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Research Paper

Effect of fertility levels, biofertilizers and brassinosteroid on productivity, profitability and nutrient uptake of fenugreek (*Trigonella foenum-graecum*)

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ABSTRACT

A field study was conducted during the winter (*rabi*) seasons of 2012–13 and 2013–14 at Ajmer, Rajasthan, to assess the response of fenugreek (*Trigonella foenum-graecum* L.) to fertility levels, biofertilizers and brassinosteroid. Three fertility levels [60, 80 and 100% recommended dose of fertilizers (RDF) 40 kg N + 40 kg P_2O_5 + 10 kg S/ha)] and 3 biofertilizer inoculations [*Rhizobium*, phosphate-solubilizing bacteria (PSB) and *Rhizobium* + PSB) in main-plots and 3 concentrations of brassinosteroid (BR), viz. water spray, BR 0.25 ppm and BR 0.50 ppm, in subplots were studied in split-plot design with 3 replications. Significantly the highest values of growth parameters, nodules/plant, yield attributes, seed yield (2.24 t/ha), haulm yield (5.24 t/ha), net return (₹56,200), benefit: cost (B:C) ratio (1.88) and content and total uptake of N, P and S were recorded with application of RDF over lower fertility levels. Dual inoculation of seed with *Rhizobium* + PSB resulted higher growth, nodules/plant, yield attributes, seed yield (2,09 t/ha), net returns (₹50,690) and total uptake of nitrogen (130.94 kg/ha), phosphorus (17.17 kg/ha) and sulphur (15.82 kg/ha) over their sole application. Interaction of fertility levels and biofertilizers was also found significant in yield attributes and consequently in seed yield. Application of 100% RDF + dual inoculation, being at par with 80% RDF + dual inoculation, gave the highest seed yield (2,287 kg/ha) and net returns (₹57,940). However, the highest benefit: cost ratio (1.96) was obtained under 80% RDF + dual inoculation. Foliar spray of brassinosteroid 0.50 ppm resulted in significantly higher plant height (69.1 cm), branches/plant (5.48), yield attributes, seed yield (2.10 t/ha), net return, (₹50,040), benefit: cost ratio (1.64) and total uptake of nutrients (N, P and S) over water spray and BR 0.25 ppm respectively. Thus, integration of 80% RDF with dual inoculation and supplemented with foliar spray of brassinosteroid 0.50 ppm at 50 and 70 DAS is better for realizing higher yield and economics in fenugreek.

Key words : Biofertilizers, Brassinosteroid, Fenugreek, Fertility level

Fenugreek (*Trigonella foenum-graecum* L.) vernacularly known as *Methi* is an important annual herbaceous winter season seed spice crop of north India particularly of Rajasthan. The seed is mainly used as condiment and seasoning agent for garnishing and flavouring dishes further it has immense medicinal value and is a good source of vitamins, protein and essential oils. The crop also plays a very important role in agricultural economy as it has bright export potential and is earning valuable foreign currency for the country. Rajasthan occupies prime position in fenugreek production (87,380 tonnes). However, productivity (1061 kg/ha) in the state is below the national average (NHB, 2013). Amongst the production constraints, imbalance and inadequate nutrition without biofertilizers inoculation and poor flowering and pod setting were considered to be the most important limiting factor (Khariya *et al.,* 2003). These constraints further aggravate in soils of low organic matter and poor fertility. Thus to sustain the productivity of land and sustainability in the productivity of crop, judicious use of fertilizer with integration of biofertilizers is important (Bhunia *et al.,* 2006) and to rectify the problem of poor flowering and pod setting, exogenous application of plant bioregulator, particularly brassinosteroid is important, as it enhances and regulates the various physiological processes and balance the source and sink thereby increase the productivity as well as quality. Considering these aspects, a study was carried out to assess the impact of fertility levels, biofertilizers and brassinosteroid in enhancing the productivity of fenugreek.

