



RESEARCH ARTICLE

# Impact of natural farming practices on growth and nutritional quality of foxtail millet (*Setaria italica* L.)

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## Abstract

Natural farming practices are increasingly recognized as sustainable alternatives to chemical-intensive agriculture, offering benefits for soil health, crop productivity and nutritional quality. A field experiment spanning 2 years (2022–23 and 2023–24) was undertaken at the College of Agriculture, Vishweshwaraiah Canal (VC) Farm, Mandya, University of Agricultural Sciences, Mandya, to evaluate the effects of natural farming systems on the agronomic traits and nutritional quality of foxtail millet (*Setaria italica* L.). The study was laid out in a randomized complete block design (RCBD) with 12 treatments comprising liquid organic manures and microbial consortia, replicated thrice. Results revealed that the combined application of Beejamrutha (seed treatment) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> (T<sub>12</sub>) significantly improved growth attributes, yield and quality parameters over the absolute control. Grain yield increased by approximately 70–72 % in T<sub>12</sub> during the respective years, while straw yield improved by over 60 %. Correlation analysis indicated strong positive associations between protein content, swelling index and water absorption capacity, whereas cooking time was negatively correlated with hydration-related traits. Principal component analysis explained 59.24 % of the total variation, clearly distinguishing the superior performance of T<sub>12</sub> compared to other treatments. Economic analysis further confirmed higher profitability with T<sub>12</sub>, achieving a benefit–cost ratio of 3.02 compared to 1.12 in control. Overall, the integration of natural farming inputs enhanced both productivity and grain quality of foxtail millet, emphasizing its potential as a sustainable strategy for resilient and nutrient-rich food production.

**Keywords:** biofertilizers; correlation; liquid manures; natural farming; quality

## Introduction

Millets are vital crops for arid and semi-arid regions of India because of their resilience and ability to flourish under challenging climatic conditions. Millets thrive even on marginal soils, requiring little water, fertilizers or pesticides and can withstand high temperatures and irregular rainfall. Millets, known for their drought tolerance, serve as suitable crops for contingency planning and help mitigate the risks associated with climate change (1). In India, minor millets are cultivated in an area of 428.92 thousand hectares with 367.44 thousand tonnes of production and productivity of 857 kg ha<sup>-1</sup>. In Karnataka, minor millets are grown in an area of 29000 ha producing 23.87 thousand tonnes with a productivity of 823 kg ha<sup>-1</sup> (2). Foxtail millet (*Setaria italica* L.) is one of the oldest domesticated crops and is one of the most ancient, domesticated millets and is cultivated extensively in Asia, particularly in China and India. In India, it is cultivated on about 80000 ha, primarily in Andhra Pradesh, Karnataka, Telangana, Rajasthan and northeastern states,

yielding around 60000 tonnes. The nutritional value of foxtail millet is highly appreciated as 100 g of foxtail millet grain contains 60.9 g carbohydrate, 8 g crude fiber, 12.3 g protein, 3.5 g ash, 4.3 g fat and minerals like 2.4 mg zinc, 31 mg calcium, 250 mg potassium, 2.8 mg iron, 4.6 mg sodium, 1.4 mg copper, 2.4 mg Zn, 290 mg phosphorous, 81 mg magnesium, 331 kilo calories of energy and also contains vitamins such as thiamin, riboflavin, niacin and folate. Due to its nutritional benefits, foxtail millet has gained popularity, particularly among those with diabetes and cardiovascular issues (3).

With the Green Revolution came the widespread use of chemical fertilizers and pesticides, which have negatively impacted soil health by reducing organic matter, increasing salinity and altering pH levels, ultimately disrupting vital microbial communities (4). Many agricultural experts emphasize that nations grappling with poverty and malnutrition should prioritize agricultural growth to advance sustainable development goals, particularly those related to food security and environmental sustainability. Recently, the

rising costs of chemical fertilizers have burdened small farmers, while their overuse continues to degrade soil fertility. As a result, there is growing emphasis on preserving soil health and promoting eco-friendly, cost-effective natural farming practices to ensure sustainable agriculture. Natural farming, often described as farming in harmony with nature without the use of chemicals; it aims to nurture the natural symbiosis between soil microorganisms and crop plants. This comprehensive agricultural practice offers an alternative to conventional methods by minimising the dependency on commercial inputs such as seeds, synthetic fertilizers and pesticides. It promotes both sustainability and self-sufficiency, while also preserving indigenous organic biodiversity. By utilising cow-based liquid organic manures and biofertilizers, natural farming maintains soil health and fosters an ecosystem conducive to long-term agricultural resilience. Liquid formulations such as Jeevamrutha, Beejamrutha, Panchagavya and biofertilizers (microbial consortia) can be used as a replacement for the chemical fertilizers (5–7).

To enhance food security for the growing population in the country, one viable approach to developing sustainable and environmentally compatible agricultural practices is through the combined use of natural nutrient sources such as Jeevamrutha, Beejamrutha, Panchagavya and biofertilizers (microbial consortia). This method minimizes negative impacts on soil health and preserves ecosystem balance. Consequently, sustainability in crop production, improved human health and the vitality of the soil can be effectively restored. Realizing the significance of natural farming practices, the current investigation entitled “Agronomic and nutritional response of foxtail millet (*S. italica* L.) to natural farming practices” has been conducted with combination of biofertilizers and liquid microbial consortia.

## Materials and Methods

### Experiment site characteristics

Field experiment was conducted during kharif 2022–23 and 2023–24 which was laid out in randomized complete block design (RCBD) with 12 treatment combinations, each replicated thrice at College of Agriculture, Vishweshwaraiah Canal (VC) Farm, Mandya (latitudes 11° 30' to 13° 05' N, longitudes 76° 05' to 77° 45' E and altitude of 695 m above mean sea level), Karnataka. The experimental site falls

within the southern dry zone (SDZ) of Karnataka (agro climatic zone-VI) and region III. The soil of the present investigation site was alkaline in reaction (pH - 8.14) with low electrical conductivity (0.20 dS m<sup>-1</sup>), medium organic carbon (0.75 %) (8), medium in available P<sub>2</sub>O<sub>5</sub> (51.30 kg ha<sup>-1</sup>) (9), medium in available K<sub>2</sub>O (275.52 kg ha<sup>-1</sup>) (9) and medium in available nitrogen (323.36 kg ha<sup>-1</sup>) (10). The Diethylenetriaminepentaacetic acid (DTPA) extractable iron (17.46 mg kg<sup>-1</sup>), Zinc (1.44 mg kg<sup>-1</sup>), Mn (17.47 mg kg<sup>-1</sup>) and Cu (1.06 mg kg<sup>-1</sup>) were observed in initial soil sample. The test variety SIA-3156 was sown at a spacing of 30 x 10 cm. The plot size was 4.2 x 3.9 m = 16.38 m<sup>2</sup>.

