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Response of fenugreek (*Trigonella foenum-graecum* L.) to varying fertilizer levels and bio-fertilizer inoculations under South Saurashtra conditions

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Abstract
A field experiment was conducted during the *rabi* season of 2019-20 at Integrated Farming Systems Research Farm, JAU, Junagadh. The soil was medium black calcareous in texture, rich in organic carbon, medium in available N, P_2O_5 and K_2O with alkaline in reaction (pH of 8.27). Total twelve treatment combinations, consisting of three fertilizer levels (Control, 75% RDF and 100% RDF) and four bio-fertilizer inoculations (Absolute control, *Rhizobium* @ 600 g ha^{-1}, PSB @ 600 g ha^{-1}, *Rhizobium* + PSB @ 600 g ha^{-1} each) were allotted randomly to different plots and tested in a randomized block design (Factorial) with three replications. The results indicated that application of 100% RDF recorded significantly higher values of yield attributes, yield, harvest index, *Rhizobium* count, PSB count and total microbial count and also higher gross and net realization along with higher B: C ratio. Yield attributes, yield, harvest index, *Rhizobium* count, PSB count and total microbial count and also higher gross and net realization along with higher B: C ratio was recorded significantly higher with the dual inoculation of seed with *Rhizobium* and PSB @ 600 g ha^{-1} each. Thus, higher seed, straw and biological yields as well as net returns in fenugreek can be realized with application of 100% RDF (20 kg N + 40 kg P_2O_5 ha^{-1}) along with dual inoculation of seed with *Rhizobium* and PSB @ 600 g ha^{-1} each.

Keywords: Nitrogen, phosphorus, *Rhizobium*, PSB, fenugreek, yield

Introduction

India is renowned world over for its repository of spices and is popularly called as “The land of spices”. Seed spices constitute an important group of agricultural commodities and play an important role in our national economy. The main seed spices of India are Coriander, Cumin, Fennel, Fenugreek, Dil, Ajwain, Celery, Anise, Nigella and Caraway (Source; ICAR-NRCSS Vision, 2050) [39]. Fenugreek (*Trigonella foenum-graecum* L.) is an important seed spice crop, originated from South-Eastern Europe and belongs to the family Fabaceae. It is an annual herb, commonly known as “Methi”. The genus *Trigonella* has two species *viz*., *Trigonella foenum-graecum* and *Trigonella corniculata*. *Trigonella foenum-graecum* plants are semi-erect, tall, moderately branched with bold, typically yellow grains. Plants of *Trigonella corniculata* are bushy green, medium sized and pods are small and sickle shaped. The name fenugreek is derived from the Latin word “Green hey” illustrating its classical use as fodder. The name of genus *Trigonella* is derived from the old Greek name, denoting ‘three angled’ probably referring to the triangular shape of the flowers (Snehalatha and Payal, 2011) [31]. Plant nutrients play specific and important role in growth and development of a plant. Fenugreek being a legume crop, does not require much nitrogen for its growth. However, intensive agriculture and adoption of exhaustive high yielding varieties of crops have led to heavy withdrawal of nutrients from the soil during past few years and fertilizer use remained much below as compared to removal. The gap between the nutrient removal and supply cannot be bridged up by the application of any single nutrient but this has to be achieved with balanced use of fertilizers. Nitrogen plays a key role in the synthesis of chlorophyll and amino acids, which contribute to the building units of protein and thus growth of plant. It also helps in early establishment of leaf area capable of photosynthesis and increased root development to enable more efficient use of water. Next to nitrogen, phosphorus is of paramount importance in legume crops for increasing yield. Phosphorus, apart from its role in root development and nodule formation, plays an important role in energy transfer in the living cell by means of high phosphate energy bonds ATP and ADP (Havlin *et al*., 2003) [11]. Thus, it plays an important role in formation and translocation of carbohydrates, fatty acid, glyceroids, nucleoprotein and other essential intermediate compounds. Therefore, there is need to work out optimum combination of nitrogen and phosphorous for fenugreek.

