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Growth, Yield and Economics of Fenugreek (*Trigonella foenum-graecum* L.) as Influenced by Inorganic Fertilizers and Bio-inoculant (*Rhizobium*, PSB and KSB)

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ABSTRACT: The investigation was done out during Rabi 2019-2020 at the Vegetable Research Centre, Maharajpur, Department of Horticulture, JNKVV, Jabalpur (M.P.). Rhizobium was applied for seed treatment at 2 g/kg of seed, while PSB and KSB were used for soil application at 3 kg/ha at the time of planting in fenugreek using variety RMt-1 par treatment in the plot. The design was implemented using Randomized Block Design (RBD) using three replications. Each replication has 16 treatments. It was concluded that treatment % RDF + Rhizobium + PSB + KSB produced higher values of all growth attributes traits, yield contributing traits such as number of pods per plant, pod length, pod width, number of seeds per pod, pod weight, seed yield per plant, total yield (12.79 q ha^{-1}) and net monetary return (Rs. 60,440 ha^{-1}) and B:C ratio (2.35).

Keywords: Fenugreek, *Rhizobium*, PSB, KSB, Bio-inoculant, Inorganic fertilizer.

INTRODUCTION

India is the world's largest grower, buyer and exporter of seed spices. Fenugreek (*Trigonella foenum-graecum* L.) widely referred to as *methi* is a multipurpose crop that is grown in northern India during in the cold season. It is an annual herb belongs to the Fabaceae family and sub-family Papilliaceae. It is one of the important major seed spice in the country. It was called, *Trigonella*, from the Latin language which means "little triangle" because of its triangular yellowish-white flowers. From the early days, the Greeks used it as a remedy, seasoning and cattle feed, and so it was still known as the Greek hay. Fenugreek is considered to have originated in South-Eastern Europe and West Asia.

Rajasthan, Gujarat, Madhya Pradesh, Haryana, Maharashtra, Uttar Pradesh, Punjab, Bihar, Tamil Nadu, and Andhra Pradesh are the leading fenugreek growing states. The total area and output of fenugreek is 219720 hectares and 311280 tons in 2017-2018, respectively (Spice Board, 2019). Rajasthan is the leading state in fenugreek production followed by Madhya Pradesh, Gujarat and Haryana. In Madhya Pradesh it is grown in an area of 53440 hectare with 104220 tonnes production (Spice Board, 2019). Nitrogen is crucial in the synthesis of chlorophyll and it being an essential constituent of compounds like amino acids, nucleic acids, nucleotides, enzymes, coenzymes, vitamins and alkaloids contributes to the growth of plant. The general role of phosphorus on plant metabolism is known to enhance the symbiotic nitrogen fixation as well as, it plays an important role in energy transfer process in the plant body. Potassium is the third major essential plant nutrient and plays an essential role for enzyme activation, protein synthesis and photosynthesis and quality of produce. However, owing to the lack of fertilizer guidelines for various agro-climatic conditions, farmers typically apply either over or under fertilizer in fenugreek, thereby impacting crop production and profit margins for farmers. Similarly there is need to evaluate the impact of different bio-fertilizers. Shekhawat *et al*. (2012) highlighted the requirement for incorporation of bio-fertilizers in the fertilizer programme to meet about one third of plant nutrient needs. Integrated use of synthetic fertilizers and bio-fertilizers in fenugreek could be much more beneficial than synthetic fertilizers alone.

In India, over the last three decades, intensive cultivation involving exhaustively high yielding varieties has led to a significant depletion of nutrients from the soil. Furthermore, imbalanced use of chemical fertilizers by farmers has deteriorated soil health and declined soil organic carbon content. The uses of various combinations of chemicals in agriculture shown much irreversible impact on the environment pollution, human health and soil health. There is also a need to seek alternative sources of nutrients that could be inexpensive and environmentally friendly, so that farmers can minimize the investment made in fertilisers while preserving good soil environmental conditions contributing to sustainable organic farming. In recent years uses of microbial inoculants as source of bio-fertilizers have become a hope for most of the countries as far as economical and environmental points of view are concerned.

