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RK Dwivedi
J.N.K.V.V. Krishi Vigyan Kendra, Damoh, Madhya Pradesh, India

NK Pandre
J.N.K.V.V. Krishi Vigyan Kendra, Panna, Madhya Pradesh, India

DK Tiwari
R.V.S.K.V.V. Kishi Vigyan Kendra, Badwani, Madhya Pradesh, India

Correspondence
RK Dwivedi
J.N.K.V.V. Krishi Vigyan Kendra, Damoh, Madhya Pradesh, India

Effect of phosphorus, sulphur and biofertilizers on growth, yield and quality of lentil (*Lens culinaris*)

RK Dwivedi, NK Pandre and DK Tiwari

Abstract
A field experiment was conducted during *rabi* season of 2015-16 and 2016-17 to study the effect of P, S and biofertilizers on growth, yield and quality of lentil cv. PL-5 Plant height, branches/plant, pods/plant, grains/pod, 1000-grain weight, seed weight/plant and grain yield were maximum at 60 Kg P_2O_5/ha, 30 kg S/ha and seed inoculation with *Rhizobium* + PSB biofertilizers. Similar was the case with grain protein, protein yield and net return. The additional net return due to P_{60}, S_{30} and *Rhizobium* +PSB was Rs.8689, 2643 and 3237/ha respectively, over their respective controls. The combined influence of these inputs augmented the yield and net return of lentil over their separate effects.

Keywords: Phosphorus, Sulphur, Quality, Yield of Lentil

Introduction
Due to heavy pressure of cropping, use of imbalanced chemical fertilizer without soil, test, extensive use of diammonium phosphate (DAP) having no sulphur, non-addition of organic matter and S-containing, fertilizers, the soil fertility is being deteriorated and lentil yield is decreasing to grater extent. Moreover, limited use of single superphosphate aggravated sulphur deficiency in soils. Much of the applied-P is fixed in the soil. Thus, the decline in yield of lentil has been mainly attributed to deficiencies of P and S which are common in most of the soils. The situation becomes more pitiable when farmers tended to row high-yielding varieties of lentil for better harvest and net pitiable when farmers tended to grow high-yielding varieties of lentil for better harvest and net income. The role of PSB biofertilizer of P and S with P-solubilizers has been found further useful in augmenting the crop yields. The information on the balanced nutrition for improving lentil yield is lacking. Hence, the present experiment was taken up.

Material and methods
A field experiment was conducted during *rabi* (winter) season of 2015-16 and 2016-17 on a field of Vidhya Beej Utpadak Samiti Sarkhede Damoh (M.P). The soil of the experiment was clay-loam having pH 7.2-7.4, electrical conductivity 0.32-0.34mm hos/cm, organic carbon 0.38-0.41 %, available N 160.2-165.4 kg/ha, available sulphur 7.55-7.79 ppm in both the seasons. The total rainfall received during the crop season (October and March) was 25.8 mm and 275.6 mm in 2015-16 and 2016-17 respectively. The treatments comprised of 3 levels of phosphorus (0.30 and 60 kg/ha), in the main-plots, 3 levels of sulphur (0,15 and 30 kg/ha) in the sub-plots and 3 biofertilizer treatment (*Rhizobium,* phosphate-solubilizing bacteria (PSB) and *Rhizobium* + PSB) in the sub-sub plots. The experiment was laid out in split plot design with three replications. Lentil cv. PL-5 was sown @ 35 kg seed/ha in rows 30 cm apart on 15th and 20th October, 2015 and 2016 respectively. An uniform dose of 23.5 kg N/ha was applied in all the treatments as basal in the 30 cm apart open furrows during sowing of seed. P and S levels were applied as basal through DAP and elemental S. Before sowing, the seeds were first treated with a Tebuconazole 2% DS seed in all treatments. Thereafter, the seeds were treated with *Rhizobium* biofertilizer 5g/kg seed and then the PSB biofertilizer @ 5 g/kg seed was applied in the same open furrows mixed with FYM according to the treatment. The crop was grown as per recommended package of practices, and harvested on 2nd and 5th March in 2015 and 2016 respectively.

Results and Discussion

Growth of lentil

The highest fertility level i.e. P60, S30 and biofertilizers *Rhizobium* + PSB resulted in the maximum plant of lentil being almost being almost significantly superior to their preceding levels (Table 1). The combined influence of these treatments further enhanced these characters. This may be due to enough supply of P and S including additional N to satisfy the need of vigorously growing plants and to activate the essential physic-chemical functions in the plant parts. These results corroborate with those of Kumar *et al*. 1995; Singh and Kumar (1996) and Chatrabhuji *et al*. (2001) [2, 5, 1].

