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Evaluation of Different Organic Nutrient Sources on Growth and Yield of Foxtail Millet (*Setaria italica*) in Acidic Soils of Meghalaya

Maram Bhargav Reddy[1], Dhara Hareesh[1], Sabyasachi Majumdar[2], Govindarajan Bhuvana Priya[3] and Sangappa[4]

[1]School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam, CAU (Imphal), Meghalaya (793 103), India

[2]Dept. of Soil Science and Agricultural Chemistry, College of Community Science, CAU (I), Tura, Meghalaya (794 005), India

[3]Division of Agricultural Extension, ICAR-Indian Institute of Millets Research (IIMR), Rajendranagar, Hyderabad (500 030), India

[4]Dept. of Animal Science, College of Agriculture, CAU (I), Kyrdemkulai, Meghalaya (793 105), India

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Corresponding bhuvana.priya20@gmail.com

0000-0002-8279-6326

ABSTRACT

The experiment was conducted during *kharif* (June to September) of 2024 at Umdiker village, Ri-Bhoi district, Meghalaya, India at a farmer's field under the broader initiative of the Indian Institute of Millets Research (IIMR) to evaluate the response of foxtail millet (*Setaria italica*) to different organic inputs with respect to growth, yield performance, and soil health indicators. The experimental layout followed a randomized block design consisting of five replications and five treatments: Vermicompost, Poultry manure, CAU Bioenhancer, their respective combinations, and an untreated control. The application of these inputs allowed for assessment of their main and interactive effects on critical crop and soil parameters across a single growing season. Findings demonstrated that plots receiving poultry manure in combination with the CAU Bioenhancer produced the most favorable results for plant growth, yield components, and essential soil nutrients, closely followed by the combined application of vermicompost with the Bioenhancer. Both integrated treatments outperformed sole applications of poultry manure or vermicompost, with the control ranking last. Significantly, the integration of Bioenhancer with poultry manure or vermicompost led to observable increases in both grain yield (by 29%) and straw yield (by 36%) compared to the untreated control plots. Among soil parameters, improvements in organic carbon and nitrogen, phosphorous, potassium were noted as statistically significant under the integrated treatments; however, soil pH remained unaffected by any input. The results underscored the productivity and soil fertility benefits of coupling organic manures with bioenhancers in finger millet-based cropping systems in northeast India.

KEYWORDS: Biofertilizer, bioenhancer, foxtail millet, organic manures and soil health

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

More than one-third of the global population relies on millets-small-seeded cereals ranked as the sixth most important cereal grain worldwide (Verma and Patel, 2012; Changmei and Dorothy, 2014). These ancient grains thrive across diverse regions, from Andhra Pradesh's plains to the high altitudes of the NEH region (Bhat et al., 2019). Millets play a crucial role in subsistence farming, supporting food and livelihood security for small and marginal farmers in rain-fed and hilly areas of the NEH region (Behera, 2017). Traditionally, tribal communities in NEH cultivate millets in mixed cropping systems alongside vegetables, pulses, and root crops under *jhum* cultivation (Layek et al., 2023). Among these, foxtail millet is one of the earliest domesticated species used for both food and fodder (Toppo et al., 2023). It is rich in protein (11–12%), fiber (6.7%), essential fats (4%), and minerals like Ca, Zn, Mg, P, and K. The crop performs well in poor soils due to its short duration, drought tolerance, and self-pollinating nature (Prajapati et al., 2023). Its slow glucose release suits diabetic diets (Mubeena et al., 2019; Hariprasanna, 2023).

Soil health is central to sustainable agriculture, particularly in India, it refers to the soil's capacity to function as a living ecosystem supporting plants, animals, and humans (Raj et al., 2024). The application of organic sources helps arrest soil degradation by restoring and enhancing nutrient cycling and maintaining ecosystem functions (Sihi et al., 2017). In the Northeastern states, low yields stem from shifting (*jhum*) cultivation, limited modern practices, poor irrigation, frequent natural disasters, and weak marketing (Sekhar et al., 2024). Poor soil fertility caused by acidity, erosion, nutrient leaching, and low fertilizer-use efficiency further limits productivity. With most soils registering pH values below 5.5, acidity is a major constraint in the region (Sharma et al., 2025).

