PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.6149

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RESEARCH ARTICLE

Response of finger millet under organic nutrient management in sodic soil

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OPEN ACCESS

ARTICLE HISTORY

Received: 20 November 2024
Accepted: 29 December 2024
Available online
Version 1.0 : 30 January 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE

Rathika S, Ramesh T, Janaki P, Vinodhini S M, Baskar M, Selvarani A, Venkatalakshmi K, Satheeshkumar N, Ayyadurai P, Jagadeesan R, Dinesh G K, Kokilavani S, Vinoth R. Response of finger millet under organic nutrient management in sodic soil. Plant Science Today (Early Access). https://doi.org/10.14719/pst.6149

Abstract

Finger millet is a traditional food crop that holds immense significance due to its versatility, climate resilience, and higher nutritional value. Finger millet growers face challenges due to poor soil properties and environmental conditions. To meet the growing demand, finger millet production must be substantially increased through suitable organic nutrient management practices. Hence, the present study was carried out to evaluate the effect of organic nutrient management on the productivity and profitability of finger millet. Field experiments were conducted during the Kharif seasons of 2019 and 2020 at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli in a randomized block design with three replications. The treatments comprised of 100 and 125% N equivalent either through farmyard manure (FYM) or vermicompost or composted poultry manure, 50% N equivalent FYM + 50% N equivalent vermicompost, 50% N equivalent FYM + 50% N equivalent composted poultry manure, 50% N equivalent vermicompost + 50% N equivalent composted poultry manure and 100% recommended dose of fertilizer (RDF) (60: 30: 30 kg NPK/ha) + FYM (12.5 t/ha). Finger millet variety TRY 1 was used as test crop. The results revealed that the application of 100% RDF (60: 30: 30 kg NPK/ha) + FYM (12.5 t/ha) registered significantly higher growth, yield attributes and yield of finger millet than other treatments. However, it was comparable with 125% N equivalent vermicompost (3.8 t/ha) and 125% N equivalent composted poultry manure (3.5 t/ha). With regard to economics, application of 125% N equivalent composted poultry manure (3.5 t/ha) registered higher net return (Rs.41621/ha) and benefit cost ratio (BCR) (2.28) over other treatments. Hence, application of 125% N equivalent vermicompost (3.8 t/ha) or 125% N equivalent composted poultry manure (3.5 t/ha) could be recommended as organic nutrient management strategy for getting higher productivity and profitability of irrigated finger millet under sodic soil.

Keywords

finger millet; manure; organic nutrient management; productivity; sodic soil

Introduction

Millets play a crucial role in ensuring food security for millions of people, especially in developing countries. Finger millet (*Eleusine coracana* L.), among all the millets, stands out due to its versatility, climate resilience, and higher nutritional value. It offers a unique combination of health benefits, including high calcium content, anti-diabetic, and antioxidant properties. It is a vital staple crop in South Asia and Africa, ranked fourth globally in importance, after sorghum, pearl millet and foxtail millet. Ragi is grown in over twenty-five African and Asian nations, with India, Uganda, Nepal, and China being the top producers. In India, it is an essential small millet crop ranked third in area, production and productivity after sorghum and pearl millet (1). India, the world's largest producer of finger millet, recorded a production of 1.74 million tonnes on 0.99 million hectares, with an average yield of 1,761 kg/ha (2). In India, finger millet is cultivated in an area of 1.2 m ha with a production of 2.06 m tonnes with average productivity of 1706 kg/ha (3). In India, it is primarily grown in the states of Karnataka, Andhra Pradesh, Odisha, and Tamil Nadu. In Tamil Nadu, finger millet is the most important traditional millet crop grown over an area of 0.69 lakhs ha with production of 2.06 lakh tonnes and the productivity of 2.98 tonnes/ha (4). Finger millet is able to grow on marginal lands with poor soil fertility with drought tolerant, disease resistant, and effective in suppressing weed growth. Majority of the finger millet grown soils are deficient in major and micronutrients, mainly due to continuous cropping, low use of mineral fertilizer, poor recycling of crop residues, and low rates of organic matter application which can limit yield potential (5). Its ability to thrive in marginal conditions makes it a "Climate Change Compliant Crop (CCCC)" (6).