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MATERIALS AND METHODS

A field experiment was carried out during the winter (*rabi*) season of 2012–13 and 2013–14 on sandy-loam soil at the ICAR-National Research Centre on Seed Spices, Ajmer (Rajasthan). The location of the experiment is 460.2 m above mean sea-level on latitude 26°22' N and longitude 74°36' E and is characterized by hot semi-arid climate. The annual rainfall is mainly confined to 3 months (July–September) and mean precipitation is about 525 mm. The soil was sandy loam with a *p*H 8.03, having low organic carbon (0.28%), low available nitrogen (151.3 kg/ha), low available phosphorus (7.8 kg/ha) and medium available potassium (197.1 kg/ha). The experiment was laid out in split plot design, comprising 3 levels of fertility F_1, 60% recommended dose of fertilizers (RDF); F_2, 80% RDF; and F_3, 100% RDF) and 3 biofertilizer inoculation i.e. B_1, *Rhizobium;* B_2, phosphate-solubilizing bacteria (PSB) and B_3, *Rhizobium* + PSB) as main-plot and 3 concentrations of brassinosteroid, i.e. G_0, water spray; G_1, brassinosteroid (BR) 0.25 ppm and G_2, BR 0.50 ppm as subplot treatment replicated thrice. The RDF comprised of 40 kg N + 40 kg P_2O_5 and 10 kg S/ha. Sowing of fenugreek 'RMt 143' using 20 kg seed/ha was done at 30 cm line-to-line spacing and plant-to-plant distance of 10 cm was maintained. Seed treatment with *Rhizobium meliloti,* PSB and combination of both was done as per treatment before sowing. Full dose of nitrogen, phosphorus and sulphur was provided at the time of sowing. The nitrogen, phosphorus and sulphur were supplied through urea, diammonium phosphate and gypsum respectively. Brassinosteroid was sprayed twice at 50 and 70 days after sowing (DAS) as per treatment under study. Five plants were selected randomly from each plot for taking biometric observations. Observation of yield and nutrient content were recorded to evaluate the effect of treatments. Nitrogen was analysed as Nesseler's reagent colorimetric method. Phosphorus was estimated by vanadomolybdo phosphate yellow colour method. Sulphur was estimated by turbidimetric method (Tabatabai and Bremner, 1970). The total uptake of nitrogen, phosphorus, potassium and sulphur by fenugreek crop at harvesting was computed by summing up the nutrient uptake of seed as well as straw. To find out economic viability of treatment, the gross realization was worked out on the basis of grain and straw yield/ha of each treatment on the basis of prevailing market prices. The net monetary returns were calculated by deducting the total cost of cultivation from the gross realization for each treatment. The data were subjected to homogeneity test and upon finding the data homogenous pooling was done and the statistical analysis was done as per procedure suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth and yield

Addition of graded dose of fertility resulted in significant increase in plant height, branches/plant and nodules/plant. Application of 100% RDF recorded the highest plant height, branches/plant and nodules/plant which were significantly higher over 80 and 60% RDF (Table 1). Likewise, the highest crop-growth rate (CGR) at successive stages were recorded under 100% RDF, being significantly higher over 80 and 60% RDF. At the same time aforesaid parameters were significantly higher under 80% RDF over 60% RDF. This was owing to adequate availability of N, P and S in soil which was resulted in higher growth rate (CGR) and its parameters because of enhanced photosynthesis with active cell-division and elongation. Greater availability of P and S might also be responsible for better nodulation. These results are in agreement with findings of Ali *et al*. (2009) and Singh *et al*. (2010). A significant improvement in pods/plant, seeds/pod, seed weight/pod, pod length and 1,000-seed weight of fenugreek were recorded with each increment in fertility level. All these yield attributes were the maximum at 100% RDF. Favourable effects of yield attributes resulted in significant yield increase at each level of fertility. The maximum seed and haulm yield were recorded at 100% RDF. The increment in seed yield was 586 and 245 kg/ha over 60 and 80% RDF, respectively, the corresponding increase in haulm yield was 559 and 302 kg/ha. Physiological role of N, P and S in enhancing growth parameters might have led to increased yield attributes and thereby yield of crop at higher levels of fertility. Bhunia *et al.* (2006) and Kumar *et al*. (2009) also reported similar results.

Amongst the inoculation treatments, dual inoculation of *Rhizobium* and PSB improved growth and yield parameters over their sole application. The highest plant height branches/plant and nodules were recorded under dual inoculation which was significantly higher over single inoculation of PSB; however, it remained on a par with *Rhizobium* alone. At the same time, *Rhizobium* alone also produced significantly taller plants, more branches and nodules over PSB alone. The highest CGR at all stages was recorded under dual inoculation, which was significantly higher over sole of PSB and *Rhizobium*. At later stage PSB and *Rhizobium* alone were found on a par with each other. Combined inoculation recorded the highest values of pods/plant, pod length, seeds/pod and seed weight/pod, which were significantly higher over single application of *Rhizobium* and PSB. Similarly, the highest 1,000-seed weight (14.68 g) was recorded under dual inoculation which was significantly higher over *Rhizobium*