Organic manures (OMs) can reduce GHGs emissions such as N_2O and CO_2, mitigating global warming (Lv et al., 2020; Wang et al., 2025). Short-term organic nutrient management involving farmyard manure (FYM), vermicompost, neem cake, and ash was shown to enhance the SMBC to SOC ratio and dehydrogenase activity under rain-fed ginger (*Zingiber officinale* Rosc.) within eight months (Gopal Ramdas et al., 2017). Long-term use of OMs improves soil fertility by enhancing physicochemical and biological properties (Wang et al., 2017; Asaye et al., 2022). Fertilizer demand must be aligned with crop yield response, nutrient requirements, native nutrient supply, and both short- and long-term soil effects (Dobermann et al., 2003). Escalating fertilizer prices, scarcity, and poor understanding of soil and crop needs result in unbalanced fertilization, reduced yields, soil degradation, and economic losses (Krishna Murthy et al., 2023). Crop yield and quality also vary with crop type and nitrogen substitution levels when switching to organic fertilizers (Sun et al., 2022; Kamdi et al., 2024). To maintain soil fertility and productivity, farmers are encouraged to use organic sources such as poultry manure, vermicompost, biofertilizers, and FYM (Selim, 2020). Biofertilizers like *Azospirillum* and PSB, integrated with recommended fertilizers and supported by nutrient management and foliar micronutrient applications, have improved millet productivity (Louhar et al., 2020; Yadav et al., 2018). In the North Eastern Region (NER), dependence on OMs remains high due to limited access to chemical fertilizers imported from other states. Although millets require fewer nutrients than major cereals like rice, wheat, and maize, they have received less research attention, particularly in NER (Anonymous, 2022; Kheya et al., 2023). Therefore, the present study was undertaken to evaluate the effect of different organic sources on soil properties and the growth and yield of foxtail millet in the acidic soils of Meghalaya.

2. MATERIALS AND METHODS

2.1. Location of the field experiment

The field experiment was conducted at farmers's field located at Umdiker village, Ri-Bhoi district, Meghalaya during the *kharif* (June-September, 2024). The field was situated at 40 km south of the Ri-Bhoi district headquarter in Nongpoh, Meghalaya and lay between 25.739834°N latitude and 91.797612°E longitude. The Umdiker village fell in the subtropical hill zone of Meghalaya with an annual rainfall of 400–1200 mm and a temperature range of 12–32°C. The soil physico-chemical properties (Table 1) were analysed at the laboratory of the Department of Soil Science and Agricultural Chemistry, College of Post-Graduate Studies in Agricultural Sciences, Umiam, Barapani, India.

2.2. Meteorological data of the experimental site

The Northeastern Hill Region of India experienced a humid subtropical climate with high rainfall and cold winters. The monsoon season generally began at the first fortnight of June and withdrew by October. From September onward, a decrease in rainfall was observed.

Average weekly data on total precipitation, average maximum and minimum temperatures (°C) and average relative humidity (%), during the crop-growth period were recorded at the meteorological station of the College of Agriculture, Kyrdemkulai, CAU (Imphal), Meghalaya, India, as shown in Figure 1. The average of maximum and minimum temperature during the cropping period of foxtail millet was ranged from 24.1°C to 16.6°C and 14.5°C to 21.7°C, respectively. Relative humidity ranged from 75% to 94% during the crop-growing period.

Table 1: Effect of different organic nutrient sources on growth attributes, yield attributes and yield of foxtail millet

Yield attributes		Yield		No. of ear heads plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	Test wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Parameters	Plant height (cm)	No. of tillers plant^{-1}	Dry matter (g plant^{-1})						
Treatments	Harvest	Harvest	Harvest						
T_1	89.55 ±1.793	3.43 ±0.002	10.68 ±0.124	2.08 ±0.025	14.54 ±0.023	729.00 ±7.300	2.27 ±0.025	1.10 ±0.023	3.13 ±0.069
T_2	85.6 ±2.120	3.15 ±0.073	10.47 ±0.066	2.07 ±0.020	13.97 ±0.221	713.00 ±2.255	2.25 ±0.018	0.99 ±0.018	3.03 ±0.002
T_3	90.28 ±0.714	3.65 ±0.081	11.15 ±0.170	2.66 ±0.064	14.95 ±0.071	747.00 ±13.386	2.35 ±0.041	1.13 ±0.006	3.40 ±0.038
T_4	90.15 ±0.570	3.57 ±0.021	11.10 ±0.222	2.37 ±0.001	14.85 ±0.094	735.00 ±13.558	2.31 ±0.038	1.12 ±0.001	3.33 ±0.063
T_5	70.55 ±1.822	2.8 ±0.035	8.19 ±0.073	1.25 ±0.027	10.72 ±0.034	554.00 ±5.840	2.12 ±0.044	0.87 ±0.016	2.50 ±0.007
SEm±	0.745	0.028	0.080	0.016	0.056	5.040	0.015	0.008	0.021
CD (p=0.05)	2.232	0.083	0.239	0.047	0.167	15.109	0.046	0.024	0.064

