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Effect of Nitrogen, Phosphorus and Bio-Fertilizer inoculation on Growth, Productivity, Nutrient Uptake and Economic Returns in Fenugreek (*Trigonella foenum-Graecum* L)

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ABSTRACT : A field experiment was carried out at Sardarkrushinagar Dantewada Agricultural University (SDAU), during two consecutive winter seasons of 2006-07 and 2007-08 to study effect of nitrogen, phosphorus and bio-fertilizer on growth dynamics, productivity and nutrient uptake of fenugreek. The experiment consisting of sixteen treatment combinations with two levels each of nitrogen (N) (10 and 20 kg N/ha) and P_2O_5 (20 and 40 kg P_2O_5/ ha) and four levels of seed inoculation with bio-fertilizers (no seed inoculation (control), seed inoculation with *Rhizobium* alone, seed inoculation with phosphate solubilising bacteria (PSB) alone and seed inoculation with both *Rhizobium*+ PSB) was laid in factorial randoblized block design (FRBD) with three replications. Application of 20 kg N and 40 kg P_2O_5/ha significantly increased dry matter accumulation per plant (DMA), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) at all the growth stages as well as seed yield, straw yield, net return, benefit cost ratio (BCR) and, N, P and K uptake by crop over their respective lower levels. Inoculation of seed with both *Rhizobium* and PSB gave the highest DMA, CGR, RGR and NAR over their sole application as well as control. Seed and straw yield as well as, net return, BCR and, N, P and K uptake by crop was also recorded significantly higher with *Rhizobium* + PSB seed inoculation followed by *Rhizobium* alone. Thus, higher seed and straw yield as well as net return and BCR of fenugreek can be realised with the application of 20 kg N/ha, 40 kg P_2O_5/ ha and seed inoculation with *Rhizobium* and PSB both.

Key words: Fenugreek, Growth dynamics, Nitrogen, Phosphorus, *Rhizobium*, PSB.

India occupies a prime position among fenugreek growing countries in the world. In India, Gujarat and Rajasthan are the major fenugreek producing states. Locally fenugreek is known as *Methi* and is an important multipurpose winter season seed spice crop in the semi-arid tropics of North -Western India. The seed of fenugreek are used as a condiment and seasoning agent for garnishing and flavourings dishes and it being a leguminous crop; enriches the soil by biologically fixing atmospheric nitrogen. Fenugreek seeds are a rich source of polysaccharide galactomannan. They are also a source of saponins such as diosgenin, yamogenin, gitogenin, tigogenin, and neotigogens. Other bioactive constituents of fenugreek include mucilage, volatile oils, and alkaloids such as choline and trigonelline. The young leaves and sprouts of fenugreek are eaten as greens, and the fresh or dried leaves are used to flavour other dishes. The dried leaves have a bitter taste and a characteristically strong smell. Fenugreek seeds are thought to be a galactagogue that is often used to increase milk supply in lactating women (Chantry et al; 2004). Nitrogen is crucial in the synthesis of chlorophyll and it being an essential constituent of compounds like amino acids, nucleic acids, nucleotides, enzymes, coenzymes, vitamins and alkaloids contributes to the growth of plant. The general role of phosphorus (P) on plant metabolism is known to enhance the symbiotic nitrogen fixation as well as, it plays an important role in energy transfer process in the plant body. But due to lack of fertilizer recommendations for different agro climatic conditions, farmers generally apply either over or under dose of fertilizers in fenugreek thus, affecting the productivity of crop and profit margins to the farmers. Information on cost effective nutrient management in semi arid agro-climatic condition is meagre. Similarly there is need to evaluate the impact of different bio fertilizers which are not only cheaper but also eco-friendly on growth and productivity of fenugreek. Therefore, this study was undertaken to evaluate the effect of nitrogen, phosphorus and bio-fertilizers on growth dynamics, yield, nutrient uptake and economic returns in fenugreek.