### Treatment details

T<sub>1</sub>: Absolute control

T<sub>2</sub>: Beejamrutha (seed treatment)

T<sub>3</sub>: Jeevamrutha at 500 L ha<sup>-1</sup>

T<sub>4</sub>: Foliar application of 2.5 % Panchagavya

T<sub>5</sub>: Microbial consortia at 5 kg ha<sup>-1</sup>

T<sub>6</sub>: Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup>

T<sub>7</sub>: Beejamrutha (ST) + Foliar application of 2.5 % Panchagavya

T<sub>8</sub>: Beejamrutha (ST) + Microbial consortia at 5 kg ha<sup>-1</sup>

T<sub>9</sub>: Jeevamrutha at 500 L ha<sup>-1</sup> + Foliar application of 2.5 % Panchagavya

T<sub>10</sub>: Jeevamrutha at 500 L ha<sup>-1</sup> + Microbial consortia at 5 kg ha<sup>-1</sup>

T<sub>11</sub>: Foliar application of 2.5 % Panchagavya + Microbial consortia at 5 kg ha<sup>-1</sup>

T<sub>12</sub>: Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + Foliar application of 2.5 % Panchagavya + Microbial consortia at 5 kg ha<sup>-1</sup>

(Note: ST - Seed treatment; Seeds of foxtail millet were treated with Beejamrutha and recommended dose of microbial consortia consisting of N-fixing (*Azotobacter chroococcum*) + P solubilizer (*Bacillus megaterium*) + K mobilizer (*Frateuria aurantia*) + PGPR (*Pseudomonas fluorescens*) + biocontrol agent (*Trichoderma viride*) was applied to the soil at the rate of 5 kg ha<sup>-1</sup> in furrows at the time of sowing. Jeevamrutha was applied through soil application at 20 and 40 DAS (Days after sowing) and foliar application of 2.5 % Panchagavya at 30 and 50 DAS.)

**Table 1.** Ingredients and method of preparation of natural farming inputs

Sl. No.	Input	Ingredients	Method of preparation
1.	Beejamrutha	Cow dung (5 kg) Cow urine (5 L) Lime (50 g) Water (20 L)	5 kg cow dung was taken in cloth and hang it in the drum containing 20 L of water. On next day, the cow dung in the cloth was squeezed in the water tub. Add lime, water, cow urine and stir well.
2.	Jeevamrutha	Cow dung (10 kg) Cow urine (10 L) Jaggery (2 kg) Pulse flour (2 kg) Soil (1 kg) Water (200 L)	10 kg of desi cow dung, 10 L of cow urine, 2 kg of jaggery, 2 kg pulse flour and 1 kg soil was taken. Mixed above these materials thoroughly in drum and volume made up to 200 L by adding water. Mixture was stirred in clockwise direction twice a day and drum was kept in shade for 7–8 days.
3.	Panchagavya	Cow dung (7 kg) Cow urine (10 L) Cow ghee (1 kg) Cow milk (3 L) Cow curd (2 L) Yeast (100 g) Jaggery (3 kg) Tender coconut water (3 L) ripened banana (12) water (10 L)	Mix thoroughly the fresh cow dung (7 kg) + cow ghee (1 kg) in plastic bucket and incubate for 2 days. Then add cow urine (3 L) and 10 L of water, stir properly (morning and evening, daily for 1 week). Add jaggery (3 kg), cow milk (3 L), cow curd (2 L), Yeast (100 g), tender coconut water (3 L) and 12 ripened bananas, stir properly (morning and evening, daily for 3 weeks). Finally, panchagavya is ready to use after 22 days after preparation.

## Preparation of liquid organic manures

Ingredients and method of preparation of fermented liquid organic manures are furnished in Table 1.

## Observation recorded

The data were recorded for growth parameters i.e., plant height, total dry matter production, root length and root density and yield parameters i.e., number of panicles per square meter, panicle length, grain and straw yield were determined.

## Cooking parameters

### Water and oil absorption capacity (mL g<sup>-1</sup>)

The water and oil absorption capacities were determined (11). One gram of sample (1.0 g) was mixed with 10 mL distilled water or refined soybean oil, kept at ambient temperature for 30 min and centrifuged for 30 min at 3000 rpm ( $\approx 2000 \times g$ ). Water or oil absorption capacity was expressed as millilitre of water or oil bound per gram of the sample.

### Cooking time (min)

Cooking time of grain sample was determined by boiling 2.0 g of whole millet grains in 20 mL of distilled water, removing a few grains at different time intervals during cooking and pressing them between 2 glass plates until no white core was left. Optimum cooking time was determined as the time when no white core remained, with slight adjustment as per standard protocol (12).

### Water uptake ratio (%)

The water uptake ratio was determined by cooking 2.0 g of whole millet in 20 mL distilled water for a for the optimum cooking time in a boiling water bath and drain the surface water from the cooked millet. The cooked samples were weighed accurately and the water uptake ratio was calculated as the ratio of final cooked weight to uncooked weight of the grain and converted to percentage (12).

Water uptake ratio (%) =

$$\frac{\text{Weight of cooked millet sample (g)}}{\text{Weight of uncooked millet sample (g)}} \times 100$$

### Solid loss (%)

The 2 g of grain sample was taken in a 20 mL distilled water and was cooked for minimum cooking time in a boiling water bath. The solids were transferred to 50 mL beakers with several washings and made

to volume with distilled water. The aliquot having leached solids was evaporated at 110 °C in an oven until completely dry. The solids were weighed and percent solids were previously reported (13).

## Quality parameters

Grain samples from each treatment were collected at harvest, oven dried, powdered in Willey mill using 2 mm sieve and used for the analysis of quality parameters viz., crude protein, carbohydrate, fat, ash content, while 1 mm sieve for crude fibre analysis. The procedures followed for the analysis of quality parameters are furnished in Table 2.

## Statistical analysis

The data were examined utilizing analysis of variance (ANOVA) following the procedures outlined by previous researchers (15). The means were further analyzed using Duncan's multiple-range tests. A *p*-value below 0.05 was considered statistically significant and the findings are shown as the mean value plus or minus the standard deviation (with a 95 % confidence interval) and correlation and principal component analysis (PCA) was done using R software with version 4.4.2.

## Results

### Growth parameters

Natural farming practices had significant influence on growth parameters i.e., plant height, total dry matter production, root length and root density (Table 3). The treatment receiving Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> (T<sub>12</sub>) displayed superior responsiveness towards plant height (125.07 cm) as compared to absolute control (74.31 cm). On a pooled basis, the total dry matter production at harvest was varied between 9.59 to 16.61 g plant<sup>-1</sup>. The same treatment resulted in significantly highest total dry matter production of 16.61 g plant<sup>-1</sup> and the lowest was noted in absolute control (9.59 g plant<sup>-1</sup>). Maximum root length and density (19.05 cm and 0.82 g cm<sup>-3</sup>, respectively) was achieved in Treatment T<sub>12</sub> and lower root length and density was noticed in Treatment T<sub>1</sub> (11.16 cm and 0.24 g cm<sup>-3</sup>, respectively).

