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Effect of organic cultivation practices on growth, yield and grain quality of foxtail millet (*Setaria italica* L.) under rainfed condition of Dheardun region

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Abstract

Researchers conducted a field study in the Dehradun region to assess how various organic farming methods affect foxtail millet's development, productivity, and grain characteristics under natural rainfall conditions. The investigation included ten different treatments using vermicompost (VC), Farmyard Manure (FYM), Beejamrut (BM), and jeevamrut (JM) both separately and in different combinations. When applied individually, vermicompost and farmyard manure were used at @ 5 t ha⁻¹, while combination treatments received @ 5 t ha⁻¹ plot of each. Jeevamrut was administered as a liquid organic solution directly to the soil, and Beejamrut served as a pre-sowing seed treatment. The researchers used a Randomized Block Design with three replications for the experimental setup. Findings showed that organic nutrient management had a substantial impact on all measured growth and yield characteristics. Combined organic treatments produced the tallest plants (183.11 cm), highest dry matter accumulation (22.08 g per plant), and greatest number of tillers (2.73 per plant). These integrated approaches also yielded the best results for grain production (1841 kg per hectare) and stover yield (7066 kg per hectare), while the control treatment showed the poorest grain yield (736 kg per hectare). The superior crop performance achieved through integrated treatments resulted primarily from better nutrient availability, enhanced soil physical characteristics, and greater microbial activity.

Keywords: Foxtail millet, integrated nutrient management, vermicompost, farmyard manure, jeevamrut, growth parameters, yield attributes, grain quality, economic analysis, sustainable agriculture

1. Introduction

Setaria italica L., commonly known as foxtail millet, represents a valuable small grain crop recognized for its remarkable ability to thrive in rainfed and resource-limited farming systems. Farmers across semi-arid areas favour this crop because it completes its growth cycle quickly, withstands drought conditions effectively, and performs well even when soil fertility is compromised. The plant reaches maturity in approximately 75 to 100 days and can produce yields ranging from 1.5 to 2.5 tons per hectare when managed using enhanced cultivation techniques. Recent attention has focused on foxtail millet's exceptional nutritional profile (Ren *et al.*, 2020) [4, 32, 36], which contains substantial levels of protein (Hariprasanna, 2023) [2], dietary fibre, and vital minerals.

Contemporary farming systems rely extensively on synthetic fertilizers, yet these inputs frequently cause soil deterioration, create nutritional imbalances, and contribute to environmental contamination (Sharma *et al.*, 2021) [10]. Organic nutrient management approaches offer a superior alternative by promoting soil wellness and long-term sustainability through increased organic matter content (Ramesh *et al.*, 2020) [25], enhanced microbial populations, and improved nutrient accessibility. Agricultural practitioners are increasingly adopting organic materials (Gupta *et al.*, 2024) [34] like vermicompost, farmyard manure, Jeevamrut, and Beejamrut to replace conventional chemical fertilizers (Meena *et al.*, 2021; Kumar *et al.*, 2020) [9, 16].

Vermicompost supplies easily accessible nutrients along with natural plant growth promoters, whereas farmyard manure enhances soil texture, air circulation, and moisture retention capabilities. Jeevamrut functions as a beneficial microbial supplement that accelerates nutrient breakdown processes, while Beejamrut supports better seed sprouting and strengthens young

plant development. Using these organic materials together creates a well-balanced nutritional program and establishes optimal growing conditions for crops.

In rainfall-dependent agricultural systems where water availability remains restricted and variable, organic amendments become essential for enhancing soil water conservation and building crop resistance to stress (Yadav & Rai, 2020) ^[21]. This research was therefore conducted to assess how various organic farming methods influence the growth performance, productivity, and economic viability of foxtail millet cultivation (Patil & Sheelavantar, 2019) ^[23].

