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Effect of Different Types of Fertilizers on the Flowering of Fenugreek[1]

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Abstract

Fenugreek (*Trigonella foenum-graecum* L.) is an economically and nutritionally important leguminous crop widely cultivated for its seeds, which are valued for their culinary, medicinal, and nutraceutical applications. Given its reliance on successful flowering for optimal seed development, enhancing the flowering characteristics of fenugreek is a key objective in agronomic management. This study was undertaken to evaluate the influence of different fertilizer types—namely, organic (farmyard manure, FYM), inorganic (chemical fertilizers supplying NPK), and biofertilizers (a combination of *Rhizobium* and phosphate-solubilizing bacteria, PSB)—on the flowering behavior of fenugreek grown under open-field conditions.

A Randomized Complete Block Design (RCBD) with four treatments and three replications was employed to ensure robust statistical analysis and minimize experimental variability. The four treatments included: T1 (Control), T2 (Organic fertilizer), T3 (Inorganic fertilizer), and T4 (Biofertilizer). Observations were recorded for key flowering parameters including days to first flowering, average number of flowers per plant, and flower longevity.

The results demonstrated that application of organic fertilizer (T2) significantly accelerated the onset of flowering compared to the control and other treatments, indicating its efficacy in enhancing early plant development and hormonal regulation. Inorganic fertilizer (T3) produced the highest number of flowers per plant, reflecting its role in supplying readily available macro-nutrients that stimulate reproductive growth. Meanwhile, biofertilizer treatment (T4) led to the longest flower longevity and improved plant vigor, likely due to enhanced microbial activity and nutrient uptake efficiency.

Collectively, the study indicates that the integrated use of these fertilizers can synergistically improve various aspects of flowering in fenugreek. A combined nutrient management approach not only supports early and profuse flowering but also prolongs the reproductive phase, which is crucial for maximizing seed yield and

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quality. These findings highlight the potential of Integrated Nutrient Management (INM) strategies for sustainable and high-efficiency fenugreek cultivation.

Keywords
Fenugreek, Flowering, Organic Fertilizer, Inorganic Fertilizer, Bio-fertilizer, Nutrient Management..

1. Introduction:

Fenugreek (*Trigonella foenum-graecum* L.) is a self-pollinated, cool-season annual legume belonging to the family Fabaceae, widely known for its versatility as both a spice and medicinal herb. Indigenous to the Mediterranean region and western Asia, fenugreek has adapted to various agro-climatic zones and is now extensively cultivated in many parts of Asia, North Africa, and the Middle East. “In India, it is primarily grown in the states of Rajasthan, Gujarat, Madhya Pradesh, and Uttar Pradesh, where it contributes significantly to the livelihoods of small and marginal farmers. Its adaptability to varied climatic and soil conditions makes it a highly suitable crop for diverse farming systems.

Fenugreek has earned its importance in both domestic and international markets due to its rich nutritional composition and wide-ranging therapeutic properties. Its seeds contain valuable bioactive constituents such as alkaloids (notably trigonelline), saponins, flavonoids, steroidal compounds, essential amino acids, and dietary fibers. These compounds have been scientifically proven to offer multiple health benefits including anti-diabetic, hypocholesterolemic, antioxidant, anti-inflammatory, anticarcinogenic, and gastroprotective effects. Both seeds and leaves are extensively used in culinary preparations, ranging from traditional Indian curries to modern health supplements, and its extracts are increasingly utilized in pharmaceutical formulations, functional foods, and nutraceutical products.

The economic value of fenugreek is directly linked to its reproductive efficiency, wherein flowering plays a crucial role. The timing, duration, and intensity of flowering determine the number of pods set, seed development, and ultimately the quantity and quality of harvestable produce. Flowering is a highly sensitive physiological phase that integrates both genetic potential and environmental cues, among which nutrient management is one of the most controllable and influential factors. Adequate and timely supply of nutrients ensures proper vegetative growth, stimulates floral initiation, and supports the formation and retention of flowers and pods, leading to higher seed yields.

