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Effect of integrated nutrient management on yield attributes and yield of finger millet (*Eleusine coracana* L.)

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Abstract

A field experiment was conducted during *rabi*, 2025-26 at the Regional Agricultural Research Station (RARS), Warangal, to evaluate the effect of integrated nutrient management on yield attributes and yield of finger millet (*Eleusine coracana* L.). The experiment was conducted in factorial randomized block design with four organic manure treatments and three foliar sprays, replicated three times. Among organic manure treatments, M₄ (75% RDN through fertilizer + 25% RDN through Black Soldier Fly larval frass) recorded the highest productive tillers, fingers, ear weight, test weight, grain yield and straw yield. Among foliar sprays, S₃ (amino acid-based biostimulant) recorded superior performance for most yield attributes and yield. The interaction M₄S₃ recorded the highest ear weight (12.26 g), test weight (7.00 g), grain yield (2612 kg ha⁻¹) and straw yield (4393 kg ha⁻¹). Thus, M₄S₃ was the most effective treatment combination for improving finger millet productivity under the prevailing conditions of Warangal.

Keywords: Finger millet, integrated nutrient management, Black Soldier Fly frass, vermicompost, poultry manure, amino acid biostimulant, yield attributes, grain yield, straw yield.

1. Introduction

Finger millet (*Eleusine coracana* L.) also known as ragi ranks third position among important millets in India, following sorghum and pearl millet. It positions among major food grains due to its high nutritional value, particularly in protein and minerals such as calcium and iron, offering 8-10 times more calcium than wheat or rice. Its slow digestibility makes it an excellent food crop for pregnant women and individuals with diabetes (Ramesh *et al.*, 2024) [13]. It also serves as staple food and livestock feed, playing a significant role in food security and livelihood for many communities with its ability to thrive in harsh environments.

India had a total area of 13.49 lakh hectares under ragi cultivation in 2025-26, yielding 20.07 lakh tonnes with an average productivity of 1,488 kg ha⁻¹ (Indiastat, 2025-26) [8]. Among the states, Karnataka leads in ragi cultivation, covering 9.52 lakh hectares and producing 14.39 lakh tonnes, with a productivity of 1,512 kg ha⁻¹. Tamil Nadu, despite having a smaller cultivated area of 0.55 lakh hectares, achieved the highest productivity at 2,648 kg ha⁻¹, resulting in a total production of 1.47 lakh tonnes (Indiastat, 2025-26) [8]. Telangana recorded ragi cultivation over 0.01 lakh hectare with a production of 1.65 thousand tonnes and productivity of 1,647 kg ha⁻¹ (Indiastat, 2021-22) [7].

Nutrient management is a crucial factor in enhancing the productivity of finger millet. Modern agriculture practices rely on chemical fertilizers, which led to self-sufficiency in food grain production but also posed several new challenges. The benefits of INM are best achieved when nutrient sources are mixed judiciously and applied in a rational, balanced manner (Gafoor *et al.*, 2021) [5]. The productivity of most of the crops had been declining with detrimental effect on soil properties (Somasundaram *et al.*, 2020) [20]. Integrated Nutrient Management (INM) is a strategy that blends organic and inorganic fertilizers to maximize nutrient efficiency, improve soil health and minimize environmental damage. The combined use of chemical fertilizers and organic sources has shown promising results in sustaining higher productivity and improving the stability of crop production (Senthilkumar *et al.*, 2018) [19]. Therefore, an integrated approach to nutrient

management is essential to prevent nutrient depletion by balanced nutrient supply, maintaining soil fertility and sustaining crop productivity by sustainable farming practices (Pallavi *et al.*, 2016) [11].

In recent times, the recycling and reuse of organic waste have become an important aspect of INM. Organic amendments, such as farmyard manure, poultry manure and vermicompost, positively impact soil fertility, improving soil condition and plant growth. To achieve optimal productivity, it is important to manage nutrients effectively by incorporating organic matter, biofertilizers and essential micronutrients in a balanced manner (Gafoor *et al.*, 2021) [5]. When chemical fertilizers are used in combination with vermicompost, they better preserve soil quality, maintain crop productivity, and produce more reliable yields than when either input is applied alone (Sarma *et al.*, 2018) [17]. The application of vermicompost supports soil microbial activity and improves the availability of essential nutrients, particularly phosphorus and nitrogen, thereby contributing to better soil fertility (Senthilkumar *et al.*, 2018) [19].

