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BIOPRIMING OF FENUGREEK (*Trigonella foenum-graecum* L.) SEEDS WITH BEEJAMRIT FOR IMPROVING SEEDLING GROWTH, BIOMASS ACCUMULATION CHARACTERISTICS

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ABSTRACT

Beejamrit, a traditional cow-based microbial bioformulation used in natural farming, was evaluated as a sustainable seed biopriming agent to improve early crop establishment in fenugreek (*Trigonella foenum-graecum* L.). Seeds were primed with Beejamrit at five concentrations (10%, 20%, 30%, 50%, and 100%) and compared with unprimed controls under natural growing conditions. Seedling performance was measured by root length, shoot length, and fresh and dry biomass. Beejamrit priming significantly enhanced all measured growth parameters relative to the control, with responses varying by concentration. The 50% and 100% treatments produced the most pronounced improvements in root and shoot length, while the 20% treatment yielded the highest fresh biomass, indicating a concentration-dependent effect on specific vigour traits. The results demonstrate that Beejamrit effectively boosts early seedling vigour and physiological performance in fenugreek, supporting its adoption as an eco-friendly biopriming strategy for sustainable agriculture.

***Keywords* :** Beejamrit, Fenugreek, Seed biopriming, Seedling Growth, Sustainable Agriculture.

Introduction

Successful crop production depends on rapid, uniform seed germination and vigorous seedling establishment, because these early stages largely determine plant survival, nutrient acquisition, biomass accumulation, stress resilience, and ultimately yield (Bewley *et al.*, 2013; Nonogaki *et al.*, 2010). Seed biopriming a seed enhancement technique involving the pre-sowing treatment of seeds with beneficial microorganisms or biologically active formulations under controlled hydration, has emerged as an effective, economical, and eco-friendly approach for improving seed performance. Biopriming activates germination-related metabolic processes while facilitating beneficial microbial colonization of the seed surface, thereby enhancing enzyme activity, membrane integrity, antioxidant defence, nutrient mobilization, and early seedling establishment, resulting in faster, more uniform germination and improved seedling vigour (Ashraf & Foolad, 2005; Paparella *et al.*, 2015; Farooq *et al.*, 2019).

The adverse environmental effects of excessive synthetic fertilizer and agrochemical use have driven the adoption of sustainable agricultural practices, with microbial inoculants, organic amendments, and plant biostimulants emerging as promising eco-friendly alternatives (Singh *et al.*, 2020; Tilman *et al.*, 2002; Verma *et al.*, 2022). Within Zero Budget Natural Farming (ZBNF), Beejamrit a simple, on-farm preparation of cow dung, cow urine, lime, and rhizosphere soil has gained attention as a low-cost microbial seed treatment. Rich in indigenous beneficial microorganisms and naturally occurring growth-promoting compounds, Beejamrit is reported to improve seed health and early seedling development, and its ease of preparation and compatibility with sustainable farming have driven widespread adoption (Palekar, 2006; Sreenivasa *et al.*, 2010; Yadav *et al.*, 2021). Microbial bioformulations and biostimulants generally enhance nutrient uptake, root architecture, rhizosphere activity, and production of plant growth regulators, thereby boosting seedling vigour and biomass (du Jardin, 2015; Rouphael & Colla, 2020). Despite Beejamrit's popularity in natural farming, rigorous, concentration-dependent evaluations of its effects on early seedling growth under controlled conditions are limited. Early root and shoot traits root length, shoot length, lateral root formation, fresh and dry biomass, and seedling vigour indices are reliable indicators of seed quality and treatment efficacy (Lynch, 2007; Taiz *et al.*, 2015). Fenugreek (*Trigonella foenum-graecum* L.), an economically important legume valued for its nutritional and medicinal properties, combines rapid germination and a short lifecycle with high responsiveness to priming, making it an excellent model for such evaluations (Acharya *et al.*, 2008; Petropoulos, 2002).

The present study therefore investigates the concentration-dependent effects of Beejamrit seed priming on fenugreek germination and early seedling growth under controlled conditions. We assessed germination percentage, root and shoot growth, lateral root development, biomass accumulation, and seedling vigour indices. Beejamrit priming was hypothesized to enhance seedling establishment and vigour, supporting its application as an economical and environmentally sustainable biostimulant for crop establishment.

Materials and Methods

Seed Material and Experimental Setup

Seeds of *Trigonella foenum-graecum* L. were procured from a local source and used as the experimental material. Healthy, uniform, and undamaged seeds were manually selected to ensure experimental consistency. A total of 300 seeds were divided into six groups comprising five Beejamrit treatments and one untreated control, with 50 seeds assigned to each group. Each treatment and the control, was replicated three times to ensure statistical reliability and experimental reproducibility. The experiment was conducted using earthen pots filled with a homogeneous mixture of garden soil and cocopeat in a 1:1 (v/v) ratio. All pots were maintained under natural environmental conditions without artificial regulation of temperature, humidity, or photoperiod, thereby simulating realistic field-like growth conditions.