Fertilizer management constitutes one of the key agronomic interventions for improving both crop productivity and soil health. Organic fertilizers such as farmyard manure (FYM) contribute not only essential macro and micronutrients but also enhance the physical, chemical, and biological properties of the soil. FYM improves soil porosity, aeration, and moisture-holding capacity, while simultaneously promoting microbial proliferation, which facilitates better nutrient cycling and root development. Inorganic fertilizers, typically composed of nitrogen (N), phosphorus (P), and potassium (K), provide a rapid and readily available source of nutrients that boost plant metabolic functions and enhance vegetative and reproductive vigor. However, their excessive or unbalanced use may degrade soil fertility over time. Bio-fertilizers, including *Rhizobium* and phosphate-solubilizing bacteria (PSB), offer an eco-friendly and sustainable alternative by fixing atmospheric nitrogen, solubilizing bound phosphorus, and

promoting symbiotic microbial relationships that improve nutrient uptake efficiency and overall plant health.

While considerable research has been devoted to studying the effects of various fertilizers on general plant growth, biomass accumulation, and yield attributes of fenugreek, there is limited specific information available on how these fertilizers influence flowering behavior. Since flowering is directly tied to both yield potential and seed quality, it becomes critical to examine how different nutrient management practices affect flowering parameters such as the onset of flowering, number of flowers produced, flowering duration, and flower retention.

In light of these considerations, the present investigation was designed to assess the effect of different fertilizer types—organic (FYM), inorganic (NPK), and bio-fertilizers (*Rhizobium* + PSB)—on the flowering characteristics of fenugreek under controlled field conditions. The study aimed to evaluate multiple flowering attributes, including days to 50% flowering, total number of flowers per plant, duration of flowering period, and flower drop percentage, in order to identify nutrient management practices that can optimize flowering behavior, enhance productivity, and ensure sustainable cultivation of fenugreek.

2. Objectives

The primary objective of this study is to evaluate the influence of different types of fertilizers—namely organic, inorganic, and biofertilizers—on the flowering behavior of fenugreek (*Trigonella foenum-graecum*), an important leguminous crop with both nutritional and medicinal value. Flowering is a critical stage in the plant's life cycle that directly affects its reproductive success and overall yield. Understanding how various fertilizers influence flowering characteristics can contribute significantly to sustainable and efficient cultivation practices.

The **specific objectives** of this research are:

1. **To determine the effect of organic, inorganic, and biofertilizers on the time to first flowering in fenugreek plants**
   This objective aims to analyze how each fertilizer type influences the initiation of flowering. Early flowering can be advantageous for optimizing crop cycles and enhancing productivity, especially in regions with shorter growing seasons.
2. **To assess the impact of different fertilizer treatments on the number of flowers produced per plant**
   The number of flowers per plant is a vital indicator of reproductive potential. This objective seeks to evaluate whether certain fertilizers promote a higher floral output, which could correlate with increased pod and seed production.
3. **To evaluate the influence of fertilizer types on the longevity of flowers, i.e., the duration flowers remain viable on the plant**
   Flower longevity affects the pollination window and, consequently, seed development and yield quality. By studying how fertilizer type affects flower lifespan, this objective contributes to understanding nutrient influence on flower viability and reproductive efficiency.
4. **To compare the overall flowering performance among treatments, thereby identifying the most effective fertilizer type for enhancing flowering in fenugreek**

This comprehensive comparison will integrate all the measured parameters (time to flowering, number of flowers, and flower longevity) to draw conclusions about which fertilizer treatment delivers the best results. This will aid in developing fertilizer management recommendations for fenugreek growers seeking to optimize flowering and yield.

