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Effect of different levels of nitrogen and bio-fertilizers on the growth and productivity of Fenugreek (*Trigonella foenum-graecum* L.)

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Abstract

A field experiment entitled “Effect of Different Levels of Nitrogen and Bio-fertilizers on the Growth and Productivity of Fenugreek (*Trigonella foenum-graecum* L.)” was conducted during the *rabi* season of 2025-26 at Block B₁ of the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur, Rajasthan. The soil of the experimental field was clay-loam in texture, low in available nitrogen (278.58 kg ha⁻¹), medium in available phosphorus (22.06 kg ha⁻¹) and high in available potassium (298.52 kg ha⁻¹). The experiment was laid out in a Factorial Randomized Block Design with three replications. Treatments consisted of four nitrogen levels, viz., Control, 100% RDN, 75% RDN (Urea) + 25% RDN (Vermicompost) and 50% RDN (Urea) + 50% RDN (Vermicompost), along with four bio-fertilizer treatments, viz., Control, *Rhizobium*, NPK consortium and *Rhizobium* + NPK consortium, thereby making 16 treatment combinations. Fenugreek variety PRM-45 was used as the test crop.

Application of 50% RDN (Urea) + 50% RDN (Vermicompost) significantly improved the growth of fenugreek by recording the highest plant height of 6.05, 54.60, 80.82 and 88.12 cm at 30, 60, 90 DAS and at harvest, respectively. The same treatment also recorded the maximum dry matter accumulation of 0.44, 5.10, 15.25 and 22.70 g plant⁻¹ at 30, 60, 90 DAS and at harvest, respectively. It further registered the highest crop growth rate of 5.18 and 11.28 g m⁻² day⁻¹ during the 30-60 DAS and 60-90 DAS intervals, respectively. However, the crop growth rate during 90 DAS to harvest and the relative growth rate during 30-60 DAS, 60-90 DAS and 90 DAS to at harvest were not significantly influenced by different nitrogen levels. The treatment also recorded the highest number of effective root nodules (21.41 plant⁻¹).

Seed treatment with *Rhizobium* + NPK consortium significantly enhanced the growth of fenugreek by recording the highest plant height of 52.76, 78.57 and 85.09 cm at 60, 90 DAS and at harvest, respectively. The same treatment also recorded the maximum dry matter accumulation of 4.85, 14.80 and 21.79 g plant⁻¹ at 60, 90 DAS and at harvest, respectively. However, the effect of bio-fertilizer treatments on plant height and dry matter accumulation at 30 DAS was found to be non-significant. Furthermore, *Rhizobium* + NPK consortium recorded the highest crop growth rate of 4.92 and 11.05 g m⁻² day⁻¹ during the 30-60 DAS and 60-90 DAS intervals, respectively, while the crop growth rate during 90 DAS to harvest and the relative growth rate during 30-60 DAS, 60-90 DAS and 90 DAS to harvest remained non-significant. The treatment also recorded the highest number of effective root nodules (21.74 plant⁻¹).

Keywords: Fenugreek crop, nitrogen, bio-fertilizers, growth parameters

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an important seed spice crop of the family Fabaceae, cultivated mainly during the *rabi* season in northern India. India is the largest producer, consumer and exporter of fenugreek and it ranks third among major seed spices after cumin and coriander (Thangaraj and Vijaykumaran, 2001)^[1]. According to the Spice Board of India^[2] (2024-25), fenugreek is cultivated on about 1.47 lakh ha area with a production of 226.85 thousand tonnes. Rajasthan is one of the major producing states, where it is commercially cultivated in districts such as Bikaner, Jodhpur, Sikar, Churu and Pratapgarh.

Fenugreek seeds possess high nutritional and medicinal value due to the presence of protein, vitamins, essential oils, diosgenin and trigonelline. Traditionally, fenugreek has been used for managing digestive disorders, diabetes and other health-related problems (Sheoran *et al.*, 1999)

[3]. Efficient nutrient management is essential for improving growth, yield and quality of fenugreek. Excessive use of chemical fertilizers negatively affects soil health by reducing microbial activity and deteriorating soil properties; therefore, integrated nutrient management has gained importance for sustainable crop production (Adediran *et al.*, 2004) [4].

