Ann. Agric. Res. New Series Vol. 33 (1&2) : 45-52 (2012)

Yield and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L) as influenced by nitrogen, phosphorus and bio-fertilizer

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ABSTRACT

A field experiment was carried out at Sardarkrushinagar during 2006-07 and 2007-08 to study the effect of nitrogen, phosphorus and bio-fertilizers on yield and nutrient dynamics of fenugreek. The experiment consisting of sixteen treatment combinations with two levels each of nitrogen (10 and 20 kg N / ha) and phosphorus (9 and 18 kg P / ha) as well as four levels of bio-fertilizer (control, seed inoculation with *Rhizobium*,PSB and *Rhizobium*+PSB) was laid in factorial RBD with three replications. Application of 20 kg N and 18 kg P / ha significantly increased plant height, dry matter accumulation, yield attributes, seed yield, straw yield, net return, benefit cost ratio,N, P and K content and uptake by seed and straw of fenugreek over their respective lower levels. Combined inoculation of seed with *Rhizobium* and phosphorus solublising bacteria resulted the highest plant height , dry matter accumulation, yield attributes, seed yield, straw yield, net return, benefit cost ratio N, P & K content and uptake by seed and straw followed by *Rhizobium*. Thus, higher yield, net return, B:C and nutrient uptake in fenugreek can be realised with the application of 20 kg nitrogen, 18 kg P / ha with seed inoculation by *Rhizobium* and phosphorus solublising bacteria.

Key words : Bio-fertilizer, nutrients, yield.

India occupies a prime position among fenugreek growing countries of the world. Gujarat and Rajasthan is the main fenugreek producing states. In most part of our country it is known as Methi and cultivated in 35737 ha area and producing 35737 tonnes of seed with a productivity of 1000 kg / ha, Nitrogen and phosphorus plays very important role in growth and development of a crop. Moreover, with increase in awareness, farmers are applying more inorganic fertilizers which leads to increase in cost of production. Hence, a biofertilizer is an important low cost input for supply of nutrient. Information on nutrient management in fenugreek (*Trigonella foenum-graecum* L) growing under semi arid climatic conditions in India is very less. Pareek and Manohar (2004) reported higher seed yield of fenugreek with application of 20 kg N + 40 kg P_2O_5 ha^{-1} under Rajasthan condition. The seed treatments of field pea with *Rhizobium*+ PSB showed higher plant height, dry matter accumulation and branches $plant^{-1}$ over control (Jain *et al.* 2003).Thus, the present study was undertaken to see the effect of nitrogen, phosphorus and bio-fertilizers on growth and yield of fenugreek.

MATERIALS AND METHODS

A field experiment was conducted during 2006-07 and 2007-08 on loamy sand soil of, Sardarkrushinagar (Gujarat). The experiment was laid on different sites during the both the years. The soil had pH (7.7 and 7.7), electrical conductivity (0.12 and 0.11 dS m^{-1}),with low in organic carbon (0.17 and 0.22) available nitrogen (152.75 and 165.25 kg / ha), medium in available P (18.0 and 21.0 kg / ha) and higher available K (216.9 and 220.6 kg / ha),respectively during 2006-07 and 2007-08. Sixteen treatment combinations consisting of two levels each of nitrogen (10 and 20 kg N / ha) and phosphorus (9.0 and 18.0 kg P / ha) and four levels of bio fertilizers (Control, *Rhizobium*, PSB and *Rhizobium* + PSB) were laid in factorial RBD

with three replications. Full dose of N and P was applied at sowing as per treatments. Inoculation of seeds of fenugreek with respective bio-fertilizer was done before sowing and after drying the seed in shade sowing was done. Crop was sown at arrow spacing of 30 cm on 18th November in both the years using 20 kg seed / ha. Primary soil samples were drawn randomly from each plot at depth of 0-15 cm before commencement of the experiment and after harvesting of the crop during both the years. A representative composite sample was prepared and subjected to available nutrient analysis using standard method for nitrogen, phosphorus and potassium. The methods used for soil analysis were acid digestion for nitrogen, vanado-molybdo-phosphoric yellow colour method for phosphorus. The concentration of N in seed and straw was determined by procedure suggested by Snell and Snell (1949) and of P and K content by methods suggested by Jackson (1973).The total uptake of N, P and K by crop at harvest in each treatment was computed by multiplying N,P and K content in seed and straw with the respective dry weight and expressed as kg / ha using following relationship. The total uptake of N,P and K (kg / ha)= (% N,P and K in seed x seed yield (kg per ha) +(% N,P and K in straw x straw yield (kg / ha). Based on apparent gain and loss of nutrients, an attempt was made to establish fate of nutrient available in soil added through different treatment and crop removal were usually taken into account during the course of fenugreek crop of two consecutive years. The nutrient balance sheet was worked out. The statistical analysis of the data was done as per procedure suggested by Panse and Sukhatme (1965).