In recent years, rise in price of chemical fertilizers, scarcity of organic manures and poor nutrient use efficiency has led to the search of some alternative source of nutrition. Microbial fertilization with *Rhizobium*, also a low cost technology is known to improve nitrogen status of soils and crop yields due to their capacity to fix atmospheric nitrogen. In addition, these microbes secrete growth promoting substances like gibberellins, indole acetic acid *etc.*, which enhance growth of plants (Somani *et al*., 1981) [33]. Inoculation with *Rhizobium* will not only improve nitrogen availability in soil by biological nitrogen fixation but also ensure prolonged and adequate supply of this vital nutrient with minimum loss in light textured soils. Therefore, the introduction of efficient strain of *Rhizobium* may be helpful in boosting greater nitrogen fixation and crop production. Inoculation of seeds with *Rhizobium* culture is low cost input in legumes and has been found beneficial by many workers. (Subba Rao, 1976; Singh, 1977 and Gill *et al*., 1987) [35, 27, 8]. Soils of India are low to medium in available phosphorous. The fertilizer use efficiency of phosphatic fertilizers is very low (20-25%) due to chemical fixation in soil, which is most important factor responsible for poor yield of legume crops on all types of soil. In recent years, several strains of phosphate solubilizing bacteria (PSB) have been isolated which posses the ability to solubilize and mobilize phosphorus and micronutrients present in non-available form in the soils (Whitelaw, 2000) [40]. The mechanism of action of these microorganisms (PSB) involve secretion of organic acid, which lowers the pH and increases the availability of sparingly soluble phosphorus sources. A favourable effect of PSB on crop yield due to greater availability of inherent or applied phosphorus from soils have been reported by several researchers *viz*., Kumawat (1997) [14], Purbey and Sen (2005) [22] and Rathore (2007) [25]. Thus, microbial inoculation has been considered to be an integral part of integrated nutrient management system in major crops. Though it can use atmospheric N through symbiotic fixation to meet major parts of its N needs, it becomes necessary to find out the optimum rate of N and P especially for heavy textured fertile soils. A judicious combination of chemical fertilizers and bio-fertilizers should be formulated for crops and cropping systems within the ecological, social and economic possibilities. Bio-fertilizers keep the soil environment rich in all kinds of micro and macro nutrients *via.*, nitrogen fixation, phosphate solubilization or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Sinha *et al.,* 2014) [30] providing better nutrient uptake and increased tolerance towards drought and moisture stress. Judicious use of bio-fertilizers in crop land, generally result in (1) Increased crop yields (2) Improvement in crop quality and (3) Improvement of soil physical, chemical and biological properties. Therefore, bio-fertilizers can solve the problem of feeding an increasing global population at a time when agriculture is facing various environmental stresses and changes. Considering the above facts and views, the present experiment was planned and conducted to study "Response of fenugreek (*Trigonella foenum-graecum* L.) to varying fertilizer levels and bio-fertilizer inoculations under south saurashtra conditions".

Materials and Methods

The experiment was conducted during the rabi season of the year 2019-20, on medium black calcareous soil of Integrated Farming Systems Research Farm, Junagadh Agricultural University, Junagadh (Gujarat). The soil had pH 8.27, electrical conductivity 0.43 dS m^{-1}, rich in organic carbon 0.98%, medium in available N (270.22 kg ha^{-1}), P_2O_5 (28.94 kg ha^{-1}) and K_2O (215.80 kg ha^{-1}). The experiment consisted of three fertilizer levels (Control, 75% RDF and 100% RDF) and four bio-fertilizer inoculations (Absolute control, *Rhizobium* @ 600 g ha^{-1}, PSB @ 600 g ha^{-1} and *Rhizobium* + PSB @ 600 g ha^{-1} each), thereby making twelve treatment combinations were allotted randomly to different plots and tested in a randomized block design (Factorial) with three replications. Observations were recorded from five plants of the net plot excluding the border plants, regarding various yield attributes and yield. The data was analysed statistically as per the methods suggested by Panse and Sukhatme (1985) [21].

Results and Discussion

Effect of fertilizers

Yield is the net result of various interactions *viz*., Soil characters, weather parameters and various metabolic and biochemical interactions taking place during crop growth. Effect of different levels of fertilizers on yield attributes is mentioned in the Table 1. Various yield attributing characters like number of pods $plant^{-1}$, number of seeds pod^{-1} and test weight (g) were influenced by the application of different levels of fertilizers.

Yield attributes

The results pertaining to number of pods $plant^{-1}$ (Table 1) revealed that different fertilizer levels exerted significant influence on the attainment of number of pods $plant^{-1}$. Significantly more number of pods $plant^{-1}$ (28.0) were produced at harvest under the treatment F_2 (100% RDF) which was statistically at par with F_1 (75% RDF). Significantly minimum number of pods $plant^{-1}$ (22.2) were produced with the treatment F_0 (Control). Physiological role of N and P in enhancing growth parameters might have led to increased number of pods $plant^{-1}$ at higher levels of fertility. The improvement in pods $plant^{-1}$ by P_2O_5 application may be attributed to profuse nodulation, leading to increased N fixation, energy transformation and metabolic process of plants and ultimately leading to better sink development. It was also observed beneficial effect of P_2O_5 on the fruiting of the plant and desired metabolites in yield contributing parts of plant. This is in close agreement with findings of Tanwar *et al*. (2003) [37], Ali *et al*. (2009) [1], Tuncturk *et al*. (2011) [38] and Meena *et al*. (2012) [15], Datta and Hore (2017) [5] and Godara *et al*. (2018) [10] in fenugreek.

The results on the number of seeds pod^{-1} (Table 1) revealed that various fertilizer levels exerted their significant influence on seeds pod^{-1}. Significantly maximum seeds pod^{-1} (14.6) were recorded under the treatment F_2 (100% RDF) which was statistically at par with F_1 (75% RDF). While, significantly minimum seeds pod^{-1} (12.2) were observed with the treatment F_0 (Control). This might be due to early and abundant availability of nutrients with 100% RDF which resulted in higher growth and yield attributes. The results corroborate with the findings of Bhunia *et al*. (2006) [3], Kumar *et al*. (2009) [13], Singh *et al*. (2010) [28], Meena *et al*. (2012) [15], Mehta *et al*. (2012) [19] and Godara *et al*. (2018) [10] in fenugreek.

