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Conjoint application of biofertilizer and phosphorous levels on growth, nodulation, nutrient uptake and productivity of lentil [*Lens culinaris* Medikus] in red and lateritic soils of West Bengal

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ABSTRACT

A field experiment was conducted during rabi season of 2011-12 and 2012-13 at Agricultural Research Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal to study the effect of biofertilizers [Untreated control, Rhizobium, PSB (phosphate solubilizing bacteria) and Rhizobium + PSB] and phosphorous levels (0, 30, 45 and 60 kg P_2O_5 ha^{-1}) on growth, nodulation, productivity and nutrient content of lentil in red and lateritic soils of West Bengal. The results showed that the application of 60 kg P_2O_5 ha^{-1} being at par with 45 kg ha^{-1} recorded the maximum plant height (38.5 cm) at harvest, dry matter accumulation (125.47gm^{-3}), seed yield (703.4 kg ha^{-1}), stalk yield (1392.6 kg ha^{-1}) and uptake of N (32.87 and 24.99 kg ha^{-1} in stalk and grain, respectively), P (6.61 and 4.77 kg ha^{-1} in stalk and grain, respectively) and K (15.71 and 7.49 kg ha^{-1} in stalk and grain, respectively) at harvest. Among seed inoculation treatments, Rhizobium + PSB produced significantly taller plants (40.0 cm), maximum dry matter accumulation (114.78 g m^{-3}), seed yield (709.10 kg ha^{-1}) and stalk yield (1363.30 kg ha^{-1}), harvest index 33.99% and uptake of N (82.51kg ha^{-1}) and P (19.33 kgha^{-1}) at harvest than other biofertilizers treatments. Combined effect of 60 kg $ha^{-1}P_2O_5$ + Rhizobium +PSB produced significantly higher grain yield (1024.30 kg ha^{-1}) and phosphorous uptake by grain (5.32kg ha^{-1}) than other combinations except 45 kg P_2O_5 kg ha^{-1} + Rhizobium +PSB. Yield advantages were obtained due to 45 Kg P_2O_5 ha^{-1} + PSB (10.52, 17.48 and 9.89%), 45 kg P_2O_5 + Rhizobium + PSB (20.31, 27.88 and 19.62%), 60 kg P_2O_5 + PSB (26.59, 34.56 and 25.87 %) and 60 Kg P_2O_5 + PSB + Rhizobium (27.70, 35.74 and 26.97%) as against only seed inoculation with PSB (802.1 kg ha^{-1}), only Rhizobium (754.6 kg ha^{-1}) and only 30 kg P_2O_5 ha^{-1} (806.7 kg ha^{-1}), respectively.

Keywords : Biofertilizers, lentil, phosphorous, PSB, *rhizobium*, yield

Lentil is cultivated mostly on marginal land without any fertilizers in rainfed condition of West Bengal. Its productivity is very low as compared to its potential yield. The wide gap may be minimized through the adequate and balanced use of fertilizers. Phosphorous is an important mineral nutrient element for grain legumes. It helps in root development, phosphate and phosphoprotein synthesis and also takes part in energy fixing and releasing process in plants. Several workers have already been reported that better response of lentil to phosphate nutrition than nitrogen application. Seed inoculation of *Rhizobium* and phosphate solubilising bacteria (PSB) which have established their capability to increase the productivity of pulses. Biofertilizers enhance soil fertility and crop yield by solubilising unavailable sources of elemental nitrogen and bound phosphate into available forms in order to facilitate the plant to absorb them. Keeping this background in view, the present study was taken to study the effect of biofertilizer and phosphorous levels on growth, nodulation, nutrient uptake and productivity of lentil [*Lens culinaris* Medikus] in red and lateritic soils of West Bengal.

MATERIALS AND METHODS

A two year field experiment were conducted during *rabi* season of 2011-12 and 2012-13 at Agricultural Research Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal to study the effect of biofertilizer and phosphorous levels on growth, nodulation, nutrient content and productivity of lentil [*Lens culinaris* Medikus] in red and lateritic soils of West Bengal. The experimental site was located at $20^0 39^/$ W latitude $87^0 42^/$ E longitude and 58.9m AMSL attitude and the soil was sandy loam having pH 6.3, organic carbon 0.52%, available P_2O_5 34 Kg ha^{-1}, available K_2O 178 Kg ha^{-1} , initial nitrogen fixing bacteria $58x10^6$ no's and phosphate solubilizing bacteria (PSB) $9.01x10^6$. The crop variety Subrata (WBL-58) was sown on November 04 and 15 during 2011-12 and 2012-13, respectively. The experiment was laid out in Factorial RBD with four phosphorous levels (0, 30, 45 and 60 Kg ha^{-1}) and four seed inoculations (uninoculated control, *Rhizobium*, PSB and *Rhizobium* + PSB) keeping the individual plot size as 4 x 3 m. The crop was fertilized with a uniform basal dose of N and K_2O at 20 Kg ha^{-1} applied through urea and muriate of potash, respectively. Seed were inoculated with *Rhizobium* and PSB prior to sowing as per treatments using 60 g. culture Kg^{-1} of seed. The crop was raised following all the recommended agronomic practices and harvested on March 15 and 21 during 2011-12 and 2012-2013, respectively.