Table 1. Growth, yield attributes, yields and economics of fenugreek as influenced by fertility levels, biofertilizers and brassinosteroid

Treatment	Plant height at harvest (cm)	Branches/ plant at harvest	Nodules/ plant	CGR(g/m^2/day) 30–60 DAS	60–90 DAS	90 DAS-maturity	Pods/ plant	Pod length (cm)	Seeds/ pods	Weight of seeds/pod (g)	1,000-seed weight (g)	Seed yield (t/ha)	Haulm yield (t/ha)	Net returns (10^3 ₹/ha)	Benefit: cost ratio
Fertility level															
60% RDF	61.91	4.39	8.13	2.43	9.43	6.72	31.98	10.48	13.59	0.178	13.28	1.66	3.93	34.82	1.20
80% RDF	67.05	5.31	9.75	2.73	10.64	8.15	34.80	11.36	14.67	0.201	14.11	2.00	4.68	47.32	1.60
100% RDF	70.27	5.92	10.84	2.96	11.50	9.10	36.37	12.16	15.37	0.220	14.78	2.24	5.24	56.20	1.88
SEm±	0.72	0.07	0.11	0.04	0.16	0.15	0.35	0.12	0.13	0.002	0.14	0.24	0.62	0.88	0.03
CD (P=0.05)	2.08	0.20	0.32	0.11	0.45	0.43	1.00	0.35	0.39	0.007	0.39	0.69	1.78	2.53	0.09
Biofertilizers															
Rhizobium	67.01	5.33	9.72	2.71	10.65	7.72	33.76	11.09	14.31	0.198	13.91	1.93	4.60	44.98	1.52
PSB	63.71	4.79	8.96	2.55	9.83	7.63	33.43	10.78	13.98	0.192	13.58	1.89	4.31	42.67	1.44
Rhizo.+PSB	68.50	5.50	10.03	2.87	11.09	8.63	35.96	12.13	15.33	0.210	14.68	2.09	4.94	50.69	1.71
SEm±	0.72	0.07	0.11	0.04	0.16	0.15	0.35	0.12	0.13	0.002	0.14	0.24	0.62	0.88	0.03
CD (P=0.05)	2.08	0.20	0.32	0.11	0.45	0.43	1.00	0.35	0.39	0.007	0.39	0.69	1.78	2.53	0.09
Brassinosteroid															
Water spray	63.64	4.92	9.55	2.67	10.07	7.75	32.98	10.79	13.84	0.185	13.79	1.83	4.32	41.90	1.47
BR 0.25 ppm	66.51	5.23	9.60	2.71	10.55	8.09	34.46	11.37	14.60	0.201	14.06	1.98	4.64	46.40	1.57
BR 0.50 ppm	69.08	5.48	9.56	2.75	10.94	8.14	35.72	11.84	15.18	0.213	14.31	2.10	4.89	50.04	1.64
SEm±	0.37	0.06	0.08	0.02	0.12	0.12	0.29	0.10	0.12	0.002	0.10	0.12	0.42	0.45	0.01
CD (P=0.05)	1.05	0.16	NS	NS	0.33	NS	0.83	0.27	0.33	0.006	0.28	0.34	1.18	1.27	0.04

REF, Recommended dose of fertilizers; PSB, phosphate-solubilizing bacteria; BR, brassinosteroids; DAS, days after sowing

and PSB alone by 5.6 and 8.2%. Inoculation with *Rhizobium* + PSB resulted in the highest seed and haulm yield which were significantly higher over *Rhizobium* and PSB alone by 7.8 and 10.6, and 7.5 and 14.7% respectively. Concomitantly sole *Rhizobium* found on a par with sole PSB in almost all yield attributes and haulm and seed yield. The better performance of dual inoculation might be on account of associative effect of both symbiotic and asymbiotic bacteria. These results are in accordance with the findings of Purbey and Sen (2007) and Mehta *et al.* (2012). Interaction effect between fertility levels and biofertilizers in respect of pods/plant, pod length, seeds/pod and seed weight/pod and thereby seed yield were observed significant (Tables 2, 3). The maximum values of aforesaid yield attributes were recorded under 100% RDF + dual inoculation which were found on a par with 80% RDF and dual inoculation. Statistically equally good performance of combination of 80% RDF + dual inoculation was might be owing to relatively better bacterial activity at lower fertility level. It is well established that N fixation decreases at higher levels of nitrogen.

