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Effect of phosphorus, irrigation and *Rhizobium* on productivity, water use and nutrient uptake in fenugreek (*Trigonella foenum-graecum*)

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ABSTRACT

An experiment was conducted during winter season of 2001–2004 for consecutive 3 years at Sriganganagar in Rajasthan to study the effect of phosphorus, irrigation and *Rhizobium* inoculation on seed, economics, water use and nutrient uptake of fenugreek (*Trigonella foneum-graecum* L.). Application of 40 kg P_2O_5/ha significantly increased the yield attributes, viz. branches/plant, pods/plant, pod length, seeds/pod and test weight and finally the yield (8.08 q/ha) over 20 kg P_2O_5. Phosphorus @ 40 kg P_2O_5/ha gave the highest mean benefit : cost ratio (1.47) in comparison with 20 (1.38) and 60 kg P_2O_5/ha (1.42). The highest P-use efficiency (35.95 kg/kg P_2O_5) was recorded at 20 kg P_2O_5/ha, and further increase in P decreased the P-use efficiency. An increase m P level, increased the consumptive use but had no effect on water-use efficiency. Highest level of P_2O_5 led to greater extraction of moisture from lower depth of rhizosphere. Application of P increased the N, P and K uptake up to 40 kg P_2O_5/ha. IW:CPE ratio of 0.8 significantly increased the yield (10.20 q/ha), benefit : cost ratio (1.81), consumptive water use (291.9 mm) and nutrient uptake compared to IW : CPE ratio of 0.4 and 0.6. Higher yield attributes as well as higher seed (8.14 q/ha) and stover yields (17.36 q/ha) were recorded with *Rhizobium* inoculation than with uninoculated crop. Higher water use (244.8 mm), water-use efficiency (3.2 kg/ha-mm) and nutrient uptake (N 31.6, P 5.5 and K 37.9 kg/ha) were also recorded with the inoculated crop.

Key words : Fenugreek, Phosphorus, Irrigation, *Rhizobium*, Yield, Nutrient uptake

Fenugreek (*Trigonella foenum-graecum*) is a multipurpose crop, whose every part is utilized as leafy vegetable, fodder and condiment (Khiriya and Singh, 2003). This seed spice is grown in northern India under limited irrigation condition and almost without fertilizers. Its productivity is controlled by many factors, of which phosphorus nutrition and judicious use of irrigation are most important. *Rhizobium* inoculation is essential to increase the productivity of leguminous crops (Solaiappan and Ramiash, 1990). To sustain the productivity of land and sustainability in the productivity of crop, judicious use of phosphorus, irrigation and integration of *Rhizobium* inoculation as well as their specific management are important. Therefore the present investigation was carried out to study the effect of phosphorus, irrigation and *Rhizobium* inoculation on fenugreek.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station, Sriganganagar during winter seasons 2001–02 to 2003–04. The soil was sandy loam with field capacity 16.2%, permanent wilting point 6.3%, bulk density 1.48 g/cc, pH (1:2) 8.1, electrical conductivity (1:2) 0.2 dS/m, organic carbon 0.28%, available P_2O_5 35 kg/ha and K_2O 340 kg/ha. There were 18 treatment combinations comprising three levels of phosphorus, viz. 20, 40 and 60 kg P_2O_5/ha in main plots; three levels of irrigation, *viz.*, IW : CPE ratios 0.4, 0.6 and 0.8 in subplots, and the presence or absence of *Rhizobium* inoculation in subplots. These were evaluated in split-split plot design with three replications. Fenugreek variety 'RMt 1' was sown on 7, 6 and 7 November in 2001–02, 2002–03 and 2003–04 respectively, using seed rate of 20 kg/ha at a row spacing of 25 cm. The crop was harvested on 8, 15 April and 30 March in 2001–02, 2002–03 and 2003–04 respectively. A general dose of 40 kg N/ha through urea and phosphorus as per treatment through single superphosphate were applied basal. A pre-sowing irrigation of 100 mm depth was applied. Post-sowing irrigations of 60 mm each were applied as per treatment. Rainfall received during the crop-growing period was 12.9, 58.5 and 19.9 mm in 2001–02, 2002–03 and 2003–04 respectively, and the respective pan-evaporation values were 439.5, 431.8 and 298.6 mm.