Bio-fertilizers are environment-friendly, less costly and do not require non renewable source of their production, therefore lead to sustainable crop production. In addition, they produce hormones, vitamins and other growth factors essential for plant growth. Fenugreek, which is a legume crop, responds to inoculation with *Rhizobium meliloti* in order to satisfy the partial nitrogen requirement. *Rhizobium* inoculation of fenugreek has been reported to increase plant and seed biomass. A number of experiments have shown that combined infection with rhizobia and rhizosphere bacteria increases nodulation and development in a wide range of legumes. Indian soil is low to average in available phosphorus. In recent years, several strains of phosphate solubilising bacteria (PSB) and fungi have been isolated which have shown to possess the ability to solubilize sparingly soluble phosphate, growth promotion and uptake of P by plants (Whitelaw, 2000). In India, the cost of potassium fertilizers is very high because there is no reserve of K-bearing minerals for manufacturing of conventional K fertilizers and the whole consumption is imported, costing huge amount of foreign exchange. *Frateuria aurantia*, a K-solubilizing bacterium, is capable of mobilizing a mixture of mica potassium into a functional shape for plants that have been reasonably added to crops in association with other bio-fertilizers without any antagonistic effects. In this context, it is important to see the microbial solubilization of K-bearing minerals in soils and their ability as K-bearing fertilizers in sustainable crop production and in the conservation of K-bearing in soil. Therefore, the present study was undertaken to evaluate the effect of nitrogen, phosphorous, potassium and bio-fertilizers on growth, yield and economics of fenugreek.

MATERIAL AND METHODS

The experiment was conducted during *Rabi* 2019-2020 at Vegetable Research Centre, Maharajpur, Department of Horticulture, JNKVV, Jabalpur (M.P.). During the growing period one light irrigation just after sowing and five irrigations at different growth stages were applied to fenugreek. The experiment was carried out in a randomized block design of three replicates. The treatment combinations comprised of sixteen, *viz*., control, RDF, 75% RDF, 50% RDF, 100% RDF + *Rhizobium*, 100% RDF + *Rhizobium*+ PSB, 100% RDF + *Rhizobium*+ KSB, 100% RDF + *Rhizobium*+ PSB+KSB, 75% RDF + *Rhizobium*, 75% RDF + *Rhizobium*+ PSB, 75% RDF + *Rhizobium*+ KSB, 75% RDF + *Rhizobium*+ PSB+KSB, 50% RDF + *Rhizobium*, 50% RDF + *Rhizobium*+ PSB, 50% RDF + *Rhizobium*+ KSB, 50% RDF +*Rhizobium*+ PSB+KSB. The seed rate used for sowing was 25 kg/ha and before sowing seed were treated with 2 g *Rhizobium* per kg of seed. Seeds of variety RMt-1 were dibbled at a row spacing of 30 cm. The recommended doses of N, P and K @ 30:30:50 kg/ha were applied in the form of urea, single super phosphate and muriate of potash, respectively as a basal application just before sowing. *Rhizobium* was used for seed treatment @ 2 g/kg of seed while PSB and KSB was used for soil application @ 3 kg/ha at the time of sowing as par treatment in the plot. The prescribed practices for the cultivation of quality crops has been followed. Data based on the mean of the individual plants chosen for observation were statistically analyzed as defined by Panse and Sukhatme (1967) in order to determine the overall variability of the material under study for each character and for all populations.

RESULT AND DISCUSSION

Result depicted in Table 1 revealed that inorganic and bio-inoculant doses as well as there combinations significantly affect growth and phenological attributes, *viz*. plant height at 30, 60 DAS and at maturity, number of branches per plant at maturity, days to first flowering, 50% flowering and days to maturity, number of nodules per plant at 30 DAS, dry weight of plant at 60 DAS in fenugreek. The application of 100% RDF + *Rhizobium* + PSB + KSB *i.e.* T_8 gave higher values of all these growth attributes.This might be due to the combined application of inorganic fertilizer and bio-inoculant which increased nutrients availability, photosynthetic activity, chlorophyll formation, nitrogen metabolism in plants which ultimately improving plant height resulting in vigorous plant growth. Similar beneficial combined effect of inorganic and bio-inoculant on growth parameters was also recorded by Ali *et al.* (2009); Raiyani *et al.* (2018). In addition, inoculation of plant with microbes increase dry matter content (Alagawadi and Gaur 1998). Over 80% of the bacteria isolated from rhizosphere can produce IAA (Arshad and Frankenberger 1998). This increase in dry matter production of inoculated plants may be attributed to enhanced nodulation, higher nitrogen fixation rate and general improvement of root development (Erum and Bano 2008). Rhizobium sp. inoculation caused an improvement in growth and yield (Akhtar and Siddiqui 2009).