Finger millet growers faces challenges due to poor soil properties and environmental conditions, particularly in sodic soils. In India 3.79 m ha and in Tamil Nadu 0.35 m ha of land have been affected by sodicity, characterized by high pH (>8.5), high water-soluble and exchangeable sodium and low biological activity (7). These conditions significantly affect the finger millet productivity. To enhance the productivity and sustainability of finger millet cultivation in sodic soil environments, it is essential to explore and optimize application of organic inputs. Sodic soils, characterized by high sodium content, pose significant challenges to crop growth, including poor soil structure, reduced water infiltration, and limited nutrient availability. Organic farming practices have gained significant attention globally for their ability to improve soil health and reduce environmental impacts. By minimizing application of synthetic agrochemicals and relying on locally available organic resources, organic farming presents a more sustainable approach, particularly in sodic soils where conventional farming methods may accelerate the soil degradation.

Nitrogen deficiency is a critical issue, especially in organic culitvation of crops under sodic soil condition. Sodic soil requires additional N supply to increase the productivity of crops with recommendations for 25% extra N over the recommended dose for some crops in Tamil Nadu (8). Organic amendments, such as farmyard manure, composted poultry manure and vermicompost, can help to reclaim sodic soils by providing essential nutrients, improving soil structure, and enhancing microbial activity (9, 10). This holistic approach to organic nutrient management can help mitigate the adverse effects of sodic soils, leading to improved finger millet productivity and long-term soil health. Hence, the present investigation was carried out with the objective of testing different organic nutrient sources and to find out optimum dose of organic manure to enhance the productivity and profitability of finger millet under sodic soil condition.

Materials and Methods

Experimental site, season and variety

A field experiment was conducted during *Kharif* season, 2019 and 2020 at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, located at 10° 45'N latitude, 78° 36'E longitude, and an altitude of 85 meters above mean sea level (MSL). The finger millet variety TRY 1 was used in this study.

Soil status

The experimental soil was sodic, alkaline in nature, sandy clay loam in texture, moderately drained, and classified as Vetric Ustropept. The soil chemical properties of the experimental field are given in Table 1. The experimental soil was low in available nitrogen, medium in available phosphorus and high in available potassium.

Table 1. Chemical properties of soil at experimental plot

Sl. No.	Soil chemical properties	2019	2020
1	pH	8.90	8.60
2	EC (dS/m)	0.64	0.58
3	ESP	21.2	19.6
4	Available nitrogen (kg/ha)	191.0	208.7
5	Available phosphorus (kg/ha)	17.4	26.2
6	Available potassium (kg/ha)	275.3	288.5
7	Organic carbon (%)	0.56	0.62

Design, treatment details and manures added

	Treatments
T_1	100% N equivalent FYM
T_2	125% N equivalent FYM
T_3	100% N equivalent vermicompost
T_4	125% N equivalent vermicompost
T_5	100% N equivalent composted poultry manure
T_6	125% N equivalent composted poultry manure
T_7	50% N equivalent FYM + 50% N equivalent vermicompost
T_8	50% N equivalent FYM + 50% N equivalent composted poultry manure
T_9	50% N equivalent vermicompost + 50% N equivalent composted poultry manure
T_{10}	100 % RDF (60: 30: 30 kg NPK/ ha) + FYM (12.5 t/ha)

The experiment was laid out in randomized block design with replicated thrice. The treatments comprising different combinations of organic sources are as follows:

Nursery was raised by adopting recommended agronomic practices given in the TNAU Crop Production Guide 2020 (8). The main field was ploughed using a cultivator and secondary tillage was done using a rotovator, resulting in pulverized soil with fine tilth. The field layouts were formed by levelling the fields, and plots measuring 25 m^2 were formed for each treatment. Twenty five days old seedlings were transplanted into the main field, spaced 30 × 10 cm apart, with one seedling per hill. Before the transplantation of finger millet, green manure (Daincha) was incorporated in all treatment plots to mitigate the illeffects of sodic soil. Nutrient content of organic manures were analyzed and given in Table 2. The organic manures were added on nitrogen equivalent basis to each plot as per the treatment schedules are given in Table 3.

