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Effect of Sulphur and Biofertilizers on nutrient contents and uptake by blackgram (*Phaseolus mungo* L.)

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Abstract
A field experiment was conducted during rainy seasons of 2017 and 2018 to study the effect of sulphur and biofertilizers on nutrient contents and uptake of blackgram. The nutrient contents in grain and straw viz., N, P, K and S deviated significantly due to sulphur levels and biofertilizers as well as their interactions. The highest sulphur level (60 kg/ha) and dual biofertilizers (Rhizobium + PSB) resulted in almost significantly higher N, P, K and S contents and their uptake of blackgram. The highest total uptake of nutrients by blackgram producing a total biomass upto 32.24 q/ha with highest S level was 102 kg N, 12.28 kg P, 53.18 kg K and 5.63 kg S/ha. Similarly, under dual biofertilizers, the corresponding uptake values were 100.4 kg N, 11.14 kg P, 42.30 kg K and 5.52 kg S/ha under 33.4 q/ha total biomass. The findings suggest that due to heavy withdrawal of nutrients by blackgram cv. JU-2, the succeeding crop must be nourished properly based on nutrients status of the soil.

Keywords: Biofertilizers, blackgram, nutrient contents, sulphur, uptake

Introduction
It is a matter of serious concern that sulphur deficiencies have become widespread in Indian soils due to increase in cropping intensity, higher nutrients removals by high-yielding varieties and addition of sulphur-free fertilizers (Singh, 2018) [13]. Sulphur is now recognized as the fourth major nutrients after N, P and K. On an average, crops absorb sulphur as much as they absorb phosphorus. The increasing reports of sulphur deficiency suggest that S deserves greater attention than that it has received so far. According to Tandon (1995) [14], blackgram yielding 8.90 q/ha removes 70 kg N, 5.6 kg P, 50.1 kg K and 5.1 kg S/ha from the soil. The extensive be use of biofertilizers viz. *Rhizobium* and phosphorus-solubilizing bacteria (PSB) in crop production is a major breakthrough as a pollution-free and low-cost input technology. The multi-nutrient deficiency in soils is the main reason of low productivity of blackgram varieties in Kymore plateau of Madhya Pradesh. The present experiment was, therefore, taken up to generate relevant information for one of the most popular blackgram variety JU-2.

Materials and methods
The field experiment was conducted during rainy season of 2017 and 2018 at the private Agriculture-cum-Research Farm, Beena-Semaria Road, Rewa (M.P.). The soil of the experimental field was silty clay-loam having pH 7.5-7.6, electrical conductivity 0.32-0.34 dS/m, organic carbon 8.6-8.8 g/kg, available N 230-238 kg/ha, available P_2O_5 13.8-14.3 kg/ha, available K_2O 372-381 kg/ha and available S 7.75-8.30 ppm in both the years. The total rainfall received during June to October was 1499 mm in 2017 and 760 mm in 2018. The treatments comprised four sulphur levels (0, 20, 40 and 60 kg/ha) and four treatments of biofertilizers (no biofertilizers, *Azotobacter* or *Rhizobium* + phosphorus-solubiling bacteria alone as well in combination. The 24 treatment combinations were laid out in the field in a factorial randomized block design with three replication. Blackgram var. JU-2 was sown @ 20 kg/ha in rows 30 cm apart between 9 to 15 July in both the years. An uniform dose of 20 kg N and 50 kg P_2O_5/ha was applied through diammonium phosphate as basal in all the treatments. Sulphur levels were applied through elemental sulphur as basal. The seeds were inoculated with both the biofertilizers @ 20 g/kg seed mixed with FYM as per treatment. The crop was grown as per package of practices. The crop was harvested between 10 to 19 October in both the years.

Results and discussion
Nutrient contents
The percentage of N, P, K and s contents was found higher in blackgram grain than in straw. The fact that seeds acted as a sink for photosynthates nitrogen and other nutrients has also been supported by Marko *et al.* (2013) [4] and Raj *et al.* (2014) [7].

Application of sulphur upto 60 kg/ha augmented the N, P, K and S contents in grain and straw almost significantly over the lower doses (Table 1 & Fig. 1). This might be due to the fact that plants absorbed these nutrients proportionately in higher amounts because the pool of available nutrients was already increased in soil by supplementing increased doses of applied sulphur. The present results agree with those of Shahi *et al.* (2003) [8], Singh (2003) [1], Singh *et al.* (2004) [1] and Singh *et al.* (2008) [13].