The results furnished in Table 1 on test weight (1000-seed weight) revealed that fertilizer levels exerted significant influence on the achievement of test weight. Significantly higher test weight (14.30 g) was recorded when fenugreek crop was fertilized with 100% RDF (F_2) which was statistically at par with the treatment F_1 (75% RDF). While, the minimum test weight of 12.46 g was observed under the treatment F_0 (Control). The higher test weight registered under F_2 (100% RDF) might be due to abundant availability of nutrients with 100% RDF which resulted in higher growth and yield attributes. And also the favorable influence of phosphorus on yield attributes could be attributed to the overall improvement in crop growth as reflected by plant height, number of branches, dry matter accumulation, and root nodulation. Adequate phosphorus resulted in proper supply of photosynthates and nutrients, synchronized with the demand of crop for formation of more reproductive structures and thus might have favoured the yield attributes *viz*., number of pods plant^{-1}, number of seeds pod^{-1} and test weight. These results are in agreement with the findings of Bhunia *et al*. (2006) [3], Kumar *et al*. (2009) [13] Singh *et al*. (2010) [28], Mehta *et al*. (2012) [19] and Godara *et al*. (2018) [10] in fenugreek.

Yield

The results on seed yield ha^{-1} of fenugreek furnished in Table 1 indicated the differences in seed yield ha^{-1} of fenugreek due to different fertilizer levels were significant. The seed yield showed an increasing trend with each successive fertilizer dose. Significantly higher seed yield of 1876 kg ha^{-1} was produced when 100% RDF (F_2) was applied, which was found statistically on same bar with F_1 (75% RDF). Significantly lower seed yield of 1298 kg ha^{-1} was obtained with the treatment F_0 (Control). Increase in seed yield under 100% RDF might be due to adequate nutrient availability at 100% RDF which favored growth and development of plant and thus increased yield attributes like number of pods plant^{-1} (Table 1), number of seeds pod^{-1} (Table 1) and test weight (Table 1) which ultimately increased seed yield of fenugreek. Increase in seed yield with 100% RDF was also reported by Kumar *et al*. (2009) [13], Mehta *et al*. (2010) [17], Meena *et al*. (2012) [15], Mehta *et al*. (2012) [19], Datta and Hore (2017) [5] and Godara *et al*. (2017) [9] in fenugreek.

The results given in Table 1 revealed that straw yield ha^{-1} of fenugreek significantly affected due to fertilizer levels. The straw yield showed an increasing trend with each successive increase in fertilizer dose. Significantly higher straw yield of 3245 kg ha^{-1} was produced when 100% RDF (F_2) was applied, which was found statistically on same bar with F_1 (75% RDF). Significantly lower straw yield of 2832 kg ha^{-1} was obtained with the treatment F_0 (Control). Higher straw yield under treatment F_2 (100% RDF) and F_1 (75% RDF) might be due to increased vegetative growth as evidenced by significant improvement in different yield attributes, resulted in increased straw and seed yields significantly. Increase in straw yield under higher fertilizer doses was also reported by Ali *et al*. (2009) [1], Meena *et al*. (2012) [15], Mehta *et al*. (2012) [19], Godara *et al*. (2017) [9] in fenugreek and Rana *et al*. (2012) [24] in cumin.

In case of biological yield, significantly higher biological yield of 5121 kg ha^{-1} was recorded when 100% RDF (F_2) was applied which was statistically at par with F_1 (75% RDF). While, lower biological yield of 4130 kg ha^{-1} was observed under the treatment F_0 (Control). Similarly significantly higher harvest index of 37.16% was recorded with the treatment F_2 (100% RDF) which was statistically at par with F_1 (75% RDF). And significantly lower harvest index of 31.33% was recorded under the treatment F_0 (Control). Increased biological yield and harvest index might be due to the role of fertilizers in improving uptake of nutrients by root system, increased chlorophyll content, photosynthesis activity and protein content in crop plants. Similar results were also reported by Rana *et al*. (2012) [24] in cumin, Das *et al*. (2013) [4] in chickpea and Godara *et al*. (2017) [9] in fenugreek.

Microbial count of soil

The data presented in Table 2 showed that the effect of different fertilizer levels on *Rhizobium* (1×10^6), PSB (1×10^6) and total microbial count (1×10^6) was found significant at 60 DAS and at harvest. Significantly higher *Rhizobium* (8.06), PSB (6.84) and total microbial counts (14.91) were recorded under the treatment F_2 (100% RDF) which was statistically at par with F_1 (75% RDF) at 60 DAS. And significantly lower *Rhizobium* (6.76), PSB (5.38) and total microbial counts (12.08) were recorded under the treatment F_0 (Control) at 60 DAS. Similarly significantly higher *Rhizobium* (8.63), PSB (7.03) and total microbial count (15.66) were recorded under the treatment F_2 (100% RDF) which was statistically at par with F_1 (75% RDF) at harvest. And significantly lower *Rhizobium* (7.06), PSB (5.63) and total microbial counts (12.68) were recorded under the treatment F_0 (Control) at harvest.

