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Subsistence of soil through organic amelioration to enhance the growth, herbage yield and quality of Fenugreek (*Trigonella foenum graecum* L.)

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Abstract

Trigonella foenum-graecum commonly called fenugreek is an important minor spice belonging to the family Fabaceae (Leguminosae). Its seeds serve as a condiment to flavor food, while its leaves are commonly used as a vegetable. Given the widespread culinary use of fenugreek leaves, enhancing herbage yield and optimizing organic inputs for leaf production is essential. A study was conducted at the Department of Spices and Plantation Crops, HC and RI, TNAU, Periyakulam, to investigate the impact of organic manures and bio-stimulants on the growth, yield of herbage and quality of fenugreek. The results demonstrated that the combination of 25% nitrogen (N) from farmyard manure (FYM), 75% N from vermicompost and Panchagavya (3%) as a foliar spray significantly improved various growth parameters. Specifically, this treatment improved plant height (30.38 cm), the number of leaves branch^{-1} (9.42), the number of branches plant^{-1} (9.34) and herbage yield metrics, including yield plant^{-1} (2.85 g), yield plot^{-1} (2*2 m) (3.39 kg) and estimated herbage yield (16.95 tons ha^{-1}) when compared to the control. Additionally, this treatment enhanced leaf quality by recording the highest contents of carbohydrate (6.63%), fiber (3.31%), iron (35.67 mg 100 g^{-1}), calcium (178.36 mg 100 g^{-1}) and protein (25.17 g 100 g^{-1}). Therefore, the application of vermicompost with FYM and Panchagavya is more effective for achieving maximum growth and yield levels compared to using these inputs individually.

Keywords

bio-stimulants; herbage; fenugreek; organic nutrients; panchagavya; vermicompost

Introduction

Fenugreek (*Trigonella foenum-graecum* L.), commonly known as Methi, is a member of the family Fabaceae. It is predominantly cultivated in northern India during the rabi season. This plant is valued for its seeds and leaves, both of which are used for culinary and medicinal purposes. Fenugreek seeds are known for their distinctive flavor and are used as a spice in various cuisines, while the leaves are often used as a herb. Additionally, fenugreek has several health benefits and is used in traditional medicine for its potential to help manage blood sugar levels, enhance digestion and improve milk production in lactating mothers. Major fenugreek-producing states include Rajasthan, Madhya Pradesh, Gujarat, Uttar Pradesh, Maharashtra and Punjab. Fenugreek

is widely used in various forms: as fresh leaves, chopped leaves, seeds, extracts and powders. These are valued for their vitamins (thiamin, riboflavin, niacin, vitamins A, B_6 and C (1). Medicinal phytochemicals such as steroidal sapogenins (diosgenin, tigogenin, yamogenin), galactomannans, dihydroxysapogenins (gitogenin), triterpenoids, alkaloids, spirostanol saponins (graecunin), flavonoids and amino acids like 4-hydroxy-isoleucine are also present in fenugreek (2). Galactomannan aids in reducing glucose absorption, thus helping manage blood glucose levels in diabetic patients (3). Similarly, isoleucine regulates insulin release from pancreatic cells (4). Steroidal sapogenins are precursors for synthetic sex steroids and are utilized in treating hypercholesterolemia. With its high fiber content, fenugreek can also act as a food stabilizing, emulsifying and adhesive agent to modify food texture (5).

The increasing therapeutic demand for fenugreek has led to a higher need for its seeds and leaves. However, the overuse of agrochemicals has caused soil degradation, groundwater contamination and environmental pollution. Therefore, organic farming practices are gaining importance for sustainable food production. Studies have shown that the organic nutrients can improve the vegetative growth and as well as yield of seed spices like coriander (6) and fennel (7). Recent agricultural trends emphasize reducing inorganic fertilizer use by incorporating organic manures and biofertilizers (8, 9).