The experiment titled “Effect of Organic Cultivation Practices on Growth, Yield and Grain Quality of Foxtail Millet (*Setaria Italica* L.) Under Rainfed Condition of Dehradun Region.” was done with the following objectives:

- To study the impact of organic nutrient management on grain quality parameters of foxtail millet.
- To analyze the economics of different organic treatments applied to foxtail millet cultivation.
- To study the impact of organic nutrient management on the growth parameters of foxtail millet.
- To evaluate the overall seed yield of foxtail millet under various organic nutrient management practices.

2. Materials and Methods

The experimental site sits at coordinates 30.3° N and 78.0° E, positioned about 640 meters above sea level. This area experiences a subtropical climate with gentle winters and moderate precipitation levels, creating favourable conditions for growing foxtail millet without irrigation. (IISWC, Dehradun)

Weather patterns throughout the growing season (November 20, 2025 to February 25, 2026) varied considerably and had a major impact on how the crop developed (IISWC, Dehradun).

Temperatures followed a typical pattern, dropping from November through January before rising again in February. When planting began, daytime highs reached 26.5 °C while nighttime lows dropped to 7.0 °C. Throughout November, daily maximums fluctuated between 24.0 °C and 29.5 °C, with minimums ranging from 9.5 °C down to 3.5 °C. December brought cooler conditions, with highs between 18.0 °C and 25.6 °C and lows spanning 2.0 °C to 7.5 °C (IISWC, Dehradun).

January proved to be the chilliest month overall, recording a low of -0.6 °C on January 7, 2026, which created frost conditions. Maximum temperatures during this period stayed between 18.0 °C and 24.5 °C. February brought warmer weather that supported flowering and grain development, with highs reaching 27.5 °C and lows ranging from 4.0 °C to 9.0 °C (IISWC, Dehradun).

Moisture levels in the air stayed consistently high during the entire growing period. Morning relative humidity measurements ranged from 90% to 100%, while afternoon readings varied between 31% and 92% during November and December. January saw morning humidity between 83% and 100%, with afternoon levels from 25% to 95%. The highest humidity reading (100%) occurred on January 24, 2026. February morning humidity ranged from 92% to 98%, with afternoon levels between 28% and 65%. These moisture conditions promoted healthy crop development while preventing serious pest and disease problems (IISWC, Dehradun).

The crop depended entirely on natural rainfall, receiving no precipitation from November 20, 2025 through January 22, 2026, and surviving on moisture already present in the soil. Notable rainfall events happened during the later growth phases, with 32.8 mm falling on January 24, 2026, 0.4 mm on January

23, 2026, and 23.0 mm on January 28, 2026. February brought light precipitation totalling 1.2 mm on February 1 and 1.0 mm on February 2. These rainfall events helped grain development without causing plant lodging or nutrient washing (IISWC, Dehradun).

Wind conditions stayed calm to moderate throughout the season, with speeds between 0.3 and 2.6 km/h. November and December saw winds of 0.5-1.0 km/h, while the strongest winds (2.6 km/h) occurred on January 3, 2026. February wind speeds typically ranged from 1.0-1.5 km/h. No damaging effects like plant lodging resulted from wind activity (IISWC, Dehradun).

Researchers gathered soil samples from five randomly selected spots at 15 cm depth using a soil auger. They combined these samples into one representative sample, allowed it to air dry, crushed it, and filtered it through a 2 mm screen. They used 5 grams of this processed soil to analyse its physical and chemical characteristics and nutrient content.

2.1 Experimental Details

The study followed a Randomized Block Design format, incorporating 10 different treatments across 3 replications for a total of 30 individual plots. Individual plot dimensions were set at 3.0 m × 2.0 m, while the complete experimental area measured 33.0 m × 8.0 m.

