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Effect of Beejamrit seed treatment on germination, seed vigour, and early growth of chickpea under field conditions

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Abstract
Conventional chemical seed treatments improve germination and control soil-borne diseases, but they leave hazardous residues and disturb native soil microbial populations, causing environmental and health problems. A field experiment was conducted during the Rabi season at the Natural Farming Research Field, Rani Lakshmi Bai Central Agricultural University (RLBCAU), Jhansi, to evaluate Beejamrit, an indigenous organic seed treatment, on chickpea (*Cicer arietinum* L.) germination and early growth to provide a sustainable alternative. T1: untreated control; T2: 25%; T3: 50%; T4: 75%; T5: 100%) were examined in a completely randomized block design with three replications. Beejamrit microbiological load increased from Day 1 to 5, then declined. By Day 7, T4 (Beejamrit 75%) had the highest germination (87.5%), seed vigour index-I (1539.03), and seed vigour index-II (12.84) than the control. T5 (100%) had longer roots (6.25 cm) but lower germination and vigour indices, presumably due to microbial competition or nutritional imbalance. Under T4, growth metrics like chlorophyll content (52.13 mg m^{-2}), shoot length (17.61 cm), and seedling dry weight (0.15 g) were optimized. Beejamrit showed promise as an eco-friendly, cost-effective seed treatment, with 75% concentration being best. To improve sustainable chickpea production, future study should clarify its biochemical and microbiological mechanisms, standardize preparation techniques, and validate performance across varied soils and agro-climatic conditions.

Keywords: Beejamrit, natural farming, chickpea, seed treatment, germination

Introduction

Pulses hold a pivotal position in both organic and natural farming systems due to their dual contribution to human nutrition and soil fertility. Among them, chickpea (*Cicer arietinum L.*) is a major legume crop known for its high protein content and nitrogen-fixing ability. It is one of the most ancient and widely cultivated pulses (Redden *et al*., 2007) [26]. Chickpea ranks third globally among pulses, with India contributing approximately 67% of global production (FAO, 2019). Despite the significant global importance and increasing demand for chickpea, its productivity remains low, particularly in arid and semi-arid regions. One of the primary causes is poor seed germination and weak stand establishment, which directly reduce yield potential (Khan *et al*., 2009) [16]. Both Desi and Kabuli chickpea types exhibit low germination percentages due to hard seed coats, seed-borne pathogens, and environmental stresses (Farooq *et al*., 2007) [9]. Poor and uneven germination results in patchy crop stands, leading to reduced competition with weeds, increased vulnerability to pests and diseases, and lower final yield (Buruchara, 2000). Hence, enhancing seed germination and seedling vigor is crucial for improving chickpea productivity and stability under diverse agro-climatic conditions.

Chemical seed treatments effective against pathogens, while shown adverse impacts on beneficial soil microorganisms, particularly Mesorhizobium species responsible for biological nitrogen fixation. The toxic residues from chemical treatments can inhibit microorganism survival in rhizosphere and root colonization, ultimately reducing nodulation efficiency and biological nitrogen fixation capacity. In response to these challenges, a paradigm shift has emerged toward sustainable and ecologically resilient farming systems that aim to restore soil health, minimize environmental damage, and sustain productivity under climate variability. Within this context, organic and natural farming practices have gained global recognition as viable alternatives to input-intensive conventional agriculture. These systems emphasize the use of eco-friendly and locally available biological resources that sustain soil fertility and biodiversity while eliminating dependence on synthetic inputs.

Organic and natural farming share the common goal of achieving agricultural sustainability through biologically driven soil fertility management. Organic farming primarily involves the application of organic manures, compost, vermicompost, green manures, and crop residues such as straw and leaves, which enhance seed germination, plant growth, and yield attributes (Ghadge *et al*., 2013; Naikwade, 2014) [12, 21]. Similarly, natural farming an indigenous approach rooted in traditional Indian agriculture emphasizes self-reliance and the use of farm-derived inputs, avoiding external agrochemicals. Both systems utilize bio-formulations such as Panchagavya, Beejamrit, and Jeevamrut, which are prepared through the fermentation of cow-based products (cow dung, cow urine, milk, curd, and ghee) and other locally available materials. These preparations act as rich microbial inoculants, improving soil enzymatic activity, plant physiological processes, and yield quality (Devakumar *et al*., 2008) [7]. The fermentation process enhances microbial diversity and produces bioactive compounds that stimulate root growth and suppress pathogens, making these formulations essential for sustainable nutrient cycling and disease management (Naikwade, 2017) [20].