Organic sources are crucial for enhancing the biological, chemical, and physical properties of the soil, benefiting yields, economic applications and environmental protection. Nitrogen, an essential element for plants, when combined with carbon, oxygen, hydrogen and sulfur, forms vital molecules like amino acids, nucleic acids and alkaloids. Inadequate nitrogen can lead to various growth issues in plants (10).

Since fenugreek is cultivated for its green leaves, nitrogen is vital for growth, yield and quality. The availability of nitrogen throughout the crop growth period is essential. To enhance fenugreek herbage yields, soil fertility should be improved using organic manures or biologically active amendments. Common organic amendments include FYM (farmyard manure), vermicompost, poultry manure, oil cake, biofertilizers and indigenous preparations like panchgavya and jeevamrita. However, there is no standardized organic practice for maximizing leaf yield in fenugreek cultivation, highlighting the need for further research.

Research indicates that integrating biofertilizers and vermicompost biofertilizers in fenugreek cultivation can be more economical, efficient and judicious compared to using chemical fertilizers alone (11, 12). Given fenugreek's significance in culinary uses, optimizing herbage yield through organic manures and bio-stimulants is crucial. Therefore, this study aims to evaluate the impact of different bio-stimulants and organic manures on fenugreek growth, leaf yield and quality.

Materials and Methods

A field study was conducted at Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, Tamil Nadu during the year 2022-23. The purpose of the experiment was to investigate the impact of various organic manures (biocompost - sugar mill pressmud, FYM, neem cake, vermicompost) and biostimulants (Panchagavya and humic acid) on the growth and herbage yield of fenugreek var. CO 2. The field is located at 10˚12' North latitude and 77˚58' East longitude, with an altitude of 356 m above Mean Sea Level. The soil in the experimental field is classified as red sandy loam, with a pH of 7.3. Each plot in the experiment measured 2*2 m, with a plant spacing of 10 × 15 cm and a total of 266 plants per plot. The initial nutrient content of the soil was 175:17:312 kg NPK/ha. The cultural practices for fenugreek cultivation were carried out according to the guidelines provided in the Horticultural Crop Production Manual (13). The experiment was laid out in a randomized block design, with nine different combinations of organic manure and bio stimulants, each replicated three times. Nutrient composition of utilized organic manures are shown in Table 1. The details of the treatments are specified as: T_1- 75% N as FYM + 25% N as Vermicompost + 3% Panchagavya; T_2- 50% N as FYM +50% N as Vermicompost + 3% Panchagavya; T_3- 25% N as FYM+ 75% N as Vermicompost + 3% Panchagavya; T_4- 50% N as FYM + 25% N as Vermicompost + 25% N as Biocompost + 3% Panchagavya; T_5- 50% N as FYM + 25% N as Vermicompost + 25% N as Neem cake + 3% Panchagavya; T_6- 50% N as FYM + 25% N as Vermicompost + 25% N as Biocompost + Humic acid (0.5%); T_7- 50% N as FYM + 25% N as Vermicompost + 25% N as Neem cake + Humic acid (0.5%); T_8- 25% N as FYM + 25% N as Vermicompost + 25% N as Biocompost +25% N as Neem cake +3% Panchagavya + Humic acid (0.5%) and T_9- FYM (25 t/ha) + 50:25:40 NPK kg/ha (RDF).

Table 1. Nutrient composition of utilized organic manures

Nutrient	Farmyard manure	Vermicompost	Neem cake	Bio-compost (Sugar mill pressmud)
Organic carbon (%)	5.10	9.50	1.20	32.60
N (%)	0.50	2.00	5.20	1.00
P_2O_5 (%)	0.20	0.31	0.98	1.15
K_2O (%)	0.57	0.52	2.30	0.62

Panchagavya consists of nine ingredients *viz*. cow dung (7 kg), cow urine (10 L), milk (3 L), curd (2 L), jaggery (3 kg), ghee (1 kg), well ripened poovan banana (12 nos.), tender coconut water (3 L) and water (10 L). Mixed cow dung and cow ghee thoroughly both in morning and evening hours and kept it for 3 days. After 3 days mixed cow urine and water and kept it for 15 days with regular mixing both in morning and evening hours. After 15 days mixed the cow milk, cow curd, tender coconut water, jaggery and well ripened poovan banana and panchagavya was ready after 30 days. The Physico chemical and biological properties of Panchagavya was shown in Table 2.

