Plant Archives Vol. 26, No. 1, 2026 pp. 2402-2408 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.333

COMPARATIVE EFFECTS OF INORGANIC AND ORGANIC NUTRIENT SOURCES ON GROWTH DYNAMICS, PHENOLOGY AND YIELD PERFORMANCE OF FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.)

Anjali Dadhich[1], Y. A. Tamboli[1*], Ajeet Singh[1], R. K. Bansal[1], G. R. Chaudhary[2] and Ashwani Kumar Singh[3]

[1]Department of Agronomy, School of Agricultural Sciences, Jaipur National University, Jaipur-302017, Rajasthan, India.
[2]Department of Plant Pathology, School of Agricultural Sciences, Jaipur National University, Jaipur-302017, Rajasthan, India.
[3]Department of Plant Breeding and Genetics, School of Agricultural Sciences, Jaipur National University, Jaipur-302017, Rajasthan, India.
*Corresponding author Email: yasirajeej.tamboli@jnujaipur.ac.in

(Date of Receiving-12-02-2026; Date of Revision-04-04-2026; Date of Acceptance-17-04-2026)

ABSTRACT

A field experiment was conducted during *rabi* 2025-26 at Jaipur National University to study the effect of inorganic and organic nutrient sources on fenugreek using a factorial randomized block design with ten treatments and three replications. The study showed that inorganic nutrient sources had significantly influenced growth, phenology and yield attributes. Among the treatments, 125% RDF (N_3) recorded the highest plant height (59.93 cm), number of branches per plant (8.24), dry matter accumulation (27.63 g plant^{-1}), number of pods per plant (33.60), seeds per pod (17.37), seed yield per plant (7.84 g) and test weight (13.67 g). This treatment remained statistically at par with 100% RDF (N_2) and showed notable increases of 7.53%, 16.06%, 14.51%, 17.44%, 12.13%, 28.31% and 10.78% over N_2, respectively and 22.89%, 63.82%, 52.23%, 34.45%, 34.65%, 102.58% and 25.76% over 75% RDF (N_1), respectively. Similarly, under organic sources, growth and yield parameters were significantly improved with vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% (V_5) recording the maximum plant height (60.27 cm), number of branches plant^{-1} (8.27), dry matter accumulation (28.44 g plant^{-1}), number of pods plant^{-1} (31.74), seeds pod^{-1} (17.39), seed yield plant^{-1} (7.60 g) and 1000-seed weight (13.40 g). This treatment remained statistically at par with vermicompost @ 3 t ha^{-1} + vermiwash @ 7.5% (V_4), while showing marked superiority over control (V_1) with increases of 30.62%, 88.38%, 78.98%, 28.60%, 34.60%, 115.91% and 25.35%, respectively. Phenological development was delayed under N_3 and organic treatments due to enhanced vegetative growth and sustained nutrient release. Both organic and inorganic treatments did not significantly affect plant population at 20 DAS and at maturity. Thus, 125% RDF (N_3) and vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% (V_5) was most effective for improving growth and yield of fenugreek.

***Key words*:** Growth, Yield, Phenology. Inorganic Fertilizers, Organic Nutrients, Vermicompost, Vermiwash, RDF, Fenugreek.

Introduction

Fenugreek (*Trigonella foenum-graecum L.*) commonly known as methi, is an important *rabi* season legume and condiment crop grown widely in northern India for its nutritional, culinary and medicinal value. All plant parts like seeds, leaves and stemsare utilized, while the seeds are rich in protein, vitamins, essential oils and bioactive compounds like trigonelline, conferring antidiabetic, antioxidant and hypocholesterolemic properties. Owing to these qualities, fenugreek holds significant importance in both food and pharmaceutical industries (Kakani *et al.*, 2021). In India, fenugreek occupies about 1.47 lakh ha with a production of 2.26 lakh tonnes and an average productivity of 1534 kg ha?[1] (Anonymous, 2023). Rajasthan is the leading producer, contributing nearly 50% of the total area and about 33-

37% of national production with major cultivation in districts like Sikar, Jaipur and Chittorgarh (Anonymous, 2022; Kakani *et al*., 2021). Despite its importance, productivity remains constrained due to imbalanced nutrient management and declining soil fertility.