Observations recorded

Growth parameters

Observations on growth parameters *viz.,* plant height, total tillers per m^2 and dry matter production (DMP) were recorded at harvest.

Plant height: The plant height was measured from base of the plant to tip of the longest leaf stretched at vegetative stage and upto earhead in flowering and harvest stages in all sampled plants and expressed in cm.

Total tillers per m2: From each plot, four quadrates (0.25 m^2 area) were selected at random and total tillers were recorded and expressed in no./m^2.

DMP: Collected samples were shade dried and oven dried at 80°C for 72 hrs. DMP was computed and expressed in kg/ ha.

Yield parameters: Productive tillers/m^2, earhead length (cm), earhead weight (g), number of grains / earhead and test weight (g) of grain were recorded at harvest.

Yield: Grain and straw yields were recorded at the time of harvest from the net plot area and expressed as kg/ha.

Economics: Cost of cultivation and gross returns for all treatments were calculated by using prevailing input cost and market price of finger millet grain. The expenditure incurred was expressed in Rs./ha.

Net return (Rs./ha) = Gross return - Cost of cultivation

$$BCR = \frac{\text{Gross return (Rs. ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

Statistical analysis

The collected data were compiled, tabulated, and analyzed statistically according to the suggested methods (11). For pooled analysis, two years replicated data was used. One-way ANOVA was conducted using AGRES software to evaluate the treatment effects, with statistical significance determined at a critical difference (CD) corresponding to a probability level of P=0.05%. Non-significant results were marked as 'NS'.

Results and Discussion

Growth parameters

Observations on key growth parameters, including plant height, dry matter production and total tillers/m^2 were meticulously recorded at harvest, with results summarized in Table 4. The application of different organic nutrient management practices had a significant impact on the plant height of finger millet. Notably, the tallest plants reached an impressive pooled mean height of 99.1 cm when applied with 100% recommended dose of fertilizer (RDF) (60:30:30 kg NPK/ha) combined with farmyard manure (FYM) at 12.5 t/ha. However, it was statistically at par with application of 125% N equivalent vermicompost (94.7 cm) and 125% N equivalent composted poultry manure (92.5 cm), indicating that these organic amendments can effectively enhance plant height. The application of organic sources supply essential nutrients for plant growth. The rapid mineralization of organics,

Table 2. Nutrient content of organic manures

Sl. No.	Organic manures	Nutrient content (%)		
		Nitrogen	Phosphorus	Potassium
1	Farmyard manure	0.50	0.20	0.35
2	Vermicompost	1.95	1.53	0.92
3	Poultry manure	2.13	1.60	1.18

Table 3. Nitrogen composition and quantity of manures added

Sl. No.	Organic manures	N content (%)	Quantity added for 50 % N (kg/ha)	Quantity added for 100 % N (kg/ha)	Quantity added for 125 % N (kg/ha)
1	Farmyard manure	0.50	6000	12000	15000
2	Vermicompost	1.95	1539	3077	3846
3	Poultry manure	2.13	1409	2817	3521

Table 4. Effect of organic nutrient management on growth parameters of irrigated finger millet

