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Effects of Organic Manures and Foliar Sprays on Growth and Yield of Finger Millet

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ABSTRACT
Experiments were conducted at the Centre of Excellence in Millets, Athiyandal, Thiruvannamalai, India to evaluate various organic nutrient sources with foliar application over three seasons from *kharif* 2015 to 2017 in Split Plot Design (SPD). Applying farmyard manure (FYM) @ 12.5 t ha^{-1} along with in-situ incorporation of sunhemp green manuring SGM @ 6.50 t ha^{-1} at 45 days after planting (DAP) resulted in higher grain and straw yields of 2,420 kg ha^{-1} and 3,549 kg ha^{-1}, respectively. A foliar spray of Panchakavya at a 3% concentration increased grain and straw yields to 2,423 kg ha^{-1} and 3,338 kg ha^{-1}. The B4 treatment yielded the highest gross income (₹84,724 ha^{-1}), net income (₹55,372 ha^{-1}), and benefit-cost ratio (2.84). Vermicompost application at 5 t ha^{-1} led to lower gross income. Among the foliar sprays, Panchakavya at 3% produced the highest gross income (₹84,478 ha^{-1}), net income (₹43,534 ha^{-1}), and benefit-cost ratio (2.36), followed by vermiwash at 3%.

Keywords: Finger millet, Grain yield, Organic Foliar spray, Organic manures and Panchagavya

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INTRODUCTION
Finger millet is a traditional cereal crop valued for its versatility, climate resilience, and high nutritional content, including significant calcium levels, anti-diabetic, and antioxidant properties. These features make it a promising solution for enhancing food security and improving the livelihoods of farmers, particularly in arid and semi-arid regions. Growing consumer health awareness has led to increased demand for nutritious cereals like finger millet. However, its cultivation faces challenges, especially for small and marginal farmers. A major obstacle is the accumulation of weed seed banks, including broadleaf weeds and sedges, which can reduce yields (Sivagamy and Chinnusamy 2014). Additionally, the high cost and limited availability of fertilizers prevent farmers from maximizing productivity. The improper or unbalanced use of chemical fertilizers harms soil health and may introduce risks to the food chain, leading to soil degradation and depletion of beneficial microorganisms (Karmakar et al 2013). In this context, organic farming presents a sustainable alternative, reducing dependence on chemical inputs and focusing on renewing and enhancing the farm ecosystem's

ecological processes. Organic farming, practiced in over 130 countries with 30.4 million hectares and around 0.7 million organic farmers globally (Willer 2008), promotes the sustainable cultivation of crops by conserving natural resources and minimizing synthetic fertilizers and pesticides. Organic practices improve soil health, increase biodiversity, and reduce environmental damage, all while producing safe and nutritious food. Recently, organic farming has gained momentum in India, driven by concerns about the safety of the environment, soil, water, and the food chain. However, maintaining high production levels through organic methods is a significant challenge, leading to growing awareness about adopting organic farming to address the problems caused by chemical agriculture.

To boost the productivity and sustainability of finger millet cultivation, it is crucial to optimize organic inputs, including soil amendments and foliar nutrition. Organic farming has attracted global attention due to its environmental and health benefits. By reducing the use of synthetic chemicals and utilizing locally available organic resources, it offers a sustainable agricultural approach. In the semi-arid regions of Southern India, where small and marginal farmers often face resource limitations, organic farming practices, such as using farmyard manure and vermicompost, can enhance soil fertility and structure. Organic foliar sprays can also provide nutrients directly to crops at critical growth stages, improving nutrient absorption and utilization (Karmakar et al 2013). This study aims to evaluate the performance of organic manures and foliar applications on irrigated finger millet in Southern India's semi-arid regions. By analyzing the effects of various organic inputs on crop growth, yield, and nutrient content, the research seeks to offer valuable insights into the effectiveness of organic practices for finger millet farming in these areas. Understanding how organic inputs affect grain and straw yields, along with economic viability, will help develop nutrient management strategies for sustainable finger millet production. This research also aims to contribute to the growing knowledge of organic farming, addressing the challenges faced by farmers in dry farming communities. By highlighting eco-friendly practices and the use of local organic resources, this study seeks to promote sustainable food production and improve farmers' livelihoods in the region. The global push for eco-friendly farming practices underscores the need for sustainable food production methods that mitigate the effects of climate change and conserve natural resources. Organic nutrient sources containing essential plant nutrients can produce comparable yields (Ghosh 2005). The continuous use of inorganic fertilizers in intensive cropping has caused widespread deficiencies in secondary and micronutrients. Organic foliar application, a simple and effective nutrient delivery method, is especially efficient during later growth stages when nutrient uptake from the soil is limited, and nutrient translocation to seeds is critical . This research aims to assess the effectiveness of organic practices in finger millet cultivation, focusing on overcoming challenges faced by small and marginal farmers in arid and semi-arid regions.