Results and Discussion

Growth parameters

Application of 20 kg N / ha exhibited 14 and 31 per cent higher plant height and dry matter accumulation / plant, respectively over,10 kg N / ha which might be due to early and abundant availability of nitrogen. Application of 18 kg P / ha resulted 13 and 34 per cent higher plant height and dry matter accumulation / plant, respectively at maturity. Increased availability of phosphorus improved nutrient availability which increased nitrogenase activity of roots creating congenial environment for plant rhizosphere that resulted higher physiological growth parameters. Application of 20 kg N and 18 kg P / ha resulted the highest plant height at maturity.These findings are similar with those of Shivaran (1995). Significantly the highest plant height and dry matter accumulation / plant was recorded with combined application of Rhyzobium + phosphorus solublizing bacteria. which was 10 and 36% higher over no inoculation of bio fertilizer. The increase in Rhizobium population leads to symbiosis of these with root hairs making more infection of roots thereby increased amount of N fixed. These results are in conformity with those reported by Purbey (2004).

Yield attributes and yield

Application of 20 kg N / ha resulted 16.0, 16.0, 35.0, 18.0 and 16.0% more seeds / pod, 1000 seed weight, seed yield / plant, seed yield and straw yield, respectively over 10 kg N / hectare. These findings are similar with those of Shivaran (1995). Application of 18 kg P / ha resulted 13.0,8.0,13.0,13.0 and 12.0%, respectively more seeds / pod, 1000 seed weight, seed yield / plant, seed yield and straw yield. Higher seed yield of fenugreek seems to be due to cumulative effect of yield attributes and growth parameters. These results corroborate with the finding of those of Kasturikrishna and Ahlawat (2000) and Bhunia *et al.* (2006). Plant height at maturity, pods / plant, seed yield and straw yields, were significantly influenced with interaction effect of nitrogen and phosphorus and the highest plant height seed yield and straw yield was obtained with application of 20 kg N and 18 kg P / ha. Improved growth and development under combined influence of N and P increased the yield attributes and seed yield significantly by improving source and sink relationship. Similar results were reported by Chaudhary, (1999). Inoculation of seed with *Rhizobium* and PSB increased seed and straw yield by 16 and 17%, respectively over control. This might be due to the fact that *Rhizobium* inoculation increased root root development, nodulation and more nutrient availability resulting in vigorous plant growth and dry matter production leading to better

Table 1. Growth, yield and economic returns of fenugreek as affected by different levels of nitrogen, phosphorus and bio-fertilizers (Pooled data of 2006-07 and 2007-08)

Treatments	Plant height (cm)	Dry matter accumulation plant/g	No of Seeds/ pod	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield (kg /ha)	Straw yield (kg/ ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Nitrogen levels (kg/ha)										
10	55.2	11.95	12.21	10.30	4.79	1156	2398	38,839	18,344	0.90
20	63.0	15.68	14.14	11.90	6.48	1367	2778	45,860	25,257	1.22
C.D. (P=0.05)	2.3	0.80	0.54	0.44	0.25	50.2	116.9	1685	875	0.04
Phosphorus levels (kg/ha)										
9	55.4	11.81	12.35	10.65	12.35	1182	2445	39,728	19,379	0.95
18	62.7	15.82	13.99	11.55	13.99	1340	2730	44,971	24,221	1.17
C.D. (P=0.05)	2.3	0.80	0.54	0.44	0.54	50.2	116.9	1685	875	0.04
Bio-fertilizer										
Without inoculation	55.3	11.68	12.23	10.30	12.23	1171	2402	39,307	18,815	0.92
Rhizobium inoculation	60.3	13.99	13.18	11.11	13.18	1262	2589	42,379	21,817	1.06
PSB inoculation	59.4	13.64	13.01	10.96	13.01	1246	2556	41,841	21,279	1.04
Rhizo.+PSB inoculation	61.3	15.95	14.27	12.02	14.27	1366	2802	45,871	25,289	1.23
C.D. (P=0.05)	2.7	1.13	0.62	0.50	0.62	57.9	135.0	-	-	-
N x P interaction	S	NS	S	NS	S	S	S	-	-	-