Treatments	Plant height (cm)			DMP (kg/ha)			Total tillers/m²		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1	65.5	65.9	65.4	7296	7508	7402	135	140	137
T_2	68.3	69.0	68.5	7352	7563	7457	140	148	141
T_3	78.8	79.1	78.7	8603	8805	8702	160	171	166
T_4	94.5	94.9	94.7	9564	9638	9603	188	192	189
T_5	76.3	77.0	76.5	8188	8354	8270	154	158	154
T_6	92.4	92.8	92.5	9456	9512	9485	182	190	187
T_7	84.2	84.9	84.3	8834	9055	8942	167	177	171
T_8	72.2	72.7	72.4	8032	8247	8140	145	154	148
T_9	86.6	87.1	86.9	8878	9106	8990	172	181	177
T_{10}	98.6	99.4	99.1	9628	9850	9739	192	198	194
Mean	81.7	82.3	81.9	8583.1	8763.8	8673.0	163.5	170.9	166.4
SEd	3.8	3.9	3.3	337	366	372	7	8	6
CD (P=0.05)	7.6	7.8	6.7	676	732	735	14	16	12

particularly its nitrogen availability, played a key role in promoting crop growth (12). Conversely, the shortest plants, measuring only 65.4 cm, were recorded in the treatment utilizing 100% N equivalent FYM, highlighting the inferior performance of this approach in promoting vertical growth.

Furthermore, a significant difference in dry matter production (DMP) was observed across the various organic nutrient management strategies employed. Based on pooled data from both the years, the study indicated that the highest DMP of 9739 kg/ha was achieved through the application of 100% RDF + FYM at 12.5 t/ha, underscoring the effectiveness of this combination in optimizing biomass accumulation. This impressive DMP was at par with application of 125% N equivalent vermicompost (9603 kg/ha) and 125% N equivalent composted poultry manure (9485 kg/ha), reaffirming the importance of diverse nutrient sources in enhancing productivity. Organic sources *viz.,* FYM, vermicompost and composted poultry manure offers a sustained release, ensuring consistent growth. It also enhances soil structure by increasing organic matter, improving aeration and water retention, and stimulating microbial activity, which supports nutrient cycling and availability which in turn increases DMP. This underscores the importance of organic inputs in sustainable agriculture (13, 14). In stark contrast, the lowest DMP of 7402 kg/ha was recorded in the treatment with 100% N equivalent FYM indicating its limitations in fostering optimal growth conditions.

In addition, different organic nutrient management practices significantly influenced the total tiller production in irrigated finger millet. The application of 100% RDF + FYM at 12.5 t/ha resulted in the highest total tillers/ m^2, with an impressive pooled mean count of 194/m^2. This performance was comparable with application of 125% N equivalent vermicompost (189/m^2) and 125% N equivalent composted poultry manure (187/m^2), suggesting that a well-balanced nutrient approach is critical for maximizing tiller production (15). In contrast, the treatment utilizing 100% N equivalent FYM produced a notably lower number of total tillers (137/m^2), further emphasizing the need for organic nutrient management strategies to achieve higher productivity in finger millet cultivation.

Table 5. Effect of organic nutrient management on yield parameters of irrigated finger millet

Treatments	Productive tillers (No./m²)			Earhead length (cm)			Earhead weight (g)			No. of grains/Earhead			Test weight (g)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1	108	110	107	5.9	7.8	6.8	3.6	3.9	3.8	1098	1121	1108	2.7	2.9	2.8
T_2	118	122	120	5.9	7.8	6.8	3.7	4.1	3.9	1216	1273	1244	2.7	2.9	2.8
T_3	142	147	145	6.1	8.0	7.0	4.7	4.9	4.8	1486	1510	1499	2.8	3.0	2.9
T_4	165	169	166	6.3	8.2	7.2	5.8	6.0	5.8	1733	1789	1763	2.9	3.2	3.1
T_5	136	140	138	6.1	8.0	7.0	4.5	4.8	4.6	1435	1498	1467	2.8	3.0	2.9
T_6	159	163	162	6.3	8.2	7.2	5.7	5.9	5.7	1654	1687	1671	2.9	3.1	3.0
T_7	146	153	150	6.3	8.2	7.2	5.2	5.6	5.4	1532	1546	1541	2.8	3.0	2.9
T_8	126	132	130	6.0	7.9	6.9	4.1	4.5	4.3	1337	1451	1395	2.7	2.9	2.8
T_9	154	160	156	6.1	8.0	7.0	5.5	5.7	5.6	1608	1648	1626	2.9	3.1	3.0
T_{10}	170	176	174	6.3	8.2	7.2	5.9	6.3	6.2	1768	1813	1791	2.9	3.2	3.1
Mean	142	147	145	6.1	8.0	7.0	4.9	5.2	5.0	1487	1534	1511	2.8	3.0	2.9
SEd	6	8	9	0.3	0.4	0.3	0.2	0.3	0.3	6	8	9	0.3	0.3	0.33
CD (P=0.05)	12	14	12	NS	NS	NS	0.4	0.6	0.5	116	134	122	NS	NS	0.67