Fertilizer application plays a crucial role in improving crop growth and yield by supplying essential nutrients such as nitrogen, phosphorus and potassium. Nitrogen enhances vegetative growth and chlorophyll synthesis, phosphorus promotes root development and nodulation, while potassium improves yield attributes and quality (Tisdale *et al*., 1985; Besford and Maw, 1975). However, excessive reliance on chemical fertilizers has led to soil degradation, reduced organic matter and environmental concerns, ultimately affecting crop productivity.

Organic sources like vermicompost and vermiwash improve soil health, microbial activity and nutrient availability. Vermicompost enhances soil structure and nutrient status, while vermiwash improves plant growth and stress tolerance (Rajasooriya and Karunarathna, 2020; Shaka*et al*., 2023). Singh and Panghal (2022) reported significant increases in seed yield with vermicompost application, while Gurjar (2024) observed that integrated use of 100% RDF with vermicompost and vermiwash improved growth, yield and economic returns.Therefore, Integrated Nutrient Management (INM), combining inorganic fertilizers with organic sources, is essential for sustaining soil fertility, improving nutrient use efficiency and enhancing fenugreek productivity under semi-arid conditions.

Materials and Methods

The experiment was conducted at the Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan, India (26°85' N, 75°87' E; 390 m amsl). The site falls under Agro-climatic Zone IIIa (Semi-Arid Eastern Plain Zone) with a hot semi-arid climate, receiving about 527 mm annual rainfall, temperatures ranging from 5°C to 45°C, relative humidity of 20-80% and wind speeds of 5-15 km h^{-1} with occasional dust storms. During the *kharif*, temperatures ranged from 22.0°C to 43.1°C with sporadic rainfall.The soil was sandy loam (69.14% sand, 22.12% silt and 8.74% clay), slightly alkaline (pH 7.88), low in organic carbon (0.49%), medium in available nitrogen (149.60 kg ha^{-1}) and phosphorus (19.15 kg ha^{-1}) and high in potassium (188.45 kg ha^{-1}). The bulk density, particle density and porosity were 1.37 Mg m^{-3}, 2.63 Mg m^{-3} and 36.82%, respectively. Soil analysis was performed using standard methods (Piper, 1950; Black, 1950; Olsen *et al*., 1954; Richards, 1954; Subbaiah and Asija, 1956; Jackson, 1973).

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising two factors, namely inorganic and organic sources of nutrients. The inorganic nutrient levels consisted of three treatments, *viz*., N_1 (75% RDF), N_2 (100% RDF) and N_3 (125% RDF). The organic nutrient treatments included five levels, namely V_1 (control), V_2 (foliar spray of vermiwash @ 10%), V_3 (vermicompost @ 2t ha^{-1} + foliar spray of vermiwash @ 10%), V_4 (vermicompost @ 3 t ha^{-1} + foliar spray of vermiwash @ 7.5%) and V_3 (vermicompost @ 4 t ha^{-1} + foliar spray of vermiwash @ 5%). All recommended agronomic practices were followed uniformly for raising the crop. Observations on growth parameters were recorded from five randomly selected plants per plot. Plant population was estimated from a 1 m^2 area, while plant height and number of branches were measured using standard methods. Dry matter accumulation was determined by oven-drying samples at 65 ± 5°C to constant weight and crop and weed biomass were recorded using a 1.0 m^2 quadrat at two locations per plot. Phenological observations and yield attributes were recorded using standard procedures. Data were analyzed using ANOVA for a split-plot design at 5% significance ($P \leq 0.05$) and correlation coefficients (r) were computed as per Gomez and Gomez (1984).

Results and Discussion

Effect of Inorganic Sources of Nutrients

The results presented in Table 1 and 2 indicate that plant height, number of branches per plant and dry matter accumulation increased with increasing levels of inorganic fertilizers, whereas plant population of fenugreek was not significantly affected by different treatments. Plant height under 125% RDF (N_3) recorded 14.61, 35.97,