### Yield and yield attributes

Different natural farming practices had shown positive impact on the yield parameters of foxtail millet (Table 4). The number of panicles

**Table 2.** Procedure for recording observations on quality parameters of foxtail millet

Sl. No.	Parameter	Formula
1.	<b>Crude protein (CP)</b>	CP (%) = Nitrogen (%) × 6.25
2.	<b>Crude fibre (CF)</b>	CF(%) = $\frac{(\text{Weight of sample before ashing}) - (\text{Weight of sample after ashing})}{\text{Weight of the dried plant sample taken}} \times 100$
3.	<b>Ether extractable fat content</b>	Ether extractable fat (%) = $\frac{\text{Weight of ether extract (g)}}{\text{Weight of the dried plant sample taken (g)}} \times 100$
4.	<b>Total ash content</b>	Total Ash content (%) = $\frac{\text{Weight of ash (g)}}{\text{Weight of the sample taken for ashing (g)}} \times 100$
5.	<b>Total carbohydrate content</b>	The total sugar was determined by anthrone method (14). Carbohydrates are dehydrated by conc. H <sub>2</sub> SO <sub>4</sub> to form furfural, this furfural condenses anthrone to form a blue green coloured complex, which is measured colorimetrically at 630 nm.

**Table 3.** Influence of natural farming practices on growth parameters of foxtail millet

Treatments	Plant height (cm)						Total dry matter production (g plant <sup>-1</sup> )						Root length (cm)						Root density (g cm <sup>-3</sup> )					
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled			
T <sub>1</sub>	73.50 <sup>f</sup> ± 3.23	75.12 <sup>g</sup> ± 4.27	74.31 <sup>f</sup> ± 3.75	9.12 <sup>f</sup> ± 0.39	10.06 <sup>f</sup> ± 0.14	9.59 <sup>f</sup> ± 0.26	11.00 <sup>f</sup> ± 1	11.31 <sup>f</sup> ± 0.32	11.16 <sup>f</sup> ± 0.6	0.21 <sup>g</sup> ± 0.04	0.28 <sup>g</sup> ± 0.04	0.24 <sup>f</sup> ± 0.02	11.31 <sup>f</sup> ± 0.32	11.16 <sup>f</sup> ± 0.6	11.16 <sup>f</sup> ± 0.6	0.21 <sup>g</sup> ± 0.04	0.28 <sup>g</sup> ± 0.04	0.24 <sup>f</sup> ± 0.02	0.21 <sup>g</sup> ± 0.04	0.28 <sup>g</sup> ± 0.04	0.24 <sup>f</sup> ± 0.02			
T <sub>2</sub>	83.39 <sup>g</sup> ± 4.47	85.00 <sup>g</sup> ± 4.35	84.20 <sup>g</sup> ± 0.58	10.33 <sup>g</sup> ± 0.44	11.54 <sup>g</sup> ± 0.14	10.93 <sup>g</sup> ± 0.26	13.15 <sup>g</sup> ± 0.14	13.32 <sup>g</sup> ± 0.19	13.24 <sup>g</sup> ± 0.15	0.28 <sup>f</sup> ± 0.01	0.42 <sup>f</sup> ± 0.04	0.35 <sup>b</sup> ± 0.02	13.32 <sup>g</sup> ± 0.19	13.24 <sup>g</sup> ± 0.15	13.24 <sup>g</sup> ± 0.15	0.28 <sup>f</sup> ± 0.01	0.42 <sup>f</sup> ± 0.04	0.35 <sup>b</sup> ± 0.02	0.28 <sup>f</sup> ± 0.01	0.42 <sup>f</sup> ± 0.04	0.35 <sup>b</sup> ± 0.02			
T <sub>3</sub>	84.08 <sup>g</sup> ± 3.9	85.46 <sup>g</sup> ± 5.46	84.77 <sup>g</sup> ± 2.74	10.41 <sup>g</sup> ± 0.14	11.56 <sup>g</sup> ± 0.5	10.98 <sup>g</sup> ± 0.18	13.24 <sup>g</sup> ± 0.43	13.42 <sup>g</sup> ± 1.01	13.33 <sup>g</sup> ± 0.5	0.29 <sup>f</sup> ± 0.01	0.45 <sup>g</sup> ± 0.03	0.37 <sup>g</sup> ± 0.02	13.24 <sup>g</sup> ± 0.43	13.42 <sup>g</sup> ± 1.01	13.33 <sup>g</sup> ± 0.5	0.29 <sup>f</sup> ± 0.01	0.45 <sup>g</sup> ± 0.03	0.37 <sup>g</sup> ± 0.02	0.29 <sup>f</sup> ± 0.01	0.45 <sup>g</sup> ± 0.03	0.37 <sup>g</sup> ± 0.02			
T <sub>4</sub>	84.24 <sup>g</sup> ± 2.36	85.65 <sup>g</sup> ± 2.31	84.94 <sup>g</sup> ± 2.24	10.48 <sup>g</sup> ± 0.33	11.62 <sup>g</sup> ± 0.28	11.05 <sup>g</sup> ± 0.29	13.31 <sup>g</sup> ± 0.43	13.47 <sup>g</sup> ± 0.5	13.39 <sup>g</sup> ± 0.3	0.32 <sup>f</sup> ± 0.02	0.48 <sup>g</sup> ± 0.03	0.40 <sup>g</sup> ± 0.03	13.31 <sup>g</sup> ± 0.43	13.47 <sup>g</sup> ± 0.5	13.39 <sup>g</sup> ± 0.3	0.32 <sup>f</sup> ± 0.02	0.48 <sup>g</sup> ± 0.03	0.40 <sup>g</sup> ± 0.03	0.32 <sup>f</sup> ± 0.02	0.48 <sup>g</sup> ± 0.03	0.40 <sup>g</sup> ± 0.03			
T <sub>5</sub>	94.02 <sup>h</sup> ± 3.01	95.55 <sup>f</sup> ± 0.96	94.79 <sup>d</sup> ± 1.13	11.74 <sup>d</sup> ± 0.39	12.95 <sup>d</sup> ± 0.28	12.35 <sup>d</sup> ± 0.33	14.58 <sup>h</sup> ± 0.41	14.77 <sup>d</sup> ± 0.52	14.67 <sup>d</sup> ± 0.42	0.41 <sup>e</sup> ± 0.02	0.56 <sup>d</sup> ± 0.01	0.49 <sup>f</sup> ± 0.01	14.58 <sup>h</sup> ± 0.41	14.77 <sup>d</sup> ± 0.52	14.67 <sup>d</sup> ± 0.42	0.41 <sup>e</sup> ± 0.02	0.56 <sup>d</sup> ± 0.01	0.49 <sup>f</sup> ± 0.01	0.41 <sup>e</sup> ± 0.02	0.56 <sup>d</sup> ± 0.01	0.49 <sup>f</sup> ± 0.01			