Nitrogen plays a vital role in chlorophyll formation, protein synthesis and plant growth, while vermicompost improves soil fertility, microbial activity and nutrient availability through the addition of organic matter and beneficial microorganisms (Manzoor *et al.*, 2024) [5]. Biofertilizers containing beneficial microbes such as *Rhizobium* and nutrient-solubilizing bacteria enhance nutrient availability and promote biological nitrogen fixation, thereby improving crop productivity (Htwe *et al.*, 2019) [6]. However, the effectiveness of nitrogen and biofertilizers varies with soil type, climatic conditions and crop genotype. Therefore, the present study was undertaken to evaluate the interactive effect of nitrogen levels and biofertilizers on growth, yield attributes and productivity of fenugreek for developing a sustainable nutrient management strategy.

Materials and Methods

A field trial was carried out during the *rabi* season of 2025-26 at Block B₁ of the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur. The experimental soil was characterized as clay-loam in texture with slightly alkaline pH (7.6), low organic carbon and available nitrogen status, medium available phosphorus content and high available potassium level. The experiment was conducted in a factorial randomized block design consisting of four nitrogen management treatments, viz., control, 100% recommended dose of nitrogen (RDN), 75% RDN through urea + 25% RDN through vermicompost and 50% RDN through urea + 50% RDN through vermicompost, along with four biofertilizer treatments, including uninoculated control, *Rhizobium* inoculation, NPK consortium inoculation and *Rhizobium* + NPK consortium inoculation, with three replications.

Fenugreek variety PRM-45 was used as the test crop and was sown with a spacing of 30 cm × 10 cm using a seed rate of 25 kg ha⁻¹. The recommended fertilizer dose of 20:40:00 kg ha⁻¹ N:P₂O₅:K₂O was applied, wherein nitrogen and phosphorus were supplied through urea and single super phosphate at the time of sowing. Growth observations, including plant height, dry matter accumulation, crop growth rate, relative growth rate and number of effective root nodules, were recorded following standard methodologies. The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for factorial randomized block design as described by Panse and Sukhatme (1985) [7].

Results and Discussion

Nitrogen

Among the nitrogen treatments, application of 50% RDN through urea + 50% RDN through vermicompost recorded the highest values for plant height, dry matter accumulation, crop growth rate and number of effective root nodules. However, the treatment remained statistically at par with 75% RDN through urea + 25% RDN through vermicompost and both integrated nitrogen treatments significantly outperformed the control and sole application of 100% RDN through urea.

Plant height increased significantly with integrated nitrogen application and reached the maximum values of 6.05, 54.60, 80.82 and 88.12 cm at 30, 60, 90 DAS and harvest, respectively,

under 50% RDN through urea + 50% RDN through vermicompost, which remained statistically at par with 75% RDN through urea + 25% RDN through vermicompost. This improvement may be attributed to the balanced and continuous supply of nitrogen from urea and vermicompost. Nitrogen promoted chlorophyll synthesis, cell division and vegetative growth, while vermicompost improved soil physical properties, nutrient availability and root development, thereby resulting in taller plants. Similar findings were reported by Choudhary *et al.* (2011) [8].

A similar trend was observed for dry matter accumulation, where the maximum dry matter of 0.444, 5.13, 15.25 and 21.69 g plant⁻¹ at 30, 60, 90 DAS and harvest, respectively, was recorded under 50% RDN through urea + 50% RDN through vermicompost, which remained at par with 75% RDN through urea + 25% RDN through vermicompost. Adequate nitrogen availability enhanced photosynthesis and carbohydrate production, whereas vermicompost ensured continuous nutrient supply and improved nutrient uptake, resulting in greater biomass accumulation. Similar findings were reported by Shivran *et al.* (2015) [9] and Shivran *et al.* (2016) [10].