Preparation of Beejamrit

Beejamrit was prepared following established protocols in organic farming (Sreenivasa *et al.*, 2010). Fresh cow dung and cow urine were procured from indigenous *Bos indicus* (Gir) cattle maintained in Gujarat, with cow urine collected 24 h prior to preparation to ensure maximal viability of native microflora. In a sterile 1-L glass vessel, ingredients were combined in the following proportions unless otherwise specified: fresh cow dung (125 g), cow urine (125 mL), calcium carbonate ($CaCO_3$; 1.25 g), neem rhizospheric soil (1.25 g), and tap water to a final volume of 500 L. The components were homogenized using a sterile glass rod to yield a uniform suspension. Fermentation was carried out under ambient laboratory conditions (25–30 °C; 40–70% relative humidity) for 72 h, with the suspension stirred twice daily to maintain aeration and uniform microbial distribution. Physicochemical parameters, including pH and temperature, were monitored daily; pH values typically ranged between 6.5 and 7.5. Following fermentation, the Beejamrit was utilized immediately for seed-priming treatments, with prepared batches processed for a standardized duration of 3 h to ensure maximal microbial viability.

Table 1: Ingredients and their respective quantities required for the formulation of Beejamrut

Sr. No.	Ingredients	Quantity
1.	Cow Dung	125g
2.	Cow Urine	125ml
3.	Calcium Carbonate	1.25g
4.	Neem Soil	1.25g
5.	Water	500ml

Seed Priming Treatment

Fenugreek seeds were subjected to priming with freshly prepared Beejamrit solutions of different concentrations. Five treatment groups along with a control (untreated) group were established as follows:

- Control (untreated seeds)
- 10% Beejamrit solution
- 20% Beejamrit solution
- 30% Beejamrit solution
- 50% Beejamrit solution
- 100% Beejamrit solution

Seeds were soaked in their respective solutions for a duration of 3 hours under room temperature conditions. After priming, seeds were removed, gently blotted to remove excess solution, and immediately sown in the prepared soil pots.

Germination and Seedling Growth Conditions

Seeds from both primed and unprimed (control) treatments were allowed to germinate under natural environmental conditions throughout the experimental period. Experimental pots were maintained in an open environment exposed to natural sunlight and adequate ventilation. Soil moisture was maintained regularly through controlled watering to avoid both excessive waterlogging and desiccation stress. Germination responses and early seedling growth parameters were monitored daily, and morphological observations were recorded throughout the experimental duration.

The experiment was carried out in the month of March 2026 under natural conditions using pots maintained in an open environment in Ahmedabad, India, the temperature ranged from 34.0–39.5°C during the day and 20.0–23.0°C at night (mean maximum 37.2°C; mean minimum 21.9°C), with an average relative humidity of 39.4% throughout the study period.

Growth Parameters

The following growth parameters were analysed:

Shoot Length of Seedling (cm)

The shoot length was measured from the collar region of the seedling (at the soil surface) to the tip of fully opened young leaf using a ruler or measuring tape. The mean length was calculated and recorded as shoot length per plant in centimeter (cm).

Root Length of Seedling (cm)

The seedlings were uprooted without causing any root damage, and length of the longest root was measured from the collar region of seedling using a ruler or tape. The mean root length was calculated and represented in centimeter (cm).

Fresh Weight of Seedling (gm)

Fresh biomass of fenugreek (*Trigonella foenum-graecum* L.) seedlings was determined to evaluate the effect of Beejamrit seed priming on early seedling growth. Seedlings from each treatment were carefully uprooted daily during the experimental period in the early morning, gently washed to remove adhering soil particles, and blotted dry with absorbent paper. The fresh weight of individual seedlings was recorded immediately using a digital analytical balance. The measurements were obtained for all Beejamrit treatments and the untreated control to assess the influence of seed priming on biomass accumulation.

Dry Weight of Seedling (gm)

Following fresh weight determination, the same seedlings were oven-dried at 60 ± 2°C for 24 h, or until a constant weight was attained. The dried seedlings were then weighed using a digital analytical balance to determine dry biomass. Dry weight measurements were recorded for all Beejamrit treatments and the untreated control to evaluate the effect of seed priming on dry matter accumulation and overall biomass production.