MATERIALS AND METHODS

Experimental location, soil properties and climatic status

The experiment was carried out at the Center of Excellence in Millets located in the Athiyandal village, Tiruvannamalai District, Tamil Nadu. The study examined the initial chemical and physical properties of the soil and the details of these properties and the methods used to determine them are presented in Table 1. The annual rainfall is 1074.7 mm which was distributed over 47 rainy days and the long-term average of maximum temperature, minimum temperature and relative humidities are 31.2ºC, 25.2ºC and 63% respectively. The experiment was designed using a split plot design (SPD) with three replications and four main plots treatments were used *viz.,* B_1: Farm Yard Manure (FYM) @ 12.50 t ha^{-1}; B_2: Vermicompost (VC) @ 5.00 t ha^{-1}; B_3: FYM @ 6.50 t ha^{-1} + sunhemp green manuring (SGM) in-situ plough on 45 DAS and B_4: recommended dose of 60 N: 30 P: 30 K kg ha^{-1} applied through urea, DAP and muriate of potash. There are five subplots viz., S_1: Panchagavya @ 3%; S_2: Vermiwash @ 3%; Jeevamruth @ 3%; S_3: water spray and S_4: Coconut water @ 5% spraying. During the Kharif seasons of 2015, 2016 and 2017, finger millet variety CO (Ra)-14 was sown at a spacing of 30 cm x 10 cm with a seed rate of 10 kg ha^{-1}. The FYM and VC were applied based on their nitrogen content of FYM at 0.50% N and VC at 2% N. The composition of FYM included 0.50%, 0.21% and 0.50% of N, P_2O_5 and K_20 respectively and the VC included 3.00% N, 1.00% P_2O_5 and 1.50% K_2O.

Table 1: **Initial physical and chemical properties of experimental soil**

Particulars	Values	Method used
Physical properties		
1. Clay (%)	33.1	
2. Silt (%)	21.2	Robinson's International pipette method
3. Fine sand (%)	18.4	(Piper 1966)
4. Coarse sand (%)	27.3	
5. Texture	Sandy clay loam	
Chemical properties		
1. pH	8.3 (Alkaline)	Jackson (1973)
2. EC (dSm^{-1})	0.1 (Safe)	Jackson (1973)
3. Organic carbon (%)	0.50 (Medium)	Chromic acid wet digestion method (Walkley and Black 1934)
4. Available N (kg ha^{-1})	285.0 (Medium)	Alkaline permanganate method (Asija and Subbiah 1956)
5. Available P_2O_5 (kg ha^{-1})	11.0 (Low)	Olsen method (Olsen 1954)
6. Available K_2O (kg ha^{-1})	89.0 (Low)	Neutral normal ammonium acetate method (Stanford and English 1949)

Observations and data collection

At the stage of panicle emergence the plant height and leaf area index were measured. The yield attributes which include the number of ear head $hill^{-1}$, number of fingers $earhead^{-1}$, finger length and 1000-grains weight were recorded at maturity by selecting 10 plants from the designated plot by following standard procedures. To determine the grain and biological yield, the harvested crop from the plots was sun-dried until it reached a constant weight. The total biomass yield was then recorded. After threshing, cleaning and further drying the grain, straw and biological yields were calculated for per hectare. The grain yield was specifically measured at a moisture content of 14%. Soil samples were collected from the initial stage of ploughing and after the harvest of individual plots from an experimental field. These samples were carefully analyzed to assess various soil reactions like pH, electrical conductivity (EC), organic carbon (OC) and available NPK. The collected experimental data was subjected to Fisher's method of analysis of variance (ANOVA). Furthermore, a pooled analysis was done for grain and straw yield.

Statistical analysis

All the collected data were analyzed and the results were presented and discussed at a significance level of five percent, by the methodology proposed by Gomez and Gomez (1984).