Materials and Methods

A field experiment was conducted during two consecutive winter seasons of 2006-07 and 2007-08 on loamy sand soil of S.D.A.U., Sardarkrushinagar (Gujarat). The experiment was laid out on different sites during both the seasons. The soil was alkaline in nature (pH 7.75 &7.73) with electrical conductivity (0.12 and 0.11 dSm^{-1}), low in organic carbon (0.17 & 0.22) and available nitrogen (152.75 & 165.25 kg /ha), medium in available P_2O_5 (40.75 and 47.6 kg /ha) and high in respect to available K_2O (260.25 &264.7 kg /ha), respectively during 2006-07 and 2007-08. Sixteen treatment combinations consisting of two levels each of N (10 and 20 kg N/ ha) and P (20 and 40 kg P_2O_5/ ha) and four levels of seed inoculation with bio-fertilizers (no seed inoculation (control), seed inoculation with *Rhizobium* alone, seed inoculation with phosphate solubilising bacteria (PSB) alone and seed inoculation with both *Rhizobium*+ PSB) were laid in factorial RBD with three replications. Full dose of N and P was drilled manually 4 cm below seed before sowing as per treatment through urea (46% N) and single super phosphate (16% P). The fenugreek (GM-2) was sown in November in both the years and harvested in March of both the years respectively. Seed rate used was 20 kg/ ha and spacing 30 cm between rows. Biofertilizers were applied to the seeds as per the treatments. Seeds of fenugreek were first inoculated with Rhizobium followed by PSB. For treating the seeds 150 gram of jaggery was boiled in 1000 ml water and allowed to cool at room temperature and then poured over the seeds. Seeds were allowed to dry in shade for four hours after treatment with bio fertilizers and then sown. Crop was grown under fully irrigated conditions. Among the plant protection measures adopted 0.02 % endosulfan 35 EC was sprayed for control of aphids and 5 % sulphur dust @ 25 kg/ha was used against powdery mildew. The RGR, CGR and NAR were computed empirically by using formulae as suggested by Redford (1967**).** The N content in seed and straw was determined by procedure as suggested by Snell and Snell (1949) and P and K content by methods suggested by Jackson (1973). The nutrient uptake was calculated by multiplying the concentration with their respective dry matter accumulation. Net returns were calculated as difference between the gross returns and total cost of cultivation. The data collected from the experiment were subjected to statistical test by following 'Analysis of variance technique' as suggested by Cochran and Cox (1957).

Results and Discussion

Effect on crop growth rate

Application of 20 kg N ha^{-1} significantly increased the DMA per plant, CGR, RGR and NAR at all the crop growth stages (Table 1). This might be due to early and sufficient availability of N to plants when biologically fixed N is not available to plants. It leads to better nutritional environment in the root zone for growth and development of plant. However, RGR and NAR decreased with advancement of age. Dry matter accumulation per plant, CGR, RGR and NAR at 30, 60, 90 DAS and at maturity was found significantly higher with the application of 40 kg P_2O_5 /ha over 20 kg P_2O_5 /ha (Table1).Phosphorus plays an important role in root development and proliferation thus it influences nutrient and water uptake by plants. Besides, it also has pivotal role in biosynthesis of proteins, phospholipids, nucleic acids, and membrane transport and cytoplasm streaming. Phosphorus increases nitrogenase activity of root nodules which result in improved biological N fixation. These results corroborate the findings of Kasturikrishna and Ahlawat (2000) and Bhunia et al. (2006). The highest DMA, CGR, RGR and NAR were recorded with seed inoculation by Rhizobium + PSB and the lowest under control. Inoculation of seed with *Rhizobium* increases their concentration in rhizosphere which leads to more infection of roots thereby increased amount of biologically fixed N is available to plants. This possibly resulted in increased uptake of N which significantly