Effect of bio-fertilizer inoculations

Yield attributes

The yield attributes *viz*., number of pods plant^{-1}, number of seeds pod^{-1} and test weight (g) (Table 1) were significantly influenced by various bio-fertilizer inoculations. Dual inoculation of *Rhizobium* + PSB @ 600 g ha^{-1} each (B_3), recorded significantly higher number of pods plant^{-1} (27.3) which was statistically at par with B_1 (*Rhizobium* @ 600 g ha^{-1}). Significantly lower number of pods plant^{-1} (24.3) were recorded with the treatment B_0 (Absolute control). Higher pods plant^{-1} under *Rhizobium* @ 600 g ha^{-1} + PSB inoculation @ 600 g ha^{-1} (B_3) might be due to the fact that bacterial inoculation increased root growth, root development, caused better nodulation. More nutrient availability could result in vigorous plant growth and dry matter production leading to a better flowering and pod formation. The higher bacterial population due to seed inoculation by bio-fertilizers led to better symbiosis activities in rhizosphere which resulted in increased amount of N fixed. The present findings are with the close vicinity of those reported by Mehta *et al*. (2012) [19], Gendy (2013) [7], Godara *et al*. (2018) [10], Soliman (2019) [32] and Reena *et al*. (2021) [26] in fenugreek.

The data presented in Table 1 showed that number of seeds pod^{-1} were significantly influenced by bio-fertilizer inoculations. Significantly maximum number of seeds pod^{-1} (14.2) were recorded under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1} each) which was statistically at par with treatments B_1 (*Rhizobium* @ 600 g ha^{-1}) and B_2 (PSB @ 600 g ha^{-1}). Significantly minimum number of seeds pod^{-1} (12.5) were recorded under the treatment B_0 (Absolute control). Maximum number of seeds pod^{-1} were recorded under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1}) might be due to the fact that *Rhizobium* inoculation increased the root nodulation through better root development and more nutrient availability. This caused vigorous plant growth and dry matter production which resulted in better flowering, fruiting and pod formation. And also PSB might have helped in reducing

P fixation by its chelating effect and also solubilized the unavailable form of P leading to more uptakes of nutrients and reflected in better yield attributes. The results obtained in the investigation are in line with the findings of Meena *et al*. (2012) [15], Godara *et al*. (2018) [10] in fenugreek, Das *et al*. (2013) [4] in chickpea and Singh and Singh (2017) [29] in cowpea.

The data furnished in Table 1 depicted that test weight (g) of fenugreek was significantly influenced by bio-fertilizer inoculations. Significantly maximum test weight (14.43 g) was recorded under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1}), which was statistically at par with treatment B_1 (*Rhizobium* @ 600 g ha^{-1}). Significantly minimum test weight (12.02 g) was recorded under the treatment B_0 (Absolute control). Highest test weight under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1}) might be due to better performance of dual inoculation on account of associative effect of both symbiotic and asymbiotic bacteria. The results are in accordance with the findings of Purbey and Sen (2007) [23], Mehta *et al*. (2012) [19], Tagore *et al*. (2013) [36], Meena *et al*. (2014) [16] and Godara *et al*. (2018) in fenugreek.

Yield

The results on seed yield ha^{-1} of fenugreek furnished in Table 1 revealed that the difference in seed yield ha^{-1} of fenugreek due to bio-fertilizer inoculations was significant. Significantly higher seed yield of 1780 kg ha^{-1} was produced when crop was given dual inoculation of *Rhizobium* + PSB @ 600 g ha^{-1} each (B_3), which was statistically at par with the treatment B_1 (*Rhizobium* @ 600 g ha^{-1}). Significantly lower seed yield of 1526 kg ha^{-1} was recorded under the treatment B_0 (Absolute control).

The results on straw yield ha^{-1} of fenugreek furnished in Table 1 revealed that the difference in straw yield ha^{-1} of fenugreek due to bio-fertilizer inoculations was significant. Significantly higher straw yield of 3354 kg ha^{-1} was produced when crop was given dual inoculation of *Rhizobium* + PSB @ 600 g ha^{-1} each (B_3), which was statistically at par with treatment B_1 (*Rhizobium* @ 600 g ha^{-1}). Significantly lower straw yield of 2855 kg ha^{-1} was recorded under the treatment B_0 (Absolute control).

The data furnished in Table 1 revealed that biological yield (kg ha^{-1}) of fenugreek was significantly influenced by bio-fertilizer inoculations. Significantly higher biological yield (5134 kg ha^{-1}) was produced when the crop was supplied with dual inoculation of *Rhizobium* + PSB @ 600 g ha^{-1} each (B_3), which was statistically at par with B_1 (*Rhizobium* @ 600 g ha^{-1}). While, significantly lower biological yield (4380 kg ha^{-1}) was produced under the treatment B_0 (Absolute control).