Table 1: Nutrient contents of blackgram as influenced by sulphur levels and biofertilizers (mean of two years)

Treatments	N-content (%)		P-content (%)		K-content (%)		S-content (%)		Total crop biomass (q/ha)
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	
Sulphur levels (kg/ha)									
0	3.25	2.30	0.263	0.179	1.49	1.20	0.167	0.124	26.98
20	3.60	2.56	0.393	0.233	1.68	1.33	0.185	0.140	29.47
40	3.72	2.66	0.417	0.268	1.74	1.45	0.192	0.150	30.67
60	3.81	2.76	0.461	0.325	1.82	1.54	0.208	0.162	32.24
C.D. (P=0.05)	NS	NS	0.049	0.030	0.300	0.028	0.032	0.031	1.83
Biofertilizers									
No biofertilizer	3.47	2.49	0.348	0.219	1.59	1.28	0.180	0.136	26.10
Rhizobium	3.56	2.59	0.363	0.241	1.63	1.35	0.187	0.143	28.22
Azotobacter	3.52	2.55	0.359	0.238	1.61	1.32	0.185	0.139	27.84
PSB	3.63	2.56	0.388	0.253	1.69	1.41	0.190	0.143	29.50
Rhi.+PSB	3.72	2.64	0.424	0.281	1.80	1.48	0.194	0.152	34.00
Azoto.+PSB	3.68	2.60	0.419	0.277	1.76	1.44	0.191	0.150	33.40
CD (P=0.05)	NS	NS	0.060	0.037	NS	NS	NS	NS	2.23
Interaction	NS	NS	Sig.	Sig.	NS	NS	NS	NS	Sig.

NS=Non-significant, Sig.= Significant

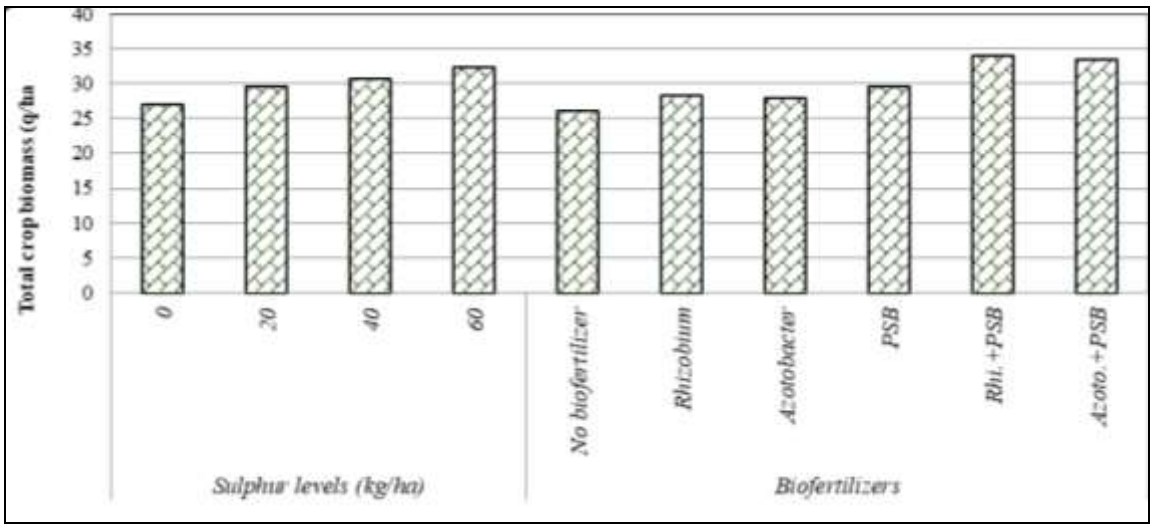

Fig 1: Graphics analysis of Mean Nutrient contents of blackgram as influenced by sulpur levels and biofertiilizers

Among the biofertilizer treatments, *Rhizobium* + PSB enhanced the N, P, K and S contents in grain and straw of blackgram significantly. The highest level of sulphur with dual biofertilizers further encouraged he nutrient contents. This might be due to stimulation of root growth, better root nodulation, increased microbial activities and chlorophyll content of leaves (Mishra and Tiwari, 2001; Kumar and Singh, 2009 and Kumawat *et al.*, 2009) [5, 2, 3].