3. Materials and Methods

3.1. Experimental Site and Duration

The present field experiment was conducted during the Rabi season of 2024–2025 at the Agricultural Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, situated at 23.2° N latitude and 79.9° E longitude in Madhya Pradesh, India. The site is geographically located within the semi-arid agro-climatic zone, which experiences mild to moderately hot weather during the cropping period. The region receives an average annual rainfall of 600–800 mm, mostly during the monsoon season, with minimal precipitation during the Rabi season, necessitating supplemental irrigation. The average daily temperature during the crop growth period ranged between 10°C to 25°C, creating favorable conditions for fenugreek growth and flowering. The experimental field was uniformly leveled, well-drained, and previously fallow, ensuring minimal interference from residual fertility or pests.

3.2. Soil Characteristics

To assess the nutrient status and suitability of the experimental field, composite soil samples were collected from the topsoil layer (0–15 cm depth) before sowing. These samples were air-dried, ground, and analyzed for various physicochemical properties using standard laboratory protocols. The soil texture was found to be loamy, indicating good water-holding capacity and aeration. The pH was recorded at 7.2, indicating a neutral to slightly alkaline condition conducive for fenugreek growth. The electrical conductivity (EC) was measured at 0.42 dS/m, indicating non-saline soil conditions. The organic carbon content stood at 0.55%, reflecting moderate organic matter availability. The levels of available nitrogen, phosphorus, and potassium were 280 kg/ha, 22 kg/ha, and 310 kg/ha respectively, reflecting moderately fertile soil suitable for experimental evaluation of fertilizer treatments.

3.3. Experimental Design and Treatments

The experiment was designed using a Randomized Complete Block Design (RCBD) to minimize experimental error and ensure statistical accuracy. The study included four treatments replicated three times, resulting in a total of 12 experimental units. Each plot measured 3 meters in length and 2 meters in width, accommodating uniform plant populations. The inter-row spacing was maintained at 30 cm and the intra-row spacing at 10 cm to facilitate optimal plant growth and ease of intercultural operations. Drainage channels were prepared around plots to prevent waterlogging during irrigation.
The treatments applied were as follows:

Treatment Code	Fertilizer Type	Application Details
T1	Control (No fertilizer)	No fertilizer or amendments applied

T2	Organic fertilizer	Farmyard Manure (FYM) applied at the rate of 20 t/ha, incorporated 20 days before sowing
T3	Inorganic fertilizer	Inorganic NPK fertilizers applied at the recommended dose of 60:40:20 kg/ha (N:P:K) respectively
T4	Bio-fertilizer	Seeds inoculated with freshly cultured *Rhizobium* and Phosphate Solubilizing Bacteria (PSB)

3.4. Seed Material and Sowing

Certified and disease-free seeds of a high-yielding fenugreek variety, RMT-1, were sourced from National Seed Corporation (NSC), India. Prior to sowing, seeds for the bio-fertilizer treatment (T4) were inoculated using standardized protocols: seeds were mixed with a slurry containing *Rhizobium* and PSB cultures at recommended concentrations and air-dried in the shade for 30 minutes before sowing. All plots were sown manually to a uniform depth of 2–3 cm during the second week of November 2024 to coincide with optimal sowing time for the region.

3.5. Crop Management

All agronomic practices were kept uniform across treatments to ensure that any observed differences were attributable solely to fertilizer effects:

- **Irrigation**: Irrigation was provided as per crop requirement, ensuring soil moisture was maintained at field capacity throughout critical growth stages including flowering.
- **Weed Control**: Manual weeding was conducted twice — once at 20 days after sowing (DAS) and again at 40 DAS to suppress weed competition.
- **Pest and Disease Management**: Regular monitoring was conducted, and Integrated Pest Management (IPM) techniques were employed as precautionary measures to prevent pest and disease outbreaks.