RESULTS AND DISCUSSION

Effect of phosphorus

Phosphorus levels influenced the seed yield and yield

Table 1. Effect of phosphorus, irrigation and *Rhizobium* inoculation on yield, yield attributes, harvest index and economics of fenugreek (mean data of 3 years)

Treatment	Seed yield (q/ha)	Straw yield (q/ha)	Harvest index (%)	Height (cm)	Branches/ plant	Pods/ plant	Pod length (cm)	Seeds/ pod	Test weight (g)	B:C ratio
P_2O_5 (kg/ha)										
20	7.19	16.24	33.39	58.3	6.5	36.3	11.2	15.2	11.22	1.38
40	8.08	17.03	34.54	62.7	7.0	40.1	11.9	15.7	11.71	1.47
60	8.16	17.41	34.26	63.0	7.0	41.0	11.9	15.7	11.92	1.42
CD (P=0.05)	0.52	0.72	0.15	0.8	0.3	2.2	0.5	0.3	0.40	
IW : CPE										
0.4	4.87	12.73	31.66	48.7	4.5	32.3	9.5	13.7	9.54	0.92
0.6	8.20	17.23	33.99	63.9	7.0	40.4	12.2	15.9	11.98	1.50
0.8	10.20	20.72	35.76	71.3	8.4	44.7	13.4	17.1	13.31	1.81
CD (P=0.05)	0.52	0.57	2.18	1.7	0.3	2.8	0.5	0.3	0.37	
Inoculation										
No inoculation	7.46	16.43	33.53	59.9	6.7	38.7	11.6	15.4	11.59	1.36
Rhizobium	8.14	17.36	34.56	62.6	6.9	39.6	11.8	15.7	11.64	1.48
CD (P=0.05)	0.31	0.47	0.59	1.2	NS	NS	NS	0.2	NS	

attributes of fenugreek significantly (Table 1). Application of 40 kg P_2O_5/ha gave 8.08 q/ha seed yield and 17.03 q/ha straw yield, which were significantly higher than of 20 kg P_2O_5/ha and on a par with those of 60 kg P_2O_5/ha. Application of 40 kg P_2O_5/ha significantly increased the height, branches/plant, pods/plant, pod length, seeds/pod and test weight compared with that of 20 kg P_2O_5/ha. These results are in conformity with those of Bhati (1993) and Chaudhary (1991). When phosphorus level was increased from 20 to 40 kg/ha, harvest index increased from 33.39 to 34.54%. Further increase in phosphorus did not influence the harvest index statistically. The better yield and yield attributes with phosphorus fertilization might be due to its key role in root development, energy translocation and metabolic process of plant, through which increased translocation of photosynthate towards sink development might have occurred.

Phosphorus-use efficiency was the highest at 20 kg P_2O_5/ha (35.95 kg/kg P_2O_5) and further increase in phosphorus level decreased the phosphorus-use efficiency (Table 2). The highest benefit : cost ratio of 1.47 was recorded at 40 kg P_2O_5/ha. Further, increase in P_2O_5 level from 20 to 40 kg/ha also increased the consumptive use. Application of higher dose of phosphorus extracted more moisture from lower depths of rhizosphere. It might be due to better root development induced by higher dose of phosphorus, which in turn secured higher extraction of moisture from deeper depth of the soil. Application of 40 kg P_2O_5/ha increased the N, P and K uptake significantly compared with that of 20 kg P_2O_5/ha.