Among such formulations, Beejamrit has emerged as a promising indigenous seed treatment in both organic and natural farming systems. It is a mixture of cow dung, cow urine, lime, and native soil, rich in beneficial microorganisms and bioactive metabolites that suppress

seed-borne pathogens and enhance physiological processes vital for germination and early seedling development. Studies have reported germination rates as high as 92% in garden pea following Beejamrit application, demonstrating its potential to enhance seed vigor and viability (Ray *et al*., 2020) [25]. Beyond its role as a seed inoculant, Beejamrit can also improve nutrient mineralization and crop performance when used as a foliar spray, contributing to yield improvement and disease resistance through microbial activation in the rhizosphere (Patel *et al*., 2024) [23]. The microbial consortium in Beejamrit activates soil enzymes and promotes a robust soil microbiome, thus fostering soil fertility and resilience to biotic and abiotic stressors (Sreenivasa *et al*., 2009) [33, 34]. Despite widespread on-farm adoption, systematic research under diverse agro-ecological conditions remains limited, emphasizing the need for scientific validation of its efficacy and mechanisms. It is hypothesized that seed treatment with Beejamrit enhances seed germination, seedling vigor, and early growth performance of chickpea by improving microbial activity and nutrient availability during the initial stages of plant development. To validate this hypothesis, an experiment was conducted to evaluate the impact of Beejamrit on the germination and initial growth of Chickpea (*Cicer arietinum L.*) Seeds.

Materials and Methods

1. Experimental details

The experiment was conducted at the Natural Farming Research Field of Rani Lakshmi Bai Central Agricultural University (RLBCAU), Jhansi, located in the Bundelkhand region of India. The study was carried out in rabi season in chickpea (Cicer arietinum L.) var. Pusa Manav using a Randomized Block Design (RBD) comprising five treatments *viz*., T1- Untreated (control), T2- Beejamrit @25%, T3 – Beejamrit @50%, T4- Beejamrit @75% and T5- Beejamrit @100% replicated thrice. The crop was sown at a spacing of 7.5 cm × 3 cm (P× R). Conceptual workflow has been depicted in figure-1.

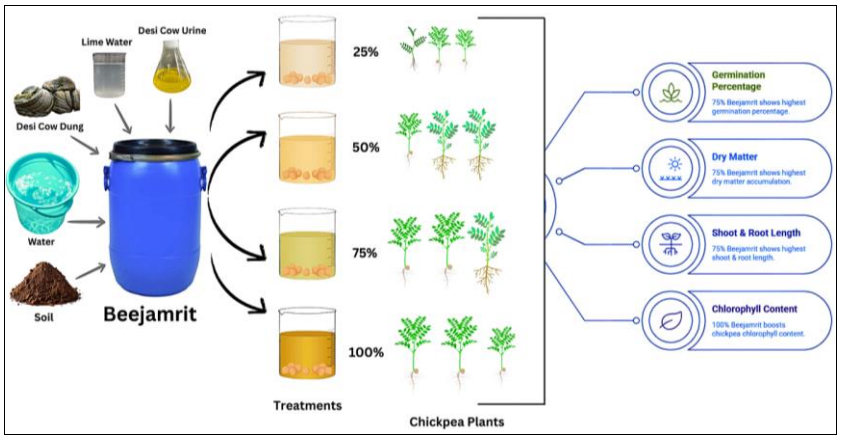

Fig 1: Conceptual representation of work flow

2. Beejamrit Preparation and characterization

Beejamrit preparation was started from collection of cow dung and cow urine from desi cow (Sahiwal). Beejamrit prepared by mixing desi cow's dung (5 kg), cow urine (5 liters), lime (50 g), uncontaminated rhizospheric soil (50 g), and clean water (20 liters) in a plastic container. The mixture was stirred thoroughly and covered with a muslin cloth to allow aeration while preventing contamination. It was placed in a shaded area and left to ferment naturally for 48 hours. Gentle stirring was performed twice daily to promote uniform microbial growth. After fermentation, the Beejamrit solution was ready for use in seed treatment. This preparation method follows traditional natural farming protocols aimed at enriching the solution with diverse beneficial microbes.