Table 1: Effect of inorganic fertilizers and bio-inoculant (*Rhizobium*, PSB and KSB) on growth and Phenological attributes in fenugreek.

Treatment	Plant height (cm)			Number of branches per plant at maturity	Days to first flowering	Days to 50% flowering	Days to maturity
	30 DAS	60 DAS	At maturity				
Control	5.37	24.81	54.09	4.27	45.67	53.00	154.33
RDF	4.46	30.33	66.11	4.33	41.67	51.33	149.67
75% RDF	7.44	40.69	64.02	4.33	42.00	49.33	153.67
50% RDF	6.45	40.78	61.08	5.10	44.33	51.00	146.67
T2+Rhizobium	6.59	42.29	63.80	5.10	43.67	51.33	152.67
T2+Rhizobium+PSB	5.63	41.27	67.61	5.13	45.00	51.67	148.67
T2+Rhizobium+KSB	4.43	34.61	61.48	4.30	42.33	50.33	152.33
T2+Rhizobium+PSB+KSB	5.89	39.49	72.53	5.37	39.33	47.00	145.00
T3+Rhizobium	6.48	33.85	56.48	4.47	43.67	49.00	155.33
T3+Rhizobium+PSB	5.79	32.89	64.12	5.10	41.00	48.33	154.00
T3+Rhizobium+KSB	6.35	41.24	64.07	4.30	44.67	52.33	154.00
T3+Rhizobium+PSB+KSB	7.46	46.09	64.02	5.37	39.67	47.67	145.33
T4+Rhizobium	5.76	35.22	62.29	5.10	46.00	52.00	153.00
T4+Rhizobium+PSB	6.53	36.13	63.93	5.10	42.67	50.00	147.67
T4+Rhizobium+KSB	4.49	35.17	64.13	4.40	40.33	50.67	150.00
T4+Rhizobium+PSB+KSB	6.4	26.81	60.10	5.10	41.67	48.67	148.33
C.D.	0.18	0.70	2.80	0.07	1.18	1.00	1.45
SE (m)	0.54	2.03	8.13	0.22	3.41	2.90	4.21

RDF-Recommended Dose of Fertilizer, PSB - Phosphorus Solubilising Bacteria, KSB -Potassium Solubilising Bacteria, C.D.-Critical Difference and SE(m)- Standard Error of the Mean

Scrutiny of data in Table 2 on yield contributing traits *viz.*, number of pods per plant, pod length, pod width, number of seeds per pod, pod weight, seed yield per plant, yield (qha^{-1}) and test weight recorded a significant increase due to various treatments of inorganic fertilizer and bio-inoculants. Maximum number of pods per plant, pod length, pod width, number of seeds per pod, pod weight, seed yield per plant, yield (qha^{-1}), test weight was recorded with treatment T_8 (RDF + *Rhizobium* + PSB + KSB). The results corroborate with those of Meena *et al.* (2014).

The superiority of inorganic fertilizer and bio-inoculant combination could be attributed to the increase in amount of growth parameters and increased availability of nitrogen throughout the life cycle of the crop. Fenugreek is leguminous crop and it fix atmospheric nitrogen consequently the increased and balanced supply of nitrogen to plant promotes flowering and fruiting and supply of food material and its subsequent partitioning in the sink. The availability of phosphorus plays a unique role in energy conservation and transfer. The balanced supply of nitrogen throughout the life cycle of the crop reduced leaf senescence and able to furnish the increased assimilate demand of plant sinks which resulted in higher number of pods and test weight due to bold grain formation. Improvement of all the yield parameters might be due to the better availability of nutrients and their translocation resulted in significantly higher seed yield in fenugreek under *Rhizobium* inoculation along with PSB and KSB in soil application.

Table 2: Effect of inorganic fertilizers and bio-inoculant (*Rhizobium*, PSB and KSB) on yield parameters in fenugreek.