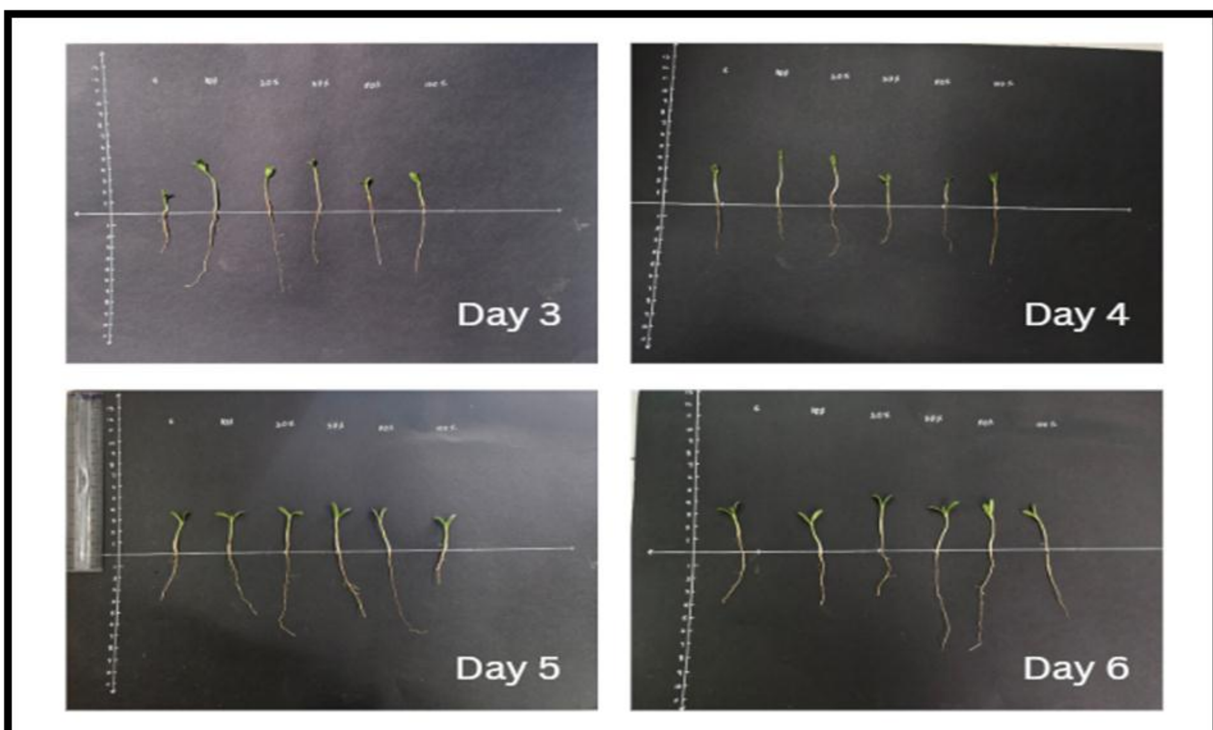

Plate 1: Daily measurements of root length and shoot length of fenugreek seedlings over a 13-day experimental period under different concentrations of Beejamrit, compared with the untreated control.

Statistical Analysis

All experimental observations were recorded carefully and expressed as mean ± standard error (SE). The data obtained from all treatments, including different Beejamrit concentrations and the untreated control, were subjected to comparative analysis to evaluate their effects on seed germination, seedling growth, and biochemical parameters of fenugreek (*Trigonella foenum-graecum* L.). Appropriate statistical software was used for data analysis, and results were presented in the form of tables and graphs to facilitate clear interpretation and comparison of treatment effects.

Results and Discussions

The root lengths of all experimental samples were measured daily over a period of 10 days, as presented in Table 2.

Table 2: Root Length (in cms) under different treatments of Beejamrit

Sr. No.		Control	10%	20%	30%	50%	100%
1	Day 3	3.28 ± 0.076	2.22 ± 0.076	4.28 ± 0.103	2.76 ± 0.082	5.12 ± 0.111	4.84 ± 0.115
2	Day 4	3.72 ± 0.103	4.98 ± 0.345	5.52 ± 0.295	4.38 ± 0.190	6.3 ± 0.189	5.94 ± 0.234
3	Day 5	4.52 ± 0.660	5.00 ± 0.547	5.84 ± 0.237	5.58 ± 0.452	7.38 ± 0.580	6.04 ± 0.900
4	Day 6	5.90 ± 0.219	5.24± 0.184	6.34 ± 0.408	5.6 ± 0.434	7.76 ± 0.360	6.1 ± 0.147
5	Day 7	6.20 ± 0.195	5.58 ± 0.150	6.48 ± 0.354	6.84 ± 0.237	7.96 ± 0.282	6.3 ± 0.255
6	Day 8	6.56 ± 0.264	5.72 ± 0.194	6.58 ± 0.549	6.9 ± 0.187	8.9 ± 0.157	7.84 ± 0.295
7	Day 9	6.92 ± 0.148	6.02 ± 0.411	7.3 ± 0.417	6.92 ± 0.225	9.04 ± 0.153	8.06 ± 0.356
8	Day 10	6.96 ± 0.177	7.14 ± 0.166	7.8 ± 0.220	7.04 ± 0.180	9.3 ± 0.226	8.7 ± 0.284
9	Day 11	7.0 ± 0.097	7.68 ± 0.270	7.9 ± 0.228	7.1 ± 0.257	9.54 ± 0.168	9.44 ± 0.289
10	Day 12	7.2 ± 0.376	8.04 ± 0.161	9.74 ± 0.294	8.06 ± 0.466	9.92 ± 0.240	9.98 ± 0.214
11	Day 13	7.42 ± 0.273	8.18± 0.194	9.5± 0.329	8.18± 0.327	10.2 ± 0.238	10.36 ± 0.488