T <sub>6</sub>	103.79 <sup>c</sup> ± 2.31	105.41 <sup>ce</sup> ± 6.2	104.60 <sup>c</sup> ± 2.39	12.97 <sup>c</sup> ± 0.65	14.42 <sup>c</sup> ± 0.45	13.70 <sup>c</sup> ± 0.46	15.87 <sup>c</sup> ± 0.12	16.12 <sup>c</sup> ± 0.63	16.00 <sup>c</sup> ± 0.26	0.49 <sup>d</sup> ± 0.03	0.63 <sup>c</sup> ± 0.04	0.56 <sup>c</sup> ± 0.02	15.87 <sup>c</sup> ± 0.12	16.12 <sup>c</sup> ± 0.63	16.00 <sup>c</sup> ± 0.26	0.49 <sup>d</sup> ± 0.03	0.63 <sup>c</sup> ± 0.04	0.56 <sup>c</sup> ± 0.02	0.49 <sup>d</sup> ± 0.03	0.63 <sup>c</sup> ± 0.04	0.56 <sup>c</sup> ± 0.02			
T <sub>7</sub>	104.07 <sup>c</sup> ± 5.55	105.74 <sup>ce</sup> ± 4.76	104.91 <sup>c</sup> ± 2.18	13.04 <sup>c</sup> ± 0.52	14.46 <sup>c</sup> ± 1.32	13.75 <sup>c</sup> ± 0.53	15.90 <sup>c</sup> ± 0.96	16.16 <sup>c</sup> ± 0.83	16.03 <sup>c</sup> ± 0.28	0.51 <sup>cd</sup> ± 0.02	0.64 <sup>c</sup> ± 0.03	0.58 <sup>c</sup> ± 0.01	15.90 <sup>c</sup> ± 0.96	16.16 <sup>c</sup> ± 0.83	16.03 <sup>c</sup> ± 0.28	0.51 <sup>cd</sup> ± 0.02	0.64 <sup>c</sup> ± 0.03	0.58 <sup>c</sup> ± 0.01	0.51 <sup>cd</sup> ± 0.02	0.64 <sup>c</sup> ± 0.03	0.58 <sup>c</sup> ± 0.01			
T <sub>8</sub>	104.1 <sup>c</sup> ± 7.94	105.92 <sup>ce</sup> ± 2.26	105.01 <sup>c</sup> ± 3.79	13.12 <sup>c</sup> ± 0.21	14.56 <sup>c</sup> ± 0.95	13.84 <sup>c</sup> ± 0.37	15.92 <sup>c</sup> ± 0.68	16.31 <sup>c</sup> ± 0.18	16.12 <sup>c</sup> ± 0.32	0.55 <sup>c</sup> ± 0.05	0.68 <sup>c</sup> ± 0.05	0.62 <sup>d</sup> ± 0.04	15.92 <sup>c</sup> ± 0.68	16.31 <sup>c</sup> ± 0.18	16.12 <sup>c</sup> ± 0.32	0.55 <sup>c</sup> ± 0.05	0.68 <sup>c</sup> ± 0.05	0.62 <sup>d</sup> ± 0.04	0.55 <sup>c</sup> ± 0.05	0.68 <sup>c</sup> ± 0.05	0.62 <sup>d</sup> ± 0.04			
T <sub>9</sub>	113.91 <sup>b</sup> ± 1.84	115.7 <sup>bcd</sup> ± 4.87	114.81 <sup>b</sup> ± 3.34	14.35 <sup>b</sup> ± 0.35	15.93 <sup>b</sup> ± 0.81	15.14 <sup>b</sup> ± 0.24	17.33 <sup>b</sup> ± 1.16	17.68 <sup>b</sup> ± 0.94	17.51 <sup>b</sup> ± 0.48	0.61 <sup>b</sup> ± 0.04	0.76 <sup>b</sup> ± 0.02	0.68 <sup>c</sup> ± 0.02	17.33 <sup>b</sup> ± 1.16	17.68 <sup>b</sup> ± 0.94	17.51 <sup>b</sup> ± 0.48	0.61 <sup>b</sup> ± 0.04	0.76 <sup>b</sup> ± 0.02	0.68 <sup>c</sup> ± 0.02	0.61 <sup>b</sup> ± 0.04	0.76 <sup>b</sup> ± 0.02	0.68 <sup>c</sup> ± 0.02			
T <sub>10</sub>	114.66 <sup>b</sup> ± 6.38	115.78 <sup>bc</sup> ± 7.89	115.22 <sup>b</sup> ± 6.93	14.42 <sup>b</sup> ± 0.47	16.02 <sup>b</sup> ± 0.7	15.22 <sup>b</sup> ± 0.58	17.41 <sup>b</sup> ± 0.54	17.75 <sup>b</sup> ± 1.25	17.58 <sup>b</sup> ± 0.7	0.64 <sup>b</sup> ± 0.04	0.77 <sup>b</sup> ± 0.08	0.70 <sup>bc</sup> ± 0.04	17.41 <sup>b</sup> ± 0.54	17.75 <sup>b</sup> ± 1.25	17.58 <sup>b</sup> ± 0.7	0.64 <sup>b</sup> ± 0.04	0.77 <sup>b</sup> ± 0.08	0.70 <sup>bc</sup> ± 0.04	0.64 <sup>b</sup> ± 0.04	0.77 <sup>b</sup> ± 0.08	0.70 <sup>bc</sup> ± 0.04			
T <sub>11</sub>	114.71 <sup>b</sup> ± 9.9	116.22 <sup>b</sup> ± 5.31	115.47 <sup>b</sup> ± 2.81	14.52 <sup>b</sup> ± 0.21	16.10 <sup>b</sup> ± 0.64	15.31 <sup>b</sup> ± 0.22	17.48 <sup>b</sup> ± 0.91	17.98 <sup>b</sup> ± 0.9	17.73 <sup>b</sup> ± 0.82	0.66 <sup>b</sup> ± 0.03	0.80 <sup>b</sup> ± 0.01	0.73 <sup>b</sup> ± 0.01	17.48 <sup>b</sup> ± 0.91	17.98 <sup>b</sup> ± 0.9	17.73 <sup>b</sup> ± 0.82	0.66 <sup>b</sup> ± 0.03	0.80 <sup>b</sup> ± 0.01	0.73 <sup>b</sup> ± 0.01	0.66 <sup>b</sup> ± 0.03	0.80 <sup>b</sup> ± 0.01	0.73 <sup>b</sup> ± 0.01			
T <sub>12</sub>	124.14 <sup>a</sup> ± 0.5	126.00 <sup>a</sup> ± 10.01	125.07 <sup>a</sup> ± 4.76	15.67 <sup>a</sup> ± 0.08	17.54 <sup>a</sup> ± 0.64	16.61 <sup>a</sup> ± 0.35	18.75 <sup>a</sup> ± 0.24	19.35 <sup>a</sup> ± 0.74	19.05 <sup>a</sup> ± 0.3	0.75 <sup>a</sup> ± 0.04	0.89 <sup>a</sup> ± 0.02	0.82 <sup>a</sup> ± 0.03	18.75 <sup>a</sup> ± 0.24	19.35 <sup>a</sup> ± 0.74	19.05 <sup>a</sup> ± 0.3	0.75 <sup>a</sup> ± 0.04	0.89 <sup>a</sup> ± 0.02	0.82 <sup>a</sup> ± 0.03	0.75 <sup>a</sup> ± 0.04	0.89 <sup>a</sup> ± 0.02	0.82 <sup>a</sup> ± 0.03			
<b>S.Em. ±</b>	<b>2.96</b>	<b>3.22</b>	<b>2.03</b>	<b>2.96</b>	<b>3.22</b>	<b>2.03</b>	<b>0.40</b>	<b>0.44</b>	<b>0.27</b>	<b>0.02</b>	<b>0.02</b>	<b>0.01</b>	<b>0.40</b>	<b>0.44</b>	<b>0.27</b>	<b>0.02</b>	<b>0.02</b>	<b>0.01</b>	<b>0.02</b>	<b>0.02</b>	<b>0.01</b>			
<b>CD at 5%</b>	<b>8.68</b>	<b>9.44</b>	<b>5.96</b>	<b>8.68</b>	<b>9.44</b>	<b>5.96</b>	<b>1.16</b>	<b>1.28</b>	<b>0.80</b>	<b>0.04</b>	<b>0.06</b>	<b>0.04</b>	<b>1.16</b>	<b>1.28</b>	<b>0.80</b>	<b>0.04</b>	<b>0.06</b>	<b>0.04</b>	<b>0.04</b>	<b>0.06</b>	<b>0.04</b>			