Table 1 : Dry matter accumulation, crop growth rate, relative growth rate per plant and net assimilation rate at various growth stages as influenced by different levels of nitrogen, phosphorus and seed inoculation with bio-fertilizers (Pooled data of 2006-07 and 2007-08)

Treatments	Dry matter accumulation per plant (g)				Crop growth rate (g/m²/day)				Relative growth rate (g/g/day)			Net assimilation rate (g/dm²/day)		
	30 DAS	60 DAS	90 DAS	Matu-rity	30 DAS	60 DAS	90 DAS	Matu-rity	30-60 DAS	60-90 DAS	90 DAS-Maturity	30-60 DAS	60-90 DAS	Matu-rity
Nitrogen levels (kg/ ha)														
10	0.375	3.045	9.795	11.950	0.417	2.971	7.510	2.119	0.03029	0.01686	0.00254	0.04804	0.04234	0.01212
20	0.400	3.650	12.400	15.680	0.444	3.607	9.719	3.182	0.03191	0.01759	0.00299	0.05123	0.04831	0.01612
SEm.±	0.004	0.040	0.192	0.278	0.005	0.042	0.173	0.054	0.00024	0.00018	0.00005	0.00073	0.00088	0.00031
CD(P=0.05)	0.013	0.113	0.543	0.802	0.014	0.119	0.490	0.152	0.00067	0.00052	0.00014	0.00207	0.00249	0.00088
Phosphorus levels(kg/ ha)														
20	0.364	2.999	9.666	11.809	0.404	2.924	7.405	2.252	0.03049	0.01687	0.00272	0.04719	0.04181	0.01290
40	0.411	3.696	12.529	15.821	0.457	3.654	9.823	3.050	0.03172	0.01757	0.00281	0.05207	0.04884	0.01533
SEm.±	0.004	0.040	0.192	0.278	0.005	0.042	0.173	0.054	0.00024	0.00018	0.00005	0.00073	0.00088	0.00031
CD(P=0.05)	0.013	0.113	0.543	0.802	0.014	0.119	0.490	0.152	0.00067	0.00052	NS	0.00207	0.00249	0.00088
Bio-fertilizer levels														
Without inoculation	0.363	3.041	9.541	11.678	0.403	2.968	7.218	2.061	0.03045	0.01648	0.00255	0.04791	0.04069	0.01178
Rhizobium inoculation	0.387	3.366	11.327	13.993	0.430	3.319	8.864	2.594	0.03119	0.01746	0.00270	0.04911	0.04591	0.01362
PSB inoculation	0.382	3.307	10.985	13.637	0.425	3.249	8.531	2.581	0.03111	0.01728	0.00265	0.04873	0.04474	0.01374
R*hizo*.+PSB inoculation	0.418	3.676	12.537	15.952	0.464	3.620	9.844	3.368	0.03170	0.01766	0.00320	0.05279	0.04997	0.01732
SEm.±	0.005	0.046	0.222	0.393	0.006	0.049	0.200	0.062	0.00027	0.00021	0.00006	0.00084	0.00102	0.00036
CD (P=0.05)	0.015	0.131	0.627	1.134	0.016	0.138	0.566	0.175	0.00077	0.00060	0.00016	0.00239	0.00288	0.00102
Interaction NXP	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	NS	NS	NS	NS	NS	NS

influenced growth parameters of fenugreek. Inoculation of fenugreek seed with PSB also had positive effect on growth of crop. The PSB help increase availability of P through solubilisation of native P. These results are in conformity with those reported by Purbey (2004). The N and P being major plant nutrients, seed inoculation with both *Rhizobium* and PSB benefit plants more than inoculation with only one of them. These results are in close conformity with findings of Jat and Shaktawat (2004) and Bhunia et al. (2006).

