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Effect of phosphorus, sulphur and biofertilizers on yield attributes and yield of fenugreek (*Trigonella foenum-graecum*) and their residual effect on pearl millet (*Pennisetum gluacum*)

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Fatehpur-Shekhawati (Sikar), Rajasthan, during 1997–98 and 1998–99. Branches/plant, pods/plant, seeds/pod and test weight of fenugreek (*Trigonella foenum-graecum* L.) significantly increased with increasing dose of P up to 80 kg P_2O_5/ha. These characters were marginally influenced by S application. Biofertilizers inoculation significantly increased branches/plant during 1998–99 and seeds/pod during both the years. Seed, straw and biological yields of fenugreek also increased significantly with phosphorus applied up to 80 kg P_2O_5/ha. Yield estimates of fenugreek also responded significantly to S application up to 100 kg/ha. Dual inoculation with *Rhizobium* + PSB significantly increased the seed and biological yields during both the years and straw yield during the first year. Phosphorus and sulphur applied to fenugreek significantly increased the grain, stover and biological yields of succeeding pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Seed treatment of fenugreek with biofertilizer did not influence the grain, straw and biological yields of succeeding pearl millet crop.

Key words : Phosphorus, Sulphur, Biofertilizer, Fenugreek, Residual pearl millet

There is a need to explore the other factors which can economize phosphorus use in crop rotation. Now-a-days traditional boundaries between primary and secondary nutrients are becoming narrower. Crop requires as much sulphur as they do phosphorus. Sulphur deficiency is increased due to intensive cropping, use of high-yielding varieties and countinuous use of sulphur-free, high analysis fertilizers. Information on nutrient management in cropping system is lacking. Moreover, the single nutrient approach has been replaced now by multi-nutrient to provide balanced nutrients to boost up crop productivity and plant nutrient-use efficiency. Besides,

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nutrient management in cropping system is more efficient and judicious than individual crop, as succeeding crop takes care of the residual effect of nutrients, particularly P and some extent to S. So much so, multi-nutrient approach along with biofertilizers in a crop and its residual on succeeding crop seems to be rational at a time of high prices and short supply of chemical fertilizers. Keeping these considerations in view, the present field investigation was undertaken.

MATERIALS AND METHODS

A field experiment was conducted during 1997-98 and 1998-99 on loamy sand soils of Agricultural Research Station, Fatehpur-Shekhawati (Sikar), Rajasthan. The soil was low in organic matter (0.15%) and available N (120 kg/ha), medium in available P (10.7 kg P/ha), and high in available K (332.9 kg/ha) and having sulphur (12.60 kg/ha). The experiment consisted of 36 treatment combinations, comprising 3 levels of phosphorus (0, 40 and 80 kg P_2O_5/ha), 3 of sulphur (0,50 and 100 kg S/ha) and 4 of biofertilizers [control, *Rhizobium*, phosphate-solubilizing bacteria (PSB) and *Rhizobium* + PSB). These treatments were evaluated under split-plot design with 3 replications. Phosphorus and sulphur were allocated to main plots and biofertilizers to subplots. A uniform dose of N (31.3 kg/ha) was maintained and phosphorus and sulphur as per treatment were drilled manually through diammonium phosphate and gypsum at the time of sowing. Inoculation of seeds with biofertilizers was also done as per treatment. The fenugreek variety 'RMt 1' was sown in the first week of November, during both the years at a depth of 5 cm in rows spaced at 30 cm using seed rate of 20 kg/ha. For residual study the pearl millet variety 'MH179' was sown at a depth of 5 cm in rows spaced at 40 cm using seed rate of 4 kg/ha.

