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Effect of liquid and solid bio-fertilizers (*Rhizobium* and PSB) on growth attributes, yield and economics of fenugreek [*Trigonella foenum-graecum* L.]

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Abstract
An experiment was conducted during *rabi*, 2015 at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, to study the "Integrated nutrient management in fenugreek [*Trigonella foenum-graecum* L.]'' under North Gujarat condition. Almost all the growth attributes of fenugreek such as plant height (cm), number of branches per plant, number of root nodules per plant and weight of fresh nodules per plant (mg) as well as seed and straw yield were recorded significantly higher by application of 75% RDF + *Rhizobium* + PSB liquid formulation as soil application (T_7) followed by T_3 than other treatments. But plant population and harvest index was not affected significantly due to different treatments. The higher net return and BCR was accrued with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) followed by treatment T_3. The lowest net realization and BCR was noticed under treatment T_{10} (75 % RDF).

Keywords: Fenugreek, Rhizobium, Phosphorus solublizing bacteria, Recomended dose of fertilizer, Gujarat Fenugreek-2, Days after sowing

Introduction
Fenugreek (*Trigonella foenum-graecum* L.) popularly known by its vernacular name "methi" is an important annual herbaceous multipurpose condiment legume which is grown during winter season mainly in the state of Rajasthan, Gujarat and Uttar Pradesh. India is the largest producer and consumer of seed spices in the world but presently, due to low productivity of seed spices in our country is able to meet only 51 per cent of total global demand. Seed spices account for about 36 per cent of total area and 17 per cent of total production of spices in the country. India exports raw spices as well as value added items to nearly 70 countries in the world. The global demand for seed spices is estimated about 98,000 tones, of which, India is able to export about 57,000 tonnes annually.

The seeds of fenugreek are mainly used as condiments and for medicinal purposes. Its young plants are used as vegetable and forage. Being a leguminous crop, it has high nutritive value and used in preparation of non-vegetarian diets during social and religious functions in middle and eastern countries. The seeds have medicinal properties, therefore, used in chronic, dysentery, chronic diarrhea and cough, enlargement of lever, diabetic, spleen and rickets. The important steroid "Diosgenin" content in seeds varies from 0.62 to 2.20 per cent which is used in synthesis of sex hormones and oval contraceptives. The seeds are bitter in taste due to presence of alkaloid "Trigonellin".

Chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop. Persistent nutrient depletion is posing a greater threat to the sustainable agriculture. Therefore, there is an urgent need to reduce the usage of chemical fertilizers and increase the usage of organics and bio fertilizers. Microbial fertilization including *Rhizobium* as well as phosphate solublizing bacteria has been found promising to improve soil health and crop yield. Moreover, bio-fertilizer also reduced the environmental pollution caused by heavy use of chemical fertilizers (Deshmukh and Bhapkar, 1982) [5].

Recently, interest has aroused to produce liquid bio-fertilizers. They are special liquid formation containing not only the desired microorganisms and nutrients but also special cell

protestants or chemicals that promote formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions (Bhattacharya and Kumar, 2002) [2]. Peat and lignite, good source of carrier materials are available only in very limited places like Nilgiris and Neyveli, thus resulting in high cost of transportation of bio-fertilizers to manufacturing units. The liquid bio-fertilizer of good quality holds great promise over the carrier material transport, pulverization and sterilization, convenience in handling, storage and transportation with its better performance (Hedge, 2002) [8]. The phosphorus solublizing bacteria (PSB) like *Pseudomonas* and *Bacillus* increase the availability of phosphorus to plants by converting insoluble phosphorus to soluble form in the soil. The PSB like *Pseudomonas striate* bacterial inoculation was found as equivalent at 50 kg P_2O_5/ha through single superphosphate (Gaur *et al.* 1980) [6].

Materials and methods

A field experiment entitled "Integrated nutrient management in fenugreek (*Trigonella foenum-graecum* L.)" was carried out during *rabi* season of 2015 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District: Banaskantha (Gujarat) to evaluate the performance of liquid and carrier based *bio-fertilizer* inoculants in fenugreek. The soil of experimental field was loamy sand in texture, low in organic carbon (0.29 %) and available nitrogen (152.56 kg/ha), medium in available phosphorus (40.65 kg/ha) and available potash (265.61kg/ha) with soil pH of 7.64. Solid carrier of *Rhizobium* and PSB were collected from the Department of Microbiology C.P. College of Agriculture, SDAU, Sardarkurshinagar and liquid carrier of *Rhizobium* and PSB from Department of Microbiology Anand Agricultural University, Anand. Ten treatments comprising of application of nutrients through different sources*viz.*,T_1 : 75% RDF + *Rhizobium* solid carrier as soil application, T_2 :75% RDF + *Rhizobium* solid carrier as seed treatment, T_3 : 75% RDF + *Rhizobium* + PSB solid carrier as soil application, T_4 : 75% RDF + *Rhizobium* + PSB solid carrier as seed treatment, T_5 : 75% RDF + *Rhizobium* liquid formulation as soil application, T_6 : 75% RDF + *Rhizobium* liquid formulation as seed treatment, T_7 : 75% RDF + *Rhizobium* + PSB liquid formulation as soil application, T_8: 75% RDF + *Rhizobium* + PSB liquid formulation as seed treatment, T_9 : 100% RDF, T_{10}: 75% RDF. The experiment was laid out in randomized block design with four replications. Fenugreek variety GF 2 was used as test crop and sown at a distance of 30 × 10 cm.