The root length of all experimental groups was recorded daily from Day 3 to Day 13, and the results are presented in Table 2. A progressive increase in root length was observed across all treatments throughout the experimental period, indicating continuous root development with advancing germination. Among the different Beejamrit concentrations, the 50% treatment consistently produced the greatest root elongation during most of the observation period, increasing from 5.12 ± 0.111 cm on Day 3 to 10.20 ± 0.238 cm on Day 13. The 100% Beejamrit treatment also demonstrated substantial enhancement in root growth, rising from 4.84 ± 0.115 cm to 10.36 ± 0.488 cm, ultimately recording the highest final root length. The 20% treatment exhibited superior root growth compared with the control, 10%, and 30% treatments, increasing from 4.28 ± 0.103 cm on Day 3 to 9.50 ± 0.329 cm on Day 13. The 30% treatment showed moderate improvement, with root length increasing from 2.76 ± 0.082 cm to 8.18 ± 0.327 cm, while the 10% treatment initially recorded the lowest root length (2.22 ± 0.076 cm) but gradually improved to 8.18 ± 0.194 cm by the end of the study. In comparison, the control seedlings exhibited comparatively slower root development, increasing from 3.28 ± 0.076 cm on Day 3 to 7.42 ± 0.273 cm on Day 13.

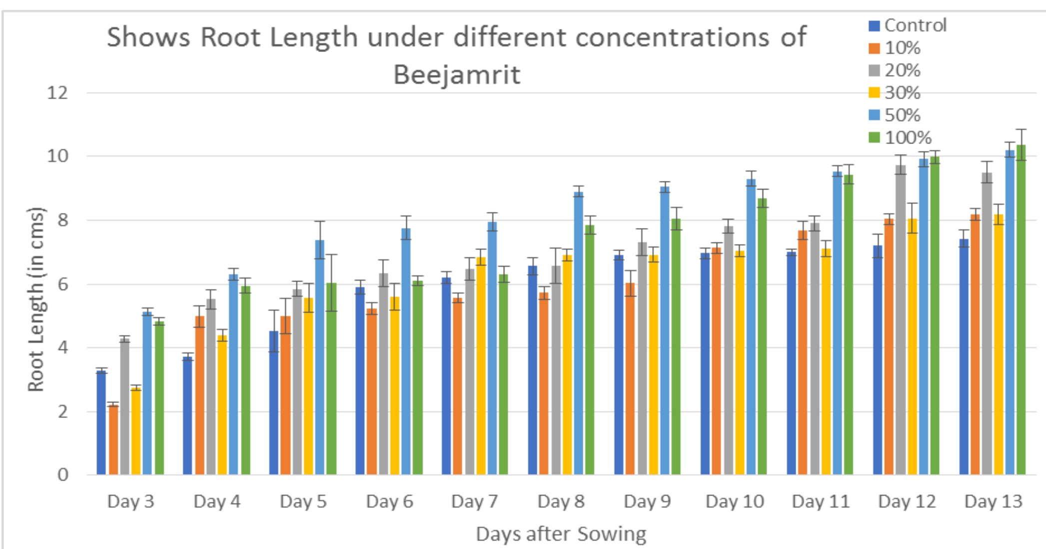

Fig. 1: Root Length (in cms) under different treatments of Beejamrit

The shoot lengths of all experimental samples were measured daily over a period of 10 days, as presented in Table 3.

