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Effect of Sulfur and Biofertilizers on Growth Characters and Economics of Fenugreek (*Trigonella foenum-graecum* L.)

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ABSTRACT

A field experiment was carried out at Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan) to study the effect of sulfur and biofertilizers on growth characters and economics of fenugreek (*Trigonella foenum-graecum* L.) during the *rabi* season of 2021-2022. Application of sulfur significantly increases growth characters and net returns and highest obtain in application of 40 kg S ha^{-1} over application of 30, 20 and 10 kg S ha^{-1} and seed inoculation with biofertilizers NPK Consortia obtain highest growth characters and net return. The experimental design was used Factorial Randomized Design (FRBD) consisted of 16 treatment combinations i.e. four levels of sulfur (10, 20, 30, 40 kg S ha^{-1}) and four biofertilizers combinations (Control, *Rhizobium*, *Rhizobium* + PSB, NPK Consortia) these were replicated thrice.

Keywords Sulfur, Biofertilizers, Growth, Fenugreek, Net return.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) popularly known by its vernacular name "methi" has been in culinary and medicinal uses due to its restorative and nutraceutical properties for more than 2500 years. Sulfur is the fourth most important mineral nutrient after nitrogen, phosphorus and potassium. It improves protein content and oil content in seed and also associated with special metabolism in plants and the structural characters of protoplasm (Meena *et al.* 2018). It is essential for the formation of chlorophyll, activation of enzymes and improvement in crop growth and yield (Tondon 1995). Crop removal is the major cause of sulfur depletion in soil. The maximum economical crop production cannot be expected from the use of NPK fertilizers alone, but that sulfur must be included in the fertilization programed.

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 texture soil. Therefore, the introduction of efficient strain of *Rhizobium* may be helpful in

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boosting greater nitrogen fixation and crop production. Inoculation of seeds with *Rhizobium* culture is low cost input in legume and has been found beneficial by many workers (Subba Rao 1976). Similarly, inoculation with phosphate solubilizing bacteria (PSB) converts the unavailable form of phosphorus into soluble or available form to the plant. Microbial fertilization along with *Rhizobium* and PSB has been found promising to improve soil health and crop production (Meena *et al.* 2014). *Rhizobium* + PSB help to maintain soil fertility and eliminate the pollution hazards to increase the productivity. Bio-fertilizer such as *Rhizobium*, PSB and KSB play an important role in increasing the availability of nitrogen, phosphorus and potassium.

MATERIALS AND METHODS

The experiment was laid out at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. It falls under agro climatic zone IVa "Sub-Humid Southern Plain and Aravali Hills" of Rajasthan. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 8.0), medium in available nitrogen (277.19 kg ha^{-1}) and phosphorus (18.02 kg ha^{-1}) while high in available potassium status (309.50 kg ha^{-1}). The treatment consisted of four levels of sulfur (10, 20, 30, 40 kg ha^{-1}) and four combinations of biofertilizers (control, *Rhizobium*, *Rhizobium* + PSB, NPK consortia) there by making 16 treatments combinations replicated thrice in FRBD. Fenugreek crop variety PRM-45 was used as test crop. A uniform dose of 40 kg N+ 20 kg P_2O_5 ha^{-1} was applied. Urea and DAP were used as a source of nitrogen and phosphorus, respectively. The whole quantity of sulfur was applied as per treatment allocation at the time of sowing. Bentonite (90% sulfur) was used as a source of sulfur and the seeds were treated with liquid biofertilizers *Rhizobium*, *Rhizobium* + PSB, NPK consortia using 5 ml kg^{-1} through standard procedure 2-3 hrs before sowing as per treatment allocation. The seeds were thoroughly mixed with biofertilizers in such a way that all the seeds were uniformly coated with a layer of biofertilizers and then seeds were allowed to dry in shade before sowing of crops. To find out economic viability of treatments, net monetary returns ha^{-1} was worked out. The cost of cultivation including the treatment cost was subtracted from the gross income obtained under each treatment using prevailing input-output prices. Further to ascertain profitability on $rupee^{-1}$ investment, benefit- cost ratio was also workout.