RESULTS

Growth attributes of finger millet

The growth attributes *viz*., plant height, higher leaf area index and higher productive tillers/hill at harvest indeed were numerically influenced by the different nutrient sources and foliar spray levels to finger millet (Table 2). At harvest, basal application of FYM @ 6.50 t ha^{-1} + SGM in situ ploughing on 45 DAS has recorded taller plants (93.00 cm), higher leaf area index (3.327 cm) and higher number of ear head $hill^{-1}$ (6.230). This was closely followed by the FYM @ 12.5 t ha^{-1} application as basal incorporation at the time of land preparation. The other two treatments *viz*., vermicompost @ 5 t ha^{-1} and RDF (60:30:30 NPK kg ha^{-1}) application as basal, performed on par with each other for growth attributes of finger millet. The application of nitrogen through organic fertilizers might be attributed due to the addition of more nitrogen into the soil and its slow release throughout the crop growth phase which might have positively influenced the growth attributes of the crop (Govindappa et al 2009). Wider spacing and loosening of soil at the right time facilitated better rooting that helped in better absorption of water and nutrients resulting in taller plants. Similar findings were also reported by Praveenkumar (2019), Sivagamy et al (2020). Among the organic foliar sprays, the application of Panchakavya @ 3% spray at flowering (40-45 DAS) recorded higher plant height (91.30 cm), leaf area index (3.123 cm) and number of ear head $hill^{-1}$ (5.803). The increased growth attributes due to the application of vermiwash @ 3% and this conforms with the findings of Lalitha et al (2002) and Yadav (2006). The overall improvement in the growth attributes may be due to the beneficial effect of vermiwash on plant growth might be due to the presence of several macros and micronutrients in vermicast and their secretions in considerable quantities reported by Surya (2012).

Table 2.Influene of organic manures and organic foliar application on growth and yield attributes of irrigated finger millet (pooled *kharif* 2015 to 2017)

Treatments	Plant height (cm)	LAI	No. of ear head hill^{-1}	No. of fingers ear head^{-1}	Finger length (cm)	Test weight (g)
Basal nutrition						
FYM @ 12.5 tha^{-1}	84.71	3.327	4.721	7.032	9.702	3.092
Vermicompost @ 5 tha^{-1}	81.84	2.336	4.562	5.123	9.136	3.123
FYM @6.5 tha^{-1}+ SGM	93.03	3.564	6.230	8.367	9.912	3.128
RDF(60:30:30 kg NPK kgha^{-1})	83.73	2.423	4.852	5.915	9.636	3.065
S.Ed	3.48	0.05	0.11	0.136	0.19	0.11
CD (P= 0.05%)	8.51	0.11	0.28	0.34	0.47	0.28
Organic foliar sprays						
Panchakavya @3.00%	91.30	3.123	5.803	7.525	10.02	3.143
Vermiwash @3.00%	88.06	3.037	5.417	6.965	9.701	3.126
Jeevamruth @3.00%	86.24	2.815	5.254	6.584	9.636	3.108
Coconut water @5.00%	83.23	2.762	4.526	5.791	9.278	3.071
Water spray (Control)	80.31	2.673	4.531	6.263	9.464	3.064
S.Ed	3.68	0.06	0.12	0.13	0.19	0.12
CD (P= 0.05%)	7.50	0.12	0.24	0.27	0.40	0.24

Yield attributes

The application of various nutrient sources and foliar spray treatments had a significant influence on the grain yield of finger millet. The basal application of FYM and sunhemp at 45 DAS resulted in the higher number of earhead hill^{-1} (6.230), number of fingers earhead^{-1} (8.367), finger length (9.912 cm) and test weight (3.128 g).

Yield

The results shows (Figure 1a) that the basal application of FYM at a rate of 6.5 t ha^{-1}combined with Sunhemp in situ ploughing on 45 DAS, resulted in the highest grain yield of 2420 kg ha^{-1} and straw yield of 3549 kg ha^{-1}. This finding aligns with the general understanding of the positive impact of organic amendments on crop productivity. Farmyard manure is a valuable organic fertilizer that contributes to soil fertility and provides essential nutrients for plant growth. It improves soil structure, enhances water-holding capacity and increases nutrient availability to plants over time. Numerous studies have shown that the application of FYM can positively affect crop yields and overall soil health (Tadesse et al 2013) and some studies says that, this might be due to the steady release of both NH_4-N and NH_3-N throughout the active growth phase of the crop period, which potentially enhanced the higher crop yield (Kumara et al 2007)