Microbial population was estimated by standard plate count technique at 24 hours intervals up to 7 days of incubation. Beejamrit samples were kept at room temperature (28–30°C). A 10 ml aliquot from each sample was subjected to microbial enumeration through the serial dilution and plating method. Nutrient Agar (NA), Potato Dextrose Agar (PDA), Actinomycetes Isolation Agar (AIA), Jensen's Medium, Pikovskaya's Agar (PSA) and King's B Medium were used for total bacterial counts, fungi, actinomycetes, free-living nitrogen-fixing bacteria, phosphate-solubilizing microorganisms, and *Pseudomonas* spp respectively.

Media preparation involved dissolving the respective ingredients in distilled water, sterilizing by autoclaving at 121°C for 15 minutes at 15 psi, and pouring into sterile Petri plates under the Laminar Air Flow. After sample inoculation, plates were incubated at 28°C for 24–48 hours for bacterial populations and up to 5 days for fungi and actinomycetes in the BOD. Microbial count was recorded as colony forming units per mL (cfu mL^{-1}) of Beejamrita sample tested. Changes in pH and electrical conductivity (EC) were determined using a calibrated pH meter and EC meter, following the standard procedures described by Rayment and Higginson (1992) [27].

3. Observation recorded

3.1 Seed germination and seedling growth: Seed germination was recorded from 9 DAS to15 DAS. Germinated seeds were manually counted in each tray. Germination percentage was calculated using the formula:

$$\text{Germination (\%)} = \left(\frac{\text{Number of germinated seeds}}{\text{Total no.of seeds sown}}\right) \text{x } 100$$

3.2 Seedling vigour indices: Seedling vigor indices were calculated by using the formula suggested by Abdul-Baki and Anderson (1973) [1] and expressed as whole number.

Seedling vigour index-I = Standard germination (%) x seedling length (cm)
Seedling vigour index-II = Standard germination (%) x seedling dry weight (mg)

3.3 Root Length: Root length was measured using a standard scale from the base of the root to the tip of the root at 30 days after sowing and is expressed in cm.

3.4 Shoot length: Shoot length was measured from the base of the shoot to tip of the seedling at 30 days after sowing and is expressed in cm.

3.5 Chlorophyll Content: The chlorophyll content in fresh leaves was measured at 30 days of sowing, as per the procedure describe by Mckinney (1941). It was measured using a SPAD chlorophyll meter (SPAD-502 Plus, Konica Minolta).

3.6 Dry Matter: The same seedlings that were used to measure root and shoot length were also used to measure dry matter accumulation. Drying them in a hot air oven at 70°C for six hours until a constant weight was achieved. The dried samples were weighed using an electronic balance.

4. Statistical analysis

The data collected on various aspects of germination, seed vigour, growth on chickpea were tabulated according to treatments and analyzed statistically using the CRD design. The analysis was carried out following the procedures outlined by Gomez and Gomez (1984).

Results

1. Composition of Beejamrit

The chemical and biological properties of Beejamrit were evaluated over a 6-day fermentation period and are summarized in Table 1 and figure 2. The pH levels decreased gradually from 6.5 on Day 0 to 5.6 on Day 5, indicating mild acidification during fermentation. The electrical conductivity (EC) showed a steady increase from 1.20 dSm^{-1} to 1.50 dSm^{-1} by Day 5, suggesting accumulation of soluble ions. On Day 6, a slight reduction in microbial populations was observed across all groups, accompanied by further reduction in pH (5.5) and a marginal decrease in EC (1.48 dSm^{-1}), indicating the onset of microbial stabilization or decline in nutrient availability.