Table 2. Physico chemical and biological properties of Panchagavya

Chemical composition		
pH	:	5.45
EC (dSm^2)	:	10.22
Total N (ppm)	:	229.00
Total P (ppm)	:	209.00
Total K (ppm)	:	232.00
Sodium	:	90.00
Calcium	:	25.00
IAA (ppm)	:	8.50
GA (ppm)	:	3.50

Microbial Load		
Fungi	:	38800 mL^{-1}
Bacteria	:	1880000 mL^{-1}
Lactobacillus	:	2260000 mL^{-1}
Total anaerobes	:	10000 mL^{-1}
Acid formers	:	360 mL^{-1}
Methanogen	:	250 mL^{-1}

Organic manures (farmyard manure, neem cake, vermicompost) and biocompost were applied before sowing as per the treatment schedule. The bio-stimulants *viz*., Panchagavya (3%) was given as foliar spray 20 days after sowing. Through soil application Humic acid (0.5%) was applied. Drip irrigation was given once in three days. Morphological parameters such as plant height (cm), number of branches $plant^{-1}$, number of leaves $branch^{-1}$ and herbage yield $plant^{-1}$ (g) were recorded at the time of harvest. In every treatment, randomly 5 plants $replication^{-1}$ were selected and utilized for recording observations on the above characters. The quality parameters like carbohydrate, fibre, iron, calcium and protein were analysed in the laboratory. The Bradford protocol (14) was used to determine protein amount in leaf. The calcium content of the leaves was analysed using the triple acid extract by the Versenate method (15). The total amount of carbohydrate present in the leaf was analysed as per the Anthrone method (16). The iron content of leaves was estimated by colorimetric iron determination method (17). Fiber content was estimated by the method proposed by (18). Each treatment's net returns were calculated by deducting the total cost of cultivation from the gross return. By dividing gross returns with cost of cultivation the Benefit Cost Ratio (BCR) was calculated.

The data was calculated at 5% level of significance and analysed using the R studio programme (Version: 2024.04.1+748). The mean values of treatments under each factor were compared using Duncan's multiple range test (DMRT) and have been represented as Mean ± Standard Deviation.

Results and Discussion

Growth attributing characters

A significant variation in growth attributes of fenugreek to foliar spray of bio stimulants and organic nutritional treatments was observed (Table 3). The plants treated with a nutrient combination of 25% N as FYM, 75% N as Vermicompost along with 3% Panchagavya foliar spray (T_3) achieved a maximum plant height of 30.38 cm (Fig. 1). Using organic manures and bio stimulants in tandem produced a beneficial effect on plant height at harvest time. Improved soil physical conditions, such as enhanced particle density, water-holding capacity, texture, pore spaces and soil-available nutrient status, may cause the rise in plant height (19). Organic amendments such as vermicompost and vermiwash promote humification, increased microbial activity and enzyme production, which, in turn, improve aggregate stability of soil particles, resulting in better aeration. They also have the ability to bind mineral particles such as magnesium, calcium and potassium in the form of colloids of humus and clay, which facilitates the stable aggregates of soil particles for desired porosity to sustain the plant growth (20). The maximum plant height may be related to enhanced cell division and elongation, as panchagavya can create growth regulators such as Auxin and Cytokinin (21). Plants treated with vermicompost and FYM grew the tallest, as described in Isabgol (22) and Mint (23).