Effect on yield

Application of 20 kg N /ha significantly produced higher seed and straw yields over 10 kg N /ha (Table 2). Higher seed yield of fenugreek seems to be due to cumulative effect of growth and yield attributes which were significantly higher (data not given) with application of 20 kg N/ ha. Increase in growth attributes due to increasing level of N has direct and positive effect on seed and straw yields of fenugreek. These findings corroborate the results of Shivran et al (1995). However, graded levels of N failed to significantly influence harvest index. Similarly, application of 40 kg P_2O_5 ha^{-1} gave significantly higher seed and straw yields over 20 kg P_2O_5 ha^{-1} (Table 2). Higher seed yield of fenugreek seems to be due to better growth of plants with application of 40 kg P_2O_5 ha^{-1}. P is important for early root development, manufacture and translocation of food material in plant body, which resulted in better uptake of nutrients and thus higher seed and straw yields. However, harvest index remain unaffected due to different levels of P. Application of both *Rhizobium* and PSB as seed inoculants significantly increased seed and straw yield over their sole application as well as control (Tables 2). This might be due to the fact that *Rhizobium* + PSB inoculation resulted in better root development, nodulation, nutrient availability resulting in vigorous plant growth and dry matter production and ultimately higher yield. These results corroborate the findings of Singh and Chauhan (2005) in lentil, and Ali et al (2009) in fenugreek. Biofertilizers failed to affect the harvest index over control.

Table 2 : Seed yield, straw yield, net return, BCR and, N, P and K uptake as influenced by different levels of nitrogen, Phosphorus and seed inoculation with bio-fertilizers (Pooled data of 2006-07 and 2007-08)

Treatments	Seed yield (kg/ ha)	Straw yield (kg /ha)	Harvest Index (%)	Net return (₹/ha)	BCR	N uptake (kg/ ha)	P uptake (kg/ ha)	K uptake (kg/ ha)
Nitrogen levels (kg/ ha)								
10	1156	2398	32.54	18344	0.90	61.56	7.52	42.07
20	1367	2778	32.98	25257	1.22	81.81	9.79	48.58
SEm.±	17.7	41.3	0.26	309	0.02	1.58	0.17	0.91
CD(P=0.05)	50.2	116.9	Ns	875	0.04	4.46	0.49	2.59
Phosphorus levels(kg/ ha)								
20	1182	2445	32.61	19379	0.95	65.11	7.86	41.73
40	1340	2730	32.91	24221	1.17	78.26	9.44	48.92
SEm.±	17.7	41.3	0.26			1.58	0.17	0.91
CD(P=0.05)	50.2	116.9	NS	875	0.04	4.46	0.49	2.59
Bio-fertilizer levels								
Without inoculation	1171	2402	32.74	18815	0.92	62.15	7.50	39.35
Rhizobium inoculation	1262	2589	32.76	21817	1.06	72.75	8.78	45.98
PSB inoculation	1246	2556	32.77	21279	1.04	70.37	8.49	44.49
R*hizo.*+PSB inoculation	1366	2802	32.77	25289	1.23	81.47	9.83	51.48
SEm.±	20.5	47.7	0.30			1.82	0.20	1.06
CD (P=0.05)	57.9	135.0	NS	1011	0.05	5.15	0.56	2.99
Interaction NXP	Sig	Sig	NS	Sig	Sig	Sig	Sig	Sig

Table 3 : Dry matter accumulation per plant as affected by interaction effect between nitrogen and phosphorus (Pooled data of 2006-07 and 2007-08)

Nitrogen/ Phosphorus levels (kg/ ha)	Dry matter accumulation per plant (g)								Crop growth rate (g/ m^2/ day)							
	30 DAS		60 DAS		90 DAS		Maturity		30 DAS		60 DAS		90 DAS		Maturity	
	20	40	20	40	20	40	20	40	20	40	20	40	20	40	20	40
10	0.364	0.39	2.83	3.26	8.88	10.71	10.58	12.82	0.404	0.429	2.74	3.20	6.72	8.30	1.89	2.35
20	0.364	0.44	3.17	4.13	10.45	14.35	12.80	17.73	0.404	0.484	3.11	4.11	8.09	11.35	2.61	3.75
SEm.±	0.005	0.046	0.22	0.27	0.006	0.05	0.20	0.06								
CD (P=0.05)	0.015	0.131	0.63	0.76	0.016	0.14	0.57	0.18								

