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Soil Fertility, Growth and Productivity of Fenugreek (*Trigonella foenum-graecum* L.) as Influence by Fertilizer Levels, Biofertilizers and Brassinosteroid

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A B S T R A C T

A field experiment was conducted during *rabi* seasons of 2012-13 and 2013-14 to find out the effect of fertility levels, biofertilizers and brassinosteroid on fenugreek productivity and soil fertility. Three fertility levels [60, 80 and 100 % RDF (40 kg N + 40 kg P_2O_5 + 10 kg S/ha)] and three biofertilizer inoculations (*Rhizobium*, PSB and *Rhizobium* + PSB) in main plot and three concentrations of brassinosteroid (water spray, BR 0.25 ppm and BR 0.50 ppm) in sub plot were studied in split plot design with three replications. The significantly highest values of growth parameters, nodules/plant, yield attributes, seed yield (2245 kg/ha) and haulm yield (5236 kg/ha) and soil fertility parameters after crop harvest *viz.*, OC (0.321%), available N, P and S were recorded with application of 100 % RDF over lower fertility levels. Dual inoculation of seed with *Rhizobium* + PSB gave significantly higher growth, nodules/plant, yield attributes, seed yield (2085 kg/ha) and OC %, available N, P and S 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 on a par with 80 % RDF + dual inoculation, gave the highest seed yield (2287 kg/ha). Foliar spray of brassinosteroid 0.50 ppm brought about significantly higher plant height (69.08 cm), branches/plant (5.48), yield attributes and seed yield (2098 kg/ha) over water spray and BR 0.25 ppm, however; its impact on soil fertility was non-significant. Thus, addition of 80 % RDF with dual inoculation and supplemented with foliar spray of brassinosteroid 0.50 ppm at 50 and 70 DAS is better for attaining higher fenugreek yield and soil health.

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) 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. Every part of its plant is useful. It also plays pivotal role in agricultural economy as it has bright export potential and is earning valuable foreign currency for the

country. Rajasthan occupies prime position (77.03 % share) in fenugreek production, contributing190360 tonnes in nation fenugreek production during 2015-16. However, productivity (1127 kg/ha) of fenugreek in the country is quite below its potential yield (2500 kg/ha, Anonymous 2017). Cultivation on inherent poor soils with inadequate nutrition without biofertilizers inoculation and poor flowering and pod setting were considered to be the most important limiting factor (Khariya and Singh, 2003). Thus to sustain the productivity and being a legume to enhance soil fertility of hungry soil of Rajasthan, judicious use of fertilizer with integration of bio-fertilizers is important (Bhunia *et al.*, 2006) and to regulate physiological processes for balancing source and sink to enhance flowering and pod setting exogenous application of plant bioregulator, particularly brassinosteroid plays vital role. Keeping these views, a study was carried out to assess the impact of fertilizer levels, biofertilizers and brassinosteroid on productivity of fenugreek and soil fertility.

Materials and Methods

A field experiment was carried out during *rabi* season of 2012-13 and 2013-14 on sandy loam soil at National Research Centre on Seed Spices, Ajmer (Rajasthan). The soil of the experimental site was sandy loam with a pH 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 (197.1kg/ha). The experiment was laid out in split plot design comprising three levels of fertilizer (F_1-60 % RDF, F_2-80 % RDF and F_3-100 % RDF) and three biofertilizer inoculation (B_1-*Rhizobium*, B_2-PSB and B_3- *Rhizobium* + PSB) as main plot and three concentrations of brassinosteroid (G_0- water spray, G_1- BR 0.25 ppm and G_2-BR 0.50 ppm) as sub plot treatment replicated thrice. Recommended dose of fertilizer (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. 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 applied at the time of sowing. The nitrogen, phosphorus and sulphur were supplied through urea, DAP and gypsum, respectively. Brassinosteroid was sprayed twice at 50 and 70 DAS as per treatment under study. Five plants were selected randomly from each plot for taking biometric observations. Yield observations were recorded to evaluate the effect of treatments. Soil was analysed before sowing and after experiment for determination of OC % and available N, P and S. The data were statistically analysed 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 highest plant height (70.27 cm), branches/plant (5.92) and nodules/plant (10.84) which was significantly higher over 80 and 60 % RDF. At the same time aforesaid parameters were significantly higher under 80 % RDF over 60 % RDF. The significant improvement in N, P and S status of soil resulted in better availability of nutrient for growth and development of nodules/plant, which helps in absorption and translocation of nutrients from vegetative to reproductive parts. The better nutritional environment in plant seems to have promoted branches/plant, height and dry matter/plant by way of active cell division and elongation. Results corroborated 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 1000 seed weight of fenugreek were recorded with each successive increment in fertility level. All these yield attributes were maximum at 100 % RDF. Favourable effects of yield attributes resulted in significant yield increase at each level of fertility. The maximum seed (2245 kg/ha) and haulm yield (5236 kg/ha) 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); Godara *et al.,* (2017) and Kumar *et al.,* (2009) also reported similar results.