Foliar spray of graded concentration of brassinosteroid (BR) resulted in significant increase in plant height and branches/plant. Spray of 0.50 ppm BR recorded the highest plant height and branches/plant, which were significantly higher over 0.25 ppm and water spray. However, nodules/plant were remained unaffected due to foliar spray of brassinosteroid. The highest CGR at 60–90 DAS stage was recorded under 0.50 ppm BR which was significantly higher over 0.25 ppm BR and water spray. Simultaneously aforesaid parameters were significantly higher under 0.25 ppm BR over water spray. A significant improvement in pods/plant, pod length, seeds/pod and 1,000-seed weight of fenugreek were recorded with each higher concentration of brassinosteroid up to 0.50 ppm. Spray of BR 0.50 ppm resulted in 8.3 and 3.7, 9.7 and 4.0, 3.8 and 1.8, and 16.0 and 6.2% higher pods/plant, seeds/pod, 1,000-seed weight and seed yield /plant over water spray and BR 0.25 ppm, respectively. Favourable effect of yield attributes resulted in significant yield increase at each higher concentration of brassinosteroid. The highest values of seed and haulm yield were recorded under BR 0.50 ppm

which were 6.2 and 14.6, and 5.5 and 13.2% higher over 0.25 ppm BR and water spray respectively. Improvement in yield attributes and thereby yield ascribed to association of brassinosteroid with enhanced photosynthetic efficiency and transport of photosynthates to reproductive parts (Mandava, 1988).These results are in close accordance with Farahat (2002) and Bera and Pramanik (2013).

Economics

There was significant improvement in net returns and benefit: cost ratio with each successive higher fertility level from 60 to 100% RDF. The highest net return (₹56,200) and benefit: cost ratio were fetched from 100% RDF, which were higher by 18.5 and 17.5% over 80% RDF and 61.4 and 56.6% higher over 60% RDF respectively.

Maximum net returns and benefit: cost ratio were obtained under dual inoculation of *Rhizobium* and PSB, which were significantly higher by 12.7 and 12.5% over sole *Rhizobium* and 18.8 and 18.8% over sole PSB respectively. However, sole *Rhizobium* and PSB were found at par with each other with respect to net returns and benefit: cost ratio. Further, interaction effect between fertility levels and biofertilizers in respect of net returns and benefit: cost ratio was realized significant (Table 3). The maximum value of net returns (₹57,940) was recorded under 100% RDF + dual inoculation, which was found on a par with 80% RDF and dual inoculation. However, the highest values of benefit: cost ratio (1.96) was obtained with 80% RDF + dual inoculation, which was on a par with 100% RDF + dual inoculation.

Foliar spray of successive higher concentration of brassinosteroid markedly enhanced net returns and B:C ratio. The highest net returns (₹50,400) was realized from foliar spray of BR 0.50 ppm which was higher by ₹8,140 and ₹3,640 over BR 0.25 ppm and water spray and simultaneously it had resulted in higher B:C ratio over BR 0.25 ppm and water spray by 4.4 and 11.6% respectively. The results conforms the findings of Purbey and Sen (2005) and Ali *et al*.(2009).

Nutrient content and uptake

The nitrogen, phosphorus and sulphur contents of fenugreek in seed and haulm and their total uptake increased significantly with increase in the level of fertility up to 100 % RDF (Table 4). It was because the application of 100% RDF improved the overall nutritional environment in the rhizoshere as well as in the plant system, resulting in increased nodulation and

Table 2. Yield attributes as influenced by interaction effect between fertility levels and biofertilizers

Fertility level	Pods/plant			Pod length (cm)			Seed weight/ pod(g)			Seeds/pod		
	Biofertilizers			Biofertilizers			Biofertilizers			Biofertilizers		
	Rhizo.	PSB	*Rhizo.*+ PSB	*Rhizo.*	PSB	*Rhizo.*+ PSB	*Rhizo.*	PSB	*Rhizo.* + PSB	*Rhizo.*	PSB	*Rhizo.* + PSB
60% RDF	31.15	30.42	34.37	10.57	10.03	10.84	0.183	0.174	0.178	13.68	13.14	13.94
80% RDF	34.56	33.24	36.62	10.86	10.50	12.74	0.195	0.184	0.224	14.17	13.84	16.00
100% RDF	35.58	36.63	36.89	11.85	11.80	12.84	0.215	0.217	0.229	15.07	14.97	16.06
SEm±	0.60		0.21		0.004		0.23					
CD (P=0.05)	1.74		0.61		0.011		0.67					

Rhizo., *Rhizobium*; PSB phosphate-solubilizing bacteria; RDF, recommended dose of fertilizers

Table 3. Yields and economics as influenced by interaction effect between fertility levels and biofertilizers