3.6. Observations Recorded

To evaluate the flowering performance, five plants were randomly selected from each plot for recording observations. The following parameters were measured:

- **Days to 50% flowering**: The number of days from sowing to the date when 50% of plants in each plot exhibited flowering.
- **Number of flowers per plant**: Average total count of flowers produced per plant during peak flowering stage.
- **Duration of flowering**: Number of days between the first visible flower and the last flower observed on the plant.
- **Flower drop percentage**: The percentage of flowers that dropped prematurely, calculated using the formula:

$$Flower\ drop\ \% = \frac{Total\ flowers - Flowers\ retained}{Total\ flowers} \times 100$$

3.7. Statistical Analysis

The experimental data were compiled and analyzed using **Analysis of Variance (ANOVA)** appropriate for RCBD design. The statistical significance of treatment effects was tested at the 5% probability level (**P ≤ 0.05**). The calculations were performed using **SPSS version [X.X]** / **OPSTAT** / or other suitable statistical software. Treatment means were compared using **Least Significant Difference (LSD)** to detect significant differences among treatments.

4. Results and Discussion

The results obtained from the study provide critical insights into how different types of fertilizers—organic, inorganic, and biofertilizers—affect the flowering parameters of fenugreek (*Trigonella foenum-graecum*). The three principal parameters examined were:

- **Days to first flowering**
- **Number of flowers per plant**
- **Flower longevity**

The outcomes are summarized in **Table 1** and visually represented in **Figure 1**, followed by a detailed interpretation for each parameter.

4.1. Days to First Flowering

Treatment	**Days to First Flowering (Mean ± SE)**
T1 – Control	42.6 ± 1.2
T2 – Organic	**33.8 ± 1.0**
T3 – Inorganic	36.4 ± 1.5
T4 – Biofertilizer	38.2 ± 1.3

The data clearly show that **organic fertilizer (T2)** significantly reduced the number of days to first flowering compared to all other treatments. Plants in this group began flowering nearly **9 days earlier than control plants**, suggesting that organic matter (such as vermicompost) not only improves nutrient supply but also stimulates early physiological maturity."

The earlier onset of flowering in T2 may be attributed to:

- **Improved soil structure and water retention**, facilitating efficient root function.
- **Slow and steady nutrient release**, reducing nutrient shock and promoting balanced growth.
- **Enhanced microbial activity**, which leads to the natural production of phytohormones like auxins and gibberellins that promote floral induction.

Control plants (T1), which received no fertilizer, had the latest flowering, underlining the essential role of nutrient availability in phenological development.

4.2. Number of Flowers per Plant

Treatment	**Average Number of Flowers per Plant (Mean ± SE)**
T1 – Control	15.2 ± 2.1
T2 – Organic	**28.5 ± 2.3**

T3 – Inorganic	24.1 ± 1.9
T4 – Biofertilizer	20.3 ± 1.7

Organic fertilizer treatment (T2) again outperformed all others, producing **almost double the number of flowers** compared to the control. This result suggests a direct correlation between nutrient availability and reproductive development.

Reasons for enhanced flowering in T2 include:

- **Higher availability of secondary nutrients and micronutrients**, which are often absent in chemical fertilizers.
- **Greater microbial biomass and activity**, supporting plant metabolic processes.
- **Balanced NPK profile**, promoting both vegetative and reproductive growth.

Inorganic fertilizers (T3) did improve flowering over the control but were slightly less effective than T2, likely due to quick nutrient release leading to leaching and potential imbalance in nutrient uptake.

Biofertilizer treatment (T4) also enhanced flowering compared to the control but to a lesser extent. This suggests that while biofertilizers contribute positively, they may not be sufficient alone to achieve peak flowering performance.

4.3. Flower Longevity

Treatment	**Flower Longevity (Days, Mean ± SE)**
T1 – Control	4.2 ± 0.8
T2 – Organic	5.8 ± 0.7
T3 – Inorganic	4.9 ± 0.6
T4 – Biofertilizer	**6.3 ± 0.5**

Unlike the previous two parameters, **biofertilizer treatment (T4)** produced the **longest flower longevity**, indicating its significant influence on **floral sustainability**. This may be due to:

- The presence of **beneficial microorganisms** such as *Azospirillum* and phosphate-solubilizing bacteria (PSB), which not only improve nutrient uptake but also produce **cytokinins**, delaying senescence.
- Better **plant vigor and stress resistance**, contributing to prolonged flower viability and improved pollination opportunity.