Uptake of nutrients

Application of higher levels of sulphur upto 60 kg/ha enhanced the N, P, K and S uptake by grain and straw significantly (Table 2). This might be attributed to increased grain and straw yields as well as nutrient contents in grain and straw at 60 kg S/ha. In contrast to the nutrient contents, the nutrients uptake was higher in straw than in grain. This was due to increased straw yields over grain yields. The present results corroborate with those of Shahi *et al.* (2003) [8], Singh (2003) [1], Singh *et al.* (2004) [1], Singh *et al.* (2008) [13] and Raj *et al.* (2014) [7].

The total crop biomass which produced up to 32.24 q/ha at 60 kg S/ha removed almost significantly higher nutrients (102 kg N, 12.28 kg P, 53.18 kg K and 5.63 kg S/ha) over the preceding S level.

Amongst the biofertilizer treatments, dual biofertilizer, dual biofertilizer inoculation resulted in significantly higher nutrients uptake by grain and straw. The total biomass produced in this treatment was 33.4 q/ha which removed 100.4 kg N,11.14 kg P, 52.30 kg K and 5.52 kg S/ha. This was followed by PSB and then *Rhizobium* inoculated individually. These results agree with those Pathak *et al.* (2003) [6], Singh *et al.* (2005) [11], Tiwari *et al.* (2005) [15], Sharma *et al.* (2006) [6] and Marko *et al.* (2013) [4].

Table 2: Uptake of nutrients of blackgram as influenced by sulphur levels and biofertilizers (mean of two years)

Treatments	N-uptake (kg/ha)			P-uptake (kg/ha)			K-uptake (kg/ha)			S-uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Sulphur levels (kg/ha)												
0	31.29	39.97	71.26	2.54	3.15	5.69	14.28	20.80	35.08	1.704	2.191	3.895
20	39.42	47.54	86.96	4.31	4.38	8.69	18.34	24.91	43.25	2.033	2.618	4.651
40	43.04	50.99	94.03	4.83	5.16	9.99	20.38	27.90	48.28	2.216	2.878	5.094
60	47.13	54.91	102.04	5.74	6.54	12.28	22.47	30.71	53.18	2.445	3.188	5.633
C.D. (P=0.05)	1.90	1.35	3.25	0.83	0.83	1.66	1.26	1.06	2.32	0.49	0.55	1.04
Biofertilizers												
No biofertilizer	33.66	41.06	83.72	3.42	3.63	7.05	15.43	21.31	36.74	1.746	2.268	4.014
Rhizobium	39.17	44.78	81.79	4.04	4.21	8.25	17.96	23.35	41.31	2.058	2.464	4.522
Azotobacter	38.16	43.63	86.89	3.94	4.10	8.04	17.71	22.56	40.27	1.994	2.386	4.380
PSB	38.13	48.76	103.70	4.12	4.87	8.99	17.75	26.90	44.65	1.998	2.743	4.741
Rhi.+PSB	47.09	56.61	133.40	5.43	6.08	11.51	22.78	31.70	54.48	2.460	3.274	5.734
Azoto.+PSB	45.12	55.28	100.40	5.20	5.94	11.14	21.62	30.68	52.30	2.339	3.179	5.518
CD (P=0.05)	2.32	1.65	3.97	1.01	1.02	2.03	1.55	1.30	2.85	0.60	0.67	1.27
Interaction	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Sig. = Significant

The best treatment interaction was 60 kg S/ha with dual biofertilizers which further augmented uptake of N, P, K and S nutrients synergistically. The positive influence of such interaction on the plant growth, grain yield and nutrient uptake might be due to its impact on the carbon cycle in plant i.e. higher CO_2 fixation and their efficient translocation towards developing grains.

The maximum uptake of these nutrients in this treatment may be owing to the increased crop biomass as well as nutrient contents (Kumar *et al.*, 2004; Kumar and Singh, 2009 and Kumawat *et al.*, 2009) [1, 11, 3].

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