Treatment	Pod length (cm)	Pod width (mm)	Pod weight (g)	Number of pods per plant	Number of seeds per pod	Yield (q ha^{-1})
Control	6.57	3.93	0.19	23.67	13.40	6.29
RDF	7.27	4.15	0.25	23.73	14.67	10.80
75% RDF	8.87	4.66	0.22	24.53	14.77	9.65
50% RDF	9.38	3.57	0.20	24.20	14.07	7.03
T2+Rhizobium	9.30	4.80	0.26	24.67	14.80	12.07
T2+Rhizobium+PSB	8.50	5.34	0.25	26.27	16.20	10.59
T2+Rhizobium+KSB	9.97	4.60	0.29	25.87	13.13	12.57
T2+Rhizobium+PSB+KSB	10.61	5.77	0.33	26.87	16.80	13.13
T3+Rhizobium	8.40	4.60	0.23	24.07	14.73	10.06
T3+Rhizobium+PSB	9.50	4.23	0.25	23.73	14.67	10.56
T3+Rhizobium+KSB	8.51	4.73	0.24	24.47	14.60	10.17
T3+Rhizobium+PSB+KSB	10.37	5.62	0.30	26.80	16.67	12.79
T4+Rhizobium	9.39	4.80	0.20	24.73	14.60	7.40
T4+Rhizobium+PSB	9.45	4.70	0.21	24.73	14.80	8.38
T4+Rhizobium+KSB	9.77	4.80	0.20	24.27	14.80	8.09
T4+Rhizobium+PSB+KSB	8.46	4.80	0.22	24.80	14.73	9.30
C.D.	0.74	0.91	0.048	1.83	1.74	1.87
SE (m)	0.25	0.31	0.017	0.63	0.60	0.65

The economics of various treatments is depicted in Table 3. The B:C ratio was significantly increased by various treatments of inorganic fertilizer and bio-inoculants. Maximum B:C ratio was secured with treatment T_8 (RDF + *Rhizobium* + PSB + KSB) (2.35) along with maximum gross return (Rs. 1,05040 ha^{-1}) and net return (Rs. 60,440 ha^{-1}). Singh and Verma (2002) with combined application of organic and inorganic with *Rhizobium* inoculation in French bean also reported similar findings. The highest benefit cost ratio was obtained with the application of 100% RDN through inorganic source along with *Rhizobium*, PSB and KSB. The lower quantity of bio-inoculant is required which resulted in lower investment and ultimately gave the highest benefit cost ratio or higher returns per rupee investment over inorganic fertilizers. Addition of bio-inoculant, although offer the twin benefits of soil quality and fertility enhancement but while meeting a part of nutrients need of crop that only sustain the high yields required these days.

Table 3: Effect of inorganic fertilizers and bio-inoculant (*Rhizobium*, PSB and KSB) on B:C ratio of fenugreek.

Treatment	Seed yield (q/ha)	Gross income (Rs/ha)	Expenditure (Rs./ha)	Net income (Rs./ha)	C:B ratio
Control	6.29	50320	40200	10120	1:1.25
RDF	10.8	86400	43250	43150	1:1.99
75% RDF	9.65	77200	42489	34711	1:1.81
50% RDF	7.03	56240	41725	14515	1:1.34
T2+Rhizobium	12.07	96560	43260	53300	1:2.23
T2+Rhizobium+PSB	10.59	84720	43860	40860	1:1.93
T2+Rhizobium+KSB	12.57	100560	43860	56700	1:2.29
T2+Rhizobium+PSB+KSB	13.13	105040	44460	60580	1:2.36
T3+Rhizobium	10.06	80480	42499	37981	1:1.89
T3+Rhizobium+PSB	10.56	84480	43099	41241	1:1.96
T3+Rhizobium+KSB	10.17	81360	43099	38261	1:1.88
T3+Rhizobium+PSB+KSB	12.79	102320	43699	58621	1:2.34
T4+Rhizobium	7.40	59200	41735	17465	1:1.41
T4+Rhizobium+PSB	8.38	67040	42335	24705	1:1.58
T4+Rhizobium+KSB	8.09	64720	42335	22385	1:1.52
T4+Rhizobium+PSB+KSB	9.30	74400	42935	31465	1:1.73

CONCLUSION

Thus, it can be concluded that the application of 100% RDF + *Rhizobium* + PSB + KSB increased the yield and net monetary return along with improvement in soil health also concept of efficient use of bio-fertilizers complemented by associated inorganic nutrients has played a crucial role in growing and maintaining the production of fenugreek.

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Conflict of Interest. None.

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