Yield parameters

The details on the yield parameters of irrigated finger millet under organic nutrient management practices are provided in Table 5.

The adoption of various organic nutrient management practices markedly influenced the number of productive tillers/m^2, exhibiting a significant variation ranging from 107 to 174 tillers/m^2. Notably, the treatment combining 100% RDF + FYM at 12.5 t/ha yielded the highest number of productive tillers, reaching an impressive pooled mean of 174/m^2. This outcome was comparable with 125% N equivalent vermicompost (166/m^2) and 125% N equivalent composted poultry manure (162/m^2), highlighting the efficacy of these organic amendments in enhancing productive tiller production (16). In contrast, the application of 100% N equivalent FYM resulted in the lowest number of productive tillers at 107/m^2, indicating the limitations of this practice in promoting tiller development.

While earhead length did not exhibit statistically significant differences among the treatments, the longest pooled mean earhead measured 7.2 cm in 100% RDF + FYM at 12.5 t/ha treatment, followed closely by the application of 125% N equivalent vermicompost and 125% N equivalent composted poultry manure. Conversely, the shortest earhead length of 6.8 cm was observed in the treatment with 100% N equivalent FYM.

Earhead weight also demonstrated significant variation among the treatments, with values ranging from 3.8 to 6.2 g. The heaviest earhead, weighing 6.2 g, was attained with the combination of 100% RDF + FYM at 12.5 t/ha , which was on par with 125% N equivalent vermicompost (5.8 g) and 125% N equivalent composted poultry manure (5.7 g) based on pooled mean values. In contrast, the lightest earhead weight of 3.8 g was recorded in 100% N equivalent FYM application.

The number of grains per earhead also varied significantly among treatments, ranging from 1108 to 1791 grains. Based on pooled data, the highest number of grains per earhead (1791) was observed in the treatment with 100% RDF + FYM at 12.5 t/ha, which was on par to both the 125% N equivalent vermicompost (1763) and 125% N equivalent composted poultry manure application (1671). Conversely, the lowest grain count of 1108 grains per earhead was noted in the 100% N equivalent FYM, emphasizing the critical role of balanced nutrient applications in achieving optimal yields. Although the test weight showed no significant variation across the different organic nutrient management practices.

The rapid nitrogen supply and mineralization process from organic manures improved crop nutrition, creating an optimal soil environment and promoting increased productive tiller numbers, earhead weight and number of grains per earhead. These findings are consistent with other studies, emphasizing the advantages of integrating organic nutrient management for improved crop performance and sustainable agriculture (17). This approach not only supports immediate growth but also ensures long-term soil health, making it a practical and effective strategy for farmers (18).

Yield

Grain yield

Organic nutrient management practices exerted significant influence on grain yield in transplanted finger millet (Fig. 1). Among the different organic nutrient