A greater number of branches $plant^{-1}$ (9.43) and number of leaves $branch^{-1}$ (9.42) was recorded in the plants that received 25% N as FYM + 75% N as Vermicompost + 3% Panchagavya as foliar spray (T_3). The rise in the number of shoots and leaves could be linked to the existence of cytokinins, auxins and gibberellins like substances found in the combined use of foliar spray of panchagavya and organic manure. This combination would activate cell

Table 3. Impact of organic nutrients on the plant growth parameters (plant height, number of branches, number of leaves) of Fenugreek var. CO 2

Treatments	Plant height (cm)	No. of branches/plant	No. of leaves/ branch
T_1	$24.810^{b} \pm 1.056$	$7.943^{ab} \pm 0.607$	$6.863^{bc} \pm 0.083$
T_2	$26.450^{a} \pm 1.098$	$8.190^{ab} \pm 0.558$	$7.207^{b} \pm 0.110$
T_3	30.383 ± 0.825	9.343 ± 0.508	9.420 ± 0.267
T_4	$20.317^{d} \pm 1.566$	$8.177^{ab} \pm 0.337$	$7.073^{b} \pm 0.189$
T_5	$22.407^{c} \pm 0.853$	$8.550^{a} \pm 0.070$	$5.787^{d} \pm 0.205$
T_6	$22.383^{c} \pm 0.623$	$7.010^{c} \pm 0.135$	$6.493^{c} \pm 0.146$
T_7	$20.507^{d} \pm 0.709$	$5.180^{d} \pm 0.495$	$5.347^{e} \pm 0.101$
T_8	$20.047^{d} \pm 1.199$	$7.103^{c} \pm 0.448$	$8.843^{a} \pm 0.483$
T_9	$20.677^{d} \pm 0.647$	$7.627^{bc} \pm 0.245$	$5.837^{d} \pm 0.239$
SE(m)±	0.665	0.158	0.047
C.D. at 0.05	1.412	0.688	0.374

Values in columns followed by the same letter are not significantly different, $P<0.05$, Duncan's multiple range test

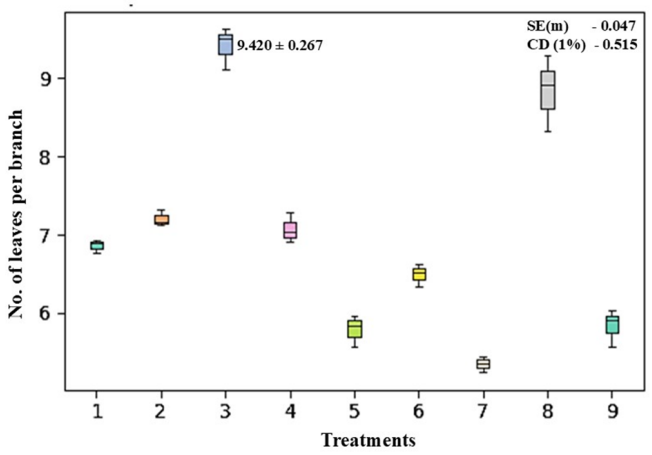

Fig. 1. Impact of organic sources on number of leaves per branch of Fenugreek var. CO2.

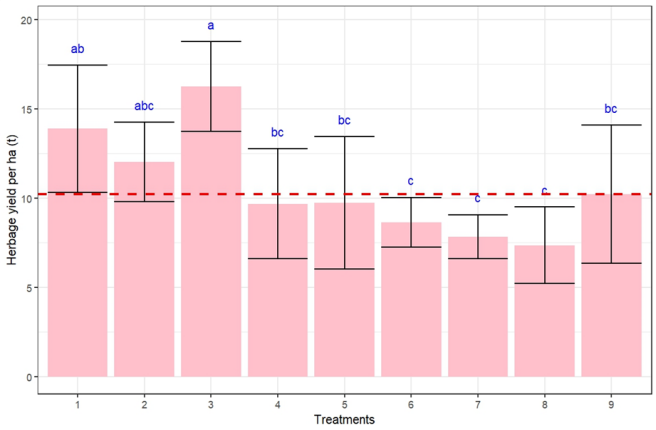

Fig.3. Effect of different organic nutrients on herbage yield of Fenugreek.