Seed, straw as well as biological yields were recorded significantly higher with dual inoculation of seed with *Rhizobium* and PSB @ 600 g ha^{-1} each, over their sole application and control. *Rhizobium* and PSB improved the N and P availability of soil which are major plant nutrients and combined inoculation of both N_2 fixer and PSB benefit plants than either group of organisms alone and might had an added advantage. Furthermore, some of the bacteria involved might be interacting on more metabolic levels, *i.e.*, P solubilizer might be also auxin, IAA and gibberellins producer and N_2 fixer might also solubilized P. Thus the increased availability of not only N and P but also growth harmones also stimulated plant metabolism which resulted in better yield attributes. The increased plant growth due to nutrients like N might also be attributed to its role in enhancing chlorophyll content as N is an integral part of the chlorophyll molecules. This resulted in higher photosynthesis thereby producing more photosynthates leading to more plant height and ultimately to higher seed, straw and biological yields. These results are in accordance with Purbey and Sen (2007) [23], Mehta *et al*. (2012) [19], Meena *et al*. (2014) and Godara *et al*. (2017) [9] in fenugreek.

Microbial count of soil

Dual inoculation increased the *Rhizobium* counts at 60 DAS and at harvest (Table 2). Significantly higher *Rhizobium* counts at 60 DAS (8.45×10^6) and at harvest (8.64×10^6) in soil were recorded with the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1} each), which were statistically at par with B_1 (*Rhizobium* @ 600 g ha^{-1}). While, lower values of *Rhizobium* counts at 60 DAS (6.73×10^6) and at harvest (7.36×10^6) were observed under the control treatment B_0 (Absolute control).

Dual inoculation increased the PSB counts at 60 DAS and at harvest (Table 2). Significantly higher PSB counts at 60 DAS (6.91×10^6) and at harvest (7.08×10^6) were recorded under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1} each), which were statistically at par with B_2 (PSB @ 600 g ha^{-1}) at 60 DAS and at harvest and also with B_1 (*Rhizobium* @ 600 g ha^{-1}) at harvest. While, lower values of PSB counts at 60 DAS (5.14×10^6) and at harvest (5.38×10^6) were observed under the control treatment B_0 (Absolute control).

Bio-fertilizers inoculation increased the total microbial counts at 60 DAS and at harvest (Table 2). Significantly higher total microbial counts at 60 DAS (15.36×10^6) and at harvest (15.72×10^6) were recorded under the treatment B_3 (*Rhizobium* + PSB @ 600 g ha^{-1} each). While, lower values of total microbial counts at 60 DAS (11.87×10^6) and at harvest (12.75×10^6) were observed under the control treatment B_0 (Absolute control). The higher bacterial population at harvest stage might be due to disintegration of nodules at later stage of crop. These results are in close vicinity with those obtained by Dhage *et al*. (2008) [6] in soybean.

Interaction effect of fertilizers and bio-fertilizers

Application of 100% RDF and dual inoculation of *Rhizobium* and PSB @ 600 g ha^{-1} each (F_2B_3), recorded significantly higher test weight and seed yield ha^{-1}. Higher seed yield of fenugreek might be due to cumulative effect of growth and yield attributes which were significantly higher with application of 20 kg N ha^{-1}. Similarly, application of 40 kg P_2O_5 ha^{-1} gave significantly higher seed yield. 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 yield. Application of both *Rhizobium* and PSB as seed inoculants significantly increased seed yield over their sole application as well as control. 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. On the other hand, 100% RDF + dual inoculation (F_2B_3) was found superior over other treatment combinations. It might be due to the fact that those remaining treatment combinations failed to supply the required quantity of nutrients to crop to realize its yield potential. In contrast, F_2B_3 might have not only supplied desired quantity of nutrients to the crop but also improved physical, chemical and biological conditions of the soil, thereby making native soil nutrients available to the plants.

Thus created favorable conditions might have improved absorption of essential nutrients, resulting in higher growth of plants and ultimately the yields. These results corroborate with the findings of Ali *et al*. (2009) [1], Mehta *et al*. (2011) [18] and Godara *et al*. (2017) [9] in fenugreek.

Economics

Economics plays an important role in deciding the adoption of a particular treatment by the farmers. The gross and net realization as well as B: C ratio was calculated for fertilizer levels as well as for bio-fertilizer inoculations and results furnished in Table 2.

The economical evaluation of different treatments revealed that the gross and net realization increased with increase in fertilizer levels and suitable bio-fertilizer inoculations (Table 2). The maximum net realization of ₹ 84,771 ha^{-1} with B: C ratio of 3.73 was obtained under treatment F_2 (100% RDF) followed by treatment F_1 (75% RDF) with ₹ 80,280 ha^{-1} and 3.64, accordingly. Data further showed that crop inoculated with *Rhizobium* + PSB @ 600 g ha^{-1} each (B_3), recorded maximum net realization of ₹ 80,036 ha^{-1} with B: C ratio of 3.65 followed by B_1 (*Rhizobium* @ 600 g ha^{-1}) with ₹ 75,427 and B: C ratio of 3.51.

The data presented in Table 3 revealed that the maximum net realization was obtained under treatment combination F_2B_3 followed by F_1B_3, whereas maximum B: C ratio was recorded under the treatment combination F_1B_3 followed by F_2B_3. This might be attributed due to significant increase in seed and straw yields (Table 1) under 100% RDF + *Rhizobium* @ 600 g ha^{-1} + PSB @ 600 g ha^{-1}. These results on economics are in close vicinity with those obtained by Jain and Trivedi (2005) [12] in soybean, Nehra *et al*. (2006) [20], Ali *et al*. (2009) [1], Kumar *et al*. (2009) [13], Somasundaram *et al*. (2010) [34], Mehta *et al*. (2011) [18], Bairwa *et al*. (2012) [2], Meena *et al*. (2014) [16], Godara *et al*. (2017) [9] in fenugreek.