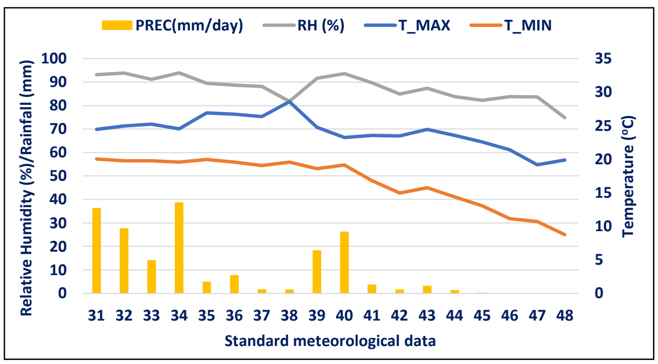

Figure 1: Meteorological data of the study area; (PREC- Precipitation; RH: Relative humidity)

2.3. Field experimental details

The field experiment was conducted using a sandy clay loam having an acidic reaction, pH 5.08. The field experiment was conducted by taking Foxtail millet was taken as test crop in a randomized block design (FRBD). The experiment included five treatments: T_1: Poultry manure (PM- 4 t ha^{-1}); T_2: Vermicompost (VC- 5 t ha^{-1}); T_3: PM (2 t ha^{-1})+Biofertilizer (7.5 1 ha^{-1}); T_4: VC (2.5 t ha^{-1})+ Biofertilizer (7.5 l ha^{-1}) (CAU- Bioenhancer; consisting of NPKZn- solubilizers) and T_5: Control. Altogether, there were 5 treatment combinations, each replicated four times, resulting in a total of 20 plots. The experimental details are presented in Table 2.

2.4. Description of variety used in the experiment

The SiA 3156 was a medium-duration variety of foxtail millet that matured in approximately 85 to 95 days. The seeds of this variety were collected from ICAR-Indian Institute of Millet Research, Rajendranagar, Hyderabad, Telangana, India. SIA 3156, was known for drought tolerance and suitability to a wide range of soil conditions. It was considered as a high-yielding variety, especially when grown with adequate nitrogen application.

Table 2: Brief experimental details of the field experiment

Experiment Location	Umdiker Village, Ri-Bhoi District, Meghalaya, India
Test crop	Foxtail millet
Spacing	25×10 cm^2
Seed rate	8 kg ha^{-1}
Crop establishment method	Line sowing
Design	Randomized block design (RBD)
No. of treatment	5
No. of replication	4
No. of plots	20
Plot size	4.5m2
Variety	SiA 3156
Date of sowing	18th, July, 2024
Date of harvesting	25th, October, 2024
Plant sample data collection	30 DAS, 60 DAS, 90 DAS, and harvest

2.5. Growth attributes and yield parameters

Plant height, number of tillers per plant, and dry matter accumulation were recorded at 30, 60 and 90 days after sowing (DAS) and at harvesting stage from the respective plots. All the observations on growth, yield attributes and yield were recorded following standard procedure. For dry matter accumulation, fresh plant samples were kept in hot air oven at 70°C until a constant weight was achieved. The data obtained from various field and laboratory observations were statistically analyzed using the technique of analysis of variance for randomized block design.

2.6. Statistical analysis

The difference between the treatment means was tested for their statistical significance with an appropriate critical difference (C.D) value at 5% level of significance, as suggested by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Effect of organic manures on growth parameters

The parameters that were recorded to evaluate the performance of crop included the plant height (cm), No. of tillers per plant and dry matter accumulation (g plant^{-1}) at 30 days interval. Treatment T_3(Poultry+CAU Bio-enhancer) recorded significantly the highest values for plant height at 30, 60 and 90 DAS (26.90±0.638, 70.96±1.346 and 93.75±0.631 cm, respectively). At harvest, plant height (90.28±0.714 cm) was significantly on par withT_4, followed by T_4 (Vermicompost+CAU Bio-enhancer), T_1 (Poultry manure), T_2 (Vermicompost) and lowest height was recorded in control (T_5). The number of tillers per plant indicated the vegetative vigour and its ability to produce productive tillers. There were significant differences among the treatments. Treatment T_3 provided significantly higher overall the growth stages of crop growth (1.45±0.037, 2.75±0.052, 3.72±0.020, 3.65±0.081) followed by T_4, $T_{1,}$ T_2 and T_5. Dry matter accumulation reflected the biomass and nutrient assimilation by plant under various management practises and environmental conditions. Among all the treatment T_3 have showed significantly higher accumulation of biomass over all the stage of growth (0.52±0.006, 5.53±0.038, 9.73±0.123, 11.15±0.170), followed by T_4 T_1, T_2 and T_5.