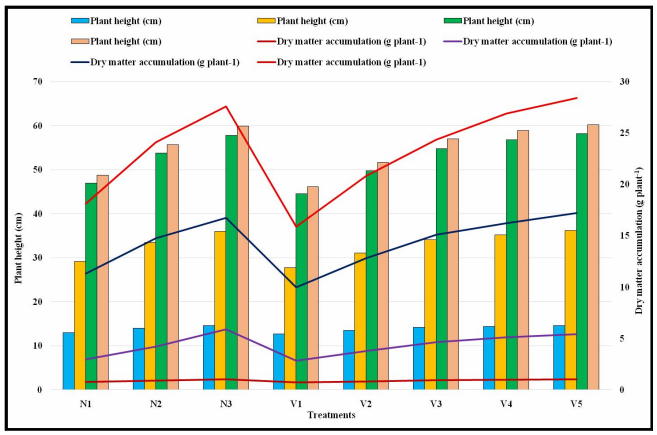

Fig. 1: Effect of inorganic and organic source of nutrients on plant height (cm) and dry matter accumulation (g $plant^{-1}$) of fenugreek.

Table 1: Effect of inorganic and organic source of nutrients on plant stand, plan height and number of branches plant^{-1} of fenugreek.

Treatments	PPP		PH				NBP	
	20 DAS	At Maturity	30 DAS	60 DAS	90 DAS	At Maturity	90 DAS	At harvest
Inorganic Source of Nutrients (N)								
N_1- 75% RDF	386.11	382.63	12.97	29.19	46.95	48.77	4.11	5.03
N_2- 100% RDF	387.80	384.91	14.03	33.47	53.79	55.73	5.74	7.10
N_3- 125% RDF	395.27	392.63	14.61	35.97	57.81	59.93	6.73	8.24
SEm±	2.51	2.58	0.35	0.63	0.96	1.29	0.31	0.42
C.D (p=0.05)	NS	NS	1.21	2.17	3.34	4.45	1.07	1.44
Organic Source of Nutrients (V)								
V_1: Control (Water spray)	389.17	385.48	12.67	27.79	44.53	46.14	3.71	4.39
V_2: Foliar spray @ 10% Vermiwash	388.39	385.46	13.49	31.09	49.81	51.71	4.87	5.92
V_3: Vermicompost 2 t ha^{-1} + Foliar spray @ 10% Vermiwash	389.08	386.07	14.16	34.12	54.83	57.02	5.98	7.36
V_4: Vermicompost 3 t ha^{-1} + Foliar spray @ 7.5% Vermiwash	390.49	387.62	14.40	35.23	56.84	58.91	6.31	8.01
V_5: Vermicompost 4 t ha^{-1} + Foliar spray @ 5.0% Vermiwash	391.50	389.00	14.62	36.16	58.23	60.27	6.77	8.27
SEm±	0.80	0.89	0.21	0.56	0.52	0.64	0.18	0.13
C.D (p=0.05)	NS	NS	0.61	1.67	1.54	1.90	0.54	0.38

PPP: Plant population plot^{-1}; PH: Plant height (cm); NBP: Number of branches plant^{-1}

57.81 and 59.93 cm at 30, 60, 90 DAS and maturity, respectively showing increases of 4.13%, 7.47%, 7.47% and 7.53% over 100% RDF (N_2) and 12.64%, 23.24%, 23.13% and 22.89% over 75% RDF (N_1), respectively; however, 125% RDF (N_3) remained statistically at par with N_2, indicating marginal response beyond the recommended dose. Similarly, number of branches per plant was significantly higher under 125% RDF (N_3), recording 6.73 at 90 DAS and 8.24 at harvest, which was 17.25% and 16.06% higher than N_2 (5.74 and 7.10) and 63.75% and 63.82% higher than N_1 (4.11 and 5.03), respectively, though it remained statistically at par with N_2. Dry matter accumulation also followed a similar trend with 125% RDF (N_3) recording 1.02, 5.89, 16.75 and 27.63 g plant^{-1} at 30, 60, 90 DAS and maturity, respectively, showing increases of 12.09%, 39.24%, 13.25% and 14.51% over N_2 and 32.47%, 98.32%, 48.10% and 52.23% over N_1, respectively. The improvement in growth parameters under higher fertilizer levels may be attributed to enhanced nutrient availability, which promotes cell division, elongation, chlorophyll formation, photosynthesis and efficient translocation of assimilates. Statistical parity between N_3 and N_2 indicates that 100% RDF is optimum, as higher levels give diminishing returns (Fig. 1).