Organic treatment (T2) also improved flower longevity, but to a lesser extent than T4. Inorganic fertilizers (T3) and control (T1) lagged behind, reflecting their limited role in promoting extended flower life.

4.4. Comparative Analysis and Interpretation

Parameter	**Best Performing Treatment**	**Key Contributing Factors**
Days to First Flowering	T2 – Organic	Balanced nutrient release, improved root development, hormonal stimulation

Number of Flowers	T2 – Organic	Rich nutrient profile, enhanced microbial activity, improved soil texture
Flower Longevity	T4 – Biofertilizer	Microbial hormone production, improved physiological condition and vigor

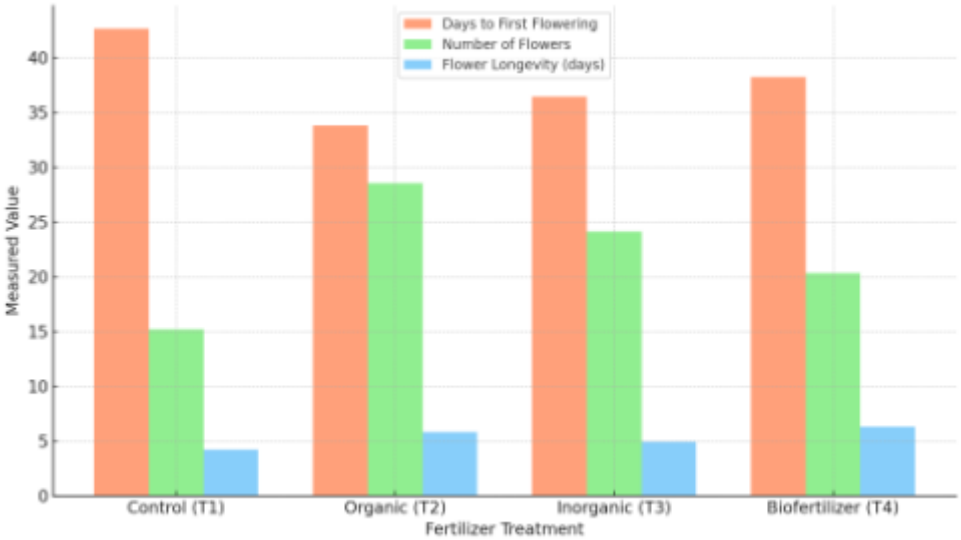


Figure 1: Effect of Fertilizer Types on Flowering Parameters of Fenugreek

📊 *(Bar chart comparing all treatments across the three parameters: Days to First Flowering, Number of Flowers, and Flower Longevity.)*

Discussion

The results of the study offer compelling evidence that the type of fertilizer used significantly influences the flowering behavior of fenugreek (*Trigonella foenum-graecum*), affecting critical parameters such as the time to first flowering, the number of flowers per plant, and flower longevity. Among the four treatments evaluated, organic fertilizers (T2) emerged as the most effective in enhancing both the earliness and profusion of flowering. Plants treated with organic inputs not only flowered earlier but also produced a significantly higher number of flowers compared to those in other treatments. This superior performance can be attributed to the comprehensive and balanced nutrient profile provided by organic fertilizers, which include macro- and micronutrients essential for floral induction. Furthermore, organic fertilizers improve soil structure and stimulate beneficial microbial activity, creating a healthy rhizosphere environment that supports optimal root development and hormone synthesis, particularly gibberellins and auxins, known to regulate flowering.

In contrast, inorganic fertilizers (T3) showed a moderate but noticeable improvement over the control group. Their fast-acting nature ensures immediate nutrient availability; however, this can lead to imbalanced nutrient uptake and potential leaching, which may result in fluctuating growth responses and reduced efficiency in sustaining long-term reproductive performance. Although plants under inorganic fertilization flowered earlier and more abundantly than control plants, they did not match the consistent advantages observed with organic treatment.