(Note: - S. Em.: Standard error of mean; CD (p = 0.05): critical difference at probability 5%)

**Table 4.** Influence of natural farming practices on yield and yield parameters in foxtail millet

Treatments	Number of panicles (m <sup>-2</sup> )						Panicle length (cm)						Grain yield (kg ha <sup>-1</sup> )						Straw yield (kg ha <sup>-1</sup> )					
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled			
T <sub>1</sub>	23.53 <sup>f</sup> ± 2.16	25.03 <sup>e</sup> ± 1.54	24.28 <sup>f</sup> ± 1.85	9.90 <sup>f</sup> ± 0.86	10.40 <sup>f</sup> ± 0.46	10.15 <sup>f</sup> ± 0.65	392 <sup>f</sup> ± 78.31	404 <sup>g</sup> ± 90.25	398 <sup>g</sup> ± 21.4	732 <sup>f</sup> ± 80.53	866 <sup>f</sup> ± 165.83	799 <sup>f</sup> ± 43.71	392 <sup>f</sup> ± 78.31	404 <sup>g</sup> ± 90.25	398 <sup>g</sup> ± 21.4	732 <sup>f</sup> ± 80.53	866 <sup>f</sup> ± 165.83	799 <sup>f</sup> ± 43.71	732 <sup>f</sup> ± 80.53	866 <sup>f</sup> ± 165.83	799 <sup>f</sup> ± 43.71			
T <sub>2</sub>	27.33 <sup>e</sup> ± 2.31	30.91 <sup>d</sup> ± 2.19	29.12 <sup>e</sup> ± 2.03	11.20 <sup>e</sup> ± 0.61	11.91 <sup>e</sup> ± 0.37	11.55 <sup>e</sup> ± 0.23	527 <sup>e</sup> ± 23.19	589 <sup>f</sup> ± 51.35	558 <sup>f</sup> ± 36.95	963 <sup>e</sup> ± 32.15	1127 <sup>e</sup> ± 71.68	1045 <sup>e</sup> ± 20.52	527 <sup>e</sup> ± 23.19	589 <sup>f</sup> ± 51.35	558 <sup>f</sup> ± 36.95	963 <sup>e</sup> ± 32.15	1127 <sup>e</sup> ± 71.68	1045 <sup>e</sup> ± 20.52	963 <sup>e</sup> ± 32.15	1127 <sup>e</sup> ± 71.68	1045 <sup>e</sup> ± 20.52			
T <sub>3</sub>	28.62 <sup>e</sup> ± 1.07	31.18 <sup>cd</sup> ± 0.53	29.90 <sup>e</sup> ± 0.73	11.37 <sup>e</sup> ± 1.02	12.02 <sup>e</sup> ± 0.77	11.70 <sup>e</sup> ± 0.82	577 <sup>e</sup> ± 88.41	606 <sup>f</sup> ± 37.85	592 <sup>f</sup> ± 63.12	996 <sup>e</sup> ± 84.31	1174 <sup>e</sup> ± 67	1085 <sup>e</sup> ± 70.01	577 <sup>e</sup> ± 88.41	606 <sup>f</sup> ± 37.85	592 <sup>f</sup> ± 63.12	996 <sup>e</sup> ± 84.31	1174 <sup>e</sup> ± 67	1085 <sup>e</sup> ± 70.01	996 <sup>e</sup> ± 84.31	1174 <sup>e</sup> ± 67	1085 <sup>e</sup> ± 70.01			
T <sub>4</sub>	29.95 <sup>e</sup> ± 1.82	31.27 <sup>d</sup> ± 0.36	30.61 <sup>e</sup> ± 0.82	11.65 <sup>e</sup> ± 0.13	12.07 <sup>e</sup> ± 0.61	11.86 <sup>e</sup> ± 0.26	596 <sup>e</sup> ± 10.27	627 <sup>f</sup> ± 38.14	611 <sup>f</sup> ± 22.33	1074 <sup>e</sup> ± 22.61	1195 <sup>e</sup> ± 15.89	1134 <sup>e</sup> ± 19.18	596 <sup>e</sup> ± 10.27	627 <sup>f</sup> ± 38.14	611 <sup>f</sup> ± 22.33	1074 <sup>e</sup> ± 22.61	1195 <sup>e</sup> ± 15.89	1134 <sup>e</sup> ± 19.18	1074 <sup>e</sup> ± 22.61	1195 <sup>e</sup> ± 15.89	1134 <sup>e</sup> ± 19.18			