The data in Table 2 indicated that days to 50% flowering and physiological maturity were significantly influenced by inorganic nutrient levels. The maximum days to 50% flowering (53.50 days) and maturity (121.71 days) were recorded under 125% RDF (N_3), which was significantly higher than N_2 and N_1, indicating delayed flowering and maturity with increasing nutrient levels, likely due to enhanced vegetative growth and prolonged crop duration.

The data in Table 3 and Fig. 2 indicated that yield attributes of fenugreek were significantly influenced by inorganic source of nutrient. Application of 125% RDF (N_3) recording the highest number of pods per plant (33.60), seeds per pod (17.37), seed yield per plant (7.84 g) and test weight (13.67 g), showing increases of 17.44%, 12.13%, 28.31% and 10.78% over N_2 and 34.45%, 34.65%, 102.58% and 25.76% over N_1, respectively. The improvement in yield attributes under higher fertilizer levels may be due to enhanced nutrient availability, leading to better growth, photosynthesis and assimilate partitioning towards reproductive parts. However, the smaller gains over 100% RDF compared

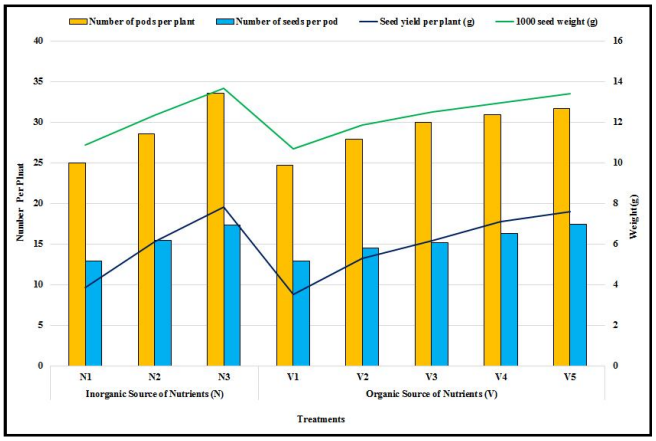

Fig. 2: Effect of inorganic and organic source of nutrients on yield attributes of fenugreek

Table 2: Effect of inorganic and organic source of nutrients on dry matter accumulation (g plant^{-1}) and phenological parameters of fenugreek.

Treatments	DMA				PP	
	30 DAS	60 DAS	90 DAS	At Maturity	Days taken to 50 % flowering	Days taken to physiological maturity
Inorganic Source of Nutrients (N)						
N_1- 75% RDF	0.77	2.97	11.31	18.15	48.50	111.11
N_2- 100% RDF	0.91	4.23	14.79	24.13	51.07	116.04
N_3- 125% RDF	1.02	5.89	16.75	27.63	53.50	121.71
SEm±	0.04	0.56	0.58	1.09	0.95	1.95
C.D (p=0.05)	0.12	1.93	1.99	3.77	3.28	6.76
Organic Source of Nutrients (V)						
V_1: Control (Water spray)	0.74	2.84	9.99	15.89	50.00	114.19
V_2: Foliar spray @ 10% Vermiwash	0.83	3.79	12.83	20.86	50.39	115.14
V_3: Vermicompost 2 t ha^{-1} + Foliar spray @ 10% Vermiwash	0.94	4.66	15.13	24.39	51.00	116.03
V_4: Vermicompost 3 t ha^{-1} + Foliar spray @ 7.5% Vermiwash	0.98	5.10	16.23	26.94	51.50	117.02
V_5: Vermicompost 4 t ha^{-1} + Foliar spray @ 5.0% Vermiwash	1.01	5.42	17.24	28.44	52.22	119.06
SEm±	0.01	0.11	0.35	0.51	0.39	0.71
C.D (p=0.05)	0.03	0.33	1.04	1.52	1.15	2.10

DMA: Dry matter accumulation (g plant^{-1}); PP: Phenological parameters

to 75% RDF indicate near-optimal nutrient requirement at the recommended dose with diminishing returns beyond this level. These results corroborate earlier findings reported by Raghuwanshi *et al.*, (2016), Ratur *et al.*, (2019), Rajasooriya and Karunarathna (2020), Kumar *et al.*, (2021), Singh and Panghal (2022), Patel *et al.*, (2022), Kumari *et al.*, (2022), Singh and Panghal (2022), Shaka *et al.*, (2023) and Gurjar (2024).