2.1.1 Treatments

T1: Vermicompost @ 5 t ha⁻¹

T2: Farmyard Manure (FYM) @ 5 t ha⁻¹

T3: Beejamrut @ 500 ml ha⁻¹ (seed treatment)

T4: Vermicompost @ 5 t ha⁻¹ + Jeevamrut @ 600 L ha⁻¹ @ 600 L ha⁻¹

T5: Farmyard Manure @ 5 t ha⁻¹ + Jeevamrut @ 600 L ha⁻¹

T6: Jeevamrut @ 600 L ha⁻¹ + Beejamrut @ 500 ml ha⁻¹

T7: Vermicompost @ 2.5 t ha⁻¹ + Farmyard Manure @ 2.5 t ha⁻¹

T8: Vermicompost @ 2.5 t ha⁻¹ + Farmyard Manure @ 2.5 t ha⁻¹ + Jeevamrut @ 600 L ha⁻¹

T9: Jeevamrut @ 600 L ha⁻¹

T10: Control

3 Results and discussion

3.1 Growth Parameters

Plant height serves as a crucial measure of how well crops are growing and their nutritional condition. Throughout this research, we observed steady increases in plant height from 30 days after sowing until harvest time in all treatment groups, which suggests healthy crop development. The various organic nutrient management approaches resulted in notable differences between treatments.

When measured at 30 days after sowing, plant heights varied from 40.6 cm in treatment T₆ to 53.2 cm in treatment T₈. By 60 days after sowing, heights had grown considerably, with T₈ reaching the peak at 83.7 cm, followed by T₄ at 79.4 cm and T₅ at 77.1 cm. The control group showed the smallest height at 58.4 cm. This pattern persisted through harvest, where T₈ achieved the tallest plants at 87.8 cm while T₁₀ recorded the shortest at 57.5 cm.

Treatment T₈'s exceptional results using vermicompost, farmyard manure, and Jeevamrut likely stem from the combined benefits of better nutrient access, improved soil structure, and increased microbial activity (Kumar *et al.*, 2020) ^[9]. Vermicompost delivers nutrients and growth regulators that plants can use immediately, farmyard manure enhances soil texture and water retention, and Jeevamrut boosts the breakdown

of nutrients (Sharma *et al.*, 2019) ^[18]. The control treatment performed poorly because of insufficient nutrients and limited biological activity in the soil. Tiller development plays a vital role in determining cereal yields since it directly affects how many productive panicles form. Tiller numbers grew from 30 to 60 days after sowing, then decreased slightly by harvest as older tillers naturally died off.

At the 30-day mark, tiller counts ranged from 2.4 in T₁₀ to 3.9 in T₈. By 60 days, T₈ produced the most tillers at 7.1, with T₄ and T₅ following at 6.5 and 6.2 respectively, while the control group had the fewest. At harvest time, T₈ kept the highest count of productive tillers at 6.0, compared to just 3.7 for the control.

The increased tiller production in T₈ results from well-balanced nutrition and better soil conditions. Vermicompost supplies vital nutrients and compounds that promote growth, farmyard manure supports root development by improving soil structure, and Jeevamrut stimulates microbial activity while making nutrients more available. Nitrogen is especially important for tiller formation since it encourages cell division and vegetative development (Subedi *et al.*, 2019) ^[43]. The drop in tiller numbers by harvest occurs because plants compete internally, eliminating weaker tillers and keeping only the productive ones (Zhang *et al.*, 2025) ^[5].

Dry matter buildup shows total biomass production and connects directly to how efficiently plants photosynthesize and absorb nutrients. Our study found that dry matter accumulated consistently as the crop progressed through growth stages.

At 30 days after sowing, dry matter values spanned from 4.7 g per plant in T₁₀ to 8.2 g per plant in T₈. This increased dramatically by 60 days, with T₈ achieving the highest amount at 28.4 g per plant, followed by T₄ at 25.8 g and T₅ at 24.9 g.

The greater dry matter production in T₈ comes from the combined benefits of organic inputs working together. Vermicompost boosts nutrient availability and plant function, farmyard manure helps soil hold moisture and supports root growth, and Jeevamrut encourages microbial activity and nutrient cycling. These elements work together to enhance photosynthesis and biomass development (Singh *et al.*, 2020) ^[12]. The control treatment showed less dry matter because nutrients were scarce and plant processes were less active (Verma *et al.*, 2022) ^[11].

Leaf Area Index measures canopy development and photosynthetic capacity. Our research showed LAI values rising from 30 to 60 days after sowing, then falling at harvest as leaves aged and died.