Table 1: Periodic changes in pH and electrical conductivity of Beejamrit

Days / Properties	Days after preparation						
	0	1	2	3	4	5	6
pH	6.5	6.4	6.2	6	5.8	5.6	5.5
EC (dSm^{-1})	1.2	1.25	1.3	1.38	1.45	1.5	1.48

A progressive increase in microbial populations was observed from Day 0 to Day 5, followed by a slight decline on Day 6 (figure 2). The total bacterial count increased from 3.1 × 10^7 CFU mL^{-1} on Day 0 to a peak of 9.3 × 10^7 CFU mL^{-1} on Day 5. Similarly, fungal populations rose from 4.8 × 10^4 CFU mL^{-1} to 7.5 × 10^4 CFU mL^{-1} by Day 5. Actinomycetes also followed a similar trend, increasing from 5.5 × 10^4 CFU mL^{-1} to 8.5 × 10^4 CFU mL^{-1} Nitrogen-fixing bacteria showed consistent growth during the fermentation period, rising from 1.1 × 10^5 CFU mL^{-1} on Day 0 to 2.4 × 10^5 CFU mL^{-1} on Day 5. A steady rise in phosphate-solubilizing bacteria was also recorded, from 6.0 × 10^5 CFU mL^{-1} to 9.5 × 10^5 CFU mL^{-1} over the same period. *Pseudomonas spp*. populations increased markedly, reaching 11 × 10^5 CFU mL^{-1} on Day 5.

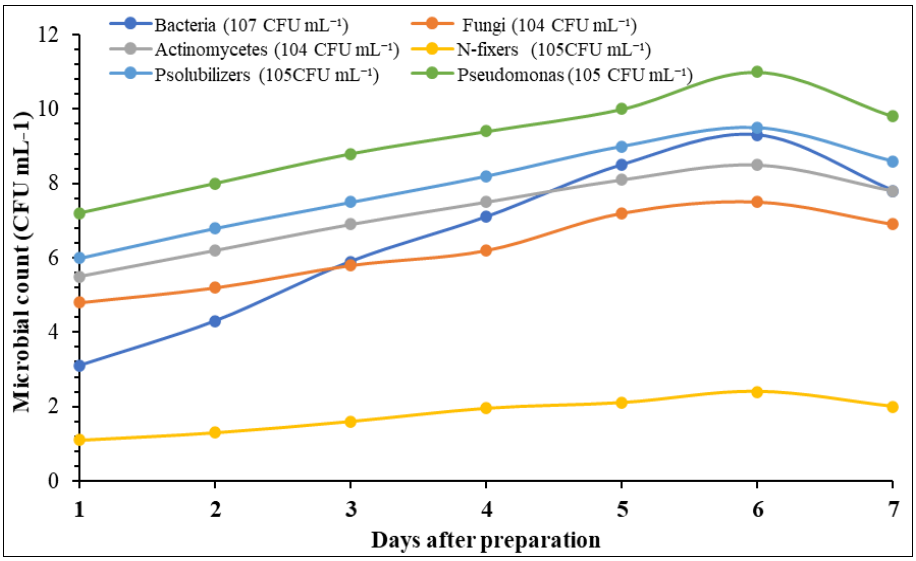

Fig 2: Periodical shift in microbial count (CFU mL-1) in Beejamrit (till 8th day after preparation)

2. Seed germination

The germination data recorded after 9 DAS indicated that Beejamrit significantly improved the germination and early growth of chickpea (*Cicer arietinum L.*) seeds compared to the T1- Untreated (control) (figure 3). Germination was initially low, but by 25 November, the T4- Beejamrit @75% showed a higher mean germination (27.7) than the Untreated (16.7). By the final day (28 November), T4-Beejamrit @75% recorded the highest mean germination (35), followed by T3- Beejamrit @50% with 32.3 and T5-Beejamrit @ 100% with 31.7, whereas the T1- Untreated (control) showed the lowest (27.7).