Table 1: Individual effect of fertilizer levels and bio-fertilizer inoculations on yield attributes and yield of fenugreek

Treatments	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Fertilizers (F)							
F_0: Control	22.2	12.2	12.46	1298	2832	4130	31.33
F_1: 75% RDF	26.6	13.9	13.46	1793	3121	4914	36.38
F_2: 100% RDF	28.0	14.6	14.30	1876	3245	5121	37.16
S.Em. ±	0.67	0.37	0.29	49.07	94.96	125.50	0.95
C.D. at 5%	1.96	1.08	0.84	143.91	278.52	368.10	2.77
Bio-fertilizers (B)							
B_0: Absolute control	24.3	12.5	12.02	1526	2855	4380	34.06
B_1: *Rhizobium* @ 600 g ha^{-1}	26.0	14.1	13.73	1705	3081	4786	35.33
B_2: PSB @ 600 g ha^{-1}	24.8	13.6	13.44	1611	2973	4584	34.96
B_3: *Rhizobium* + PSB @ 600 g ha^{-1} each	27.3	14.2	14.43	1780	3354	5134	35.49
S.Em. ±	0.77	0.43	0.33	56.66	109.65	144.91	1.09
C.D. at 5%	2.26	1.25	0.97	166.18	321.61	425.04	NS
Interaction: F×B							
S.Em.±	1.33	0.74	0.57	98.13	189.92	250.99	1.89
C.D. at 5%	NS	NS	1.67	287.82	NS	NS	NS
C.V.%	9.02	9.41	7.37	10.27	10.73	9.21	9.36

Table 2: Individual effect of fertilizer levels and bio-fertilizer inoculations on periodical *Rhizobium* count, PSB count, total microbial counts of soil and economics of fenugreek as influenced by different fertilizer levels and bio-fertilizer inoculations

Treatments	*Rhizobium* count (CFU ml^{-1}) at (1×10^6)		PSB count (CFU ml^{-1}) at (1×10^6)		Total microbial count (CFU ml^{-1}) at (1×10^6)		Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest			
Initial status	6.50		4.20		10.70				
Fertilizers (F)									
F_0: Control	6.76	7.06	5.38	5.63	12.08	12.68	80729	52376	2.84
F_1: 75% RDF	7.92	8.21	6.43	6.57	14.42	14.83	110676	80280	3.64
F_2: 100% RDF	8.06	8.63	6.84	7.03	14.91	15.66	115777	84771	3.73
S.Em. ±	0.15	0.22	0.18	0.19	0.28	0.29	--	--	--
C.D. at 5%	0.45	0.63	0.52	0.54	0.83	0.85	--	--	--
Bio-fertilizers (B)									
B_0: Absolute control	6.73	7.36	5.14	5.38	11.87	12.75	94400	64822	3.16
B_1: *Rhizobium* @ 600 g ha^{-1}	7.93	8.06	6.18	6.47	14.11	14.58	105371	75427	3.51
B_2: PSB @ 600 g ha^{-1}	7.21	7.81	6.63	6.70	13.85	14.51	99653	69619	3.30
B_3: *Rhizobium* + PSB @ 600 g ha^{-1} each	8.45	8.64	6.91	7.08	15.36	15.72	110152	80036	3.65
S.Em. ±	0.18	0.25	0.20	0.21	0.33	0.34	--	--	--
C.D. at 5%	0.52	0.73	0.60	0.63	0.96	0.98	--	--	--
Interaction: F×B									
S.Em.±	0.31	0.43	0.35	0.37	0.57	0.58	--	--	--
C.D. at 5%	NS	NS	NS	NS	NS	NS	--	--	--
C.V.%	6.96	9.37	9.78	9.99	7.14	6.99	--	--	--

Table 3: Interaction effect of fertilizer levels and bio-fertilizer inoculations on test weight, seed yield and economics of fenugreek

Treatment Combinations	Test weight (g)	Seed yield (kg ha^{-1})	Gross return (₹ ha^{-1})	Total Cost (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
T_1: F_0B_0	10.89	934	58504	27586	30918	2.12
T_2: F_0B_1	11.67	1493	92263	28522	63741	3.23
T_3: F_0B_2	13.98	1210	75134	28611	46524	2.63
T_4: F_0B_3	13.28	1557	97014	28692	68322	3.38
T_5: F_1B_0	12.07	1773	109323	30269	79054	3.61
T_6: F_1B_1	14.45	1758	108740	30351	78389	3.58
T_7: F_1B_2	12.69	1751	108220	30440	77780	3.56
T_8: F_1B_3	14.64	1888	116419	30522	85897	3.81
T_9: F_2B_0	13.09	1870	115373	30880	84493	3.74
T_{10}: F_2B_1	15.08	1864	115111	30962	84149	3.72
T_{11}: F_2B_2	13.63	1873	115605	31050	84554	3.72
T_{12}: F_2B_3	15.38	1895	117021	31132	85889	3.76
S.Em.±	0.57	98.13	--	--	--	--
C.D. at 5%	1.67	287.82	--	--	--	--
C.V. %	7.37	10.27	--	--	--	--