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In order to study the nodulation in lentil, five plants from each plot were uprooted, their roots were gently washed with water, nodules were removed and counted. Dry weight of root nodules and crop plants was recorded at periodic intervals after drying in hot-air oven at 80ºC till constant weight. Observations on plant height and dry matter accumulation (DMA) were recorded at 45 DAS and harvest. Soil sample was also taken before sowing for analysis. Seed yields along with yield attributes, microbial population (Page, 1982) and soil analysis (Jackson, 1973) report were also recorded after crop harvest.

RESULTS AND DISCUSSION

Phosphorous fertilization

Perusal of data (Table 1 and 3) revealed that the application of phosphorous up to 60 kg ha^{-1} increased growth, nodulation, yield attributes, yield and nutrient uptake and was found *at par* with 45 kg ha^{-1}.The seed yield obtained with 60 kg P_2O_5 ha^{-1} was 42.5,22.59 and 1.93% higher over 0,30 and 45 kg P_2O_5 ha^{-1}, respectively obviously due to improvement in nodulation, crop growth and yield attributes. Higher nodule numbers (9.1 and 19.5 nos. $plant^{-1}$) and dry weight (13.0 and 26.9 mg $plant^{-1}$) were observed under the application of 60 kg P_2O_5 ha^{-1} as compared to no phosphorous application (8.6 and 17.0 nos. $plant^{-1}$, and 11.5 and 23.1 mg $plant^{-1}$) at 30 and 60 DAS, respectively. Phosphorus has effectiveness on nodulation of legumes like lentil crop (Singh *et al*., 2000; Kumari *et al.,* 2009). This result is in conformity with the findings of Saha *et al*. (2004), Dhingra *et al*. (1988), Yeshim *et al*. (2008). It was further recorded that application of 45 kg ha^{-1} showed progressive increase over lower levels with respect to plant height, dry matter accumulation , pods $plant^{-1}$, 1000-seed weight, grain yield and stalk yield. It is also found that significant effect of phosphorous on yield, yield attributes and NPK contents in grain and stalk of lentil with application of 60 Kg P_2O_5 ha^{-1}. Phosphorous application was found beneficial in respect of nitrogen and phosphorous uptake. Maximum nitrogen and phosphorous uptake were recorded with 60 Kg P_2O_5 ha^{-1} which was found significantly superior to the remaining levels except 45 Kg P_2O_5 ha^{-1}. Application of phosphorous improved the nutrient availability, resulting into greater uptake which might have increased the photosynthesis and translocation of assimilates to different parts for enhanced growth and yield of the crop. In later stage, more assimilates are produced than used in growth and development and the excess assimilates are diverted to storage compounds resulting in to increased seed yield.

Effect of biofertilizers

Seed inoculation with biofertilizers proved superior to untreated control with respect to all the growth parameters, yield attributes, yield and nitrogen,

Table 1: Effect of phosphorous and biofertilizers on growth, nodulation and yield attributes in lentil (pooled)