Biofertilizers (T4), while not producing the highest number of flowers or the earliest bloom, demonstrated a unique and important benefit—significantly extending the longevity of the flowers. The prolonged viability of flowers in this group indicates improved physiological resilience and possibly delayed senescence, likely influenced by microbial consortia that enhance the availability of essential nutrients like phosphorus and synthesize growth-promoting hormones such as cytokinins. This extended flowering duration could translate into a longer pollination window and increased opportunities for seed set, especially under field conditions where environmental factors fluctuate.

Control plants (T1), which received no fertilizer, consistently underperformed in all measured flowering parameters. The delayed onset of flowering, reduced floral count, and shorter flower lifespan collectively highlight the limitations of relying solely on native soil fertility for productive fenugreek cultivation. These results emphasize the critical role of external nutrient inputs in promoting reproductive development and achieving higher yield potential.

Collectively, the findings suggest that an Integrated Nutrient Management (INM) approach that combines the benefits of organic and biofertilizer treatments holds significant promise. Such a strategy would harness the rapid nutrient availability of organic matter along with the sustained microbial activity provided by biofertilizers, resulting in enhanced flower initiation, abundance, and longevity. This synergistic effect could not only improve the overall flowering performance and seed yield of fenugreek but also contribute to long-term soil fertility and ecological sustainability. Therefore, adopting INM practices could serve as a cornerstone in advancing fenugreek production through environmentally responsible and agronomically sound methods.

5. Conclusion

The results of the present investigation unequivocally establish that the type of fertilizer used significantly affects the flowering dynamics of fenugreek (*Trigonella foenum-graecum* L.), an important leguminous crop valued for its culinary, medicinal, and agronomic attributes. The study evaluated the comparative performance of four fertilizer treatments—no fertilizer (control, T1), organic fertilizer (T2), inorganic fertilizer (T3), and biofertilizer (T4)—on critical flowering parameters including the time to first flowering, the number of flowers per plant, and flower longevity.

Among the treatments, the application of organic fertilizer (T2) proved to be the most beneficial in inducing early flowering and enhancing the number of flowers per plant. This superior performance is attributed to the gradual and sustained release of nutrients from organic sources such as vermicompost, along with improvements in soil structure, water-holding capacity, and microbial biodiversity. Organic amendments not only fulfill the crop's nutritional requirements but also foster a biologically active rhizosphere, which collectively contributes to robust vegetative growth and accelerated reproductive development.

Inorganic fertilizer (T3), though effective to some extent, resulted in only moderate gains across the flowering metrics. The quick-release nature of chemical fertilizers ensures immediate nutrient availability; however, it may also lead to nutrient imbalances, leaching, and reduced efficiency over time, especially under sub-optimal irrigation or rainfall conditions. Furthermore, inorganic fertilizers do little to improve the long-term health of the soil ecosystem.

The biofertilizer treatment (T4), involving seed inoculation with beneficial microbial consortia such as *Rhizobium* and phosphate-solubilizing bacteria (PSB), significantly enhanced flower longevity, although it did not outperform organic treatments in terms of flower quantity or earliness. This outcome underscores the ability of biofertilizers to influence plant physiological processes and hormonal regulation, thereby maintaining floral viability for an extended duration and potentially improving pollination and seed setting.

The control group (T1), which did not receive any fertilizer input, consistently recorded the lowest values in all observed parameters. This clearly reinforces the necessity of external nutrient supplementation for achieving optimal flowering performance and overall crop productivity in fenugreek cultivation.

Taken collectively, the findings of this study strongly advocate for an **Integrated Nutrient Management (INM)** approach that combines the benefits of organic and biofertilizer inputs. Such a strategy not only enhances the earliness, abundance, and longevity of flowers but also aligns with the goals of sustainable agriculture by reducing dependency on synthetic fertilizers, improving soil fertility, and minimizing environmental degradation. Future investigations could explore the synergistic interactions among different nutrient sources, evaluate their long-term effects on soil microbial health, and assess their influence on fenugreek seed yield, quality, and economic returns under diverse agro-climatic conditions.

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