RESULTS AND DISCUSSION

Effect of sulfur

Application of 40 kg sulfur ha^{-1} significantly increase growth characters of fenugreek crop compare to 30, 20 and 10 kg sulfur ha^{-1} the maximum plant height at harvest (88.12 cm), dry matter accumulation at harvest (23.41 g $plant^{-1}$), number of effective nodules (21.90 $plant^{-1}$), fresh weight of effective nodules (0.1492 g $plant^{-1}$), dry weight of effective nodules (36.97 mg $plant^{-1}$), primary branches (8.28 $plant^{-1}$) and secondary branches (9.73 $plant^{-1}$) was observed under application of 40 kg sulfur ha^{-1} (Table 1). Increasing level of sulfur application up to 40 kg ha^{-1} significantly increased net returns of crop maximum net returns 102180 (₹ ha^{-1}) and B-C ratio 3.31 was observed under application of 40 kg sulfur ha^{-1} (Table 2). In general, the overall improvement in growth of fenugreek with the addition of sulfur could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for development of the plants. It is well established that sulfur in the form of sulfate (SO_4^{-2} – S) is involved in synthesis of sulfur containing amino acids (methionine and cystine), various enzymatic processes and variety of oxidation- reduction reactions in the plants (Nelson and Tisdale 2013). In the preceding section, it has been well emphasized that sulfur fertilization significantly improved overall growth of the crop in terms of dry matter accumulation $plant^{-1}$ by virtue of its impact on morphological and photosynthetic components of growth along with accumulation of nutrients. This suggests greater availability of nutrients and metabolites for growth and development of each reproductive structure which ultimately led to realization of their genetic potential up to highest level. The results of present investigation indicating positive response of various yield attributes to sulfur fertilization corroborated finding of several researchers (Yadav 2011, Lal *et al.* 2015, Manohar *et al.* 2017, Parmar *et al*. 2021).

Table 1. Effect of sulfur and biofertilizers on growth characters of fenugreek.

Treatments	Plant height at harvest (cm)	Dry matter accumulation at harvest (g plant^{-1})	Effective nodules (plant^{-1})	Weight of nodules (plant^{-1})		Branches plant^{-1} at harvest	
				Fresh weight (g)	Dry weight (mg)	Primary	Secondary
Sulfur (kg ha^{-1})							
10	75.10	17.60	19.07	0.1312	29.69	6.35	7.91
20	80.46	19.66	20.12	0.1423	32.53	7.16	8.60
30	84.29	21.66	20.96	0.1453	34.90	7.73	9.17
40	88.12	23.41	21.90	0.1492	36.97	8.28	9.73
SEm±	1.27	0.23	0.27	0.0009	0.673	0.14	0.18
CD (p=0.05)	3.67	0.66	0.79	0.0027	1.94	0.41	0.52
Bio-fertilizers							
Control	77.17	17.70	18.99	0.1229	30.55	6.48	8.00
Rhizobium	80.87	20.18	20.18	0.1413	33.02	7.18	8.68
Rhizobium + PSB	84.82	21.95	21.25	0.1516	35.13	7.77	9.24
NPK consortia	85.09	22.50	21.63	0.1521	35.28	7.85	9.37
SEm±	1.27	0.23	0.27	0.0009	0.673	0.14	0.18
CD (p=0.05)	3.67	0.66	0.79	0.0027	1.94	0.41	0.52

Effect of biofertilizers

Amongst biofertilizers, inoculation with NPK consortia recorded highest plant height at harvest (85.09 cm), dry matter accumulation at harvest (22.50 g plant^{-1}), number of effective nodules (21.63), fresh weight of effective nodules (0.1521 g plant^{-1}), dry weight of effective nodules (35.28 g plant^{-1}), number of primary (7.85) and secondary (9.37) branches plant^{-1} which was found at par with combined inoculation of *Rhizobium* + PSB plant height at harvest (84.82 cm), dry matter accumulation at harvest (21.95 g plant^{-1}), number of effective nodules (21.25), fresh weight of effective nodules (0.1516 g plant^{-1}), dry weight of effective nodules (35.13 g plant^{-1}), number of primary (7.77) and secondary (9.24) branches plant^{-1} and significantly higher compare to *Rhizobium* alone and uninoculation (Table 1).

Table 2. Effect of sulfur and biofertilizers on net return and B-C ratio.

Treatments	Net return (₹ ha^{-1})	B-C ratio
Sulfur (kg ha^{-1})		
10	72262	2.47
20	86022	2.89
30	94490	3.12
40	102180	3.31
SEm±	2546	0.09
CD (p=0.05)	7354	0.25
Bio-fertilizers		
Control	78055	2.60
Rhizobium	86130	2.86
Rhizobium + PSB	94741	3.14
NPK consortia	96029	3.19
SEm±	2546	0.09
CD (p=0.05)	7354	0.25

Rhizobium bacteria fix atmospheric nitrogen and these bacteria are also capable to secret some auxins, gibberellins, vitamins which are considered to be important for proper growth and development of the plant. Potassium mobilizing bacteria (KMB) dissolve silicate minerals and release potassium through the production of organic and inorganic acids, acidolysis, chelation and exchange reactions. The results of present investigation indicating positive response of fenugreek crop to inoculation with biofertilizers are

alike findings of several researchers (Ali *et al.* 2009, Mehta and Patel 2011, Biswas *et al*. 2019 and Bhutadiya *et al.* 2019).

CONCLUSION

On the basis of results emanated from the present investigation it can be concluded that fenugreek crop must be fertilized with 40 kg sulfur ha^{-1} to significantly increase growth characters, net returns and B-C ratio. Whereas *Rhizobium* + PSB was found next in order with seed inoculation with NPK consortia.

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