T <sub>5</sub>	33.23 <sup>d</sup> ± 0.78	34.78 <sup>c</sup> ± 0.26	34.01 <sup>d</sup> ± 0.37	13.05 <sup>d</sup> ± 0.19	13.61 <sup>d</sup> ± 0.42	13.33 <sup>d</sup> ± 0.28	708 <sup>d</sup> ± 90.07	757 <sup>e</sup> ± 13.12	733 <sup>e</sup> ± 44.29	1244 <sup>d</sup> ± 45.04	1368 <sup>d</sup> ± 47.91	1306 <sup>d</sup> ± 32.23	708 <sup>d</sup> ± 90.07	757 <sup>e</sup> ± 13.12	733 <sup>e</sup> ± 44.29	1244 <sup>d</sup> ± 45.04	1368 <sup>d</sup> ± 47.91	1306 <sup>d</sup> ± 32.23	1244 <sup>d</sup> ± 45.04	1368 <sup>d</sup> ± 47.91	1306 <sup>d</sup> ± 32.23			
T <sub>6</sub>	36.37 <sup>c</sup> ± 2.06	38.33 <sup>b</sup> ± 2.29	37.35 <sup>c</sup> ± 1.59	14.53 <sup>c</sup> ± 0.51	15.18 <sup>c</sup> ± 1.17	14.86 <sup>c</sup> ± 0.78	830 <sup>c</sup> ± 76.75	898 <sup>d</sup> ± 56.09	864 <sup>d</sup> ± 59.16	1400 <sup>c</sup> ± 107.95	1585 <sup>c</sup> ± 98.99	1493 <sup>c</sup> ± 76.05	830 <sup>c</sup> ± 76.75	898 <sup>d</sup> ± 56.09	864 <sup>d</sup> ± 59.16	1400 <sup>c</sup> ± 107.95	1585 <sup>c</sup> ± 98.99	1493 <sup>c</sup> ± 76.05	1400 <sup>c</sup> ± 107.95	1585 <sup>c</sup> ± 98.99	1493 <sup>c</sup> ± 76.05			
T <sub>7</sub>	36.52 <sup>c</sup> ± 0.91	38.46 <sup>b</sup> ± 3.61	37.49 <sup>c</sup> ± 1.36	14.84 <sup>c</sup> ± 0.32	15.23 <sup>c</sup> ± 0.41	15.04 <sup>c</sup> ± 0.28	894 <sup>c</sup> ± 55.22	987 <sup>cd</sup> ± 85.48	941 <sup>cd</sup> ± 66.2	1414 <sup>c</sup> ± 67.9	1608 <sup>c</sup> ± 106.5	1511 <sup>c</sup> ± 84.03	894 <sup>c</sup> ± 55.22	987 <sup>cd</sup> ± 85.48	941 <sup>cd</sup> ± 66.2	1414 <sup>c</sup> ± 67.9	1608 <sup>c</sup> ± 106.5	1511 <sup>c</sup> ± 84.03	1414 <sup>c</sup> ± 67.9	1608 <sup>c</sup> ± 106.5	1511 <sup>c</sup> ± 84.03			
T <sub>8</sub>	36.95 <sup>c</sup> ± 1.93	38.48 <sup>b</sup> ± 0.59	37.71 <sup>c</sup> ± 1.01	14.92 <sup>c</sup> ± 0.68	15.34 <sup>c</sup> ± 0.33	15.13 <sup>c</sup> ± 0.48	917 <sup>c</sup> ± 28.43	1030 <sup>c</sup> ± 67.55	974 <sup>c</sup> ± 46.12	1481 <sup>c</sup> ± 100.17	1633 <sup>c</sup> ± 59.69	1557 <sup>c</sup> ± 79.45	917 <sup>c</sup> ± 28.43	1030 <sup>c</sup> ± 67.55	974 <sup>c</sup> ± 46.12	1481 <sup>c</sup> ± 100.17	1633 <sup>c</sup> ± 59.69	1557 <sup>c</sup> ± 79.45	1481 <sup>c</sup> ± 100.17	1633 <sup>c</sup> ± 59.69	1557 <sup>c</sup> ± 79.45			
T <sub>9</sub>	40.05 <sup>b</sup> ± 1.7	41.93 <sup>ab</sup> ± 1.17	40.99 <sup>b</sup> ± 1.21	16.30 <sup>b</sup> ± 0.52	16.83 <sup>b</sup> ± 0.95	16.56 <sup>b</sup> ± 0.69	1046 <sup>b</sup> ± 114.45	1161 <sup>b</sup> ± 61.44	1103 <sup>b</sup> ± 86.26	1687 <sup>b</sup> ± 87.22	1795 <sup>b</sup> ± 20.56	1741 <sup>b</sup> ± 53.87	1046 <sup>b</sup> ± 114.45	1161 <sup>b</sup> ± 61.44	1103 <sup>b</sup> ± 86.26	1687 <sup>b</sup> ± 87.22	1795 <sup>b</sup> ± 20.56	1741 <sup>b</sup> ± 53.87	1687 <sup>b</sup> ± 87.22	1795 <sup>b</sup> ± 20.56	1741 <sup>b</sup> ± 53.87			
T <sub>10</sub>	40.32 <sup>b</sup> ± 1.59	41.98 <sup>ab</sup> ± 1.34	41.15 <sup>b</sup> ± 1.35	16.55 <sup>b</sup> ± 0.61	16.89 <sup>b</sup> ± 1.19	16.72 <sup>b</sup> ± 0.37	1111 <sup>b</sup> ± 42.76	1210 <sup>b</sup> ± 84.71	1161 <sup>b</sup> ± 60.6	1709 <sup>b</sup> ± 57.5	1878 <sup>b</sup> ± 51.74	1793 <sup>b</sup> ± 52.14	1111 <sup>b</sup> ± 42.76	1210<										