Effect of irrigation

Irrigation had a marked effect on seed yield (Table 1). As irrigation frequency was increased from IW : CPE ratio 0.4 to 0.8, yield increased significantly, and the highest seed (10.20 q/ha) and straw (20.72 q/ha) yields were recorded at IW : CPE ratio 0.8. These findings are in agreement with those of Bhati (1993). Higher yield with higher levels of irrigation might be due to its key role in root development by reducing mechanical resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis due to better metabolic activities in the plant. Increase in irrigation level also increased the harvest index. Irrigation at 0.8 IW : CPE ratio gave significantly higher harvest index of 35.76%. Application of irrigation at 0.8 IW : CPE ratio recorded the highest benefit : cost ratio of 1.81, which was higher than that at IW : CPE ratios 0.4 and 0.6. An increase in irrigation frequency increased the consumptive use of water and phosphorus-use efficiency. Similarly, higher frequency of irrigation water increased the availability of nutrients, and thus encouraged greater root development, which in turn extracted more moisture from lower depths. Under moisture-stress condition (IW : CPE 0.4) due to poor growth of roots, more moisture was extracted from upper layer of the rhizosphere. Higher irrigation levels also increased the nutrient uptake significantly (Table 2). Higher nutrient uptake by higher levels of irrigation might be attributed to greater root growth and availability of more nutrients along with higher transpiration rate.

Effect of Rhizobium

All yield attributes except seeds/pod were not affected significantly, but the yield was higher (8.14 q/ha) with *Rhizobium* inoculation compared with no inoculation treatment (7.46 q/ha). Similar beneficial effect of *Rhizo-*

Table 2. Effect of phosphorus, irrigation and *Rhizobium* inoculation on consumptive use, water-use efficiency (WUE), phosphorus-use efficiency (PUE), and nutrient uptake of fenugreek (mean data of 3 years).

Treatment	*No. of irrigations	Water applied (mm)	Consumptive use (mm)	WUE (kg/ha-mm)	PUE (kg/kg P_2O_5)	Nutrient uptake (kg/ha)			Moisture-extraction pattern (%)		
						N	P	K	0-30 cm	30-60 cm	60-90 cm
P_2O_5 kg/ha											
20	2.77	308.2	236.8	3.0	35.95	25.8	4.1	32.1	55.4	32.9	11.7
40	2.77	308.2	245.5	3.2	20.20	29.7	5.6	33.2	52.3	31.8	15.9
60	2.77	308.2	248.9	3.3	13.60	30.7	6.1	35.6	51.8	31.9	16.3
CD (P=0.05)						1.6	0.8	1.0			
IW/CPE ratio											
0.4	1.66	230.4	192.7	2.5	12.18	16.9	3.5	21.7	57.2	33.5	9.3
0.6	2.66	290.4	247.3	3.3	20.50	31.8	5.3	34.2	52.2	32.6	15.3
0.8	4.00	403.8	291.9	3.5	25.50	39.5	7.4	45.5	50.8	31.6	17.6
CD (P=0.05)						1.5	0.7	0.7			
Rhizobium Inoculation											
No inoculation	2.77	308.2	242.6	3.1	18.65	23.4	4.8	31.5	53.5	32.4	14.1
Inoculation	2.77	308.2	244.8	3.3	20.35	31.6	5.5	37.9	52.9	32.0	15.1
CD (P=0.05)						1.0	0.5	0.8			

bium inoculation on fenugreek was reportedby Chaudhary (1991) and Sivran *et al. (1995).* Inoculation with *Rhizobium* might have increased the nodulation and there by fixed more atmospheric nitrogen, which was used by the crop. Higher harvest index and benefit : cost ratio were also given by *Rhizobium* inoculated crop (Table 1). Higher water-use efficiency (3.3 kg/ha-mm) was also recorded when the crop was inoculated with *Rhizobium* than uninoculated crop. *Rhizobium* inoculation had favourable effects on nutrient uptake, and higher amount of N, P and K were taken up by the crop when inoculated with *Rhizobium* than by the uninoculated crops (Table 2). *Rhizobium* inoculation also recorded higher phosphorus-use efficiency (20.34 kg/kg P_2O_5/ha). Higher nitrogen availability in plant through *Rhizobium* inoculation might have increased the uptake of all other nutrients, which in turn helped the crop for better performance in respect to phosphorus use efficiency, consumptive water use and water-use efficiency.

Fenugreek gave optimum yield with irrigation level of 0.8 IW : CPE ratio and 40 kg P_2O_5/ha as well as seed treatment with *Rhizobium*.

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