Fertility level	Seed yield (t/ha)			Haulm yield (t/ha)			Net return (10^3₹/ha)			Benefit: cost ratio		
	Biofertilizers			Biofertilizers			Biofertilizers			Biofertilizers		
	Rhizo.	PSB	*Rhizo.*+ PSB	*Rhizo.*	PSB	*Rhizo.*+PSB	*Rhizo.*	PSB	*Rhizo.*+ PSB	*Rhizo.*	PSB	*Rhizo.*+ PSB
60% RDF	1.67	1.61	1.70	4.05	3.70	4.06	35.53	32.61	36.32	1.23	1.12	1.25
80% RDF	1.90	1.83	2.27	4.48	4.18	5.37	43.50	40.65	57.81	1.48	1.38	1.96
100% RDF	2.23	2.21	2.29	5.27	5.05	5.39	55.91	54.75	57.94	1.87	1.83	1.93
SEm±		0.42			1.07			1.52			0.05	
CD (P=0.05)		1.20			3.08			4.38			0.15	

Table 4. Nutrient contents (%) and their total uptake (kg/ha) as influenced by fertility levels, biofertilizers and brassinosteroid

Treatment	N content		P content		S content		Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total S uptake (kg/ha)
	Seed	Haulm	Seed	Haulm	Seed	Haulm			
Fertility level									
60% RDF	3.125	1.089	0.416	0.133	0.299	0.160	95.06	12.16	11.26
80% RDF	3.334	1.160	0.455	0.144	0.322	0.171	121.49	15.90	14.47
100% RDF	3.498	1.215	0.478	0.151	0.341	0.179	142.35	18.68	17.04
SEm±	0.032	0.010	0.004	0.001	0.003	0.002	1.60	0.18	0.18
CD (P=0.05)	0.092	0.030	0.011	0.004	0.009	0.005	4.61	0.51	0.53
Biofertilizers									
Rhizobium	3.351	1.164	0.445	0.141	0.317	0.168	119.21	15.20	13.92
PSB	3.175	1.109	0.439	0.138	0.311	0.164	108.75	14.38	13.03
Rhizo.+ PSB	3.430	1.192	0.466	0.149	0.334	0.177	130.94	17.17	15.82
SEm±	0.032	0.010	0.004	0.001	0.003	0.002	1.60	0.18	0.18
CD (P=0.05)	0.092	0.30	0.011	0.004	0.009	0.005	4.61	0.51	0.53
Brassinosteroid (BR)									
Water spray	3.178	1.107	0.431	0.137	0.316	0.167	106.71	13.91	13.13
BR 0.25 ppm	3.337	1.158	0.451	0.143	0.322	0.170	120.53	15.65	14.35
BR 0.50 ppm	3.441	1.200	0.468	0.148	0.324	0.172	131.66	17.17	15.29
SEm±	0.025	0.009	0.003	0.001	0.003	0.001	0.95	0.12	0.14
CD (P=0.05)	0.070	0.028	0.010	0.003	NS	NS	2.68	0.33	0.38

Rhizo., *Rhizobium*; PSB phosphate-solubilizing bacteria; RDF, recommended dose of fertilizers

dry weight of nodules, which might have increased the availability of N, P and S and of some other nutrients from deeper layers and larger surface area on account of better root development and proliferation. Thus the favourable influence of RDF on higher nutrient absorption and production of assimilates and their efficient partitioning into different sinks led to higher content of N,P and S in seed and haulm and ultimately in higher uptake due to significant increase in both seed and haulm yields. Amongst the biofertilizers, highest N, P and S content and uptake were recorded under dual inoculation which was significantly higher over PSB and *Rhizobium* alone, except nitrogen content in seed and haulm which was on a par with that recorded under *Rhizobium* alone. At the same time *Rhizobium* alone treated plot recorded significantly higher N, P and S uptake over PSB alone. The N and P contents of fenugreek in seed and haulm and total uptake of N,P and S increased significantly with increase in concentration of brassinosteroid up to 0.50 ppm BR. Sulphur content in seed and haulm were differed non significantly and it will be due to brassinosteroid spray. Ali *et al*. (2009) and Singh *et al*. (2010) also reported similar results in fenugreek.

It was concluded that application of 80% recommended dose of fertilizers (32 : 32 : 0 : 8 kg N, P, K and S/ha) along with co inoculation of *Rhizobium* + PSB and supplemented with foliar sprays of brassinosteroid 0.5 ppm appeared to be the best integrated nutrient option in getting higher yield and net returns in fenugreek crop.

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