Effect of Organic Sources of Nutrients

A perusal of the data in Table 1 and 2 revealed that plant height, number of branches per plant and dry matter accumulation increased significantly with growth stages with vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% (V_5) recording the highest plant height (14.62, 36.16, 58.23 and 60.27 cm at 30, 60, 90 DAS and maturity), number of branches (6.77 at 90 DAS and 8.27 at harvest) and dry matter (1.01, 5.42, 17.24 and 28.44 g plant^{-1}), remaining at par with vermicompost @ 3 t ha^{-1} + vermiwash @ 7.5% (V4) and vermicompost @ 2 t ha^{-1} + vermiwash @ 10% (V_3) but superior over vermiwash @ 10% (V_2) and control (V_1). Plant population was not significantly affected. The results clearly indicate that higher levels of vermicompost combined with vermiwash (V_5 and V_4) significantly improved growth parameters due to sustained nutrient release, improved soil physical properties, enhanced microbial activity and better nutrient uptake. However, the consistent statistical parity between V5 and V_4 suggests that beyond a certain optimum level, additional organic inputs result in marginal gains, indicating higher efficiency at moderate integrated organic nutrient levels (Fig. 1).

Similarly, among organic nutrient sources, vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% (V_5) recorded the maximum days to 50% flowering (52.22 days) and physiological maturity (119.06 days), remaining at par with vermicompost @ 3 t ha^{-1} + vermiwash @ 7.5% (V_4) and vermicompost @ 2 t ha^{-1} + vermiwash @ 10% (V_3) but significantly higher than vermiwash @ 10% (V_2) and control (V_1) with increases of 0.72-2.22 days for flowering and 2.04-4.87 days for maturity. The results indicate that higher organic nutrient levels delayed flowering and maturity due to enhanced vegetative growth, sustained nutrient release and prolonged crop growth duration.

The data in Table 3 and Fig. 2 indicated that yield attributes of fenugreek were significantly influenced by organic nutrient sources, with vermicompost @ 4 t ha^{-1} + vermiwash @ 5% (V_5) recording the highest number of pods per plant (31.74), seeds per pod (17.39), seed yield per plant (7.60 g) and test weight (13.40 g). It showed increases of 13.64% and 28.60%, 14.71%, 19.60% and 34.60%, 23.18%, 43.40% and 115.91% and 7.03%, 12.89% and 25.35% over V_3, V_2 and V_1, respectively, while remaining statistically at par with vermicompost @ 3 t ha^{-1} + vermiwash @ 7.5% (V_4). The improvement in yield attributes under V_5 and V_4 may be attributed to sustained nutrient release from vermicompost, improved

Table 3: Effect of inorganic and organic source of nutrients on yield attributes of fenugreek.

Treatments	Yield attributes			
	Number of pods per plant	No. of seeds per pod	Seed yield per plant (g)	1000 seed weight (g)
Inorganic Source of Nutrients (N)				
N_1- 75% RDF	24.99	12.90	3.87	10.87
N_2- 100% RDF	28.61	15.49	6.11	12.34
N_3- 125% RDF	33.60	17.37	7.84	13.67
SEm±	1.49	0.95	0.58	0.59
C.D (p=0.05)	5.16	3.28	2.01	2.03
Organic Source of Nutrients (V)				
V_1: Control (Water spray)	24.68	12.92	3.52	10.69
V_2: Foliar spray @ 10% Vermiwash	27.93	14.54	5.30	11.87
V_3: Vermicompost 2 t ha^{-1} + Foliar spray @ 10% Vermiwash	30.01	15.16	6.17	12.52
V_4: Vermicompost 3 t ha^{-1} + Foliar spray @ 7.5% Vermiwash	30.96	16.26	7.11	12.98
V_5: Vermicompost 4 t ha^{-1} + Foliar spray @ 5.0% Vermiwash	31.74	17.39	7.60	13.40
SEm±	0.38	0.38	0.19	0.28
C.D (p=0.05)	1.13	1.14	0.57	0.83

soil structure, enhanced microbial activity and better nutrient uptake, which together promoted better flowering, pod formation, seed development and assimilate partitioning towards reproductive sinks. The integrated organic nutrient management improved yield attributes due to sustained nutrient release, enhanced soil biological activity, improved physiological efficiency and better assimilate partitioning towards reproductive structures.

