh *et al.* (2010). PSB inoculation with and without 60 kg P_2O_5/ha significantly increased the harvest index.

Table 1. Growth of lentil as influenced by bio-fertilizers and phosphorus application

Treatment	Plant height (cm)			Dry matter accumulation (g/m^2)			Nodules/plant	
	90 DAS	120 DAS	Harvest	90 DAS	120 DAS	Harvest	90 DAS	120 DAS
Biofertilizer								
BF_0 (No inoculation)	12.7	23.3	26.2	29.7	60.3	155.0	4.1	6.7
Rhizobium	13.2	24.6	27.7	29.6	64.6	159.6	4.9	7.4
Phosphorus solubilizing bacteria (PSB)	13.2	25.4	27.9	29.7	63.9	163.9	4.7	7.2
Rhizobium + PSB	14.3	26.1	29.4	33.2	75.2	185.5	5.3	8.3
LSD (P=0.05)	1.2	NS	2.1	1.9	7.8	20.5	0.7	NS
Phosphorus (P)								
P_0 (control)	11.8	21.8	24.8	24.3	52.9	130.2	4.0	6.2
P_{20} (20 kg P_20_5/ha)	12.4	23.4	27.0	28.5	62.3	146.2	4.3	6.8
P_{40} (40 kg P_20_5/ha)	14.1	26.7	29.4	33.0	70.0	186.0	4.8	8.0
P_{60} (60 kg P_20_5/ha)	15.1	27.4	29.9	36.3	78.7	201.7	6.0	8.8
LSD (P=0.05)	1.2	2.3	2.1	1.9	7.8	20.5	0.7	1.1
Interaction (P x Bio-fertilizer)								
P_0 + BF_0	11.2	19.0	24.0	23.8	47.9	119.8	3.0	5.7
P_{20} + BF_0	12.0	21.0	26.0	27.1	57.1	135.0	3.7	5.7
P_{40} + BF_0	13.0	26.0	26.0	32.7	63.7	176.0	4.0	8.0
P_{60} + BF_0	14.0	27.0	28.7	35.3	72.6	189.0	5.7	7.7
P_0 + *Rhizobium*	11.7	22.0	24.7	22.8	57.4	128.0	4.0	6.7

P_{20} + *Rhizobium*	12.0	23.7	28.0	27.0	62.0	141.0	5.0	6.7
P_{40} + *Rhizobium*	14.0	26.0	29.0	31.4	64.4	176.9	5.0	7.7
P_{60} + *Rhizobium*	15.0	26.7	29.0	37.3	74.7	192.4	5.7	8.7
P_0 + PSB	11.7	23.0	23.7	25.4	48.5	133.7	4.0	5.7
P_{20} + PSB	12.7	24.0	27.0	29.0	62.7	144.5	3.7	7.0
P_{40} + PSB	13.7	27.0	31.0	32.0	68.3	177.2	5.0	7.7
P_{60} + PSB	14.7	27.7	30.0	32.3	75.9	200.3	6.0	8.7
P_0 + *Rhizobium* + PSB	12.0	23.3	27.0	25.4	57.8	139.3	5.0	6.7
P_{20} + *Rhizobium* + PSB	13.0	25.0	27.0	31.0	67.7	164.0	4.7	8.0
P_{40} + *Rhizobium* + PSB	15.7	27.7	31.7	36.0	83.8	214.2	5.0	8.7
P_{60} + *Rhizobium* + PSB	16.7	28.3	32.0	40.2	91.7	224.7	6.7	10.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Yield attributes and yield of lentil as influenced by biofertilizers and phosphorus

Treatment	Primary branches/plant	Pods/ plant	Seeds/pod	100-seed weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	HI (%)
Biofertilizer								
BF_0 (No inoculation)	4.3	54.2	1.7	2.5	545	1067	1612	34
Rhizobium	4.7	62.4	1.8	2.5	605	1132	1737	35
Phosphorus solubilizing bacteria (PSB)	4.6	66.2	1.7	2.5	649	1121	1770	36
Rhizobium+PSB	5.1	70.8	1.8	2.6	706	1253	1959	35
LSD (P=0.05)	0.6	4.6	0.02	NS	26.6	75.0	83.5	1.6
Phosphorus (P)								
P_0 (control)	3.8	49.9	1.7	2.4	492	902	1394	35
P_{20} (20 kg P_20_5/ha)	4.3	54.9	1.7	2.4	506	974	1480	34
P_{40} (40 kg P_20_5/ha)	5.1	70.3	1.8	2.6	713	1299	2012	35
P_{60} (60 kg P_20_5/ha)	5.3	78.4	1.8	2.6	794	1397	2192	36
LSD (P=0.05)	0.6	4.6	0.02	0.14	26.6	75.0	83.5	NS

Interaction (P x Biofertilizer)								
P_0 + BF_0	3.7	35.7	1.7	2.4	429	819	1247	34
P_{20} + BF_0	4.0	46.0	1.7	2.4	455	879	1334	34
P_{40} + BF_0	4.7	62.3	1.8	2.5	612	1247	1859	32
P_{60} + BF_0	4.7	72.7	1.8	2.7	684	1322	2006	34
P_0 + *Rhizobium*	3.7	53.0	1.7	2.4	512	896	1408	36
P_{20} + *Rhizobium*	5.0	54.7	1.7	2.4	522	985	1507	34
P_{40} + *Rhizobium*	5.0	65.7	1.8	2.6	659	1315	1975	33
P_{60} + *Rhizobium*	5.0	76.3	1.8	2.6	727	1331	2058	35
P_0 + PSB	4.0	55.3	1.7	2.4	511	950	1467	35
P_{20} + PSB	4.7	60.3	1.7	2.4	523	983	1505	34
P_{40} + PSB	4.7	70.7	1.8	2.5	721	1230	1951	36
P_{60} + PSB	5.0	78.3	1.8	2.5	841	1324	2165	38
P_0 + *Rhizobium* + PSB	4.0	55.7	1.7	2.4	516	945	1461	35
P_{20} + *Rhizobium* + PSB	3.7	58.7	1.7	2.5	525	1050	1575	33
P_{40} + *Rhizobium* + PSB	6.0	82.7	1.8	2.7	861	1405	2265	37
P_{60} + *Rhizobium* + PSB	6.7	86.3	1.8	2.7	924	1613	2537	36
LSD (P=0.05)	1.2	NS	0.04	NS	53.4	150.0	167	3.3

From the present study it can be concluded that for better crop growth and productivity of lentil, the seed must be inoculated with dual culture of *Rhizobium* and PSB and crop must be fertilized with 60 kg P_2O_5/ha subsequently along with other package of practices for the crop recommended by the university.

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