Crop growth rate was also significantly influenced by nitrogen management, with the highest values of 5.18 and 11.28 g m⁻² day⁻¹ during 30-60 and 60-90 DAS, respectively, under 50% RDN through urea + 50% RDN through vermicompost, which remained statistically comparable with 75% RDN through urea + 25% RDN through vermicompost. The higher crop growth rate may be attributed to sustained nutrient availability, improved photosynthetic efficiency and continuous dry matter production under integrated nutrient management.

The number of effective root nodules was significantly enhanced by integrated nitrogen application and the highest number of effective nodules (21.41 plant⁻¹) at 60 DAS was recorded with 50% RDN through urea + 50% RDN through vermicompost, which remained statistically at par with 75% RDN through urea + 25% RDN through vermicompost. Vermicompost improved soil biological activity, root growth and rhizosphere conditions, thereby favouring *Rhizobium* multiplication and effective nodulation.

Biofertilizers

The experimental results revealed that seed inoculation with different bio-fertilizers significantly influenced the growth of fenugreek throughout the crop growth period. Among the bio-fertilizer treatments, inoculation with *Rhizobium* + NPK consortia recorded the highest values for plant height, dry matter accumulation, crop growth rate and effective root nodules. However, the treatment remained statistically at par with NPK consortia and both treatments significantly outperformed the uninoculated control.

Plant height was significantly influenced by bio-fertilizer inoculation and the highest plant height of 52.76, 78.57 and 85.09 cm at 60 DAS, 90 DAS and harvest, respectively, was recorded with *Rhizobium* + NPK consortia, which remained statistically at par with NPK consortia. The increase in plant height may be attributed to the synergistic action of *Rhizobium* and NPK consortia in improving nutrient availability and uptake. *Rhizobium* fixed atmospheric nitrogen through symbiotic association with fenugreek, while NPK consortia enhanced the availability of phosphorus and potassium by solubilizing insoluble nutrient complexes. The combined effect of enhanced nutrient supply and growth-promoting substances resulted in vigorous vegetative growth and taller plants. Similar findings were reported by Dwivedi and Gurjar (2023) [11].

A similar trend was observed for dry matter accumulation, where the highest dry matter accumulation of 4.95, 14.80 and 21.79 g plant⁻¹ at 60 DAS, 90 DAS and harvest, respectively, was recorded with *Rhizobium* + NPK consortia, which remained statistically at par with NPK consortia. The increase in dry matter accumulation at harvest under *Rhizobium* + NPK consortia and NPK consortia was 16.77 and 10.56 per cent, respectively, over the uninoculated control. The increased biomass production may be attributed to enhanced nitrogen fixation, improved solubilization of phosphorus and potassium and greater nutrient uptake by plants. The improved nutritional status promoted chlorophyll synthesis, photosynthetic activity and carbohydrate production, resulting in greater accumulation of photosynthates and biomass throughout the crop growth period. These findings are in close conformity with those reported by Kumar *et al.* (2021)^[12] and Kumari *et al.* (2022)^[13]

Crop growth rate was also significantly influenced by bio-fertilizer inoculation, with the highest values of 4.92, 11.05 and

9.66 g m⁻² day⁻¹ during 30-60 DAS, 60-90 DAS and 90 DAS to harvest, respectively, under *Rhizobium* + NPK consortia, which remained statistically at par with NPK consortia. The higher crop growth rate may be attributed to continuous nutrient availability, enhanced photosynthetic efficiency and efficient conversion of assimilates into plant biomass under bio-fertilizer inoculation. The combined activity of *Rhizobium* and NPK consortia also improved nutrient use efficiency, mineralization of organic residues and rhizosphere microbial activity, thereby sustaining rapid crop growth during vegetative and reproductive stages.

The number of effective root nodules was significantly enhanced by bio-fertilizer inoculation and the highest number of effective nodules (21.74 plant⁻¹) at 60 DAS was recorded with *Rhizobium* + NPK consortia, which remained statistically at par with NPK consortia (20.70 plant⁻¹). The improvement in nodulation may be attributed to enhanced root proliferation, increased development of lateral roots and root hairs and favourable rhizosphere conditions created by beneficial microorganisms.