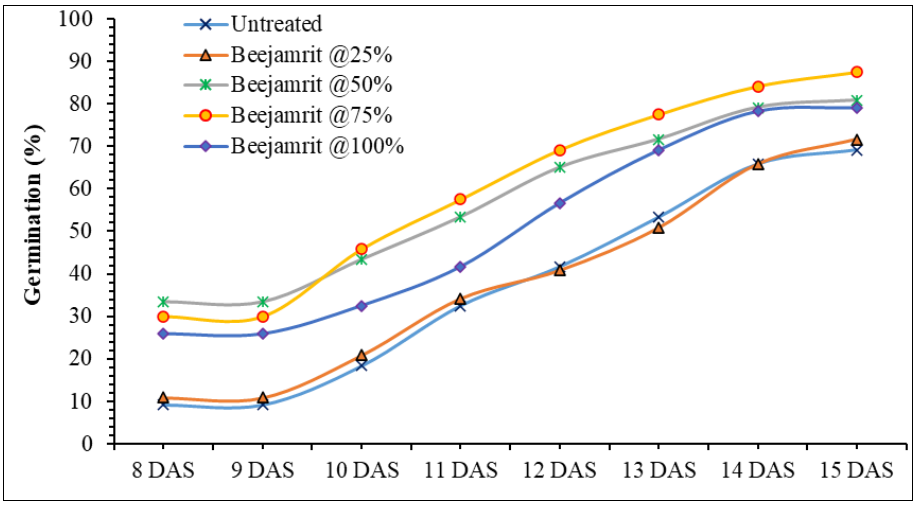

Fig 3: Effect of Beejamrit on seed germination rate

The enhanced germination in Beejamrit treated seeds can be attributed to the presence of diverse plant growth-promoting microorganisms and bioactive compounds that facilitate enzymatic activity and hormone synthesis such as indole-3-acetic acid (IAA) and gibberellins, enhancing seed vigor and root initiation (Sreenivasa *et al*., 2009; Ray *et al*., 2020; Devakumar *et al*., 2014) [8, 25, 33, 34]. The organic ingredients of Beejamrit, derived from cow dung, cow urine, lime, and native soil, supply essential nutrients, beneficial enzymes, and microbial metabolites that promote rapid and uniform germination (Naikwade, 2017; Patel *et al*., 2024) [20, 23]. Similar findings have been reported in legumes and cereals, where Beejamrit and Jeevamrit improved microbial activity, soil enzyme function, and plant growth. The slightly reduced germination @ 100% concentration could be due to higher organic load affecting oxygen diffusion. Overall, Beejamrit @ 75% concentration proved most effective for enhancing chickpea seed germination and early vigor.

3. Seedling Vigour Index

The seed vigour index I (SV-I) of chickpea was significantly influenced by different concentrations of Beejamrit across all observation dates, with noticeable differences from 10 DAS (Table 2). Among the treatments, T4- Beejamrit @75% recorded the highest SV-I values throughout the study period, reaching 490.52 at 10 DAS. This was followed by T3 – Beejamrit @50% and T5- Beejamrit @100%, which recorded values of 437.55 and 421.15, respectively, on the same date. The T1- Untreated (control) consistently recorded the lowest SV-I, with a value of 87.47 on the 10 DAS. Similarly, SV-II showed a consistent and significant improvement with increasing concentrations of Beejamrit (Table 2). T4- Beejamrit @75% resulted in the highest SV-II value (12.84) AT 15 DAS, followed by T3 – Beejamrit @50% at 10.56 and T5- Beejamrit @100%, at 11.04. The lowest SV-II values were recorded in the T1- Untreated (control), which reached only 8.58 by the end of the observation period.

Table 2: Effect of different concentrations of Beejamrit seed treatment on SV - I and SV-II of chickpea