RESULTS AND DISCUSSION

Yield attributes of fenugreek

Phosphorus application up to 80 kg P_2O_5/ha significantly increased the branches/plant, pods/plant, seeds/pod and test weight. Application of 80 kg P_2O_5/ha increased the number of branches 21.89 and 10.55% over the control and 40 kg P_2O_5/ha respectively. This dose also significantly increased the pods/plant by 9.83 and 3.49% during 1997–98, 25.01 and 12.01 % during 1998–99 and 17.14 and 7.70 % of mean data, while seeds/pod significantly increased by 11.28 and 5.34 % during 1997–98, 16.82 and 3.89 % during 1998–99 over the control and 40 kg P_2O_5/ha respectively. Test weight also increased significantly with 80 kg P_2O_5/ha by 11.04 and 6.05% during 1997-98 and 24.44 and 23.59 % during 1998–99 over the control and 40 kg P_2O_5/ha respectively (Table 1).

The significant increases seems to have resulted on account of improved nutritional condition of the plant. It may be due to the fact that all metabolic processes like photosynthesis, glycolysis and respiration are depending upon the action of coenzymes like NAD, NADP which are phosphorus dependent. Almost similar findings were also reported by Detroja (1995).

Sulphur application significantly increased the branches/plant and pods/plant during 1998–99 only. Application of 100 kg S/ha increased the branches by 7.27 and 4.42% over control and 50 kg S/ha

Table 1. Effect of phosphorus, sulphur and biofertilizers on yield attributes of fenugreek

Treatment	Branches/plant			Pods/plant			Seeds/pod			Test weight (g)		
	1997–98	1998–99	Mean	1997–98	1998–99	Mean	1997–98	1998–99	Mean	1997–98	1998–99	Mean
Phosphorus (kg P_2O_5/ha)												
0	6.21	6.08	6.15	24.01	22.31	23.16	18.80	15.99	17.40	10.42	09.86	10.14
40	6.77	6.78	6.78	25.48	24.90	25.19	19.86	17.98	18.92	10.91	10.91	10.91
80	7.38	7.60	7.49	26.71	27.89	27.30	20.92	18.68	19.80	11.57	12.25	11.91
CD (P=0.05)	0.39	0.37		0.68	1.38		1.24	1.04		0.28	0.64	
Sulphur (kg S/ha)												
0	6.62	6.60	6.61	25.04	24.18	24.61	19.36	17.11	18.24	10.83	10.67	10.75
50	6.76	6.78	6.77	25.22	24.91	25.07	19.72	17.54	18.63	10.98	10.95	10.97
100	6.98	7.08	7.03	25.61	26.01	25.81	20.44	18.01	19.23	11.10	11.40	11.25
CD (P=0.05)	NS	0.37		NS	1.38		NS	NS		NS	NS	
Biofertilizer inoculation												
Control	6.70	6.69	6.69	25.13	24.58	24.86	19.41	17.19	18.30	10.94	10.80	10.87
Rhizobium	6.76	6.81	6.79	25.24	24.93	25.09	19.48	17.54	18.51	10.95	10.92	10.94
Phosphate-solubilizing bacteria (PSB)	6.81	6.85	6.83	25.40	25.10	25.25	20.15	17.70	18.93	10.98	11.03	11.01
Rhizobium + PSB	6.88	6.94	6.91	25.37	25.52	25.45	10.41	17.78	19.10	11.01	11.27	11.14
CD (P=0.05)	NS	0.14		NS	NS		0.72	0.42		NS	NS	