The lowest grain yield of 2027 kg ha^{-1} and straw yield of 2668 kg ha^{-1} were recorded with the application of vermicompost @ 5 t ha^{-1}. While vermicompost is generally considered beneficial for soil health and plant growth, the specific conditions of this experiment may have resulted in lower yields compared to other treatments. Factors such as nutrient composition, application timing or interactions with other treatments could have influenced the observed outcomes. The foliar spray treatment the results indicate that the Panchakavya treatment led to higher grain yield (2423 kg ha^{-1}) and straw yield (3338 kg ha^{-1}) compared to the Coconut water treatment, which resulted in lower yields (1984 kg ha^{-1} grain and 2750 kg ha^{-1} straw) (Figure 1b). These treatments can be used to supply nutrients, enhance plant growth, mitigate nutrient deficiencies or improve overall crop performance.

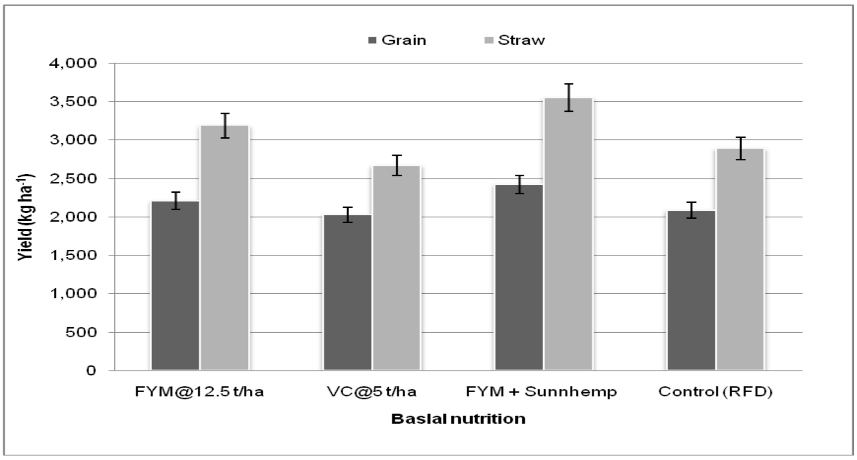

Figure 1a. Performance of finger millet for various sources of organics for basal nutrition

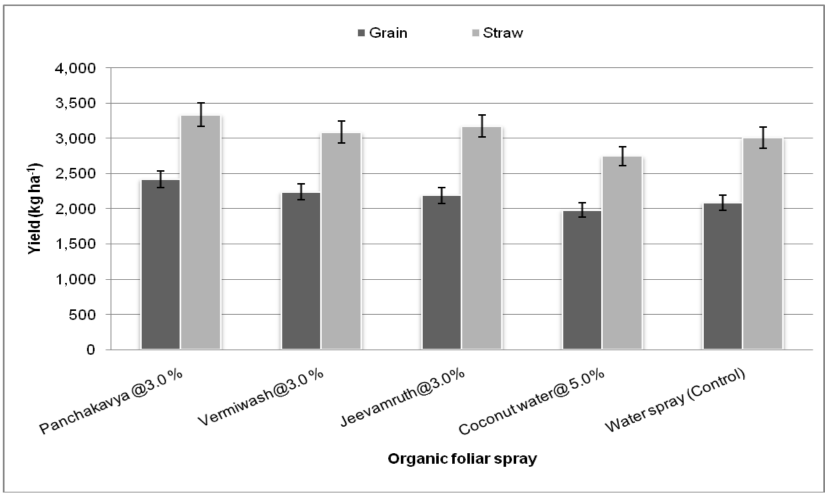

Figure 1b. Performance of finger millet for various sources of organic foliar spray

Economics

The finger millet cultivation revealed significant variations in farm income when different nutrient resources and organic foliar sprays were employed. The application of FYM at a rate of 6.5 t ha^{-1} combined with sunhemp in situ ploughing at 45 days after sowing resulted in a higher gross income of Rs. 84,724 ha^{-1}, net income of Rs. 55,372 ha^{-1} and benefit-cost ratio of 2.84. On the other hand, the basal application of vermicompost at a rate of 5 t ha^{-1} led to a lower gross income of Rs. 70,612 ha^{-1}, a negative net income of Rs. -4,490 ha^{-1} and B:C ratio of 0.91. The foliar application of Panchakavya at a concentration of 3% recorded the highest gross income (Rs. 84,478 ha^{-1}), net income (Rs. 43,534 ha^{-1}) and B:C ratio (2.36), followed by Vermiwash at a concentration of 3% spray. Based on the study's findings and considering the sustainability of the production system in semi-arid tracts (SAT) in southern India, it is recommended to apply FYM at a rate of 6.5 t ha^{-1} combined with SGM in situ ploughing at 40-45 DAS (before flowering). Additionally, applying Panchakavya at a concentration of 3% at 45 days after planting can further enhance the sustainability of finger millet production in the dry North Eastern Zone region of Tamil Nadu.