Treatment	9 DAS		10 DAS		11 DAS		12 DAS		13 DAS		14 DAS		15 DAS	
	SV-I	SV-II	SV-I	SV-II	SV-I	SV-II	SV-I	SV-II	SV-I	SV-II	SV-I	SV-II	SV-I	SV-II
T1: Untreated (Control)	15.07	1.14	87.47	2.28	165.65	4.03	332.25	5.16	588.13	6.61	753.27	8.17	959.20	8.58
T2: Beejamrit @25%	48.75	1.39	118.75	2.66	222.40	4.35	434.35	5.2	719.00	6.47	859.40	8.39	1067.10	9.13
T3: Beejamrit @50%	206.08	4.34	437.55	5.65	770.38	6.96	985.63	8.49	1194.67	9.35	1461.40	10.34	1616.80	10.56
T4: Beejamrit @75%	204.35	4.42	490.52	6.73	735.00	8.45	1125.98	10.16	1412.15	11.38	1698.75	12.35	1905.43	12.84
T5: Beejamrit @100%	160.84	3.6	421.15	4.53	620.95	5.8	778.43	7.89	1003.78	9.64	1366.08	10.92	1660.74	11.04
S.Em. +	72.30	0.89	92.70	0.67	172.84	0.76	141.30	0.86	156.45	0.64	189.01	0.47	173.01	0.44
C.D. at 5%	NS	NS	292.09	2.12	544.63	2.38	445.23	2.71	493.00	2.03	595.58	1.47	545.18	1.39
C.V. %	98.59	52.02	51.61	26.67	59.53	22.14	33.46	20.22	27.55	12.83	26.66	8.06	20.78	7.32

4. Growth Attributes of Chickpea

The application of Beejamrit at different concentrations had a noticeable influence on key growth attributes of chickpea seedlings, including chlorophyll content, root length, shoot length, and dry weight (Table 3). Among the treatments, T4-Beejamrit @75% consistently recorded the highest values for most parameters, indicating its superior efficacy in enhancing seedling vigor and early growth. Maximum chlorophyll content (52.13 mg/m²) was observed in T4-Beejamrit @75%, followed by T5- Beejamrit @100% (51.01 mg/m²), while the T1- Untreated (control) recorded the lowest value (44.94 mg/m²). This suggests that Beejamrit positively influenced chlorophyll synthesis, likely due to improved microbial activity and nutrient availability. In terms of shoot length, T4- Beejamrit @75% again recorded the highest value (18.13 cm), showing significant increase over the T1 untreated (12.59 cm). The root length was found to be highest in T4- Beejamrit @75% (6.47 cm), followed by T5- Beejamrit @100% (6.14 cm), and whereas lowest volue recorded in T1 untreated (5.28 cm).

Table 3: Effect of different concentrations of Beejamrit seed treatment on growth characteristics of chickpea (*Cicer arietinum L.*)

Treatment	Chlorophyll Content (mg m^2)	Root Length (cm)	Dry weight (g)	Shoot Length (cm)	Shoot – Root Length ratio
T1: Untreated (Control)	44.94	5.28	0.12	12.59	2.39
T2: Beejamrit @25%	46.41	5.71	0.13	15.33	2.68
T3: Beejamrit @50%	48.07	5.77	0.13	16.33	2.82
T4: Beejamrit @75%	52.13	6.47	0.15	18.13	2.80
T5: Beejamrit @100%	51.01	6.14	0.14	17.91	2.92
SEm±	1.15	0.11	0.00	0.68	0.19
C.D. at 5%	3.64	0.34	0.00	2.15	NS
C.V. %	4.24	3.22	1.47	7.42	11.94

The dry weight of seedlings also showed a measurable significantly improvement, with the highest value (0.15 g) in T4- Beejamrit @75%, compared to the control (0.12 g). Different concentrations of Beejamrit exerted a noticeable effect on the shoot–root length ratio of chickpea seedlings, although the differences were statistically non-significant. The lowest shoot–root length ratio (2.39) was recorded in the T1- Untreated (control). Application of Beejamrit gradually increased the ratio up to T5- Beejamrit @100%, where the maximum value (2.92) was observed. Treatments with 25% (2.68), 50% (2.82), and 75% Beejamrit (2.80) also showed comparatively higher ratios than the control.