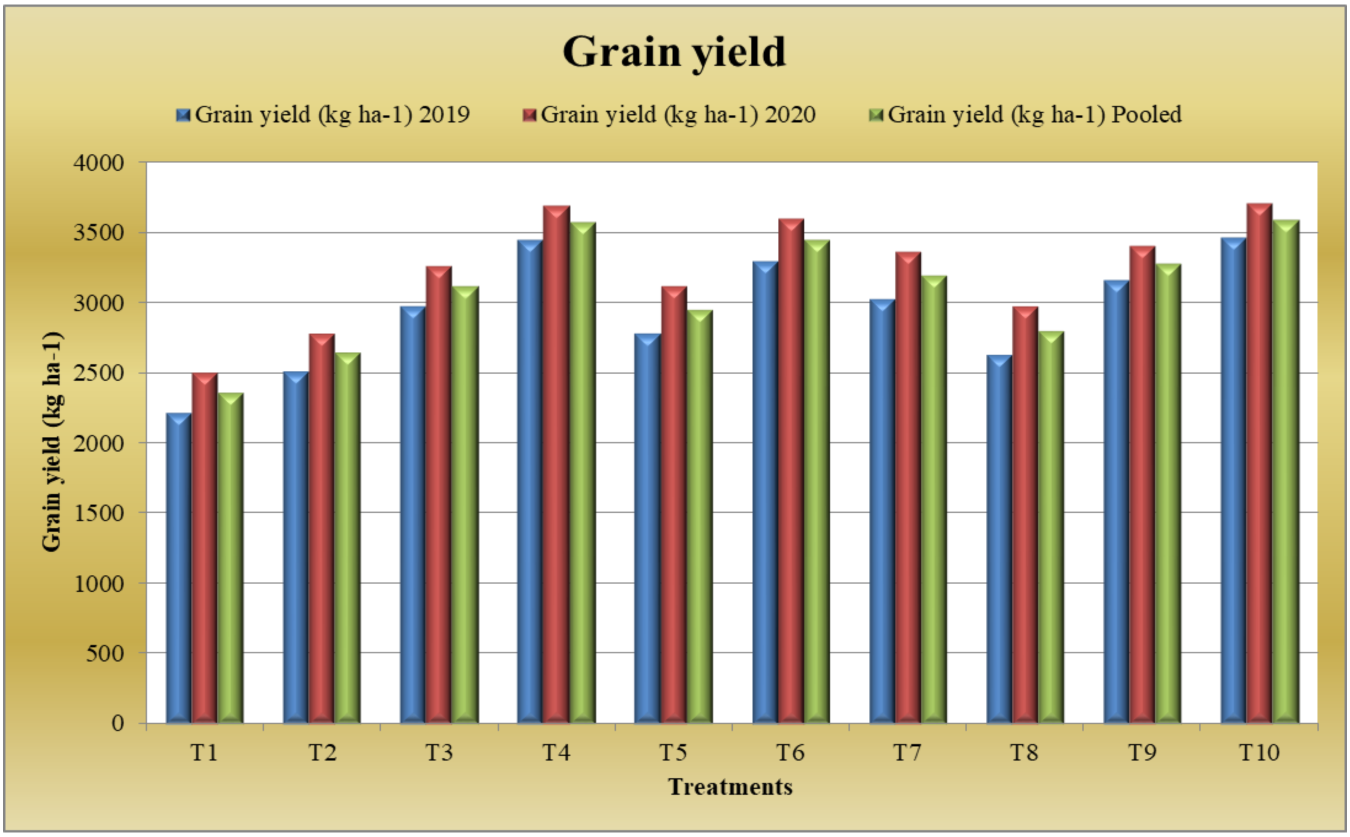

Fig. 1. Effect of organic nutrient management on grain yield of irrigated finger millet.

management practices, application of 100 % RDF (60: 30: 30 kg NPK/ ha) + FYM (12.5 t/ha) recorded higher pooled mean grain yield (3587 kg/ha) and it was on par with application of 125% N equivalent vermicompost and 125% N equivalent composted poultry manure with grain yield of 3569 kg/ha and 3447 kg/ha. The balanced nitrogen supply from organic manure facilitated the assimilation of photosynthetic products, increasing dry matter production and improving nutrient translocation. This resulted in more productive tillers with greater earhead length, weight, and a higher grain count, ultimately enhancing grain yield. These findings are consistent with numerous studies (13,15,19), demonstrating the long-term benefits of incorporating organic matter into nutrient management practices. These practices not only improve immediate crop performance but also support sustainable agriculture by improving the productivity. The lowest grain yield (2360 kg/ha) was recorded in 100% N equivalent FYM.