Treatments	Plant height (cm)			DMA (g m^{-2})			Nodule no. $plant^{-1}$		Nodule wt. (mg $plant^{-1}$)		No. of pods $plant^{-1}$	1000 grain wt.(g)
	Days after sowing											
	30	60	Harvest	30	60	Harvest	30	60	30	60		
Phosphorous levels (P) in Kg ha^{-1}												
0	6.5	15.8	34.2	6.48	16.01	73.69	8.6	17.0	11.5	23.1	63.0	20.02
30	8.0	17.6	35.5	6.50	16.03	97.28	8.7	17.8	11.6	23.2	68.3	21.08
45	9.5	19.1	36.9	6.61	19.07	125.03	8.8	18.7	12.3	23.6	78.6	22.03
60	10.0	20.1	38.5	7.01	19.87	125.47	9.1	19.5	13.0	26.9	85.3	22.16
SEm(±)	**0.25**	**0.42**	**0.89**	**0.04**	**0.53**	**2.29**	**0.05**	**0.63**	**0.04**	**0.61**	**1.41**	**0.26**
LSD (0.05)	**0.67**	**1.20**	**2.53**	**NS**	**1.47**	**6.51**	**NS**	**1.80**	**NS**	**1.73**	**3.98**	**0.73**
Seed inoculation (S)												
Control	8.2	17.7	33.0	6.31	17.11	96.03	8.6	17.1	11.6	23.0	67.5	20.96
Rh.	8.3	17.8	35.0	6.60	17.33	103.70	8.7	18.1	12.8	24.4	70.7	21.14
PSB	8.7	18.1	37.1	6.80	18.07	106.97	8.8	17.8	11.0	23.8	77.4	21.29
Rh. + PSB	8.8	19.1	40.0	6.91	18.47	114.78	9.0	19.9	12.9	25.5	79.5	21.40
SEm(±)	**0.04**	**0.06**	**0.89**	**0.04**	**0.05**	**1.94**	**0.03**	**0.43**	**0.05**	**0.57**	**1.40**	**0.06**
LSD (0.05)	**NS**	**NS**	**2.53**	**NS**	**NS**	**5.51**	**NS**	**1.23**	**NS**	**1.63**	**3.98**	**NS**
Interaction (P x S)												
SEm(±)	**0.04**	**0.03**	**0.05**	**0.06**	**0.02**	**2.51**	**0.04**	**0.49**	**0.05**	**0.50**	**1.63**	**0.04**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**7.1**	**NS**	**1.40**	**NS**	**1.41**	**4.6**	**NS**
CV (%)	**9.56**	**9.56**	**7.94**	**12.29**	**7.73**	**8.40**	**9.93**	**11.8**	**17.5**	**8.56**	**6.48**	**4.1**

DAS: Days after sowing; PSB: Phosphate solubilizing bacteria; Rh.: Rhizobium; NS: Not significant

Table 2: Interaction effect between phosphorus levels and seed inoculation on grain yield (pooled)

Seed inoculation	Seed yield (kg ha^{-1})			
Phosphorus levels	**Uninoculated control**	***Rhizobium* @ 60 g kg^{-1} seed**	**PSB @ 60 g kg^{-1} seed**	***Rhizobium* +PSB @ 60 g kg^{-1} seed**
0 kg ha^{-1}	643.7	754.6	802.1	814.6
30 kg ha^{-1}	806.7	695.2	855.5	837.0
45 kg ha^{-1}	855.2	689.7	886.5	965.0
60 kg ha^{-1}	874.2	808.3	1015.4	1024.3
SEm (±)		**35.79**		
LSD (0.05)		**103.6**		

phosphorous and potassium uptake in lentil (Table 1 and 3). Highest seed yield (709.1 kg ha^{-1}) was recorded with seed inoculation by *Rhizobium* + PSB and followed by inoculation with PSB (659.8 kg ha^{-1}) and *Rhizobium* (557.6 kg ha^{-1}), irrespective of uninoculated control. The yield increments under these treatments were 32.72, 23.49 and 4.36% over uninoculated control and it might be due to improvement in crop growth and yield attributes besides better nodulation (Table 1). DMA increase under combined inoculation of *Rhizobium* + PSB (7.95 and 19.53 %), inoculation of PSB (5.61 and 11.39%) and *Rhizobium* (1.29 and 7.99 %) as compared with uninoculated control (17.11 and 96.03 g m^{2}), both at 60 DAS and harvest, respectively. Higher nodulation under seed inoculation with *Rhizobium* + PSB and PSB was also observed in both the years of experimentation. Inoculations of PSB which are known to produce growth hormones (Sattar and Gaur, 1987) are likely to favour increase plant height. These results were in agreement with the earlier findings of Mukherjee and Rai (2000), Yadav and Shrivastava, (1997) in lentil and Biswas *et al*. (2008) in urdbean. In case of nitrogen and phosphorous uptakes, maximum values (N 32.95 & 27.58 and P 6.0 & 4.26 kg ha^{-1} in stalk and grain, respectively) were obtained with *Rhizobium* + PSB which were found significantly superior to other biofertilizers treatments except PSB alone. Rhizobium inoculation fixes nitrogen through nodules of the plant where as PSB solubilizes native phosphorous bringing more phosphorous to soil solution. Thus, combined effect of *Rhizobium* and PSB improved the availability N and P in soil and ultimately increased N and P uptakes which enhanced growth, yield attributes and yield of lentil. Increase in grain yield of lentil by seed

Table 3: Effect of phosphorous and biofertilizers on yield, microbial population and nutrient uptake in lentil (pooled)