per square meter (44.63) and panicle length (18.26 cm) was maximum in the combined application of Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5% Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> over other treatments. But the lowest number of panicles per square meter (24.28) and panicle length (10.15 cm) was noticeable in absolute control. The data on effect of various applications on grain yield of foxtail millet revealed that T<sub>12</sub> significantly increased the grain yield over T<sub>1</sub> by 70.15 % and 71.59 % during 2022–23 and 2023–24, respectively. In 2022–23, the grain yield ranged from 1313 kg ha<sup>-1</sup> with adoption of Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> to 392 kg ha<sup>-1</sup> with absolute control. Conversely, in 2023–24 grain yield was varied from 1422 kg ha<sup>-1</sup> in T<sub>12</sub> and 404 kg ha<sup>-1</sup> in T<sub>1</sub>. The pattern of influence of natural farming practices on straw yield was also similar to that of grain yield. However, the treatment T<sub>12</sub> showed highest straw yield (2057 kg ha<sup>-1</sup>) which was superior over other treatments. The increase in straw yield with T<sub>12</sub> was to the tune of 62.79 % and 59.68 % over T<sub>1</sub> in 2022–23 and 2023–24, respectively.

### Correlation between cooking and quality parameters

The correlation heatmap among cooking and quality parameters of foxtail millet grown under natural farming revealed several significant trait interrelationships (Fig. 1). A strong positive correlation was observed between swelling index (SI) and water absorption capacity (WAC), suggesting that millet grains with higher swelling ability also absorbed more water during cooking. Similarly, protein content exhibited a positive correlation with both SI and WAC, indicating that nutrient-rich grains also tend to demonstrate better cooking quality. In contrast, cooking time showed a negative correlation with hydration index (HI) and water absorption capacity, implying that grains which absorbed water more effectively and hydrated well required less time to cook. Additionally, fiber content had mild positive associations with hydration-related traits, suggesting its supportive role in water

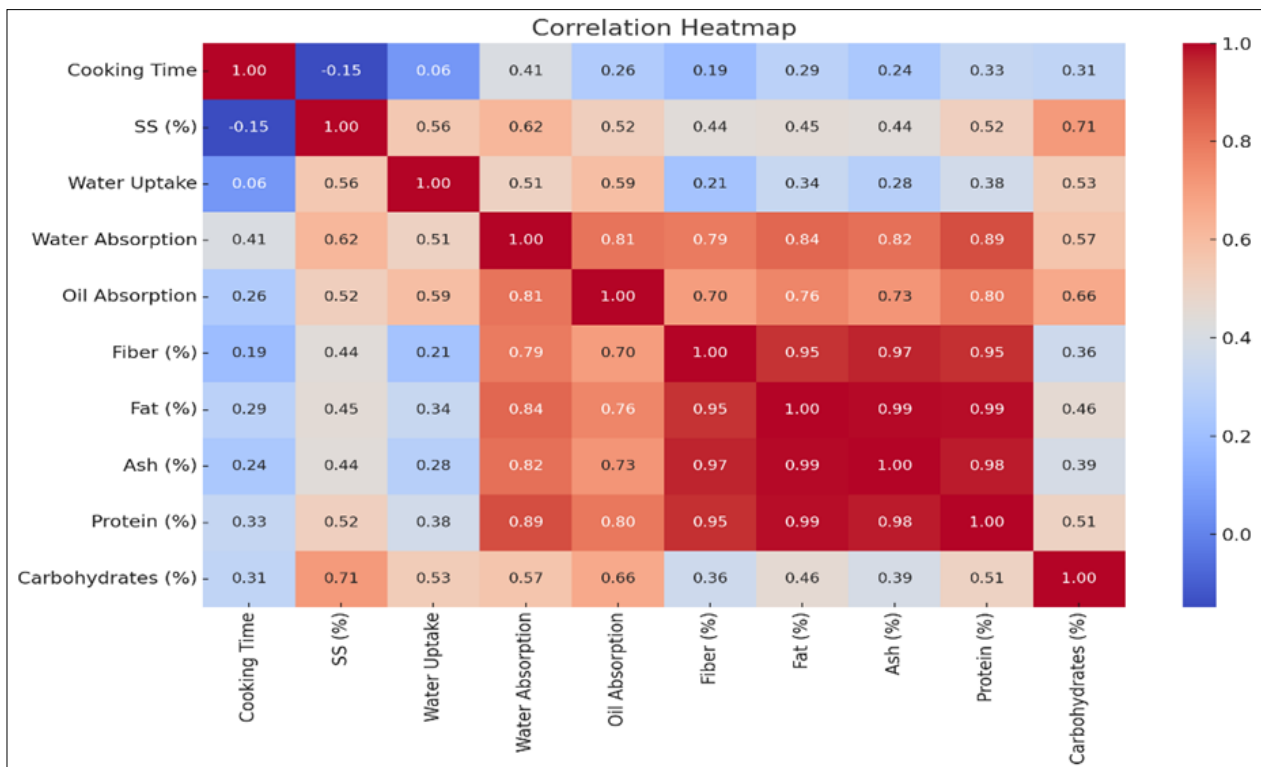
retention. These correlations provide valuable insights for selecting foxtail millet varieties that combine high nutritional value with better cooking performance, thereby aiding in varietal improvement under natural farming systems.

### Principal component analysis (PCA) for cooking and quality parameters

The PCA biplot based on two-year pooled data of foxtail millet revealed that the first 2 principal components (PC1 and PC2) together explained 59.24 % of the total variation, with PC1 accounting for 44.26 % and PC2 for 14.98 % (Fig. 2). Treatments exhibited distinct clustering patterns, indicating differential responses in growth and yield attributes. Treatments T<sub>1</sub> and T<sub>2</sub> were grouped on the negative axis of PC1, whereas T<sub>6</sub> and T<sub>9</sub> were positioned on the positive side, suggesting contrasting effects of these treatments on the measured traits. Notably, the best-performing treatment (T<sub>12</sub>, which recorded the highest yield and nutrient uptake) was distinctly separated from the absolute control (T<sub>1</sub>) and recommended practice (T<sub>2</sub>), highlighting its superiority across the measured parameters. Treatments such as T<sub>4</sub>, T<sub>8</sub> and T<sub>10</sub> showed partial overlap with other groups, implying relatively less distinctiveness. The clear separation of clusters indicates that PCA efficiently discriminated the treatments, with the superior performance of T<sub>12</sub> being evident from its distinct positioning in the ordination space.

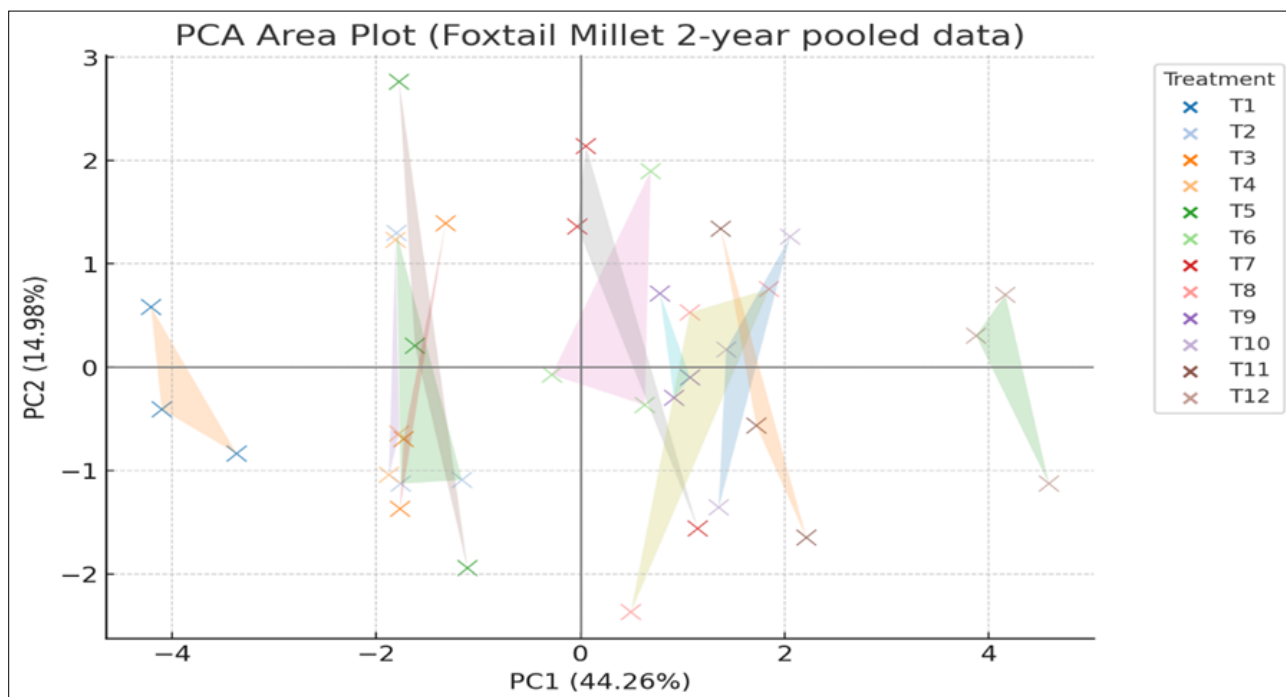
### Economics

A perusal of data on benefit-cost (B:C) ratio of foxtail millet for both years are presented in Table 5. The increase in the B:C with T<sub>12</sub> (Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup>) was to the tune of 62.06 and 63.70 % over T<sub>1</sub> (absolute control) during 2022–23 and 2023–24, respectively. Among the different natural farming practices, a significant increment in economics was incurred in T<sub>12</sub> treatment (2.90) than rest of the treatments and the lowest value (1.10) was



**Fig. 1.** Correlation heatmap showing relationships among the cooking and quality parameters of foxtail millet as influenced by natural farming practices.