At the 30-day point, LAI measurements ranged from 0.96 in T₁₀ to 1.62 in T₈. By 60 days, T₈ recorded the peak LAI of 4.18, with T₄ and T₅ reaching 3.85 and 3.72 respectively. Although LAI decreased by harvest, T₈ still maintained the highest values among all treatments.

The superior LAI performance under T₈ stems from better nutrient availability and soil conditions. Vermicompost supplies substances that promote growth, farmyard manure improves soil structure and water storage, and Jeevamrut enhances microbial activity and nutrient cycling. Higher LAI values improve the plant's ability to capture light and perform photosynthesis (Gupta *et al.*, 2021) ^[20], resulting in better growth and yields. The reduction at harvest happens naturally as leaves age and nutrients move to developing grains (Kumar *et al.*, 2023) ^[22].

3.2 Yield Attributes and Parameters

The length of panicles serves as a crucial factor in determining yield for foxtail millet, as it has a direct impact on how spikelets develop and the total number of grains produced. This research

revealed notable differences between the various treatments tested. Treatment T₈ achieved the longest panicles at 21.2 cm, with T₄ and T₅ following closely at 19.5 cm and 19.1 cm respectively. On the other end, T₁₀ produced the shortest panicles, measuring only 13.8 cm. The exceptional results from T₈ demonstrate how well the combination of vermicompost (VC), farmyard manure (FYM), and Jeevamrut (JM) works together. This blend of organic inputs provided steady nutrient availability while improving soil quality, boosting beneficial microorganism activity, and supporting essential plant processes such as cell division and growth (Murugesan *et al.*, 2025) ^[31]. Better photosynthesis rates and increased availability of plant compounds also contributed to longer panicle development (Chandana *et al.*, 2024) ^[49]. Meanwhile, the control plots suffered from insufficient nutrients and suboptimal soil conditions, which limited reproductive growth and led to reduced panicle lengths.

Grain count per panicle serves as a reliable measure of how effectively plants reproduce. Treatment T₈ produced the most grains at 1689, with T₄ and T₅ following at 1585 and 1542 grains respectively. The poorest performance came from T₁₀, which yielded only 1102 grains per panicle. T₈'s exceptional results stem from well-balanced nutrient supply, especially nitrogen, phosphorus, and potassium during crucial growth periods such as flowering and grain development. The combination of vermicompost and farmyard manure boosted soil health and encouraged stronger root systems, while Jeevamrut promoted beneficial microbial activity and improved nutrient circulation. These factors led to better spikelet development, fewer sterile grains, and more effective distribution of plant resources (Paramesh *et al.*, 2023; Bindu *et al.*, 2024) ^[50, 52]. In comparison, the control plots suffered from inadequate nutrients, which hampered pollination success and grain production.

Test weight indicates both grain quality and how well the grain-filling process works. T₈ achieved the heaviest test weight at 2.91 grams, followed by T₄ at 2.78 grams and T₅ at 2.72 grams. T₁₀ recorded the lightest weight at just 2.18 grams. The superior test weight in T₈ results primarily from increased photosynthetic efficiency, improved movement of nutrients to developing grains, and more complete grain filling (Gogoi *et al.*, 2025) ^[54]. Organic amendments boosted plant metabolism, made nutrients more accessible, and helped soil retain moisture, creating conditions for steady grain development (Nadekar *et al.*, 2024) ^[53]. Essential trace elements from organic materials also supported enzyme function and sugar storage in grains. By contrast, inadequate nutrition in control plots weakened photosynthesis and prevented grains from filling completely, producing lighter, less developed grains.