Amongst inoculation, dual inoculation of *Rhizobium* and PSB improved growth and yield parameters over their sole application. The highest plant height (68.50cm), branches/plant (5.50) and nodules (10.03) 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 (Table 1).

At later stage PSB and *Rhizobium* alone found on a par with each other. Combined inoculation recorded highest values of pods/plant (35.96), pod length (12.13 cm), seeds/pod (15.33) and seed weight/pod (0.210 g) which was significantly higher over single application of *Rhizobium* and PSB. Similarly highest 1000-seed weight (14.68 g) was recorded under dual inoculation which was significantly higher over *Rhizobium* and PSB alone by 5.6 and 8.2 %. Inoculation with *Rhizobium* + PSB resulted in highest seed (2085 kg/ha) and haulm yield (4941 kg/ha) 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 (Table 2 and 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 due 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 highest plant height (69.08 cm) and branches/plant (5.48) which was significantly higher over 0.25 ppm and water spray. However, nodules/plant were remained unaffected due to foliar spray of brassinosteroid. A significant improvement in pods/plant, pod length, seeds/pod and 1000 seed weight of fenugreek were recorded with each higher concentration of brassinosteroid up to 0.50 ppm. Spray of BR 0.50 ppm gave 8.3 and 3.7, 9.7 and 4.0, 3.8 and 1.8, and 16.0 and 6.2 per cent higher pods/plant, seeds/pod, 1000-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.

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

Treatments	Plant height at harvest (cm)	Branches/ plant at harvest	Nodules/ plant	Pods plant^{-1}	Pod length (cm)	No. of seeds pods^{-1}	Wt. of seeds pod^{-1} (g)	1000-seed weight (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)
Fertility level										
60 % RDF	61.91	4.39	8.13	31.98	10.48	13.59	0.178	13.28	1659	3934
80 % RDF	67.05	5.31	9.75	34.80	11.36	14.67	0.201	14.11	2000	4677
100 % RDF	70.27	5.92	10.84	36.37	12.16	15.37	0.220	14.78	2245	5236
SEm ±	0.72	0.07	0.11	0.35	0.12	0.13	0.002	0.14	24	62
CD (P=0.05)	**2.08**	**0.20**	**0.32**	**1.00**	**0.35**	**0.39**	**0.007**	**0.39**	**69**	**178**
Biofertilizers										
Rhizobium	67.01	5.33	9.72	33.76	11.09	14.31	0.198	13.91	1934	4597
PSB	63.71	4.79	8.96	33.43	10.78	13.98	0.192	13.58	1885	4308
***Rhizo.*+PSB**	68.50	5.50	10.03	35.96	12.13	15.33	0.210	14.68	2085	4941
SEm ±	0.72	0.07	0.11	0.35	0.12	0.13	0.002	0.14	24	62
CD (P=0.05)	**2.08**	**0.20**	**0.32**	**1.00**	**0.35**	**0.39**	**0.007**	**0.39**	**69**	**178**
Brassinosteroid										
Water spray	63.64	4.92	9.55	32.98	10.79	13.84	0.185	13.79	1831	4320
BR 0.25 ppm	66.51	5.23	9.60	34.46	11.37	14.60	0.201	14.06	1975	4636
BR 0.50 ppm	69.08	5.48	9.56	35.72	11.84	15.18	0.213	14.31	2098	4891
SEm ±	0.37	0.06	0.08	0.29	0.10	0.12	0.002	0.10	12	42
CD (P=0.05)	**1.05**	**0.16**	**NS**	**0.83**	**0.27**	**0.33**	**0.006**	**0.28**	**34**	**118**

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

Fertility level	Pods/ plant			Seeds/pod			Seed weight/ pod(g)			Seed yield (kg/ha)		
	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	13.68	13.14	13.94	0.183	0.174	0.178	1672	1609	1697
80 % RDF	34.56	33.24	36.62	14.17	13.84	16.00	0.195	0.184	0.224	1898	1833	2270
100 % RDF	35.58	36.63	36.89	15.07	14.97	16.06	0.215	0.217	0.229	2233	2214	2287
SEm ±	0.60			0.23			0.004			42		
CD (P=0.05)	**1.74**			**0.67**			**0.011**			**120**		

Table.3 Organic carbon (%) and available nutrient contents (kg ha^{-1}) of soil after crop harvest as influenced by fertility levels, biofertilizers and brassinosteroid