Different letters indicate significant differences at P<0.05 according to the LSD test

division and cell elongation in the axillary buds, resulting in the production of more shoots and an increase in the number of leaves in fenugreek, as observed in curry leaf (24) and Palak (25). In this current study, a foliar spray of panchagavya (3%) in combination with the use of FYM and vermicompost led to an improvement in growth parameters. This may be attributed to the presence of an optimal C: N ratio, upon which decomposition, releases usable nutrient ions like ammonium. Increase in the soil mineral constituents may have contributed to better growth parameters, as nitrogen is the primary component of amino acids and coenzymes of biological significance (26). These findings are consistent with the results of various researchers in curry leaf (27) and mint (28).

Yield and related parameters

Major yield components in fenugreek are leaves. The highest herbage yield of 6.10 g plant^{-1} was recorded in the plants raised in the soil supplemented with 25% N as FYM + 75% N as Vermicompost + 3% Panchagavya as foliar spray (T_3). Highest fresh herbage yield of 6.49 kg plot^{-1} (2*2 m) was recorded in the plants fed with 25% N as FYM + 75% N as Vermicompost + Panchagavya (3%) as foliar spray (T_3) (Fig. 2). The highest estimated herbage yield of 16.24 tons hectare^{-1} was recorded in the plants raised in the soil supplemented with 25% N as FYM + 75% N as Vermicompost along with Panchagavya (3%) as foliar spray (T_3) (Fig. 3). The higher leaf yield could be attributed to the presence of growth-promoting hormones. This outcome aligns with the research of palak and amaranthus (29), who suggested that the use of organic materials led to improved plant growth and increased yields through the gradual release of nutrients for absorption, along with the production of plant growth-promoting substances such as gibberellin, cytokinin and auxins. The rise in herbage production due to the addition of FYM appears to be a result of enhanced photosynthetic efficiency and the greater development of vegetative structures. These results are consistent with the findings reported in previous studies (30, 31).

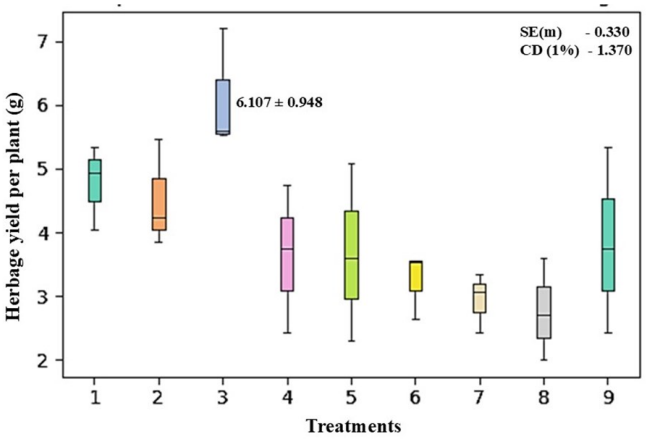

Fig. 2. Influence of organic nutrients on herbage yield per plant of Fenugreek var. CO 2 .

The BCR was the highest (2.41) in T_3*i.e.*, application of 25% N as FYM + 75% N as Vermicompost + Panchagavya (3%) as foliar spray followed by T_1 (75% N as FYM + 25% N as Vermicompost + 3% Panchagavya) (2.10) (Table 4). The increase in BCR may be linked to the cost-effectiveness of organic manure (Vermicompost and FYM) and the superior quality of the resulting products. The application of organic manures demonstrated a higher benefit: cost ratio, with advantages observed in terms of enhanced quality and nutritional value. Organic manures have the potential to deliver comparable yields while improving quality attributes (32). Furthermore, (33) highlighted the higher net returns and benefit cost ratio associated with organic manure application.