Table 4: Interaction effect between inorganic (N) and organic (V) sources of nutrients on growth parameters.

Treatments	PH	PHH	NB	DM	DMH
N_1V_1	43.07	44.60	3.87	9.23	14.33
N_1V_2	43.97	45.57	4.23	10.23	15.57
N_1V_3	47.83	49.83	5.30	11.67	18.83
N_1V_4	49.53	51.23	5.67	12.33	20.33
N_1V_5	50.33	52.60	6.07	13.10	21.67
N_2V_1	44.67	46.23	4.50	10.40	16.17
N_2V_2	51.73	53.80	6.50	13.67	22.67
N_2V_3	55.83	58.03	7.53	15.57	25.33
N_2V_4	57.83	60.00	8.20	16.77	27.83
N_2V_5	58.90	60.60	8.77	17.57	28.67
N_3V_1	45.87	47.60	4.80	10.33	17.17
N_3V_2	53.73	55.77	7.03	14.60	24.33
N_3V_3	60.83	63.20	9.23	18.17	29.00
N_3V_4	63.17	65.50	10.17	19.60	32.67
N_3V_5	65.47	67.60	9.97	21.07	35.00
SEm±	1.16	1.43	0.29	0.78	1.14
CD (p=0.05)	3.45	4.24	0.85	2.32	3.39

PH: Plant height 90 DAS at (cm); PHH: Plant height at harvest (cm), NB: Number of branches/plants; DM: Dry matter at 90 DAS (g/plant); DMH: Dry matter at harvest (g/plant)

These results corroborate earlier findings reported by Lunagariya *et al.,* (2018), Ratur *et al.,* (2019), Sahu *et al.,* (2020), Kumar *et al.,* (2021), Muwal *et al.,* (2022), Singh and Panghal (2022), Patel *et al.,* (2022), Kumari *et al.,* (2022), Singh and Panghal (2022) and Gurjar (2024).

Interaction Effect

The data in Table 4 revealed that the interaction between inorganic and organic nutrient sources significantly influenced all growth parameters, indicating a synergistic effect. The maximum plant height at 90 DAS (65.47 cm) and harvest (67.60 cm) and dry matter (21.07 and 35.00 g $plant^{-1}$) were recorded under N_3V_5, remaining at par with N_3V_4. The highest number of branches per plant (10.17) was observed under N_3V_4 at par with N_3V_5, indicating an optimum response and plateau at higher nutrient levels. These findings are in agreement with previous reports by Raghuwanshi *et al.,* (2016), Singh and Panghal (2022), Gurjar *et al.,* (2023), Gurjar (2024) and Prashar *et al.,* (2025).

Conclusion

In light of the results obtained from the present study, it can be concluded that, inorganic and organic nutrient treatments significantly enhanced growth and yield of fenugreek. Among inorganic sources, 125% RDF recorded highest values but remained at par with 100% RDF. Whereas, among the organic sources, vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% performed best and was at par with vermicompost @ 3 t ha^{-1} + vermiwash @ 7.5%. Thus, 125% RDF + vermicompost @ 4 t ha^{-1} + vermiwash @ 5.0% is most effective for maximum productivity, while 100% RDF + Vermicompost 3 t ha^{-1} +

Foliar spray @ 7.5% Vermiwash is a more economical and efficient option under Jaipur agro-climatic conditions.

Recommendation

Adopt balanced fertilization with 125% RDF along with integrated use of vermicompost at 4 t ha^{-1} and vermiwash at 5.0% foliar spray to improve soil fertility and enhance availability of N, P, K and micronutrients, thereby promoting sustainable fenugreek production through efficient nutrient management and maintenance of soil health. It is also recommended to repeat similar experiments over multiple years and in different agro-climatic zones to develop consistent, location-specific recommendations for wider applicability.

Acknowledgement

I sincerely thank the School of Agricultural Sciences, Jaipur National University, Jaipur for providing necessary facilities. I am grateful to my supervisor for guidance and support and to all staff and colleagues for their help in completing this research.

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