Table 2. N, P, K content, uptake and quality of fenugreek as affected by different levels of nitrogen, phosphorus and bio-fertilizers (Pooled data of 2006-07 and 2007-08)

Treatments	N Content		P Content		K Content		N Uptake		P Uptake		K Uptake	
	Seed (%)	Straw (%)	Seed (%)	Straw (%)	Seed (%)	Straw (%)	(kg/ha) Seed	Straw	(kg/ha) Seed	Straw	(kg/ha) Seed	Straw
Nitrogen level (kg/ha)												
10	3.109	1.061	0.380	0.130	1.140	1.202	36.03	25.53	4.40	3.12	13.21	28.86
20	3.460	1.217	0.415	0.145	1.205	1.143	47.73	34.08	5.72	4.07	16.64	31.94
CD(P=0.05)	0.099	0.034	0.011	0.004	0.033	0.028	2.65	1.99	0.30	0.22	0.94	1.77
Phosphorus levels (P kg / ha)												
9	3.184	1.104	0.385	0.133	1.137	1.151	37.92	27.19	4.58	3.28	13.53	28.21
18	3.385	1.174	0.409	0.142	1.208	1.193	45.84	32.42	5.54	3.90	16.32	32.59
CD(P=0.05)	0.099	0.034	0.011	0.004	0.033	0.028	2.65	1.99	0.30	0.22	0.94	1.77
Bio-fertilizer levels												
Without inoculation	3.078	1.067	0.372	0.129	1.099	1.100	36.33	25.82	4.38	3.12	12.97	26.38
Rhizobium inoculation	3.328	1.154	0.402	0.139	1.188	1.187	42.49	30.26	5.13	3.64	15.14	30.84
PSB inoculation	3.272	1.135	0.396	0.137	1.168	1.168	41.11	29.26	4.97	3.52	14.65	29.84
Rhizo.+PSB inoculation	3.459	1.200	0.418	0.145	1.235	1.234	47.59	33.88	5.75	4.09	16.94	34.54
CD (P=0.05)	0.114	0.039	0.013	0.005	0.038	0.033	3.06	2.30	0.34	0.26	1.09	2.05

Table 3. Plant height, fenugreek as influenced by interaction effect between nitrogen and phosphorus (Pooled data of 2006-07 and 2007-08)

Nitrogen/ Phosphorus levels (kg/ha)	Plant height (cm)		No of seeds /pod		Seed yield /plant	
	9	18	9	18	9	18
10	53.50	56.80	11.84	12.58	4.64	4.93
20	57.33	68.66	12.86	15.41	5.89	7.06
CD (P=0.05)	2.71		0.62		0.64	

Table 4. Seed and straw yield as well as N,P and K uptake of fenugreek as influenced by interaction effect between nitrogen and phosphorus (Pooled data of 2006-07 and 2007-08)

Nitrogen/ Phosphorus levels	Seed yield (kg /ha)		Straw yield (kg/ ha)		N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
					Seed		Straw		Seed		Straw		Seed		Straw	
	9	18	9	18	9	18	9	18	9	18	9	18	9	18	9	18
10	1121	1190	2338	2457	34.24	37.82	24.38	26.67	4.18	4.62	2.98	3.25	12.56	13.86	27.68	30.04
20	1244	1490	2553	3002	41.59	53.87	29.99	38.17	4.97	6.46	3.58	4.56	14.49	18.78	28.73	35.15
CD (P=0.05)57.9	135.0	3.06	2.30	0.34	0.26	1.09	2.05									

Table 5 . Nitrogen and phosphorus balance sheet of soil during crop season (Pooled data of 2006-07 and 2007-08)