Conclusion

On the basis of one year field experimentation, it seems quite logical to conclude that under medium black calcareous soils of South Saurashtra Agro-climatic zone for getting higher yields and net realization, fenugreek (cv. GF 2) crop should be fertilized with 100% RDF (20 kg N + 40 kg P_2O_5 ha^{-1}) along with the dual inoculation of seed with bio-fertilizers namely, *Rhizobium* @ 600 g ha^{-1} and PSB @ 600 g ha^{-1}. Whereas, 75% RDF (15 kg N + 30 kg P_2O_5 ha^{-1}) along with the dual inoculation of seed with *Rhizobium* @ 600 g ha^{-1} and PSB @ 600 g ha^{-1} recorded maximum B: C ratio.

References

1. Ali A, Sammauria R, Yadav RS. Response of fenugreek (*Trigonella foenum-graecum* L.) to various fertility levels and bio-fertilizer inoculations. Indian Journal of Agricultural Sciences. 2009;79(2):145-147.
2. Bairwa RC, Kaushik MK, Jatav MK. Effect of fertility levels and growth regulators on quality and economics of fenugreek (*Trigonella foenum-graecum* L.) varieties. International Journal of Agricultural and Statistical Sciences. 2012;8(1):73-78.
3. Bhunia SR, Chauhan RP, Yadav BS, Bhati AS. Effect of phosphorus, irrigation and rhizobium on productivity, water use and nutrient uptake in fenugreek (*Trigonella foenum-graecum* L.). Indian Journal of Agronomy. 2006;5(1):239-241.
4. Das S, Pareek BL, Kumawat A, Dhikwal SR. Effect of phosphorus and biofertilizers on productivity of chickpea (*Cicer arietinum* L.) in North Western Rajasthan, India. Legume Research. 2013;36(6):511-514.
5. Datta N, Hore JK. Effect of nitrogen, phosphorus and potassium on growth and yield of fenugreek (*Trigonella foenum-graecum* L.). Journal on Crop and Weed. 2017;13(3):55-60.
6. Dhage SJ, Kachhave KG, Shirale ST. Effect of bio-fertilizers on nodulation, uptake of nutrients, yield and economics of soybean production in vertisol. Asian Journal of Soil Science. 2008;3(2):299-303.
7. Gendy ASH. Growth, yield and chemical constituents of fenugreek as influenced by *Rhizobium* inoculation and molybdenum foliar spray. Middle East Journal of Agriculture Research. 2013;23(3):84-92.
8. Gill MA, Naimawat A, Nayer MM. Relative effect of phosphorus combined with potash and *Rhizobium phaseoli* on the yield of *Vigna aureus*. Journal of Agricultural Research, Pakistan. 1987;23:279-282.
9. Godara AS, Singh R, Chouhan GS, Nepalia V. Yield and economics of fenugreek (*Trigonella foenum-graecum* L.) as influenced by fertility levels, bio-fertilizers and brassinosteroid. Legume Research. 2017;40(1):165-169.
10. Godara AS, Singh R, Chouhan GS. Soil fertility, growth and productivity of fenugreek (*Trigonella foenum-graecum* L.) as influenced by fertilizer levels, bio-fertilizers and brassinosteroid. International Journal of Current Microbiology and Applied Sciences. 2018;7(9):462-468.
11. Havlin JL, Beaton JD, Tisdale SL, Nelson WL. Soil fertility and fertilizers, IV Edition, Pearson Education (Singapore) Private Limited. Indian Branch, 482 FIE Patpargani, New Delhi, India, 2003.
12. Jain PC, Trivedi SK. Response of soybean (*Glycine max* L.). Merril. to phosphorous and bio-fertilizers. Legume Research. 2005;28(1):30-33.
13. Kumar S, Singh D, Nepalia V. Performance of fenugreek (*Trigonella foenum-graecum* L.) varieties at various fertilizer levels and bio-fertilizer inoculations. Indian Journal of Agricultural Sciences. 2009;79(1):80-83.
14. Kumawat SK. Effect of row spacing and phosphorus levels on fenugreek (*Trigonella foenum-graecum* L.) with and without *Rhizobium* inoculation. M.Sc. (Agri.) thesis Submitted to Rajasthan Agriculture University, Bikaner, Rajasthan 1997.
15. Meena RK, Meena RN, Lalji Yadav, Sharma OP. Effect of phosphorus, molybdenum, PSB levels on growth, productivity and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L.). Environment and Ecology. 2012;30(3B):825-829.
16. Meena SS, Mehta RS, Bairwa M, Meena RD. Productivity and profitability of fenugreek (*Trigonella foenum-graecam* L.) as influenced by biofertilizers and plant growth regulators. Legume Research. 2014;37(6):646-650.
17. Mehta RS, Patel BS, Meena SS, Meena RS. Influence of nitrogen, phosphorus and bio-fertilizers on growth characters and yield of fenugreek (*Trigonella foenum-graecum* L.). Journal of Spices and Aromatic Crops. 2010;19(1&2):23-28.
18. Mehta RS, Patel BS, Jat RA. Effect of nitrogen, phosphorus and biofertilizer inoculation on growth, productivity, nutrient uptake and economic returns in fenugreek (*Trigonella foenum-graecum* L.). Indian