Results and discussion

The data pertaining to plant population per meter row length (Table-1) at 25 DAS was recorded for different treatments was not significantly influenced due to different liquid and solid bio-fertilizers which indicated that no adverse effect of bio-fertilizers were observed on germination of fenugreek seed as well as on survival of fenugreek plants. It indicates that uniform plant population was maintained during crop growth period in all the treatments.

The mean data pertaining to plant height of fenugreek measured at 30 DAS, 60 DAS and at harvest. The data provided in Table-1 indicated that significantly higher plant height of 7.07 cm and 29.19 cm at 30 DAS and 60 DAS was recorded with treatment T_3 (75% RDF + *Rhizobium* + PSB solid carrier as soil application) and was found statistically at par with treatments T_4, T_7 and T_8 at 30 DAS but 60 DAS at par found the treatments T_1, T_4, T_7 and T_8. Further, the magnitude of increase in plant height at 30 DAS and 60 DAS under treatment T_3 was to the tune of 12.57 and 11.32 per cent, respectively over treatment T_9 (100% RDF). Data indicated in Table-1 significantly higher plant height of 68.50 cm was observed with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) but it stood at par with treatments T_3, T_4, T_5 and T_8 having plant height of 66.80, 62.24, 61.59 and 63.63 cm, respectively. While at harvest time the rise in plant height is 12.20 percent under treatment T_7 was obtained over treatment T_9 (100% RDF). This might be due to adequate supply of nitrogen and P_2O_5 through inorganic fertilizers which helped to rapid release and increase availability of N and P at the early stages of crop growth and application of bio-fertilizers (*Rhizobium* + PSB) which enhanced cell division, cell enlargement and inter-nodal length by producing the growth regulating hormones (auxin, gibberellins, vitamins etc.). This results in higher photosynthesis there by producing more number of nodulation, BNF, chlorophyll content, photosynthates and protein metabolism leading to more plant height reported by Girisha *et al.* (2006) [7]. Ahmed *et al.* (2006) [1] in mungbean and Pindkurwar *et al.* (2015) [11] in soybean.

Significant differences were observed in number of branches per plant as influenced due to different treatments at harvest are cited in Table-1. Significantly higher number of branches per plant at harvest (4.88) were found with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) which was found statistically at par with treatments T_3, T_4, T_5 and T_8 having number of branches per plant of 4.70, 4.46, 4.39 and 4.53, respectively. The magnitude of increase in number of branches per plant under treatment T_3 was to the tune of 9.55 per cent, respectively over treatment T_9 (100% RDF). This might be due to the enhanced biological nitrogen fixation and transformation of N in plants as application of liquid formulation *Rhizobium* + PSB that resulted in better crop growth manifested by higher number of branches per plant obtained by Pindkurwar *et al.* (2015) [11].

The data on number and weight of fresh root nodules per plant of fenugreek at 45 DAS as influenced by different treatments are summarized in Table-1. Data revealed that significantly higher number of root nodules per plant (30.22) and higher weight of fresh root nodules per plant (68.76 mg) at 45 DAS were achieved with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application), which was remaimed at par with treatments T_3 (27.55) and T_8 (27.01). Significantly lower number of root nodules per plant and weight of fresh root nodules per plant was recorded with treatment T_{10} (75% RDF) compared to rest of the treatments except T_2, T_6 and T_9. Further, the magnitude of increase in number of root nodules per plant and weight of fresh root nodules per plant at 45 DAS under treatment T_7 was 32.25 per cent and 35.83 per cent over treatment T_9 (100% RDF), respectively. This might be due to in-furrow or soil application of liquid *Rhizobium* inoculant, allowing the delivery of an elevated number of inoculant cells of *Rhizobium* and better survival of inoculated organisms in rhizophere, which gives competitive advantage to the inoculated *Rhizobium* recorded by Biswas and Bhowmick (2007) [4]. This might have attributed to better compatibility and efficiency of liquid inoculated *Rhizobium* compared to the native carrier based *Rhizobium* in forming effective nodules in the root system as shown by Yadav *et al.* (2006) [15], Bhattacharya and Chandra (2013) [3].