Table 3: Shoot Length (in cms) under different treatments of Beejamrit

Sr. No.		Control	10%	20%	30%	50%	100%
1	Day 3	1.42 ± 0.148	1.8 ± 0.228	2.54 ± 0.108	1.64 ± 0.140	1.32 ± 0.071	2.2 ± 0.228
2	Day 4	1.66 ± 0.242	2.88 ± 0.086	3.00 ± 0.135	1.7 ± 0.152	1.92 ± 0.103	2.48 ± 0.148
3	Day 5	2.26 ± 0.212	3.72 ± 0.243	3.32 ± 0.172	3.3 ± 0.228	2.3 ± 0.228	2.7 ± 0.187
4	Day 6	2.4 ± 0.260	3.9 ± 0.260	4.48 ± 0.381	3.5 ± 0.144	2.6 ± 0.260	2.82 ± 0.099
5	Day 7	2.78 ± 0.110	4.0 ± 0.193	4.54 ± 0.277	4.0 ± 0.452	3.72 ± 0.184	3.14 ± 0.326
6	Day 8	3.32 ± 0.168	4.1 ± 0.141	5.08 ± 0.314	4.1 ± 0.089	3.8 ± 0.332	4.12 ± 0.239
7	Day 9	3.82 ± 0.172	4.12 ± 0.548	5.1 ± 0.149	4.44 ± 0.282	4.2 ± 0.347	5.38 ± 0.168
8	Day 10	4.22 ± 0.235	4.24 ± 0.100	5.52 ± 0.316	4.82 ± 0.170	5.9 ± 0.157	7.04 ± 0.260
9	Day 11	4.72 ± 0.214	4.82 ± 0.081	5.96 ± 0.229	4.9 ± 0.428	6.45 ± 0.225	7.1 ± 0.381
10	Day 12	5.04 ± 0.214	5.48 ± 0.225	6.00 ± 0.141	4.92 ± 0.314	7.54 ± 0.305	7.6 ± 0.607
11	Day 13	5.22 ± 0.219	5.44± 0.280	6.16± 0.175	5.18± 0.219	7.7± 0.195	8.24 ± 0.618

The shoot length of all experimental seedlings was recorded daily from Day 3 to Day 13, and the observations are presented in Table 3. A gradual increase in shoot length was observed across all treatments throughout the experimental period, indicating continuous seedling growth under the influence of Beejamrit. Although the initial response varied among treatments, all Beejamrit-treated seedlings exhibited improved shoot elongation compared with the untreated control as the experiment progressed. Among the different concentrations, the 100% Beejamrit treatment recorded the highest shoot length, increasing from 2.20 ± 0.228 cm on Day 3 to 8.24 ± 0.618 cm on Day 13, followed closely by the 50% treatment, which increased from 1.32 ± 0.071 cm to 7.70 ± 0.195 cm. The 20% treatment also demonstrated a substantial enhancement in shoot growth, increasing from 2.54 ± 0.108 cm to 6.16 ± 0.175 cm, whereas the 10% and 30% treatments showed moderate improvements, reaching 5.44 ± 0.280 cm and 5.18 ± 0.219 cm, respectively, by the end of the study. In contrast, the control seedlings exhibited the lowest overall shoot growth, increasing from 1.42 ± 0.148 cm on Day 3 to 5.22 ± 0.219 cm on Day 13. Overall, the results indicate that Beejamrit application significantly enhanced shoot elongation compared with the untreated control, with the 100% and 50% concentrations proving most effective in promoting early shoot development.

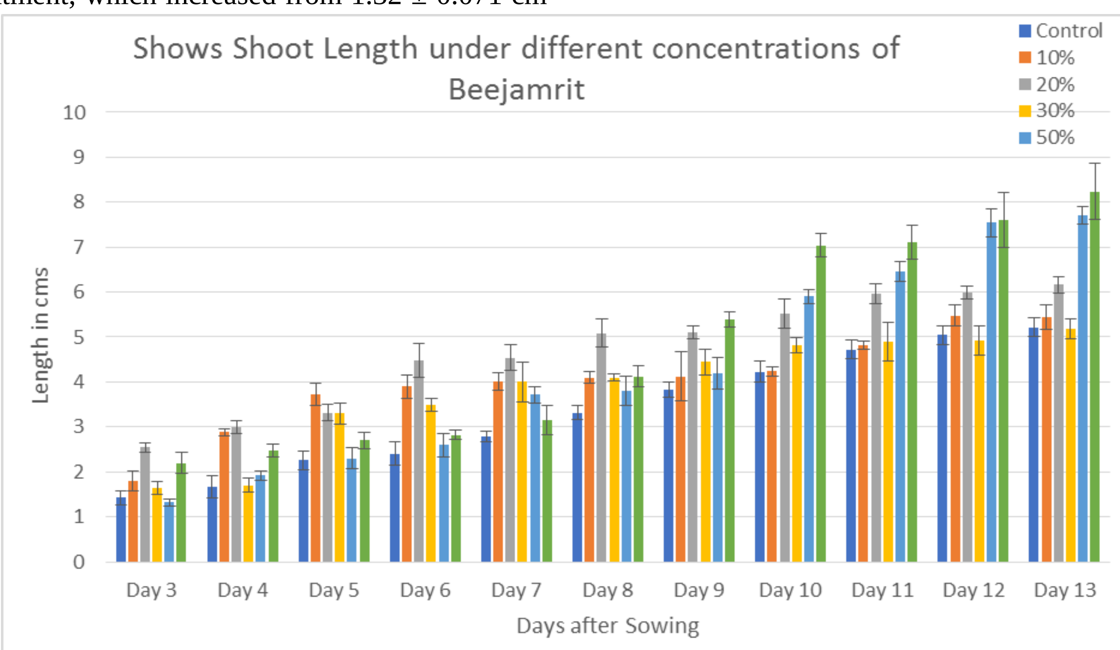

Fig. 2: Shoot Length (in cms) under different treatments of Beejamrit

The fresh weight of all experimental samples were measured daily over a period of 9 days, as presented in Table 5.