Soil enriched with vermicompost has also demonstrated superior performance over soil treated with chemical fertilizers, showing improvements in physical and chemical characteristics as well as higher productivity (Somasundaram *et al.*, 2020) [20]. Similarly, poultry manure is regarded as one of the most effective organic fertilizers due to its rich nutrient content. Application of poultry manure significantly enhanced various chemical properties of the soil, such as pH level, organic matter content, total nitrogen, available phosphorus, exchangeable cations and base saturation percentage (Pallavi *et al.*, 2016) [11]. One promising organic waste product in this context is frass, a residue produced by black soldier fly larvae, which show potential for agricultural applications (Beesigamukama *et al.*, 2020 and Tanga *et al.*, 2022) [2, 22].

In contrast, organic foliar sprays deliver nutrients directly to plant leaves, offering a fast and efficient nutrient uptake. Foliar application of vermiwash acts as a natural growth promoter, as it supplies plant-growth-promoting substances, enzymes and micronutrients that help improve physiological processes and ultimately enhance yield-related attributes (Chaudhari *et al.*, 2024) [3]. Sea weed extracts used as biostimulants, play a crucial role in supplying comprehensive mix of essential macro and micronutrients needed for healthy plant development during critical growth phases of crops. They offer natural protection against pests and fungal infections and they also rich in plant hormones like cytokinins and gibberellins, these extracts are widely promoted as liquid fertilizers (Harika *et al.*, 2019 and Ramesh *et al.*, 2024) [6, 13]. Seaweed extract is a natural biostimulant rich in bioactive compounds and plant growth regulator-like substances, and its application has been reported to promote plant growth and productivity (Seemansethupathi *et al.*, 2023) [18].

Amino acid-based biostimulants are increasingly used in sustainable agriculture to improve nutrient assimilation, photosynthesis, and stress resistance. Studies have shown that foliar application of protein hydrolysates and amino acid-based biostimulants improves growth and yield-related traits in finger millet under integrated nutrient management practices (Karak *et al.*, 2024) [9]. Similarly, amino acid-based biostimulants have been reported to enhance growth and yield performance in cereal crops (Popko *et al.*, 2018) [12]. Therefore, the combined use of organic nutrient sources and foliar biostimulant application under INM is considered beneficial for sustaining soil health and increasing crop productivity.

2. Materials and Methods

The field experiment was conducted in the “A” block of the Regional Agricultural Research Station (RARS), Warangal during the *rabi* season of 2025-26, in the Department of Agronomy, Professor Jayashankar Telangana Agricultural University (PJTUA), Telangana. The research site was geographically located at an altitude of 266 m above mean sea level (MSL), at 18°0.96' N latitude and 79°0.36' E longitude. Prior to sowing of the finger millet crop, the experimental soil was sandy clay loam in texture, comprising 64.1 per cent sand, 8.2 per cent silt and 27.7 per cent clay, with a bulk density of 1.46 Mg m⁻³. The soil was slightly alkaline in reaction (pH 7.75), non-saline (EC 0.20 dS m⁻¹) and low in organic carbon (0.27%). The soil contained 214.2 kg ha⁻¹ of available nitrogen, 24.68 kg ha⁻¹ of available phosphorus and 227.32 kg ha⁻¹ of available potassium. The experiment was laid out in a factorial randomized block design (FRBD) comprising twelve treatment combinations with three replications, resulting in a total of 36 plots. Finger millet variety PRS-38 was sown during *rabi*, 2025-26 on 17 October 2025 at a spacing of 30 × 15 cm, using a seed rate of 4 kg ha⁻¹. The gross and net plot sizes were 6.0 × 4.2 m and 4.8 × 3.6 m, respectively. The treatments consisted of four organic manure treatments and three foliar spray treatments.