Data shown in Table-2 revealed that significantly higher seed yield (1799 kg/ha) and straw yield (3413 kg/ha) of fenugreek was produced with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) as compared to all other treatments, except treatments T_3, T_8 and T_9, having seed yield of 1773 kg/ha, 1619 kg/ha and 1607 kg/ha and straw yield of treatments T_3 (3341 kg/ha), T_4 (3019 kg/ha), T_8 (3223 kg/ha) and T_9 (3007 kg/ha), respectively. An application of 75% recommended dose of fertilizer (T_{10}) registered significantly lower seed yield (1233 kg/ha) to rest of the treatments except those T_2 and T_6. The per cent increase in seed yield by treatment T_7 was to the tune of 11.94 per cent over treatment T_9 (100% RDF) and the per cent increase in straw yield by treatment T_7 was to the tune of 13.50 per cent over treatment T_9 (100% RDF), respectively. Increase in seed yield was mainly because of increase in plant height and number of branches per plant which resulted from combined effect of *Rhizobium* + PSB and chemical fertilizers that provided balanced nutrition and favourable soil environment for better plant growth and ultimately maximum seed yield. The limited yield increases associated with use of the *Rhizobium* inoculant, placed below the seed as soil application may be due to better moisture conditions in this soil zone and extra protection from heat for the *Rhizobium* and subsequently, for the nodules favoring N_2 fixation and bio-fertilizers might have helped in increase of uptake of nutrients due to release of nutrients or mobilizing unavailable plant nutrients into available form by PSB at its optimum amount for a longer period and at the same time improved soil physical condition that in turn gave higher yield. These results are in close vicinity with the findings of Sharma *et al*. (2003) [13] in mungbean and Sahai and Chandra (2010) [12] in pea.

The data exhibited in Table-2 showed that the harvest index was not significantly influenced due to different treatments.

A perusal of data on net return and BCR as influenced due to different treatments are exhibited in Table-2 revealed that higher net return of ₹ 53073/ha was accrued with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) followed by treatment T_3 (₹ 50792/ha). The lowest net realization (₹27546/ha) was noticed under treatment T_{10} (75 % RDF). Examination of data on BCR as influenced due to different treatments indicated that higher BCR of 2.82 was observed with treatment T_7 (75% RDF + *Rhizobium* + PSB liquid formulation as soil application) followed by treatment T_3 (2.68). The lowest BCR of 1.95 was noted with treatment T_{10} (75 % RDF). This could be attributed to higher seed and straw yield received in these treatments. The results are well supported with those reported by Singh *et al.* (2010) [14], Mehta *et al.* (2011) [10] and Meena *et al.* (2014) [9].

Table 1: Effect of different treatments on plant population, plant height, number of branches, number of root nodules and weight of fresh root nodules of fenugreek

Treatments	Plant population (per meter row length)	Plant height (cm)			Number of branches per plant	Number of root nodules per plant	Weight of fresh root nodules (mg) per plant
		30 DAS	60 DAS	At harvest			
T_1	10.05	6.36	26.60	60.03	4.22	23.91	58.53
T_2	9.70	6.18	25.22	57.88	4.08	23.14	51.63
T_3	10.70	7.07	29.19	66.80	4.70	27.55	67.19
T_4	10.40	6.60	27.83	62.24	4.46	25.17	61.14
T_5	10.10	6.19	25.46	61.59	4.39	24.42	59.89
T_6	9.95	6.16	25.22	59.48	4.13	23.26	54.75
T_7	11.00	6.96	29.17	68.50	4.88	30.22	68.76
T_8	10.50	6.44	27.75	63.63	4.53	27.01	62.58
T_9	10.10	6.28	26.22	61.05	4.29	22.85	50.62
T_{10}	9.55	5.86	24.68	54.23	3.85	21.57	48.81
S.Em. ±	0.47	0.24	0.90	2.40	0.19	1.11	2.31
CD (P = 0.05)	NS	0.70	2.62	6.97	0.54	3.25	6.72
CV %	9.14	7.58	6.76	7.81	8.52	8.98	7.93

Table 2: Effect of different treatment on seed yield, straw yield, harvest index and economics of fenugreek

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net realization (₹/ha)	BCR
T_1	1544	2900	34.85	40809	2.37
T_2	1379	2687	34.05	34274	2.18
T_3	1773	3341	34.67	50792	2.68
T_4	1595	3019	34.59	43850	2.51
T_5	1548	2931	34.75	41712	2.43
T_6	1394	2701	34.06	34997	2.21
T_7	1799	3413	34.59	53073	2.82
T_8	1619	3223	33.33	45551	2.57
T_9	1607	3007	34.97	44046	2.50
T_{10}	1233	2309	35.03	27546	1.95
S.Em. ±	69.9	156.5	1.46	-	-
CD (P = 0.05)	203	454	NS	-	-
CV %	9.03	10.60	8.49	-	-

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