Table 4: Fresh weight (in gms) under different treatments of Beejamrit

Days	Control	10%	20%	30%	50%	100%
Day 5	0.35	0.34	0.43	0.501	0.405	0.46
Day 6	0.366	0.35	0.533	0.505	0.487	0.415
Day 7	0.378	0.352	0.589	0.266	0.524	0.566
Day 8	0.401	0.353	0.66	0.289	0.555	0.603
Day 9	0.405	0.301	0.75	0.315	0.589	0.62
Day 10	0.416	0.25	0.799	0.345	0.624	0.666
Day 11	0.422	0.263	0.853	0.369	0.701	0.695
Day 12	0.429	0.299	0.863	0.399	0.775	0.75
Day 13	0.435	0.354	0.899	0.421	0.801	0.796

The fresh weight of seedlings under different Beejamrit treatments was recorded daily from Day 5 to Day 13, and the results are presented in Table 4. Fresh weight increased progressively in most treatments throughout the experimental period, indicating continuous biomass accumulation. Among the treatments, the 20% Beejamrit concentration recorded the highest fresh weight, increasing from 0.43 g on Day 5 to 0.899 g on Day 13, followed by the 50% (0.801 g) and 100% (0.796 g) treatments. The control and 10% treatments exhibited comparatively lower fresh weights, while the 30% treatment showed moderate variation during the study. Overall, Beejamrit application enhanced fresh weight compared with the untreated control, with the 20% concentration proving most effective in promoting early seedling biomass accumulation.

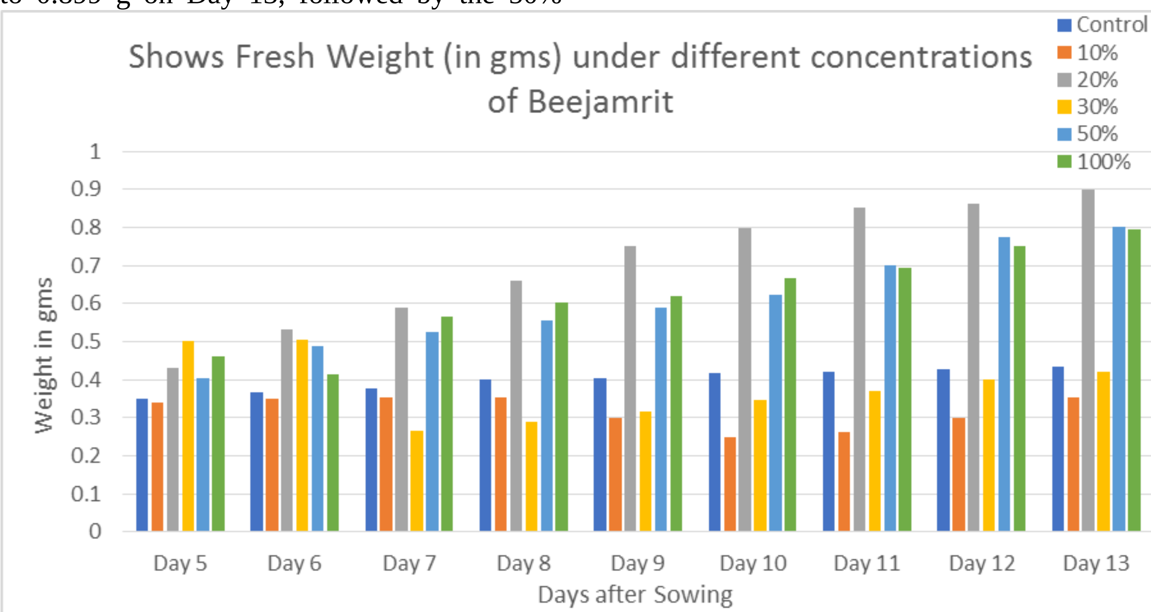

Fig. 3: Fresh weight (in gms) under different treatments of Beejamrit

The dry weight of all experimental samples were measured daily over a period of 9 days, as presented in Table 5.