The growth parameters that influenced the vigour and quality of the plant were found to better under different organic sources (Gao et al., 2020). The use of microbial consortium along with the organic sources improved the mineralisation of nutrients that can be readily available to the plant for growth and development (Alori et al., 2017). The present study focused combined use of microbial consortium along organic manures, which increased all the growth parameters (Table 1). The poultry manure, which contained the highest concentration of nitrogen, led to increased plant growth and biomass accumulation (Murakami et al., 2011). The microbial consortium contained microbes that can mobilize nutrients like P, K and other micronutrients that were limited in acid effected soils (Walpola et al., 2014).

Yield and yield attributes were critical indicators of final crop yield, as they reflected the combined influence of environmental, agronomic and management factors. The parameters recorded included the number of ear heads per plant, panicle length (cm), number of grains per panicle, test weight (g), grain yield (t ha^{-1}) and straw yield (t ha^{-1}), Based on yield parameters showed in Table 2. The number of ear heads per plant differed significantly among treatments. The highest number was recorded in T_3 (2.66±0.064) followed by T_4 (2.37±0.001) and T_1 (2.08±0.025) and T_2 (2.07±0.020), while the lowest was recorded in T_5 (1.25±0.027). Panicle length differed significantly among treatments, with the highest value in T_3 (14.95±0.071), which was on par with T_4 (14.85±0.094) followed by T_1 (14.54±0.023), T_2 (13.97±0.221) and the lowest in T_5 (10.72±0.034). The number of grains per panicle was significantly higher in T_3 (747.00±13.386) which was on par with T_4 (735.00±13.558) and T_1 (729.00±7.300) but differed significantly from T_2 (713.00±2.255). The lowest grain number was recorded in T_5 (554.00±5.840). Test weight of grains differed significantly among treatments. T_3 (2.35±0.041) recorded highest, followed by T_4 (2.31±0.038), T_1 (2.27±0.025) and T_2 (2.25±0.018) with the lowest test weight in T_5 (2.12±0.044). Both grain yield and straw yields showed significant difference across treatments. T_3 (1.13±0.006; 3.40±0.038 t ha^{-1}) recorded highest yields, followed by T_4 (1.12±0.001; 3.33±0.063 t ha^{-1}) while T_5 (0.87±0.016; 2.50±0.007 t ha^{-1}) recorded the lowest.

The application of poultry and vermicompost along with the microbial consortium increased the nutrient availability and mineralisation, resulting in greater nutrient assimilation by plants and thereby enhancing yield and related attributes (Du et al., 2016). The increased yield and plant growth could be attributed to soil microbial enzymes that enhanced root cell division and photosynthetic activity (Maqshoof et al., 2014). Similar results were reported by Lu et al., 2012 for increased rice yields using bio-inputs.

Based on the data, soil parameters were influenced by different treatments presented in table 3. Soil pH was not significantly affected by the treatments; the highest pH was recorded in T_3 (5.26±0.017) followed by T_4 (5.25±0.033) and the lowest in T_5 (5.10±0.081; 2.25±0.007). Soil organic carbon (SOC) differed significantly among treatments. The highest SOC was recorded in T_3 (2.39±0.028), followed by T_4 (2.32±0.034), T_1 (2.30±0.035) and T_2 (2.30±0.035), with the lowest in T_5 (2.25 %). The initial available nitrogen level was 322 kg ha^{-1}. The highest level of nitrogen was recorded in T_3 (338.00±3.028 kg ha^{-1}), which was statistically similar to T_4 (336.00±6.021 kg ha^{-1}) and T_1 (334.00±0.528 kg ha^{-1}) but significantly higher than the other treatments. T_5 recorded the lowest available nitrogen (325.00±1.884 kg ha^{-1}). The initial available phosphorus level was 32.32 kg ha^{-1}. Available phosphorus was significantly higher in T_3 (44.00±0.348 kg ha^{-1}) followed by T_4 (41.48±0.437 kg ha^{-1}), T_1 (38.11±0.301 kg ha^{-1}) and T_2 (35.58±0.206 kg ha^{-1}). The lowest phosphorus content was recoded in T_5- Control (34.42±0.871 kg ha^{-1}). The initial available potassium was 278.73 kg ha^{-1}. The highest available potassium was recorded in T_3 (286.07±3.769 kg ha^{-1}), followed by T_4 (284.20±1.049 kg ha^{-1}), T_1 (283.87±4.638 kg ha^{-1}) and T_2 (282.45±2.531 kg ha^{-1}), while the lowest was recoded in T_5 (280.37±6.797 kg ha^{-1}).

4. CONCLUSION

The grain and straw yields were considerably increased by 29% and 36%, respectively, when the biofertilizer (CAU Bioenhancer) and bio-inputs (poultry manures and vermicompost) were used in conjunction. When poultry manure and CAU Bioenhancers were combined, the soil metrics showed a significant increase in OC and NPK, whereas pH was non-significant.

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