Table 2. Effect of phosphorus, sulphur and biofertilizers on yield of fenugreek

Treatment	Seed yield (q/ha)			Straw yield (q/ha)			Biological yield (q/ha)		
	1997–98	1998–99	Pooled	1997–98	1998–99	Mean	1997–98	1998–99	Mean
Phosphorus (kg P_2O_5/ha)									
0	13.08	13.40	13.24	23.71	24.18	23.95	36.79	37.57	37.18
40	14.50	14.94	14.72	26.38	26.50	26.44	40.88	41.44	41.16
80	16.32	16.75	16.54	29.35	29.62	29.49	45.68	46.37	46.03
CD (P=0.05)	0.59	0.82	0.946	0.94	1.17		1.59	1.93	
Sulphur (kg S/ha)									
0	14.10	14.51	14.31	25.54	25.83	25.69	39.64	40.35	39.96
50	14.57	14.96	14.77	26.40	26.57	26.49	40.96	41.53	41.25
100	15.24	15.61	15.43	27.50	27.89	27.70	42.74	43.51	43.13
CD (P=0.05)	0.59	0.82	0.946	0.94	1.17		1.59	1.93	
Biofertilizers inoculation									
Control	14.38	14.76	14.57	26.01	26.45	26.23	40.39	41.21	40.80
Rhizobium	14.56	14.98	14.77	26.34	26.69	26.52	40.90	41.66	41.28
PSB	14.70	15.08	14.89	26.58	26.94	26.76	41.28	42.02	41.65
Rhizobium + PSB	14.91	15.30	15.11	26.98	26.98	26.98	41.89	42.28	42.09
CD (P=0.05)	0.33	0.30	0.453	0.62	NS		0.96	0.59	
CV I	8.06	10.97	11.27	7.07	8.76		7.59	9.22	
CV II	4.21	3.70	4.92	4.29	3.67		4.29	2.58	

PSB, Phosphate-solubilizing bacteria

Table 3. Effect of residual phosphorus, sulphur and biofertilizers on yield of pear millet

Treatment	Grain yield (q/ha)			Stover yield (q/ha)			Biological yield (q/ha)		
	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean
Phosphorus (kg P_2O_5/ha)									
0	14.48	15.09	14.79	40.71	41.71	41.23	54.91	56.83	55.87
40	16.41	17.13	16.77	46.87	51.30	49.09	63.84	68.43	66.14
80	19.51	20.58	20.05	56.74	57.74	57.24	76.24	78.32	77.28
CD (P=0.05)	1.08	1.41		2.74	2.67		3.68	2.77	
Sulphur (kg S/ha)									
0	16.17	16.70	16.44	46.91	47.72	47.32	62.79	64.42	63.61
50	16.69	17.55	17.12	47.19	50.23	48.71	64.43	67.78	66.11
100	17.54	18.56	18.05	50.23	52.83	51.53	67.77	71.38	69.58
CD (P=0.05)	1.08	1.41		2.74	2.67		3.68	2.77	
Biofertilizer inoculation									
Control	16.55	17.32	16.93	47.38	49.42	48.40	63.94	46.72	65.33
Rhizobium	16.69	17.50	17.10	47.69	50.02	48.86	64.75	67.52	66.14
PSB	16.85	17.65	17.25	47.94	50.41	49.18	65.16	68.06	66.61
Rhizobium + PSB	17.11	17.96	17.54	49.92	51.19	50.31	66.15	69.15	67.65
CD (P=0.05)	NS	NS		NS	NS		NS	NS	

PSB, Phosphate-solubilizing bacteria

respectively. Application of 100 kg S/ha increased the pods/plant by 7.57 and 4.42% over the control and 50 kg S/ha respectively. Sulphur application had no significant effect on seeds/pod and test weight of fenugreek (Table 1). The significant increase in yield attributes under sulphur fertilization seem to have resulted on account of improved rhizosphere environment. Thus the concomitant influence of sulphur on availability of nutrient from the soil and their extraction by plants seems to have provided congenial nutritional environment in the plants. These improvement under sulphur application might have increased metabolic processes in plants resulting in more branches/plant. Sulphur plays vital role in improving vegetative structure for nutrient absorption strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink (Sacchidanand *et al.*, 1980).

Seed inoculation with biofertilizers significantly increased branches/plant during 1998–99 and seeds/pod during both the years. Though pods/plant and test weight remained unaffected. Seed treatment with PSB + *Rhizobium*, PSB alone and *Rhizobium* alone increased seeds/pod by 4.15, 3.22 and 0.76 % over the control respectively (Table 1). The increase in yield attributes through biofertilizers inoculation might be due to inoculation increased the roots through better root development, nodulation, nutrient availability resulting in vigorous plant growth which resulted in better flowering and increase in sink capacity both in size and numbers.