Table 1: Effect of different levels of nitrogen and bio-fertilizers on plant height and dry matter accumulation of fenugreek

Treatments	Plant height (cm)				Dry matter accumulation (g plant ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Nitrogen								
Control	5.12	44.50	67.36	74.85	0.36	4.18	11.91	17.64
100% RDN	5.53	48.95	71.24	80.29	0.39	4.31	12.87	20.04
75% RDN (Urea) + 25% RDN (Vermicompost)	5.80	52.25	75.80	84.29	0.42	4.82	14.73	21.70
50% RDN (Urea) + 50% RDN (Vermicompost)	6.05	54.60	80.82	88.12	0.44	5.10	15.25	22.69
S.E.m.±	0.129	1.191	1.885	1.494	0.01	0.11	0.326	0.500
C.D. (P=0.05)	0.373	3.439	5.444	4.316	0.03	0.32	0.94	1.44
Bio-fertilizers								
Control	5.39	47.37	68.25	77.17	0.38	4.33	12.39	18.66
<i>Rhizobium</i>	5.53	48.97	72.76	80.45	0.40	4.57	13.30	20.63
NPK consortia	5.80	51.19	75.64	84.82	0.41	4.70	14.27	20.99
<i>Rhizobium</i> + NPK consortia	5.79	52.76	78.57	85.09	0.42	4.85	14.80	21.79
S.E.m.±	0.129	1.191	1.885	1.494	0.01	0.110	0.326	0.50
C.D. (P=0.05)	NS	3.439	5.444	4.316	NS	0.32	0.94	1.44

Table 2: Effect of different levels of nitrogen and bio-fertilizers on CGR, RGR and number of effective root nodules fenugreek

Treatments	CGR (g m ⁻² day ⁻¹)			RGR (g g ⁻¹ day ⁻¹)			Number of effective root nodules at 60 DAS
	30 -60 DAS	60-90 DAS	90 DAS - at harvest	30 - 60 DAS	60-90 DAS	90 DAS- at harvest	
Nitrogen							
Control	4.24	8.58	6.37	0.0811	0.0351	0.0129	17.31
100% RDN	4.34	9.51	7.97	0.0793	0.0361	0.0152	18.93
75% RDN (Urea) + 25% RDN (Vermicompost)	4.88	11.02	8.85	0.0812	0.0372	0.0144	20.50
50% RDN (Urea) + 50% RDN (Vermicompost)	5.18	11.28	7.16	0.0818	0.0364	0.0117	21.41
S.Em.±	0.12	0.39	0.68	0.0013	0.0013	0.0013	0.507
C.D. (P=0.05)	0.35	1.14	NS	NS	NS	NS	1.465
Bio-fertilizers							
Control	4.35	9.00	6.96	0.0807	0.0350	0.0139	17.34
<i>Rhizobium</i>	4.62	9.70	8.55	0.0807	0.0356	0.0152	18.37
NPK consortia	4.75	10.64	7.07	0.0805	0.0371	0.0122	20.70
<i>Rhizobium</i> + NPK consortia	4.92	11.05	7.77	0.0816	0.0371	0.0129	21.74
S.Em.±	0.12	0.39	0.68	0.0013	0.0013	0.0013	0.507
CD (P= 0.05)	0.35	1.14	NS	NS	NS	NS	1.465

Conclusion

The present investigation clearly demonstrated that integrated nitrogen management and bio-fertilizer inoculation significantly improved the growth performance of fenugreek. Application of 50% RDN through urea + 50% RDN through vermicompost proved to be the most effective nitrogen treatment, while seed inoculation with *Rhizobium* + NPK consortia recorded superior growth attributes. The improvement in plant height, dry matter accumulation, crop growth rate and effective nodulation may be attributed to balanced nutrient availability, enhanced biological nitrogen fixation, improved nutrient solubilization and favourable

soil microbial activity. Thus, integrated use of inorganic and organic nitrogen sources along with *Rhizobium* + NPK consortia can be considered an efficient nutrient management strategy for achieving better vegetative growth of fenugreek.

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