Table 4 : Yields, net return, BCR and nutrient uptake of fenugreek as influenced by interaction effect between nitrogen and phosphorus (Pooled data of 2006-07 and 2007-08)

Nitrogen/ Phosphorus levels (kg /ha)	Seed yield (kg /ha)		Straw yield (kg/ ha)		N uptake (kg /ha)		P uptake (kg/ ha)		K uptake (kg/ ha)		Net return ₹/ha		BCR	
	20	40	20	40	20	40	20	40	20	40	20	40	20	40
10	1121	1190	2338	2457	58.63	64.49	7.16	7.87	40.24	43.90	17394	19293	0.86	0.93
20	1244	1490	2553	3002	71.58	92.04	8.56	11.02	43.22	53.93	21364	29149	1.05	1.40
SEm.±	20.5	47.7	1.82	0.20	1.06	358.5	0.018							
CD (P=0.05)	57.9	135.0	5.15	0.56	2.99	1011	0.05							

Effect on Nutrient uptake

Application of 20 kg N/ ha was found to significantly improve uptake of N, P and K over its lower dose (Table 2). Increase in uptake of N, P and K by crop with 20 kg N/ ha might be attributed to cumulative effect of increased yield and comparatively higher content of N, P and K in seed and straw than 10 kg N/ ha. Nitrogen fertilization resulted in larger accumulation of nutrient from a fast growing root system. Rathore and Manohar (1988) have also reported increased N uptake with application of 20 kg N /ha in fenugreek over no application. Uptake of N, P and K was found significantly higher with application of 40 kg P_2O_5 /ha. This may be due to smaller increase in P content in both grain and straw and significant increase in both grain and straw yield with 40 kg P_2O_5 /ha compared to 20 kg P_2O_5 /ha. Inoculation with *Rhizobium* and PSB bio fertilizers alone significantly enhanced both N and P uptake over no inoculation but highest N and P uptake was found when inoculated with both the bio fertilizers. Ali et al. (2009) have also reported higher N and P uptake in fenugreek with *Rhizobium* and PSB bio fertilizers inoculation.

Effect on economic returns

Application of 20 kg N/ ha gave higher net returns Rs ha^{-1} and BCR over 10 kg N /ha which was due to significant increase in yield with increased level of N application. Application of 40 kg P_2O_5/ha significantly enhanced the net returns and BCR over its lower dose. Similarly, increased yield with *Rhizobium* + PSB inoculation resulted into higher net return and BCR as compared to control as well as inoculation with *Rhizobium* and PSB alone.

Interaction effect between nitrogen and phosphorus

The DMA and CGR, seed yield, straw yields, net return, BCR and, N P and K uptake were significantly influenced with interaction effects between nitrogen and phosphorus (Table 3 and 4) .The DMA, CGR, seed yield, straw yield, net return, BCR, N, P and K uptake were recorded higher with combined application of 20 kg N + 40 kg P_2O_5 /ha which was at par with 10 kg N + 40 kg P_2O_5 /ha. Application of N enhances absorption of P because it increases CEC of soil solution. Similarly, P leads to vigorous root development and proliferation which improves nutrient uptake. Thus, combined application of N and P created favourable environment, which increased uptake of nutrients and water from the soil for better growth and development. 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 also reported by Rathore and Manohar (1989).

Conclusion

Thus, it can be concluded that for higher yield and economic returns in fenugreek, application of 20 kg N/ ha and 40 kg P_2O_5/ha in combination with seed inoculation with both *Rhizobium* and PSB is required.

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