Journal on Dryland Agricultural Research and Development. 2011;26(1):102-108.
19. Mehta RS, Anwer MM, Aishwath DP, Meena RS. Yield and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L.) as influenced by nitrogen, phosphorus and bio-fertilizers. Annals of Agricultural Research. 2012;33(1&2):45-52.
20. Nehra KC, Kumawat PD, Singh BP. Response of fenugreek (*Trigonella foenum-graecum* L.) to phosphorus, sulphur and plant growth regulators under semi arid eastern plains zone of Rajasthan. Indian Journal of Agronomy. 2006;51:73-76.
21. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Fourth England Edition. Indian Council of Agricultural Research, New Delhi, 1985, 97-123.
22. Purbey SK, Sen NL. Response of fenugreek to bioinoculants and plant bioregulators. Indian Journal of Horticulture. 2005;62(4):416-418.
23. Purbey SK, Sen NL. Effect of bioinoculants and bioregulators on yield and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L.). Indian Journal of Agricultural Research. 2007;41(2):154-156.
24. Rana S, Singh PP, Naruka IS, Rathore SS. Effect of nitrogen and phosphorus on growth, yield and quality of black cumin (*Nigella sativa* L.). International Journal of Seed Spices. 2012;2(2):5-8.
25. Rathore HS. Studies on date of sowing, microbial inoculation and weed management in fenugreek (*Trigonella foenum-graecum* L.). Ph. D. thesis submitted to Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 2007.
26. Reena N, Pandey SK, Jyothsna J. Growth and yield of fenugreek (*Trigonella foenum-graecum* L.) in response to different levels of phosphorus and bio-fertilizer (Rhizobium and PSB) under kymore plateau and satpura hill agro-climatic zone of Madhya Pradesh. The Pharma Innovation Journal. 2021;10(1):419-422.
27. Singh SD. Effect of *Rhizobia* inoculation on nodulation and yield of green gram (*Vigna radiata* L. Wilczek). Annals of Arid Zone. 1977;16:79-84.
28. Singh D, Nepalia V, Singh AK. Performance of fenugreek (*Trigonella foenum-graecum* L.) varieties at varying fertilizer levels and bio-fertilizer inoculations. Indian Journal of Agronomy. 2010;55(1):75-78.
29. Singh R, Singh AP. Effect of phosphorus, sulphur and bio-fertilizer on yield, quality and uptake of nutrients in cowpea (*Vigna unguiculata* L.). Annals of Plant and Soil Research. 2017;19(2):175-179.
30. Sinha RK, Valani D, Chauhan K. Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: reviving the dreams of Sir Charles Darvin. International Journal of Agriculture and Biology. 2014;1:50-64.
31. Snehalatha HS, Payal DR. Fenugreek (*Trigonella foenum-graecum* L.): An overview. International Journal of Current Pharmaceutical Review and Research. 2011;2(1):69-87.
32. Soliman MAE. *Rhizobium*-Fenugreek symbiosis affected by nitrogen fertilizer rates and seeds irradiation: A Field Experiment. Journal of Soil Science and Agricultural Engineering, Mansoura University. 2019;10(3):179-185.
33. Somani LL, Bhandari SC, Saxena SN, Gulati IJ. Biofertilizers. Scientific Publishers, Jodhpur. 1981;2:271-274.
34. Somasundaram E, Chandrasekharan R, Kumar M, Krishnan R, Mohamed MA, Meyyappan M. Influence of plant density and fertilizer levels on the yield attributes, yield and economics of groundnut (*Arachis hypogaea* L.). International Journal on Agricultural Sciences. 2010;6(1):259-261.
35. Subba Rao NS. Field response of legumes in India to inoculation and fertilizer application. In*: Symbiotic Nitrogen Fixation in Plants* (ed.). P.S. Nutman, International Biological Programme, WI. Cambridge University Press, London, 1976, 255-268.
36. Tagore GS, Namdeo SL, Sharma SK, Kumar N. Effect of *Rhizobium* and Phosphate Solubilizing Bacterial inoculants on symbiotic traits, nodule leghemoglobin and yield of chickpea genotypes. International Journal of Agronomy, 2013.
37. Tanwar SPS, Sharma GL, Chahar MS. Effect of phosphorus and biofetilizer on yield, nutrient concentration and uptake by black gram (*Vigna mungo* L. Hepper). Legume Research. 2003;26(1):39-41.
38. Tuncturk R, Celen AE, Tuncturk M. The effects of nitrogen and sulphur fertilizers on the yield and quality of fenugreek (*Trigonella foenum-graecum* L.). Turkish Journal of Field Crops. 2011;16(1):69-75.
39. Vision. Perspective Plan-2050, National Research Centre on Seed Spices, Ajmer 2050.
40. Whitelaw MA. Growth promotion of plants inoculated with phosphate solubilizing fungi. Advances in Agronomy. 2000;6(9):100-151.