The organic manure treatments were: M₁: recommended dose of fertilizers (RDF) @ 40:20:20 kg N, P₂O₅ and K₂O ha⁻¹; M₂: 75% recommended dose of nitrogen (RDN) through fertilizer + 25% RDN through vermicompost; M₃: 75% RDN through fertilizer + 25% RDN through poultry manure; and M₄: 75% RDN through fertilizer + 25% RDN through Black Soldier Fly (BSF) larval frass. The foliar spray treatments were: S₁: vermiwash @ 50 mL litre⁻¹ of water, sprayed twice at vegetative and flowering stages; S₂: seaweed extract @ 2.5 mL litre⁻¹ of water, sprayed twice at vegetative and flowering stages; and S₃: amino acid-based biostimulant @ 2 mL litre⁻¹ of water, sprayed twice at vegetative and flowering stages. Thus, the experiment comprised 12 treatment combinations (4 organic manure treatments × 3 foliar spray treatments) with three replications.

Parameters	Vermicompost	Poultry manure	Black soldier fly larval frass
pH	7.33	7.57	7.72
EC (1:10) dS m ⁻¹	1.21	7.59	6.31
Total organic carbon (%)	29	23.14	24.2
Total Nitrogen (%)	2.0	2.6	1.6
Total Phosphorus (%)	1.5	1.84	1.7
Total Potassium (%)	1.15	1.4	1.21

2.1 Nutrient composition of organic manures

The recommended dose of fertilizers (40:20:20 kg N:P₂O₅: K₂O ha⁻¹) was applied through urea, single superphosphate (SSP) and muriate of potash (MOP). Under the integrated nutrient management treatments, 25 per cent of the recommended nitrogen was supplied through vermicompost, poultry manure and Black Soldier Fly (BSF) larval frass, while the remaining 75 per cent of nitrogen was supplied through inorganic fertilizer. The quantities of organic manures required to supply 25 per cent of the recommended nitrogen were calculated based on their respective nitrogen contents. Nitrogen fertilizer was applied in two equal splits, at sowing and 30 days after sowing (DAS), whereas the recommended doses of phosphorus and potassium were applied basally at the time of sowing.

Yield attributes were recorded from five randomly selected and tagged plants in each experimental plot. The experimental data

were subjected to analysis of variance (ANOVA) appropriate for a factorial randomized block design (FRBD) following the procedure described by Panse and Sukhatme (1985). The significance of differences among treatment means was tested using the F-test at the 5 per cent level of probability. Wherever the treatment effects were significant, the Critical Difference (CD) at $P = 0.05$ was calculated for comparison of treatment means, while non-significant differences were denoted as NS.

3. Results and Discussion

3.1 Yield attributes and yield

Integrated nutrient management practices significantly influenced the yield attributes and yield of finger millet. Among the organic manure treatments, M₄ (75% RDN through fertilizer + 25% RDN through BSF larval frass) recorded the highest number of productive tillers (118.18 m⁻²), number of fingers (175.33 m⁻²), ear weight (11.38 g), test weight (6.90 g), grain yield (2489 kg ha⁻¹) and straw yield (4324 kg ha⁻¹). Among the foliar spray treatments, S₃ (amino acid-based biostimulant) recorded the highest number of productive tillers (104.50), number of fingers (159.23 m⁻²), ear weight (10.47 g), test weight (6.39 g), grain yield (2410 kg ha⁻¹) and straw yield (4149 kg ha⁻¹), while the effect of foliar sprays on productive tillers was non-significant. The interaction between organic manure and foliar spray was significant for ear weight, test weight, grain yield and straw yield, with M₄S₃ recording the highest ear weight (12.26 g), test weight (7.00 g), grain yield (2612 kg ha⁻¹) and straw yield (4393 kg ha⁻¹), whereas the interaction effect on productive tillers and number of fingers was non-significant.

The superior yield attributes and yield recorded under M₄S₃ may be attributed to the combined effect of balanced and sustained nutrient availability through inorganic fertilizer and BSF larval frass, along with enhanced physiological activity due to the amino acid-based biostimulant. The relatively nutrient-rich BSF larval frass probably improved nutrient availability during critical reproductive stages, thereby promoting productive tiller

formation, finger and ear development, grain filling and assimilate production. The amino acid-based foliar application may have further enhanced nutrient assimilation, photosynthetic activity and translocation of photosynthates towards developing reproductive structures, resulting in higher ear weight, test weight, grain and straw yields. The improved nutrient supply and physiological activity under M₄S₃ consequently resulted in superior crop growth, better development of yield attributes and greater accumulation and translocation of assimilates towards the grains.