The meteorological observations showed large variation in amount and distribution of rainfall, maximum and minimum temperature but the difference observed in other parameters were smaller. The total amount of rainfall received during the winter 1997–98 and 1998–99 was 33.8 and 19.2 mm respectively. The mean temperature was quite high in the first year that might have some harmful effect on crop establishment and initial growth. On the other hand, the maximum and minium temperature at the time of sowing was favourable which resulted in good growth and yield in second year than previous year.

Yield of fenugreek

Phosphorus increased the seed, straw and biological yields of fenugreek significantly. Application of 80 kg P_2O_5/ha increased seed straw and biological yields by 24.89, 23.14 and 23.79 % over the control; and 12.33, 20.64 and 11.82% over 40 kg P_2O_5/ha respectively. Branches/plant, pods/plant, seeds/pod and test weight increased with P up to 80 kg P_2O_5/ha leading to more seed yield. Phosphorus increased the rate of symbiotic nitrogen fixation and in turns stimulated the growth of plants, thereby having beneficial effects in giving higher yields. These results are in close conformity with the findings of Detroja (1995) and Choudhary (1999).

Increased application of sulphur increased seed, straw and biological yields of fenugreek significantly. Application of 100 kg S/ha increased the seed, straw and biological yields by 7.83, 7.82 and 7.83% over the control respectively. The increased yield under increased sulphur fertilization might be ascribed to increased branches/

plant and pods/plant. Thus in the present study significant improvement in yield and yield-attributing characters obtained under sulphur fertilization seems to have resulted on account of increased concentration of sulphur in various parts of fenugreek, which maintained the critical balance of other essential nutrients in the plant. Tiwari and Pathak (1998) also noticed increased yield of fenugreek with application of sulphur.

Seed, straw and biological yields of fenugreek increased with biofertilizer inoculation. Seed treatment with PSB + *Rhizobium*, PSB alone and *Rhizobium* alone increased the seed yield by 3.67, 2.20 and 1.37%; straw yield by 2.86, 2.02 and 1.09%; and biological yield by 3.15, 2.08 and 1.18 % over the control respectively (Table 2). *Rhizobium* culture increases the nodulation by increased nitrogen supply to the plants through almospheric nitrogen fixation. In the present study, since the soil was low in available phosphorus, PSB might have helped in reducing P fixation by it's chelating effect and also solubilized the fixed form of P leading to more uptake of nutrient. The increase in seed and straw yields is due to cumulative effect of increased growth and yield attributes. These findings corroborate the results of Shinde and Saraf (1991) and Meena (1997).

Effect of residual P, S and biofertilizers on yield of pearl millet

Phosphorus applied in fenugreek significantly increased the yield of succeeding pearl millet. Residual effect of 80 kg P_2O_5/ha increased the mean grain, stover and biological yields by 35.58, 37.13 and 38.32% over the control; and 19.53, 16.61 and 16.85% over 40 kg P_2O_5/ha respectively. The increase in yield estimates, viz grain, stover and biological yields, of pearl millet owing to residual effect of phosphorus levels may be ascribed to relatively increase and availability of nutrients in soil and their better absorption by the plants, ultimately resulting in better yield with increased residual phosphorus. Nimje and Seth (1998) and Giri (1993) also reported significant residual effect of phosphorus.

Sulphur application to fenugreek significantly increased the grain, stover and biological yields of pearl millet. Residual effect of 100 kg S/ha increased the grain , stover and biological yields of pearl millet by 9.83, 8.91 and 9.39% over the control; and 5.43, 5.79 and 5.25% over 50 kg S/ha respectively. The increase in grain yield may be attributed to enrichment of soil with sulphur, resulting in more uptake of sulphur. The results are in close conformity with the findings of Nad and Goswami (1983).

Residual effect of seed inoculation with biofertilizers had no significant effect on grain, stover and biological yields of succeeding pearl millet.

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