Straw yield

Adoption of different organic nutrient management practices produced significant variation in straw yield (Fig. 2). Based on pooled mean, application of 100 % RDF (60: 30: 30 kg NPK/ ha) + FYM (12.5 t/ha) registered the highest straw yield of 6371 kg/ha and it was comparable with application of 125% N equivalent vermicompost and 125% N equivalent composted poultry manure with straw yield of 6336 kg/ha and 6134 kg/ha. The increased straw yield due to the sufficient nitrogen supply from FYM, composted poultry manure and vermicompost, which boosted photosynthetic activity and biomass production. These results align with previous studies (20-26). The application

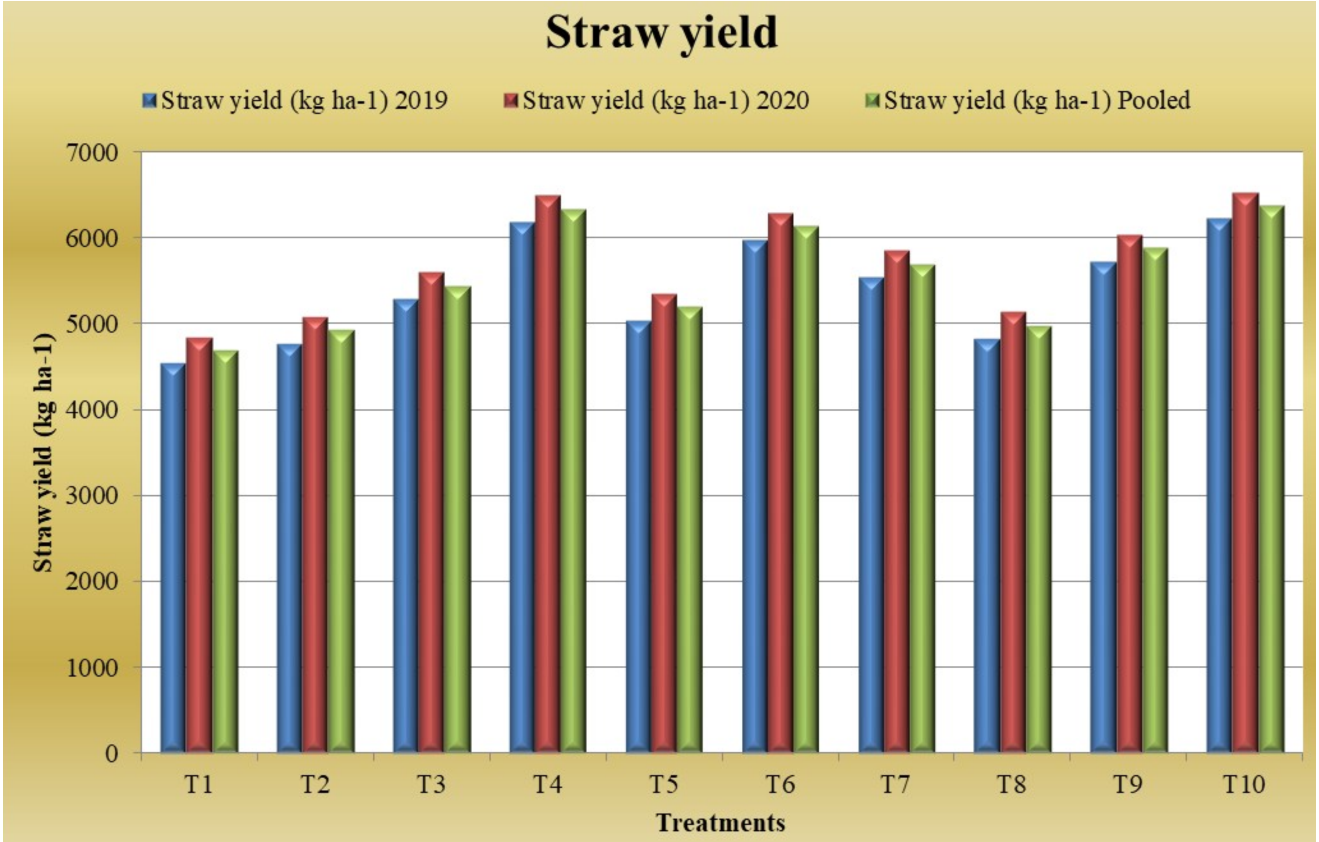

Fig. 2. Effect of organic nutrient management on straw yield of irrigated finger millet.

Table 6. Effect of organic nutrient management on the economics of irrigated finger millet

Treatments	Total cost of cultivation (Rs./ha)			Gross return (Rs./ha)			Net return (Rs./ha)			BCR		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1	33270	33750	33509	46628	57066	51846	13358	18777	16068	1.40	1.56	1.48
T_2	36070	36550	36309	52626	63065	57845	16556	21542	19049	1.46	1.59	1.53
T_3	44040	44520	44279	62143	72583	67362	18103	23443	20773	1.41	1.53	1.47
T_4	47730	48210	47969	72049	82489	77268	24319	28793	26556	1.51	1.60	1.56
T_5	30172	33652	33411	58177	68617	63366	28005	33462	30734	1.93	2.06	2.01
T_6	31096	34576	34335	68846	79286	74065	39750	43492	41621	2.25	2.31	2.28
T_7	33460	33940	33699	66020	76459	71239	26134	32537	29336	1.70	1.87	1.79
T_8	33724	34240	33963	55074	65512	60292	21614	28071	24843	1.65	1.83	1.74
T_9	37114	37594	37353	63248	73688	68467	32296	37400	34848	1.98	2.09	2.04
T_{10}	35062	35542	35301	72350	82790	77569	37288	39583	37436	2.06	2.09	2.07

of 100% N equivalent FYM registered lower straw yield of 4692 kg/ha.

Economics