Similar findings were reported by Feyanbule *et al.* (2025) [4], Kidd *et al.* (2025) [10], Sahoo *et al.* (2025) [15], Sureshkannan *et al.* (2025) [21], Reddy *et al.* (2025) [14], Vasavi *et al.* (2024) [23], Bandita *et al.* (2022) [1], Santos *et al.* (2021) [16] who observed significant improvements in yield attributes, grain and straw yield of finger millet with the integrated application of organic manures, inorganic fertilizers and foliar sprays. The present findings are also supported by studies on BSF larval frass, which reported improved crop growth, nutrient availability and yield with the integrated use of BSF frass and inorganic fertilizers.

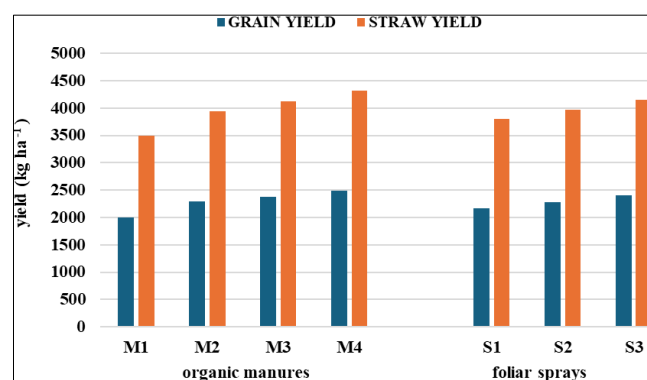


Fig 1: Grain yield and straw yield in (kg ha⁻¹) of finger millet during rabi, 2025-26 as influenced by organic manures and foliar sprays

Table 1: Effect of organic manures and foliar sprays on yield attributes and yield of finger millet

Treatments		No. of productive tillers (m ⁻²)	No. of fingers (m ⁻²)	Ear weight (g)	Test weight (g)	Straw yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Harvest index (%)
Organic manures								
M ₁	RDF (40:20:20 Kg N, P ₂ O ₅ & K ₂ O ha ⁻¹)	86.39	125.44	7.08	5.18	2001	3498	36.31
M ₂	75%RDN through fertilizer + 25% RDN through Vermicompost	90.08	141.56	9.70	6.14	2290	3946	36.76
M ₃	75% RDN through fertilizer +25% RDN through Poultry Manure	112.06	167.26	10.52	6.65	2379	4120	36.64
M ₄	75% RDN + 25% RDN through Black Soldier Fly larval Frass	118.18	175.33	11.38	6.90	2489	4324	36.50
SE(m)±		2.10	2.75	0.30	0.09	49	71	0.61
CD (p = 0.05)		6.16	8.07	0.80	0.26	143	208	NS
Foliar sprays								
S ₁	Spraying of vermiwash @ 50 mL L ⁻¹ of water twice at vegetative and flowering stages.	99.04	144.98	8.66	6.02	2172	3796	36.37
S ₂	Spraying of seaweed extract @ 2.5 mL L ⁻¹ of water twice at vegetative and flowering stages.	101.48	152.98	9.88	6.24	2287	3970	36.52
S ₃	Spraying of amino acid based biostimulant @ 2 mL L ⁻¹ of water twice at vegetative and flowering stages.	104.50	159.23	10.47	6.39	2410	4149	36.77
SE(m)±			2.38	0.26	0.08	42	61	0.53
CD (p = 0.05)		NS	NS	0.75	0.23	124	180	NS
Interaction of manures with sprays (M x S)								
SE(m)±		3.63	4.76	0.51	0.15	84.28	122.69	1.05
CD (p = 0.05)		NS	NS	1.50	0.45	247.18	359.84	NS