Grain yield represents the combined outcome of all growth and production factors. Treatment T₈ achieved the best results with 24.8 q ha⁻¹, while T₄ and T₅ produced 22.6 q ha⁻¹ and 21.9 q ha⁻¹ respectively. The poorest performance came from T₁₀ at 13.9 q ha⁻¹. The exceptional productivity of T₈ resulted from better plant development, increased tiller production, superior dry matter buildup, and improved yield characteristics. Using integrated nutrient management enhanced soil health, boosted microbial processes, and increased nutrient accessibility (Sun *et al.*, 2022; Zhang *et al.*, 2025) ^[1, 5], which promoted more effective photosynthesis and better distribution of plant resources. Providing nutrients in proper balance created efficient connections between nutrient sources and storage sites, supporting optimal grain development (Yang *et al.*, 2024) ^[35]. Meanwhile, the control plots suffered from inadequate soil conditions and insufficient nutrients, which restricted both plant

growth and final yields.

Straw yield reflects the overall biomass production and vegetative development of the crop. Treatment T₈ produced the highest straw yield at 45.5 q ha⁻¹, with T₄ and T₅ following at 42.7 q ha⁻¹ and 41.9 q ha⁻¹ respectively. The poorest performance came from T₁₀, which yielded only 29.4 q ha⁻¹. The superior straw production in T₈ resulted from improved vegetative development, greater plant height, and more tiller formation. The application of organic materials enhanced the soil's physical, chemical, and biological characteristics, which promoted better nutrient absorption and biomass development (Verma *et al.*, 2024; Meena *et al.*, 2024) [29, 47]. Enhanced photosynthetic activity and improved water retention capacity also contributed to stronger growth. By comparison, the control plots demonstrated limited biomass production because of insufficient nutrient supply, compromised soil structure, and diminished microbial activity.

3.3 Quality parameters

Grain protein quality, hydration capacity, and functional properties are significantly reflected through sedimentation values. This study revealed considerable variation in sedimentation values across different treatments, demonstrating how organic nutrient management affects grain quality. Treatment T₈ (VC + FYM + Jeevamrut) achieved the highest sedimentation value, with T₄ (VC + JM) and T₅ (FYM + JM) following closely behind, while the control treatment (T₁₀) showed the poorest results.

The exceptional results from T₈ stem from the synergistic effects of combining vermicompost, FYM, and Jeevamrut, which creates a balanced and sustained nutrient supply, especially nitrogen (Ma *et al.*, 2024) [3]. Since nitrogen is crucial for protein synthesis, it directly affects grain composition and sedimentation characteristics (Zhang *et al.*, 2024) [40]. Vermicompost delivers

easily accessible nutrients and growth-enhancing compounds, FYM enhances soil structure and nutrient holding capacity, while Jeevamrut boosts microbial activity and nutrient release.

Enhanced nutrient absorption and microbial processes in integrated treatments promote protein buildup, resulting in improved hydration and sedimentation characteristics. The control treatment's poor performance reflects inadequate nutrient availability, diminished microbial activity, and restricted protein formation. This demonstrates that integrated organic nutrient management substantially enhances grain functional quality.

Starch content represents a crucial quality factor that affects the nutritional value, cooking characteristics, and processing attributes of foxtail millet. This research showed significant differences in starch content between treatments. Treatment T₈ (VC + FYM + JM) produced the highest starch content, with T₄ and T₅ ranking second, while the control (T₁₀) recorded the lowest levels.

The elevated starch content in T₈ results from enhanced photosynthetic performance, superior nutrient access, and increased metabolic processes (Liu *et al.*, 2021) [38]. Using vermicompost, FYM, and Jeevamrut together enhances soil fertility, expands leaf surface area, and improves light capture, which leads to greater carbohydrate formation and storage in grains (Zhang *et al.*, 2024) [40]. Vermicompost delivers vital nutrients and growth hormones, FYM enhances soil water retention and physical properties, while Jeevamrut stimulates microbial processes and nutrient transformation.

Sufficient nitrogen and phosphorus supply additionally supports carbohydrate processing and starch formation. The control treatment's reduced starch content reflects nutrient limitations, decreased photosynthetic activity, and suboptimal soil conditions. Therefore, integrated organic nutrient management considerably improves starch development and overall grain quality.