Table 5: Dry weight (in gms) under different treatments of Beejamrit

Days	Control	10%	20%	30%	50%	100%
Day 5	0.031	0.03	0.045	0.042	0.033	0.04
Day 6	0.028	0.03	0.046	0.031	0.04	0.032
Day 7	0.044	0.032	0.051	0.033	0.066	0.038
Day 8	0.036	0.031	0.043	0.025	0.032	0.046
Day 9	0.041	0.015	0.049	0.03	0.046	0.066
Day 10	0.045	0.029	0.055	0.0301	0.059	0.079
Day 11	0.051	0.035	0.065	0.045	0.055	0.088
Day 12	0.055	0.032	0.069	0.049	0.063	0.086
Day 13	0.059	0.041	0.0701	0.055	0.076	0.091

The dry weight of seedlings under different Beejamrit treatments was recorded daily from Day 5 to Day 13, and the results are presented in Table 5. A gradual increase in dry weight was observed in all treatments throughout the experimental period, indicating continuous accumulation of dry matter during seedling growth. Among the treatments, the 100% Beejamrit concentration recorded the highest dry weight, increasing from 0.040 g on Day 5 to 0.091 g on Day 13, followed by the 50% treatment (0.076 g) and the 20% treatment (0.0701 g). The 30% treatment showed moderate improvement, while the 10% treatment and the untreated control exhibited comparatively lower dry weight throughout the study. Overall, Beejamrit application enhanced dry matter accumulation compared with the control, with the 100% concentration proving most effective in promoting dry biomass production during the early stages of seedling development.

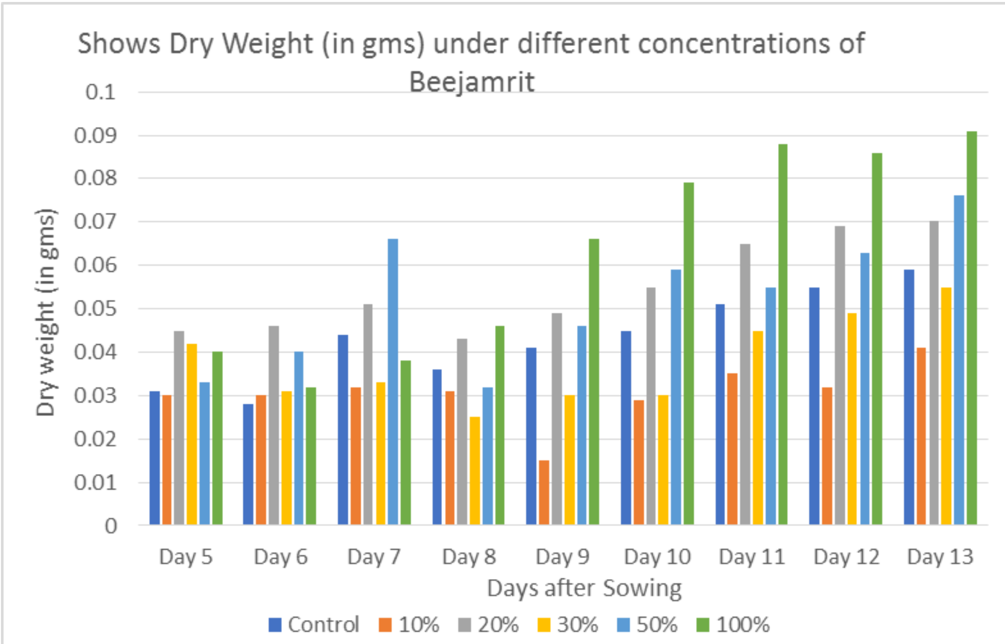

Fig. 4: Dry weight (in gms) under different treatments of Beejamrit

Discussion

The present investigation demonstrates that Beejamrit seed priming significantly enhanced the early growth and biomass accumulation of *Trigonella foenum-graecum* L. seedlings. All Beejamrit treatments outperformed the untreated control, although the magnitude of improvement varied with concentration, indicating a clear concentration-dependent response. Among the treatments, 100% Beejamrit was the most effective in promoting shoot growth and dry matter accumulation, while the 50% treatment produced the greatest root elongation. Interestingly, the 20% treatment recorded the highest fresh biomass, suggesting that moderate concentrations favour tissue hydration and rapid metabolic activity during early seedling establishment. Overall, these findings indicate that Beejamrit creates a biologically active environment that enhances seedling growth through improved nutrient availability, stimulation of beneficial microbial activity, and activation of plant metabolic processes.

Root development is a critical determinant of successful seedling establishment because an extensive root system enhances water absorption, nutrient acquisition, and overall plant vigour. The present study revealed a progressive increase in root length throughout the experimental period, with seedlings treated with 50% and 100% Beejamrit exhibiting significantly greater root elongation than the untreated control. Enhanced root growth is likely attributable to the synergistic action of beneficial microorganisms and readily available nutrients present in Beejamrit. These microorganisms facilitate nutrient mineralization, biological nitrogen fixation, phosphorus solubilization, and micronutrient mobilization while simultaneously synthesizing plant growth regulators such as auxins, gibberellins, and cytokinins. Collectively, these processes stimulate cell division, cell elongation, and lateral root development, thereby producing a more efficient root system capable of supporting vigorous seedling growth.