Quality characters

A significant treatmental difference was observed among various treatments on biochemical contents of fenugreek leaf (Table 5 and 6). Highest leaf carbohydrate of 7.01%was recorded in the plants fed with 25% N as FYM + 75% N as Vermicompost + Panchagavya (3%) as foliar spray (T_3). The enhancement of total carbohydrate content in plants receiving treatment with organic manure and panchagavya may be associated with the growth of root surface area, greater water-use efficiency, and improved photosynthetic activity. These factors significantly impact physiological processes and the effective use of carbohydrates. These results corroborate earlier findings related to anise, coriander and sweet fennel (34) as well as those concerning *Thymus vulgaris* (35). Application of 25% N as FYM + 75% N as Vermicompost + Panchagavya (3%) as foliar spray recorded the highest calcium content (178.30 mg 100 g^{1}) and iron content (36.30 mg 100 g^{-1}) in fenugreek leaves. The combination of organic manure application and foliar

Table 4. Herbage yield and benefit: cost ratio of different treatments of organic cultivation of Fenugreek var. CO 2

Treatments	Herbage yield (g plant^{-1})	Herbage yield (Kg plot^{-1}) (2*2 m)	Herbage yield (tons hectare^{-1})	BCR
T_1	4.773^{a} ± 0.666	5.553^{ab} ±1.423	13.88	2.10
T_2	4.520^{ab} ± 0.836	4.810^{bc} ± 0.889	12.02	1.83
T_3	6.107 ± 0.948	6.497^{a} ± 1.008	16.24	2.41
T_4	3.640^{bc} ± 1.153	3.873^{cd} ±1.223	9.68	1.41
T_5	3.660^{bc} ± 1.391	3.897^{cd} ±1.481	9.74	1.44
T_6	3.247^{c} ± 0.525	3.457^{cd} ±0.560	8.64	1.39
T_7	2.947^{c} ± 0.461	3.137^{d} ±0.487	7.84	1.38
T_8	2.767^{c} ± 0.802	2.943^{d} ±0.852	7.36	1.35
T_9	3.840^{abc} ±1.453	4.087^{cd} ±1.543	10.21	1.78
SE(m)±	0.330	0.574	-	-
C.D. at 0.05	0.994	1.311	-	-

Values in columns followed by the same letter are not significantly different, *P*<0.05, Duncan's multiple range test

Table 5. Effect of organic inputs on carbohydrate, fibre and iron content of Fenugreek leaves

Treatments	Carbohydrate content (%)	Fibre content (%)	Iron Content (mg 100 g^{-1})
T_1	4.673^{c} ± 0.595	2.467^{c} ± 0.325	35.087^{ab} ±0.657
T_2	5.743^{ab} ±0.354	3.117^{ab} ±0.176	33.517^{c} ±0.618
T_3	7.010 ± 0.510	3.387^{a} ± 0.291	36.300^{a} ±0.556
T_4	5.407^{abc} ±0.560	2.753^{bc} ±0.340	34.030^{bc} ±0.509
T_5	5.947^{a} ± 0.578	2.943^{b} ± 0.296	33.330^{c} ±1.232
T_6	5.207^{abc} ±0.578	3.083^{ab} ±0.254	34.153^{bc} ±0.520
T_7	5.217^{abc} ±0.268	3.053^{ab} ±0.194	33.353^{c} ±0.457
T_8	4.663^{c} ±0.503	3.027^{ab} ±0.214	33.153^{cd} ±1.105
T_9	4.843^{bc} ±0.662	2.990^{b} ± 0.140	31.777^{d} ±0.478
SE(m)±	0.262	0.039	0.528
C.D. at 0.05	0.887	0.343	1.258

Values in columns followed by the same letter are not significantly different, *P*<0.05, Duncan's multiple range test

Table 6. Effect of organic inputs on calcium and protein content of Fenugreek leaves