Yield components

The number of pods/plant, grains/pod, 1000-grain weight/plant were augmented almost significantly due to increased supply of phosphorus, sulphur and biofertilizers (*Rhizobium* + PSB) over the preceding levels. The combined influence of the higher levels of these inputs further raised these 4 parameters. These treatments might have exerted more pronounced effect on the population of Rhizobia and phosphobacteria in the rhizosphere, and due to their unique functions, additional supply of N, P and S was met with which reflected positively upon all these characters. The present results closely agree with those of Kumar *et al*., 1995; Singh and Kumar, 1996; Chaturbhuji *et al*., 2001) [2, 5, 1]

Grain yield and harvest index

The grain yield of lentil cv. PL-5 was found higher by 7.22 q/ha due to P60, by 2.22 q/ha due to S30 and 2.36 q/ha due to dual biofertilizers over their respective controls (Table-1). The combined application P60S30 and biofertilizers further raised the grain yield significantly up to 17.10 q/ha over their combined lower doses (Table-2). This may be due to increased yield components as a result of above inputs. Similar results have been reported by Singh *et al*., 2002 [4] and Pathak *et al*., 2003 [3]. Harvest index encouraged up to P60, S15 and due to dual biofertilizers. This is an indication of the fact that more photosynthates were diverted from source vegetative parts to the sink (reproductive organs) due to increased supply of nutrients.

Economics and grain yield

The net return from lentil cv. PL-5 was estimated to be higher by Rs.8669, 2643 and 3237/ha due to application of P60,S30 and *Rhizobium* +PSB, respectively over their respective controls. The combined application of P60S30 + *Rhizobium* +PSB further augmented the net return up to maximum (Rs.15680/ha). The beneficial: cost ratio eventually followed the similar trend. The grain protein content and protein yield per hectare were found to increase significantly with the increasing levels of phosphorus, sulphur and dual biofertilizers. The highest protein yield was found up to 345.4 kg/ha with P60, 282.4kg/ha with S30 and 279.1kg/ha with *Rhizobium* +PSB as against 138.9, 211.4 and 213.5kg/ha in case of respective control treatments. This may be attributed to the significant role of these high level inputs in regulating the photosynthesis, root enlargement and better microbial activities. These results are in close agreement with those of many workers (Tomar *et al*., 2000; Singh *et al*;2002 and Pathak *et al*., 2003) [6, 4, 3].

Table 1: Growth, yield and yield components, economic and quality of lentil as influenced by various treatments (Pooled for two seasons)

Treatments	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	No. of seeds/ pod	1000-grain weight(g)	Grain weight/ plant (g)	Grain yield (q/ha)	Havest index (%)	Net return (Rs./ha)	B:C ratio	Grain protein (%)	Protein yield (kg/ha)
	P-levels (kg/ha)											
	P_o	3.5	41.60	1.00	16.1	1.15	5.77	31.36	8395	1.27	22.35	138.9
	P_{30}	5.4	54.65	1.36	16.4	2.04	9.71	31.96	16343	2.14	23.73	255.8
	P_{60}	5.9	65.75	1.60	17.2	2.97	12.99	32.30	19775	2.86	25.27	345.4
C.D. 5%	0.76	0.46	1.41	0.34	0.08	0.05	0.37				0.026	5.99
S-levels (kg/ha)												
S_0	39.6	4.5	51.10	1.20	16.5	1.82	8.38	31.70	6765	1.85	23.29	211.4
S_{15}	41.6	4.9	53.95	1.30	16.5	2.06	9.49	32.08	8730	2.08	23.81	246.3
S_{30}	43.5	5.4	57.00	1.40	16.7	2.28	10.60	31.86	12915	2.34	24.24	282.4
C.D. 5%	0.50	0.33	0.96	0.10	0.14	0.06	0.43				0.026	7.98
Biofertilizers *Rhizobium*	39.9	4.6	50.65	1.20	16.3	1.74	8.32	31.60	6645	1.84	23.65	213.5
PSB	41.6	4.9	54.10	1.30	16.6	2.08	9.47	31.92	8970	2.08	23.78	247.5
Rh+PSB	43.1	5.4	57.30	1.45	16.8	2.34	10.68	32.11	13765	2.35	23.90	279.1
C.D.5%	0.51	0.25	0.72	0.16	0.23	0.05	0.29				0.026	6.87

Table 2: Grain, yield and net return per hectare for lentil var. PL-5 as influenced by various treatments (Pooled for two seasons)

Phosphorus x Biofertilizers	Sulphur levels (kg/ha)			
	So	S15	S30	
Grain yield (q/ha)				
P_0 *Rhizobium*	3.95	5.59	6.28	5.27
PSB	5.00	5.92	6.21	5.71
Rh.+PSB	5.91	6.41	6.69	6.33
P_{30} *Rhizibium*	7.39	8.38	9.79	8.52
PSB	8.39	9.49	10.78	9.55
Rh.+PSB	9.76	11.46	12.00	11.07
P_{60} *Rhizobium*	10.23	11.10	12.21	11.18
PSB	12.02	13.07	14.41	13.16
Rh.+PSB	12.84	14.00	17.10	14.64
Mean	8.38	9.49	10.60	-
$P_{o\ Rhizobium}$	-769	1296	1975	834
PSB	691	1726	1904	1440

Rh.+ PSB	1914	2342	2543	2266
P_{30} *Rhizobium*	3382	4483	6260	4700
PSB	4760	5963	7651	6125
Rh.+ PSB	6577	8746	9262	8195
P_{60} *Rhizobium*	6581	7549	8936	7689
PSB	9051	10299	11974	10441
Rh.+ PSB	10207	11558	15680	12482
Mean	4710	5996	7354	-
Grain yield (q/ha)	p	S	B	Px SxB
C.D. (5%)	0.37	0.43	0.29	0.60

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