Interaction effects

Interaction		Ear weight (g)	Test weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
M ₁ S ₁	RDF (40:20:20 Kg N, P ₂ O ₅ & K ₂ O ha ⁻¹) + spraying of vermiwash @ 50 mL per litre of water twice at vegetative and flowering stages.	5.05	5.16	1670	3007
M ₁ S ₂	RDF (40:20:20 Kg N, P ₂ O ₅ & K ₂ O ha ⁻¹) + spraying of sea weed extract @ 2.5 mL per litre of water twice at vegetative and flowering stages.	7.98	5.18	2040	3563
M ₁ S ₃	RDF (40:20:20 Kg N, P ₂ O ₅ & K ₂ O ha ⁻¹) + spraying of amino acid based biostimulant @ 2 mL per litre of water twice at vegetative and flowering stages.	8.20	5.20	2292	3925
M ₂ S ₁	75%RDN through fertilizer + 25% RDN through VC + spraying of vermiwash @ 50 mL per litre of water twice at vegetative and flowering stages.	9.66	5.52	2240	3908
M ₂ S ₂	75%RDN through fertilizer + 25% RDN through VC+ spraying of sea weed extract @ 2.5 mL per litre of water twice at vegetative and flowering stages.	9.71	6.39	2306	3952
M ₂ S ₃	75%RDN through fertilizer + 25% RDN through VC+ spraying of amino acid based biostimulant @ 2 mL per litre of water twice at vegetative and flowering stages.	9.72	6.50	2315	3979
M ₃ S ₁	75% RDN through fertilizer +25% RDN through PM+ spraying of vermiwash @ 50 mL per litre of water twice at vegetative and flowering stages.	9.87	6.53	2353	4026
M ₃ S ₂	75% RDN through fertilizer +25% RDN through PM+ spraying of sea weed extract @ 2.5 mL per litre of water twice at vegetative and flowering stages.	10.02	6.55	2361	4032
M ₃ S ₃	75% RDN through fertilizer +25% RDN through PM+ spraying of amino acid based biostimulant @ 2 mL per litre of water twice at vegetative and flowering stages.	11.67	6.86	2422	4301
M ₄ S ₁	75% RDN through fertilizer + 25% RDN through BSFF+ spraying of vermiwash @ 50 mL per litre of water twice at vegetative and flowering stages.	10.04	6.84	2414	4245
M ₄ S ₂	75% RDN through fertilizer + 25% RDN through BSFF+ Spraying of sea weed extract @ 2.5 ml per litre of water twice at vegetative and flowering stages.	11.82	6.85	2442	4334
M ₄ S ₃	75% RDN + 25% RDN through BSFF+ Spraying of amino acid based biostimulant @ 2 ml per litre of water twice at vegetative and flowering stages.	12.26	7.00	2612	4393

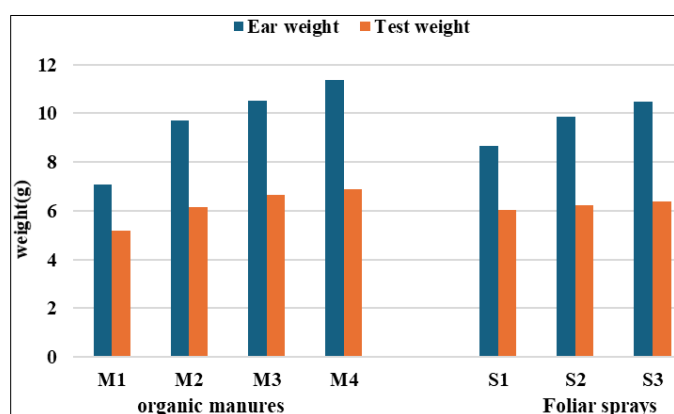


Fig 2: Ear weight (g) and test weight in (g) of finger millet during rabi, 2025-26 as influenced by organic manures and foliar sprays

4. Conclusion

Integrated nutrient management significantly improved the yield attributes and yield of finger millet compared with RDF alone. Among organic manure treatments, application of 75% RDN through fertilizer + 25% RDN through Black Soldier Fly larval frass (M₄) recorded superior productive tillers, number of fingers, ear weight, test weight, grain yield and straw yield. Among foliar sprays, amino acid-based biostimulant (S₃) performed better than vermiwash and seaweed extract. The interaction M₄S₃ recorded the highest ear weight, test weight, grain yield and straw yield. Thus, under the agro-climatic conditions of Warangal during rabi 2025-26, M₄S₃ may be considered a promising integrated nutrient management practice for enhancing productivity of finger millet.

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