The effect of organic nutrient management on economics of irrigated finger millet mentioned in Table 6. The highest gross return of Rs. 82790/ha was recorded in application of 100% RDF (60: 30: 30 kg NPK/ ha) + FYM (12.5 t/ha) followed by 125% N equivalent composted poultry manure. However, the highest net return and BCR of Rs. 44710/ha and 2.29, respectively were recorded in application of 125% N equivalent composted poultry manure followed by 100 % RDF (60: 30: 30 kg NPK/ ha) + FYM (12.5 t/ha). The application of 100% N equivalent FYM registered the lowest gross return, net return and BCR of Rs. 23316/ha, Rs. 13358/ha and 1.60.

Conclusion

Nitrogen deficiency is an important issue in sodic soil and requires additional N application to improve the finger millet yield. Application of nitrogen through organic sources not only reduces the soil sodicity and but also improves the finger millet yield. The present study confirms that applying 25% extra N application through either vermicompost or composted poultry manure improved the growth, yield attributes and grain yield of finger millet grown organically. Thus, the application of 125% N equivalent vermicompost (3.8 t/ha) or 125% N equivalent composted poultry manure (3.5 t/ha) is recommended as organic nutrient management strategy for getting higher productivity and profitability of irrigated finger millet under sodic soil. These salient findings will definitely help the organic growers to produce finger millet successfully in sodic soil.

Acknowledgements

We gratefully acknowledge the funding support received from the TNAU – Core project Scheme, Tamil Nadu Agricultural University, Coimbatore, India.

Authors' contributions

SR and TR did conceptualization and methodology of the experiment. SR collected data, analyzed and wrote the first draft of the manuscript. TR did overall supervision of the experiment and reviewed and edited the manuscript. AS, KV, NS and PA did execution of research on agronomic aspects, PJ and MB did execution of research on organic nutrient sources aspects. SMV, RJ, GKD, SK and RV did the final revision of the manuscript. All authors have read and agreed to the published version of manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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