Treatments	OC (%)			Available N			Available P			Available K			Available S		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
Fertility levels															
F_1: 60 % RDF	0.282	0.302	0.292	157.16	161.65	159.41	7.88	8.39	8.13	195.01	193.28	194.14	18.54	18.72	18.63
F_2: 80 % RDF	0.299	0.316	0.308	165.01	169.31	167.16	8.62	9.03	8.83	192.98	191.90	192.44	19.04	19.24	19.14
F_3: 100 % RDF	0.313	0.329	0.321	172.10	176.57	174.34	9.17	9.63	9.40	192.77	190.51	191.64	19.47	19.79	19.63
SEm ±	0.004	0.004	0.003	2.07	2.32	1.55	0.13	0.13	0.09	2.61	2.71	1.88	0.23	0.28	0.18
CD (P=0.05)	**0.011**	**0.012**	**0.008**	**6.20**	**6.96**	**4.48**	**0.39**	**0.39**	**0.26**	**NS**	**NS**	**NS**	**0.70**	**0.83**	**0.52**
Biofertilizers															
B_1: *Rhizobium*	0.296	0.313	0.305	166.41	170.68	168.54	8.06	8.57	8.32	193.10	191.50	192.30	19.01	19.17	19.09
B_2: PSB	0.290	0.306	0.298	157.15	162.02	159.59	8.76	9.18	8.97	195.79	194.21	195.00	19.18	19.52	19.35
B_3: *Rhizobium*+PSB	0.308	0.328	0.318	170.70	174.84	172.77	8.86	9.29	9.08	191.87	189.97	190.92	18.86	19.07	18.96
SEm ±	0.004	0.004	0.003	2.07	2.32	1.55	0.13	0.13	0.09	2.61	2.71	1.88	0.23	0.28	0.18
CD (P=0.05)	**0.011**	**0.012**	**0.008**	**6.20**	**6.96**	**4.48**	**0.39**	**0.39**	**0.26**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction (FXB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Brassinosteroid															
G_0: Water spray	0.294	0.311	0.302	162.67	166.98	164.83	8.61	9.15	8.88	195.82	193.55	194.68	18.98	19.39	19.18
G_1: BR 0.25 ppm	0.298	0.317	0.308	165.08	169.44	167.26	8.61	8.99	8.80	192.91	191.66	192.28	19.15	19.24	19.19
G_2: BR 0.50 ppm	0.302	0.318	0.310	166.51	171.11	168.81	8.45	8.91	8.68	192.04	190.47	191.26	18.91	19.12	19.02
SEm ±	0.003	0.003	0.002	1.53	1.85	1.20	0.12	0.13	0.09	2.09	2.18	1.51	0.17	0.25	0.15
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interactions (FXG, BXG & FXBXG)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Soil fertility parameters before experimentation were 0.28 % OC, 151.28 kg N,7.81 kg P, 197.12 kg K and 18.39 kg S/ha.

The highest values of seed (2098 kg/ha) and haulm yield (4891 kg/ha) were recorded under BR 0.50 ppm which were 6.2 and 14.6, and 5.5 and 13.2 per cent 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).

Soil fertility

Soil fertility parameters (OC %, available N, P and S) analysed after crop harvest registered significant improvement over the values recorded prior to experimentation with successive higher fertility level from 60 to 100 % RDF. The highest pooled OC % (0.321), available N (174.34 kg/ha), P (9.40 kg/ha) and S (19.63kg/ha.) were recorded from 100 % RDF which were significantly higher over 80 and 60 % RDF, however, K content was found unaffected. Increasing OC %, available N, P and S at each higher fertility level can be ascribed to higher litter fall and more root mass at higher fertility level. These parameters were recorded higher even at 60 % RDF over the values obtained before experiment which might be due to being a legume crop it builds soil fertility. The results well corroborate with findings of Kumar (2007) and Kumar *et al.*, (2009).

Maximum values of OC %, available N and P at crop harvest were obtained under dual inoculation of *Rhizobium* and PSB. Co-inoculation of *Rhizobium* and PSB found significantly better over sole *Rhizobium* and sole PSB in respect of OC%, and over sole PSB regarding available N, and over sole *Rhizobium* with respect to available P. Available K and S content after crop harvest were found unaffected due to microbial inoculation. It might be due to direct involvement of *Rhizobium* in N fixation and PSB in phosphorus solubilisation. Co-inoculation of both kinds of bacteria have synergistic effect resulting in higher OC % due to more root and shoot growth, more N fixation and phosphorus solubilisation than their sole application. The results conforms the findings of Jat and Shaktawat (2001). Foliar spray of brassinosteroid didn't affect the soil fertility parameters markedly.

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