A similar concentration-dependent trend was observed for shoot development. Seedlings primed with 100% Beejamrit produced the greatest shoot elongation, followed by the 50% and 20% treatments. Enhanced shoot growth reflects improved nutrient translocation, increased photosynthetic efficiency, and active cellular metabolism during early vegetative development. The favourable rhizosphere environment established by Beejamrit likely promoted continuous nutrient availability together with sustained production of endogenous growth-promoting substances, resulting in accelerated stem elongation and vegetative growth. The superior performance of higher Beejamrit concentrations suggests that increased microbial activity and nutrient supply provided optimal conditions for sustained shoot development.

Fresh biomass accumulation also responded positively to Beejamrit seed priming. The highest fresh weight was observed in seedlings treated with 20% Beejamrit, followed by the 50% and 100% treatments. Fresh weight primarily reflects tissue hydration, water uptake, and metabolic activity during active growth. The superior fresh biomass recorded under the moderate concentration suggests that 20% Beejamrit provided an optimal balance between microbial activity and nutrient availability, promoting efficient water absorption, rapid cell expansion, and accumulation of metabolic assimilates. Beneficial microorganisms present in the formulation further enhance physiological activity by improving nutrient mineralization and producing growth-promoting compounds, thereby increasing overall seedling vigour.

Dry biomass accumulation, an important indicator of net photosynthetic productivity and structural biomass formation, was greatest in seedlings treated with 100% Beejamrit, followed by the 50% and 20% treatments. Increased dry weight reflects greater synthesis and accumulation of carbohydrates, proteins, lipids, and structural compounds resulting from improved photosynthetic efficiency and nutrient assimilation. Enhanced nutrient availability through biological nitrogen fixation, phosphorus solubilization, and micronutrient mobilization, together with microbial production of phytohormones, likely promoted efficient conversion of absorbed nutrients into structural tissues. Consequently, higher Beejamrit concentrations supported greater dry matter accumulation, indicating improved biomass partitioning and overall physiological performance.

The growth-promoting effects observed in the present study are consistent with the multifunctional role of Beejamrit as a microbial bioinoculant and biostimulant. Cow dung and cow urine provide a diverse consortium of beneficial microorganisms together with essential macro- and micronutrients, while the fermented formulation enriches the rhizosphere with biologically active compounds that improve soil microbial diversity, nutrient cycling, enzymatic activity, and plant health. These integrated biological processes collectively enhance seed germination, root architecture, photosynthetic performance, nutrient uptake, and biomass production during early seedling establishment.

The present findings are in close agreement with previous studies on Beejamrit and other cow-based bioformulations. Patel *et al.*, (2024) reported significant improvements in germination, root and shoot growth, biomass accumulation, chlorophyll content, and physiological performance following Beejamrit application. Similarly, Bhoi *et al.* (2025) observed enhanced root length, shoot growth, seedling vigour, and biomass production in green gram and cowpea treated with Beejamrit. Duddigan *et al.* (2024) demonstrated that natural farming bioformulations stimulate microbial diversity, nutrient mobilization, phytohormone production, and stress tolerance, thereby improving plant growth and productivity. Likewise, Surpura *et al.* (2025) highlighted the importance of nitrogen-fixing and phosphate-solubilizing microorganisms in improving nutrient availability, soil biological activity, and root proliferation under natural farming systems. The agreement between the present findings and these earlier reports further validates the effectiveness of Beejamrit as a sustainable biological seed-priming agent.

Overall, the present study confirms that Beejamrit is an effective eco-friendly bioformulation for improving early growth and biomass accumulation in *Trigonella foenum-graecum* L. Although all concentrations positively influenced seedling performance, distinct responses were observed among treatments. The 20% concentration was most effective in promoting fresh biomass, whereas higher concentrations (50–100%) were superior for root development, shoot elongation, and dry matter accumulation. These concentration-dependent responses are primarily mediated through enhanced microbial activity, improved nutrient availability, increased phytohormone production, and stimulation of plant metabolic processes. Collectively, these findings demonstrate that Beejamrit has considerable potential as a sustainable biological seed-priming agent for improving early crop establishment and productivity while reducing dependence on synthetic agricultural inputs.

Conclusion

The present study provides empirical evidence that Beejamrit is an effective, sustainable biological seed-priming agent for enhancing early seedling establishment in fenugreek. Results demonstrate that Beejamrit improves plant growth and physiological performance via the synergistic action of beneficial microorganisms, bioavailable nutrients, and naturally occurring plant growth–promoting compounds, leading to enhanced metabolic activity and seedling vigour. Across treatments, higher Beejamrit concentrations generally produced superior responses, underscoring the need to optimize application rates to maximize biological efficacy. These findings strengthen the scientific rationale for integrating traditional cow-based bioformulations into sustainable agricultural management and support their potential to reduce reliance on synthetic agrochemicals. The study also provides a basis for future field-based investigations to validate these results, refine seed-priming protocols for diverse crops, and assess the long-term impacts of Beejamrit on crop productivity, soil microbial diversity, nutrient-use efficiency, and overall agroecosystem sustainability.

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