Treatments	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index (%)	Nutrient uptake (kg ha^{-1})						No. of N fixer (CFU×10^{6})	No. of P solubilizers (CFU×10^{6})
				Stalk			Grain				
				N	P	K	N	P	K		
Phosphorous levels (P) in Kg ha^{-1}											
0	493.6	1179.1	29.07	26.46	4.16	10.00	20.98	2.95	3.76	68.43	9.17
30	573.8	1232.1	31.72	27.64	4.49	10.85	22.80	3.05	4.18	70.52	9.93
45	690.1	1405.8	32.86	29.52	5.65	14.43	23.71	4.22	5.87	69.02	13.97
60	703.4	1392.6	33.49	32.87	6.61	15.71	24.99	4.77	7.49	71.06	14.51
SEm(±)	**13.69**	**23.70**	**0.37**	**0.86**	**0.19**	**0.35**	**0.62**	**0.32**	**0.20**	**0.06**	**0.49**
LSD (0.05)	**38.88**	**67.30**	**1.05**	**2.42**	**0.55**	**0.97**	**1.77**	**0.89**	**0.53**	**NS**	**1.40**
Seed inoculation (S)											
Control	534.3	1312.8	29.22	26.63	4.65	11.80	19.43	3.13	3.59	64.01	7.08
Rh.	557.6	1186.2	31.10	28.34	5.04	11.17	20.08	3.70	4.30	75.43	9.66
PSB	659.8	1341.4	32.84	29.57	5.23	13.48	25.40	3.89	6.02	66.42	14.74
Rh. + PSB	709.1	1369.3	33.99	32.95	6.00	14.56	27.58	4.26	7.38	76.18	16.10
SEm(±)	**13.69**	**23.70**	**0.37**	**0.86**	**0.19**	**0.35**	**0.62**	**0.32**	**0.20**	**0.06**	**0.49**
LSD (0.05)	**38.88**	**67.30**	**1.05**	**2.42**	**0.55**	**0.97**	**1.77**	**0.89**	**0.53**	**NS**	**1.40**
Interaction (P × S)											
SEm(±)	**36.45**	**18.32**	**1.25**	**0.59**	**0.18**	**0.68**	**0.59**	**0.18**	**0.37**	**2.28**	**1.21**
LSD (0.05)	**103.6**	**NS**	**NS**	**1.67**	**0.52**	**1.94**	**1.67**	**0.52**	**1.06**	**NS**	**NS**
CV (%)	**7.58**	**6.20**	**3.98**	**9.90**	**12.52**	**9.14**	**9.16**	**8.27**	**11.90**	**5.28**	**14.18**

PSB: Phosphate solubilizing bacteria; Rh.: Rhizobium; NS: Not significant

Table 4: Interaction effect between phosphorus levels and seed inoculation on phosphorus uptake by grain after harvest (pooled)

Seed inoculation	Uptake (kg ha^{-1})			
Phosphorus levels	**Uninoculated control**	***Rhizobium* @ 60 g kg^{-1} seed**	**PSB @ 60 g kg^{-1} seed**	***Rhizobium* +PSB @ 60 g kg^{-1} seed**
0 kg ha^{-1}	2.37	2.78	2.99	4.38
30 kg ha^{-1}	3.00	2.92	4.62	4.28
45 kg ha^{-1}	3.28	2.90	4.05	5.-08
60 kg ha^{-1}	3.17	3.58	5.21	5.32
SEm (±)		**0.18**		
LSD (0.05)		**0.52**		

inoculation with PSB has also been reported by Bera *et al*. (2013).

Effect of interaction

Interaction effect of phosphorous and biofertilizers on grain yield and phosphorous uptake by grain was found significant (Table 2 and 4). In general combined effect of 60 kg P_2O_5 ha^{-1} +*Rhizobium* + PSB gave significantly higher values of grain yield (1024.3kg ha^{-1}) and phosphorous uptake (5.32 kg ha^{-1}) over other combinations excepting 45 kg P_2O_5 ha^{-1} +*Rhizobium* + PSB (grain yield 965.0 kg ha^{-1} and uptake of phosphorous in grain 5.-08 kg ha^{-1}). The interactive effects revealed that inoculation of seeds with Rhizobium + PSB along with 45 kg P_2O_5 ha^{-1} proved as good as 60 kg P_2O_5 ha^{-1} +*Rhizobium* + PSB. Similar results were also reported by Mukherjee and Rai (2000) in chickpea.

Results of the present investigation reveals that the maximum seed yield was recorded in the seed inoculation conjointly with *Rhizobium* + PSB along with application of 60 kg P_2O_5 ha^{-1} and it was statistically *at par* with the seed inoculation conjointly with *Rhizobium* + PSB plus application of 45 kg P_2O_5 ha^{-1}. Therefore, seed inoculation with *Rhizobium* + PSB along with 45 kg P_2O_5 ha^{-1} may be effectively recommended for improving crop growth, microbial population in respect of soil health, nodulation and seed yield of lentil.

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