Discussion

1. Microbial and Biochemical Dynamics of Beejamrit

The microbial and physicochemical characterization of Beejamrit during the seven-day incubation period revealed an active and dynamic microbial ecosystem essential for its bioefficacy. A progressive rise in total bacterial, fungi and actinomycetes from 3.1×10^7 CFU mL^{-1}, 4.8×10^4 CFU mL^{-1} and 5.5×10^4 on 0 incubation day to 9.3×10^7 CFU mL^{-1}, 7.5×10^4 CFU mL^{-1} and 8.5×10^4 on 5 days incubation respectively, followed by a slight decline on Day 6, indicates a classical microbial growth curve associated with fermentation-based organic formulations (Weintraub & Schimel, 2003) [39]. The availability of readily metabolizable substrates such as simple sugars from jaggery and nitrogen from cow dung and urine promotes rapid microbial proliferation during the initial stages of fermentation. This phase is succeeded by a stationary or decline phase due to nutrient depletion and increased competition (Ferreira & Mendes-Faia, 2020) [11]. Fungal population continues to increase till 5th days of incubation (Devakumar *et al*., 2014) [8] as they prefer acidic to near neutral pH and because of their natural ability to degrade the undigestible and partially degraded polysaccharides better than other microbial groups. Concurrently, the populations of nitrogen-fixing bacteria (N-fixers) and phosphate-solubilizing bacteria (PSBs) increased markedly up to Day 5 (2.4×10^5 and 9.5×10^5 CFU mL^{-1}, respectively), reflecting the maturation of Beejamrit into a functionally enriched bioinoculant. These groups are known to enhance soil fertility and plant nutrition by fixing atmospheric nitrogen and mobilizing phosphorus through the secretion of organic acids (Smercina *et al*., 2019) [31]. The increased abundance of *Pseudomonas* spp. (up to 1.1×10^6 CFU mL^{-1}) is particularly significant, as these rhizobacteria synthesize phytohormones such as indole-3-acetic acid (IAA) and gibberellins, suppress phytopathogens, and promote root elongation (Saharan & Nehra, 2011; Ahamed *et al*., 2008) [28].

The decline in pH from 6.5 to 5.5 during fermentation indicates the predominance of acidogenic microbial metabolism. The conversion of free sugars to volatile fatty acids (VFAs) and organic acids contributes to acidification, whereas subsequent deamination of amino acids upon sugar depletion can slightly increase pH (Ferreira & Mendes-Faia, 2020) [11]. The concurrent increase in electrical conductivity (EC) from 1.20 to 1.50 dSm^{-1} corresponds to the accumulation of soluble ions derived from organic matter decomposition, consistent with microbial mineralization processes. The acidic pH of Beejamrit at the end of incubation lead to the conclusion that it is a fermentative type of product. There was an increase in electrical conductivity due to the build-up of free ions at the end of fermentation period. This fermentative nature categorizes Beejamrit as a biologically active organic input capable of nutrient solubilization and microbial enrichment (Devakumar *et al*., 2014) [8]. The cow breeds do not have influence on changes in pH and EC, however, the nutrient content and microbial load of Beejamrit depends on feeding habit of the animal.

Interestingly, while bacterial and beneficial microbial groups thrived, fungal and actinomycete populations exhibited relatively subdued growth, possibly due to the antimicrobial properties of cow urine and acidic pH conditions (Sreenivasa *et al*., 2009) [33, 34]. These selective pressures favor bacterial dominance, thereby explaining Beejamrit's capacity to suppress seed-borne pathogens and improve germination health. Similar microbial succession patterns were reported in *Jeevamruth* and other cow-based bioformulations, where bacterial populations peaked between the fourth and fifth days of incubation (Devakumar *et al*., 2014) [8].

2. Germination, Seedling Vigour and Early Growth Response

The biological implications of Beejamrit's microbial composition were clearly reflected in seed vigour and early seedling growth. Treatments with 75% Beejamrit concentration (T_4) consistently outperformed the control and other concentrations in both Seed Vigour Index I (SVI-I) and Seed Vigour Index II (SVI-II) across all observation intervals. At 10 DAS, the highest SVI-I (490.52.) and SVI-II (4.53) values under T_4 demonstrate the formulation's superior capacity to promote physiological activity and metabolic efficiency during germination. These findings are congruent with the results of Subramaniyan and Malliga (2016) [37] in maize and Pawar *et al*. (2015) [24] in garden pea, who observed significant enhancement in germination and vigour following Beejamrit or biofertilizer-based seed treatments. The enhanced vigour indices and seedling growth under Beejamrit treatment can be attributed to the synergistic effect of microbial metabolites, enzymatic stimulation, and nutrient availability. Beejamrit, enriched