DISCUSSION

Growth attributes of finger millet

The growth attributes *viz*., plant height, higher leaf area index and higher productive tillers/hill at harvest indeed were numerically influenced by the different nutrient sources and foliar spray levels to finger millet (Table 2). The application of nitrogen through organic fertilizers might be attributed due to the addition of more nitrogen into the soil and its slow release throughout the crop growth phase which might have positively influenced the growth attributes of the crop (Govindappa et al 2009). Wider spacing and loosening of soil at the right time facilitated better rooting that helped in better absorption of water and nutrients resulting in taller plants . Similar findings were also reported by Praveenkumar (2019); Sivagamy et al (2024). The increased growth attributes due to the application of vermiwash @ 3% and this conforms with the findings of Lalitha et al (2002) and Yadav (2006). The overall improvement in the growth attributes may be due to the beneficial effect of vermiwash on plant growth might be due to the presence of several macros and micronutrients in vermicast and their secretions in considerable quantities reported by Surya (2012).

Yield attributes

The application of various nutrient sources and foliar spray treatments had a significant influence on the grain yield of finger millet (Table 2). This positive effect may be due to the sufficient supply of nutrients and beneficial soil microbes from the combined sources of well-decomposed and decomposing organic sources enhanced nutrient mineralization and availability, stimulated the production of plant growth hormones, and acted as biocontrol agents against plant pests, parasites or diseases (Jacoby et al 2017). The foliar spray of Panchakavya @ 3% spray had shown a higher number of earhead hill^{-1} (5.803), number of fingers earhead^{-1} (7.525), finger length (10.02 cm) and test weight (3.143 g). The use of Panchakavya as a foliar application improves the photosynthetic activity of the plants and promoted the development of an extensive root system. This allowed the plants to extract nutrients more efficiently from the soil which result in improved yield components (Vimalendran and Wahab 2013).

Yield

The results shows (Figure1a) that the basal application of FYM at a rate of 6.5 t ha^{-1}combined with Sunhemp in situ ploughing on 45 DAS, resulted in the highest grain yield of 2420 kg ha^{-1} and straw yield of 3549 kg ha^{-1}. The incorporation of Sunhemp through in situ ploughing further enhances the soil's nutrient content. Sunhemp is a leguminous cover crop (Andrew et al 2011) that has the ability to fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing bacteria. This process increases the soil nitrogen availability, which is crucial for plant growth and yield (Tanveer et al 2019). This finding aligns with the general understanding of the positive impact of organic amendments on crop productivity. Farmyard manure is a valuable organic fertilizer that contributes to soil fertility and provides essential nutrients for plant growth. It improves soil structure, enhances water-holding capacity and increases nutrient availability to plants over time. Numerous studies have shown that the application of FYM can positively affect crop yields and overall soil health (Tadesse et al 2013) and some studies says that, this might be due to the steady release of both NH_4-N and NH_3-N throughout the active growth phase of the crop period, which potentially enhanced the higher crop yield (Kumara et al 2007)

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Economics

The finger millet cultivation revealed significant variations in farm income when different nutrient resources and organic foliar sprays were employed (Figure 1b). Based on the study's findings and considering the sustainability of the production system in semi-arid tracts (SAT) in southern India, it is recommended to apply FYM at a rate of 6.5 t ha^{-1} combined with SGM in situ ploughing at 40-45 DAS (before flowering). Additionally, applying Panchakavya at a concentration of 3% at 45 days after planting can further enhance the sustainability of finger millet production in the dry North Eastern Zone region of Tamil Nadu.

CONCLUSION

From the study,it was concluded that using farmyard manure (FYM) along with sunhemp green manure as a base application, combined with a 3% foliar spray of Panchakavya at recommended concentrations, can significantly enhance the productivity and profitability of finger millet farming. These techniques help farmers improve their cultivation methods through organic practices. This approach not only meets the crop's nutritional needs but also encourages sustainable and organic farming, offering long-term advantages for both farmers and the environment.

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