Treatments	Nitrogen (kg / ha)					Phosphorus(kg / ha)								
	Initial status													
A	Nutrient added													
B														
	Crop uptake C	Expected Nutrient balance D=A+B-C		Actual nutrient balance E		Apparent gain / loss F=E-D								
	Actual gain / loss G=E-A		Initial status											
A	Nutrient added													
B														
	Crop uptake													
C	Expected Nutrient balance D=A+B-C		Actual nutrient balance E			Apparent gain / loss F=E-D								
	Actual gain / loss G=E-A													
Nitrogen levels (kg N / ha)														
10	159	10	61.56	107.44	185.9	78.435	26.875	19.5	13.5	7.5	25.5	27.5	2.0	8.0
20	159	20	81.81	97.19	191.6	94.435	32.625	19.5	13.5	9.8	23.2	27.0	3.8	7.5
Phosphorus levels (kg P / ha)														
9	159	15	65.11	108.89	190.3	81.36	31.25	19.5	9.0	7.9	20.6	25.0	4.4	5.5
18	159	15	78.26	95.74	187.3	91.51	28.25	19.5	18.0	9.4	28.1	29.5	1.4	10.0
Bio-fertilizer														
Without inoculation			159.00	15.00	62.15	111.85	183.50	71.65	24.50	19.5	13.5	7.5	25.5	27.2	1.7	7.7
Rhizobium inoculation			159.00	15.00	72.75	101.25	189.25	88.00	30.25	19.5	13.5	8.8	24.2	28.2	4.0	8.7
PSB inoculation	159.00		15.00	70.37	103.63	185.50	81.87	26.50	19.5	13.5	8.5	24.5	26.8	2.3	7.3	
Rhizo.+PSB inoculation			159.00	15.00	81.47	92.53	196.75	104.22	37.75	19.5	13.5	9.8	23.2	26.7	3.5	7.2

flowering and pod formation. These results corroborated with the findings of Chaudhary (1999) in fenugreek.

Economics

Application of 20 kg N/ha increased net return and BCR by 37 and 35% respectively, over 10 kg N/ha. The application of increasing levels of N resulted in higher yield attributes, thereby giving more seed yield, which fetched higher net return. Application of 19 kg P/ ha increased, net return and BCR by 25 and 23% respectively over lower level. The magnitude of increase in yield was higher as compared to cost incurred on application of 20 kg N/ha, and 18 kg P/ha hence resulted higher BCR over 10 kg N and 9 kg P/ ha. These findings are similar with those of Shivaran *et al.* (1995) and Chaudhary (1999). Combined inoculation of seed with *Rhizobium* and PSB resulted in significantly higher gross return, net return and BCR over their sole application and control. Higher net return and BCR with combined inoculation with *Rhizobium* and PSB was obtained due to higher seed yield coupled with very less cost involved in inoculation. These results are in conformity with those of Chaudhary (1999).

Nutrient content and uptake

Application of 20 kg N and 18 kg P/ha significantly increased content and uptake of N, P and K by crop. Increase in uptake of N, P and K by crop might be attributed to cumulative effect of increased yield and higher content of N, P and K in seed and straw. These results corroborate with the findings of Rathore and Manohar (1988). N, P and K uptake were significantly influenced with interaction effects between nitrogen and phosphorus. The N, P and K uptake were recorded higher with combined application of 20 kg N + 19 kg P/ha which was at par with 10 kg N + 18 kg P/ha. Synergistic effects of both N and P improved nutrient levels in plant system and enhanced plant growth by promoting the merismetic activity and dry matter production. Similar results were reported by Rathore and Manohar (1989). Combined inoculation of seed with *Rhizobium* and PSB resulted in significantly higher N, P and K content and uptake over control.This might be due to the fact that *Rhizobium* inoculation increased root through better root development, nodulation, more nutrient availability resulting in more nutrient in plant system leading to higher N,P and K uptake. These results are in close conformity with findings of Jat (2004) and Bhunia *et al.* (2006).

Nutrient balance sheet

Application of higher level of N enhanced apparent and actual gain of available nitrogen but application of more phosphorus resulted lesser actual gain of available nitrogen in experimental soil.The highest apparent and actual gain of available N was recorded with seed inoculation by *Rhizobium* + phosphorus solublizing bacteria followed by seed inoculation with *Rhizobium* only. The application of increasing levels of nitrogen resulted nearly equal apparent and actual gain in available phosphorus in experimental soil as compared to lower levels of nitrogen but higher gain in available phosphorus in soil was recorded with application of higher level of phosphorus. Seed inoculation with PSB resulted the highest apparent and actual gain in available phosphorus followed by seed inoculation with PSB only.

Thus, higher yield, net return, BCR and nutrient uptake in fenugreek can be realised with the application of 20 kg nitrogen, 18 kg P/ha with seed inoculation by *Rhizobium* and phosphorus solublising bacteria.

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