(Note: - SS: Solid loss)



**Fig. 2.** Principal component analysis (PCA) area plot for the foxtail millet cooking and quality parameters.

(**Note:** - Overlapping polygons suggest shared characteristics between treatment groups. Large gaps between polygons indicate clear differences in trait combinations. Each shaded polygon represents the “area” occupied by a treatment group in PCA space. Treatments that are tightly clustered (small area) have more similar trait profiles, while larger polygons indicate more within-group variation. Some treatments form clear, non-overlapping areas, suggesting they are very distinct in their performance or traits.)

**Table 5.** Influence of natural farming practices on economics of foxtail millet

Treatments	B:C		
	2022-23	2023-24	Pooled
T <sub>1</sub>	1.10	1.14	1.12
T <sub>2</sub>	1.44	1.62	1.53
T <sub>3</sub>	1.48	1.56	1.52
T <sub>4</sub>	1.52	1.61	1.56
T <sub>5</sub>	1.88	2.01	1.95
T <sub>6</sub>	2.09	2.26	2.17
T <sub>7</sub>	2.23	2.46	2.34
T <sub>8</sub>	2.38	2.67	2.52
T <sub>9</sub>	2.46	2.72	2.59
T <sub>10</sub>	2.70	2.94	2.82
T <sub>11</sub>	2.73	2.97	2.85
T <sub>12</sub>	2.90	3.14	3.02

(**Note:** B:C-Benefit cost ratio)

recorded with absolute control in 2022–23. The trend was similar to that of the previous year in 2023–24. However, T<sub>12</sub> treatment was found to be significantly higher in achieving maximum in economics of both seasons of experiment.

## Discussion

Combined application of Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> improved the plant height in both years of experiment over control by about 40 % over control, respectively which might be ascribed due to the application of Jeevamrutha enhances nutrient solubilization and moisture absorption in the soil leading to improved plant growth (16, 17). Foliar sprays of

Panchagavya enhance nutrient transfer and stimulate plant growth regulators, while microbial consortia, including nitrogen fixers, phosphorus-solubilizing bacteria and potassium mobilizers, improve nutrient availability and release growth hormones like IAA, auxins and gibberellins, boosting plant height (18, 19). Enhanced nutrient uptake from liquid manures increases chlorophyll content, improves photosynthesis and boosts dry matter accumulation (19, 20). Liquid formulations also improve soil structure, porosity and water retention, promoting root growth and deeper root systems, which in turn support better nutrient absorption and photosynthetic activity (21, 22).

In general, the productivity of foxtail millet was more in the second year (2023–24) than in the first year (2022–23) but the response to different treatments was similar in both years of experimentation. The increase in yield with the application of nutrients through Beejamrutha, Jeevamrutha, Panchagavya and microbial consortia was to an extent of 70.90 and 61.17 % with respect to grain yield and straw yield, respectively, While 45.59 % and 44.41 % with respect to a number of panicles per square meter and panicle length, respectively over control. The improvement in yield attributes and yield of foxtail millet with various natural farming practices during the progressive years could be due to the increased number of panicles per square meter was primarily attributed to the consistent availability of both macro and micronutrients from liquid manure throughout crop growth period significantly improved growth parameters like plant height and dry matter accumulation, as well as yield components such as panicle number and length (23–25). Furthermore, the application of liquid manures improved soil physico-chemical properties, while the microbial load and growth hormones from organic supplements contributed to higher yields. These findings align with earlier research (26, 27).

A significant increase in the B:C ratio was observed under natural farming practices (treatment T<sub>12</sub>). This improvement can be

attributed to enhanced growth and yield parameters that resulted in higher grain and straw outputs, which in turn boosted net returns compared to other treatments. The differences in the B:C ratio can be traced back to yield variations and the differing costs associated with using various liquid organic manures (28).

The progressive improvement in crude protein content in foxtail millet was primarily due to the positive effects on root development, nodulation, photosynthesis and enhanced activity of the protein synthase enzyme, which collectively contributed to higher protein levels. These observations are consistent with previous findings (29). Organic supplements, particularly liquid Jeevamrutha, play a crucial role in improving crop quality (30). The gradual enhancement in crude fiber, ash content and ether-extractable fat in foxtail millet with the application of liquid organic manures may be attributed to improved growth parameters, leading to better nutrient uptake and increased enzymatic activity (28, 31). These correlations provide valuable insights for selecting foxtail millet varieties that combine high nutritional value with better cooking performance, thereby aiding in varietal improvement under natural farming systems.

The PCA plot demonstrates that foxtail millet treatments (T<sub>1</sub>–T<sub>12</sub>) form distinct clusters, with T<sub>1</sub>–T<sub>2</sub> grouping on the negative PC1 side and T<sub>6</sub>–T<sub>9</sub> on the positive PC1 side, highlighting major contrasts in trait performance. Treatments like T<sub>4</sub>, T<sub>8</sub>, T<sub>10</sub>, T<sub>12</sub> overlap, suggesting less pronounced differences. Overall, PCA successfully differentiates treatments, explaining ~ 59 % of variation through the first 2 principal components (32).

## Conclusion

By integrating biofertilizers (microbial consortia) with liquid organic manures, this study examined the agronomic and nutritional response of foxtail millet under natural farming practices. Findings revealed that this integrated method improved major growth traits while also contributing to greater yields than conventional farming practices. However, it is evident that the combined application of Beejamrutha (ST) + Jeevamrutha at 500 L ha<sup>-1</sup> + foliar application of 2.5 % Panchagavya + microbial consortia at 5 kg ha<sup>-1</sup> recorded significantly higher growth and yield as well as higher benefit cost ratio of foxtail millet as compared to absolute control. Thus, natural farming can be regarded as an innovative and sustainable agricultural strategy that resonates with global priorities for regenerative farming, while simultaneously improving soil health, yield performance and environmental sustainability.

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## Authors' contributions

HK, YSB, CH and YTC are responsible for the conception and design of the study. PKM participated in the sequence alignment and drafted the manuscript. SML and TT performed the statistical analysis and review the manuscript. DB, SGS and RMN participated

in the reviewing of the manuscript and editing process. All the authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare no conflict of interest.

**Ethical issues:** None

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