Treatments	Calcium content (mg 100 g^{-1})	Protein content (g 100 g^{-1})	Ascorbic acid (mg 100 g^{-1})
T_1	177.153^{ab} ±0.627	21.790^{d} ±0.533	217.803^{a} ±0.586
T_2	174.073^{c} ±1.199	22.843^{bc} ±0.133	215.857^{cd} ±0.671
T_3	178.037^{a} ±0.694	25.083 ±0.893	221.057 ±0.358
T_4	170.230^{d} ±0.529	22.590^{bcd} ±0.282	215.430^{d} ±0.577
T_5	174.583^{c} ±0.586	23.353^{b} ±0.546	217.200^{ab} ±0.513
T_6	175.987^{b} ±0.060	22.893^{bc} ±0.697	216.160^{bcd} ±0.627
T_7	173.880^{c} ±0.633	24.223^{a} ±0.329	216.073^{bcd} ±0.867
T_8	173.960^{c} ±1.162	22.120^{cd} ±0.710	216.710^{abc} ±0.792
T_9	169.087^{d} ±1.036	19.447^{e} ±0.662	215.200^{d} ±0.656
SE(m)±	0.539	0.229	0.412
C.D. at 0.05	1.271	0.828	1.111

Values in columns followed by the same letter are not significantly different, *P*<0.05, Duncan's multiple range test

spraying of panchagavya can stimulate greater soil microbial activity, leading to increased levels of Ca and Fe in fresh leaves and higher leaf yield. The improved nutritive values, regulation of nitrification and efficient nutrient transfer to plants may also play a role in enhancing the quality parameters of fenugreek leaves. These results are in accordance with the research findings of (36) on *Gymnema*.

Highest fibre content (3.38%) was recorded in the plants which received 25% N as FYM + 75% N as Vermicompost + 3% Panchagavya as foliar spray (T_3). This is due to easy availability of organic carbon and nitrogen lead to balanced C:N ratio which enhanced the quality of produce. Similar result was recorded by (37) in okra. The protein content (25.08 g 100 g^{-1}) and ascorbic acid content (221.05 mg 100 g^{-1}) were the highest in the plants applied with 25% N as FYM + 75% N as Vermicompost + 3% Panchagavya as foliar spray. The highest protein and ascorbic acid content achieved through the use of both organic manures and bio stimulants may be attributed to the presence of growth-promoting substances such as enzymes and hormones in organic manures (38). The enhancement of quality attributes through all organic treatments is evident, as these sources provide all the necessary micro and macro nutrients and also improve the physio-chemical and biological properties of the soil, allowing roots to proliferate and better utilize the nutrients required to enhance crop quality (39).

Yield represents a complex interplay of morphological and physical factors, which can be influenced by genetic traits and agricultural practices. The current research identified that the treatment combining farmyard manure (FYM), vermicompost and a 3% foliar application of panchagavya produced the greatest number of branches, leaves and herbage yield. These results align with the observations made by (40).

Conclusion

With this background, the various treatments of this experiment were critically analyzed and found that the treatment T_3 as 25% N as FYM + 75% N as Vermicompost + foliar spray of Panchagavya (3%) ranked first with respect to the yield and quality. From the economics of cultivation also the treatment T_3 as 25% N as FYM + 75% N as Vermicompost + foliar spray of Panchagavya (3%) recorded the higher net return and higher BC ratio which could be recommended for exploitation of commercial cultivation of fenugreek. Though the treatment T_1 i.e. 75% N as FYM + 25% N as Vermicompost + foliar spray of Panchagavya (3%) ranks second with respect to all growth, yield, quality parameters, the net returns ha^{-1} and BC Ratio is lesser than T_3. By considering all these it could be concluded that the soil application of 25% N as FYM + 75% N as Vermicompost + Panchagavya (3%) as foliar spray yields positive effects on the growth, productivity and quality of fenugreek leaves.

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Authors' contributions

RC conducted field trials from cultivation to data collection and also involved in drafting of manuscript and approval of the final manuscript and performed the data analysis. DJ formulated the treatment details of the experiment. MPK participated in the laboratory work and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

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