with indigenous microorganisms such as *Azotobacter*, *Rhizobium*, *Pseudomonas*, and actinomycetes, stimulates early enzymatic activity (e.g., amylases and proteases) essential for the mobilization of stored food reserves (Karuppaswamy & Perumal, 2013) [15]. Furthermore, the microbial metabolites, including auxins, gibberellins, and cytokinins, promote root and shoot elongation, leading to vigorous seedling establishment. The increased chlorophyll content observed at Beejamrit @75% concentration indicates enhanced photosynthetic competence, likely due to improved nitrogen assimilation and micronutrient uptake (Arteca, 1997; Bewley & Black, 1985) [4, 5].

3. Mechanistic Insights into Beejamrit Functionality

The mechanism underlying Beejamrit's biostimulant action lies in its microbial and biochemical synergy. During fermentation, a rich microbial consortium converts complex organic substrates into simpler, bioavailable nutrients, while simultaneously synthesizing plant growth regulators and antimicrobial compounds. The inclusion of lime ($CaCO_3$) stabilizes pH and enhances the survival of beneficial microbes, while the addition of native forest soil introduces a diverse microbial inoculum essential for ecological functionality. The microbial enzymatic activities particularly those related to carbon, nitrogen, and phosphorus cycling are central to Beejamrit's growth-promoting effect. These processes improve nutrient availability, accelerate metabolic activation during germination, and strengthen plant defense mechanisms. Such mechanisms align with the findings of Devakumar *et al*. (2014) [8], who reported that the microbial load, especially nitrogen fixers and phosphorus solubilizers, reached optimum levels in freshly prepared Beejamrit, emphasizing the importance of its application timing. Additionally, organic acid secretion by microbial consortia enhances phosphorus solubility and micronutrient bioavailability, indirectly contributing to improved seedling chlorophyll content and dry matter accumulation (Jin *et al*., 2018) [14].

4. Integration with Organic and Natural Farming Paradigms

The demonstrated efficacy of Beejamrit underscores its significance within the broader framework of organic and natural farming. In contrast to synthetic seed dressers or chemical priming agents, Beejamrit offers a holistic, self-sustaining alternative that enriches the rhizosphere, improves nutrient cycling, and reduces environmental impact (Naikwade, 2014; Ghadge *et al*., 2013) [12, 21]. The results validate the underlying philosophy of Zero Budget Natural Farming (ZBNF), which emphasizes the use of locally sourced biological inputs for sustainable crop production (Ray *et al*., 2020; Patel *et al*., 2024) [23, 25]. The microbial activation and enzymatic enhancement triggered by Beejamrit contribute directly to soil biological health and crop productivity, reaffirming its role as a vital component of ecologically resilient farming systems.

In essence, the present findings substantiate that Beejamrit particularly at 75% concentration optimally balances microbial diversity, nutrient enrichment, and biochemical activation, thereby enhancing seed germination and early growth in chickpea. The formulation's multifunctional role as a microbial inoculant, bio-stimulant, and pathogen suppressor makes it a cornerstone input for sustainable legume cultivation and a viable substitute for synthetic seed treatments in organic and natural farming systems.

Conclusion

The present study clearly demonstrates that Beejamrit a traditional, low-cost seed treatment materiel rich in beneficial microorganisms significantly enhances seed germination, seedling vigour, and early growth in chickpea (Cicer arietinum L.). The chemical properties of Beejamrit, including slightly acidic pH, high organic carbon content, and the presence of plant growth-promoting substances contribute to improved soil health and seed metabolism. Biologically, its rich microbial consortia help in nutrient solubilization, disease suppression, and hormone-like activity that stimulate root and shoot development. The Beejamrit @75% concentration proved most effective, likely offering an optimal balance of microbial activity and nutrient availability. These findings confirm the potential of Beejamrit as a sustainable and eco-friendly seed treatment, especially suitable for organic and natural farming systems aimed at enhancing early crop establishment and productivity.

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