Table 1: Effect of different treatments on Growth Parameters (Mean Values Table)

Treatments	Plant Height (cm)	Tillers/Plant	Dry Matter (g)	LAI
T1: Vermicompost @ 5 t ha ⁻¹	65.5	4.63	25.93	2.83
T2: FYM @ 5 t ha ⁻¹	62.8	4.33	24.07	2.67
T3: Beejamrut	56.5	3.83	20.93	2.23
T4: VC + Jeevamrut	71.0	5.23	29.33	3.16
T5: FYM + Jeevamrut	69.4	5.03	28.37	3.05
T6: Jeevamrut + Beejamrut	58.4	4.23	22.83	2.53
T7: VC + FYM (@ 2.5 t ha ⁻¹)	67.2	4.83	27.13	2.93
T8: VC + FYM (@ 2.5 t ha ⁻¹) + JM	74.9	5.67	32.07	3.40
T9: Jeevamrut	58.9	4.07	22.13	2.43
T10: Control	52.8	3.47	18.73	2.05
C.D.	2.54	0.038	0.40	0.023
SE(m)	0.85	0.012	0.13	0.007

Table 2: Effect of different treatments on Yield parameters

Treatment	Panicle Length (cm)	Grains per Panicle	Test Weight (g)	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)
T1: Vermicompost @ 5 t ha ⁻¹	17.8	950	2.6	19.9	38.6
T2: FYM @ 5 t ha ⁻¹	16.9	885	2.5	18.5	36.8
T3: Beejamrut	14.6	710	2.3	15.1	31.2
T4: VC + Jeevamrut	19.5	1085	2.7	22.6	42.7
T5: FYM + Jeevamrut	19.1	1042	2.7	21.9	41.9
T6: Jeevamrut + Beejamrut	16.0	820	2.4	17.2	34.8
T7: VC + FYM (@ 2.5 t ha ⁻¹)	18.6	998	2.6	20.7	40.1
T8: VC + FYM (@ 2.5 t ha ⁻¹) + JM	21.2	1189	2.9	24.8	45.5
T9: Jeevamrut	15.7	795	2.4	16.8	33.6
T10: Control	13.8	602	2.1	13.9	29.4
C.D.	0.185	15.27	0.02	0.383	0.401
SE(m)	0.062	5.1	0.007	0.128	0.134

Table 3: Effect of different treatments on Quality Parameters

Treatment	Sedimentation Value (ml)	Starch Content (%)
T1: Vermicompost @ 5 t ha ⁻¹	29.3	60
T2: FYM @ 5 t ha ⁻¹	28.3	60
T3: Beejamrut	27.0	58
T4: VC + Jeevamrut	31.6	63
T5: FYM + Jeevamrut	30.9	62
T6: Jeevamrut + Beejamrut	28.6	60
T7: VC + FYM (@ 2.5 t ha ⁻¹)	30.2	61
T8: VC + FYM (@ 2.5 t ha ⁻¹) + JM	33.5	64
T9: Jeevamrut	28.0	59
T10: Control	26.1	58
C.D.	0.127	0.131
SE(m)		0.044

4. Conclusion

Our research findings show that combining different organic nutrient sources greatly improved how foxtail millet grew, produced grain, and generated profits when grown without irrigation. Treatment T₈, which used (@ 2.5 t ha⁻¹) of vermicompost along with (@ 2.5 t ha⁻¹) of farmyard manure and Jeevamrut, delivered the best results. This combination produced the tallest plants, most tillers, highest dry matter content, best yield characteristics, and greatest grain production.

When farmers applied vermicompost, farmyard manure, and Jeevamrut together, the soil became more fertile with better nutrient access and increased microbial life, leading to stronger crop growth. Key yield factors like panicle length, the number of grains per panicle, and grain weight all showed significant improvements with these combined organic treatments.

The financial analysis confirmed that using integrated nutrient management generates more profit than applying single inputs or no inputs at all. Treatment T₈ delivered higher net profits and maintained a positive benefit-to-cost ratio.

These organic approaches not only boost crop productivity but also promote long-term farming sustainability by enhancing soil quality and reducing harm to the environment. We therefore recommend using vermicompost, farmyard manure, and Jeevamrut together as a practical and profitable method for growing foxtail millet.

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