EFFECT OF ORGANIC MANURES AND FOLIAR APPLICATION OF DIFFERENT ORGANIC SOURCES OF NUTRIENTS ON IRRIGATED FINGER MILLET IN THE SEMI-ARID REGION OF SOUTHERN INDIA

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Abstract. The field experiments were carried out at the Centre of Excellence in Millets, Athiyandal, Thiruvannamalai, to evaluate different organic sources of nutrients with foliar application over three seasons from *kharif* 2015 to 2017. The application of Farm Yard Manure (FYM) at a rate of 6.5 t ha^{-1} along with sunhemp green manuring (SGM) in-situ incorporation on 45 days after sowing (DAS) recorded higher grain and straw yields of 2420 kg ha^{-1} and 3549 kg ha^{-1}, respectively. The foliar spray of Panchakavya at 3% concentration on 45 DAS enhanced grain yield to 2423 kg ha^{-1} and straw yield to 3338 kg ha^{-1}. The recommended dose of fertilizer (RDF) {60:30:30 kg N, P_2O_5 K_2O $kgha^{-1}$} resulted in higher gross income (Rs. 84,724 per ha), net income (Rs. 55,372 per ha), and benefit-cost ratio (2.84). However, the application of vermicompost at 5 t ha^{-1} resulted in a lower gross income. Among the foliar spray treatments, Panchakavya at 3% concentration recorded the highest gross income (Rs. 84,478 per ha), net income (Rs. 43,534 per ha), and benefit-cost ratio (2.36), followed by vermiwash at 3% concentration.
Keywords: *finger millet, grain yield, organic foliar spray, organic manures, Panchagavya*

Introduction

Finger millet is a traditional cereal crop that holds immense significance 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. These qualities make finger millet a promising solution for addressing food security challenges and improving the livelihoods of farmers, particularly in arid and semi-arid regions. Moreover, increasing health consciousness

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among consumers has resulted in a growing demand for nutritious cereals like finger millet. However, the cultivation of grain crops like finger millet faces several obstacles in regions where small and marginal farmers are prevalent. The major challenges faced by farmers is the accumulation and predominance of weed seed banks, comprising broad leaved weeds and sedges, which may reduce crop yields (Sivagamy and Chinnusamy, 2014). Additionally, affordability and accessibility of fertilizers in the market hinder farmers' ability to maximize crop productivity. Improper and unbalanced use of chemical fertilizers can have detrimental effects on soil health and may enter the food chain, posing risks to human health. Excessive application of chemical fertilizers can lead to soil degradation, nutrient imbalances, and depletion of beneficial microorganisms (Karmakar et al., 2013). In this context, organic farming emerges as a viable alternative that reduces reliance on external inputs and focuses on optimizing crop productivity by renewing and strengthening the ecological processes and functions of the farm ecosystem.

Organic farming is currently being implemented in over 130 countries with a total area of 30.4 m ha and there are approximately 0.7 million organic farmers globally (Willer, 2008). It promotes the sustainable cultivation of crops, emphasizing the conservation of natural resources and the minimization of synthetic inputs such as chemical fertilizers and pesticides. By relying on organic inputs and local resources, farmers can improve soil health, enhance biodiversity, and reduce environmental degradation, while also producing nutritious and safe food. Over the past few years organic farming has gained momentum in India owing to the concerns expressed on the safety of environment, soil, water and food chain. Cultivating crops organically and at the same time maintaining higher production levels is a big challenge. At this juncture, a keen awareness has sprung on the adoption of organic farming as a remedy to cure the ills of chemical agriculture.

In order to enhance the productivity and sustainability of finger millet cultivation, there is a need to explore and optimize the use of organic inputs both in terms of soil application and foliar nutrition. Organic farming practices have gained significant attention worldwide due to their environmental and health benefits. By minimizing the use of synthetic agrochemicals and relying on locally available organic resources, organic farming offers a more sustainable approach to agriculture. In the semi-arid dry tracts of Southern India, where small and marginal farmers often face resource constraints, the adoption of organic farming practices can be particularly beneficial. Organic manures, such as farmyard manure and vermicompost provide essential nutrients to the soil, improving its fertility and structure. Organic foliar sprays, on the other hand offer a direct and effective means of supplying nutrients (Karmakar et al., 2013) to the crop during critical growth stages, promoting better nutrient uptake and utilization. The aim of this study is to evaluate the performance of organic manures and organic foliar applications on irrigated finger millet in the semi-arid dry tract of Southern India. By assessing the impact of different organic inputs on crop growth, yield and nutrient content, this research intends to provide valuable insights into the suitability and effectiveness of organic farming practices for finger millet cultivation in this region. Understanding the performance of organic inputs in terms of grain and straw yield as well as economic viability, will aid in formulating appropriate nutrient management strategies for sustainable finger millet production. Furthermore, this study seeks to contribute to the growing body of knowledge on organic farming practices and their potential to address the challenges faced by farmers in dry farming communities.

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By emphasizing the importance of eco-friendly cultivation practices and the utilization of locally available organic resources, this research aims to promote sustainable food production and improve the livelihoods of farmers in the region.

The current global scenario further highlights the need to adopt eco-friendly cultivation practices in the production of millets. Sustainable food production methods are essential to mitigate the adverse effects of climate change and preserve natural resources. Various bulky organic nutrient sources are available which contain good amount of major plant nutrients to produce comparable yields (Ghosh, 2005). The continuous use of inorganic fertilizers under intensive cropping system has caused widespread deficiency of secondary and micronutrients in soil. Organic foliar application was a simple and effective method of providing nutrients to crops (Alexander and Schroeder, 1987). Foliar spray will be more efficient than the soil application at the later growth stages when there is preferential assimilates translocation into seeds and root activity for nutrient uptake is limited. This research intends to shed light on the suitability and effectiveness of organic farming practices for finger millet cultivation in arid and semi-arid regions, with a focus on addressing the challenges faced by small and marginal farmers.

Materials and methods

Experimental site

The experiment was carried out at the Center of Excellence in Millets located in the Athiyandal village, Tiruvannamalai District, Tamil Nadu. The precise geographical coordinates of the location are 12.007°N latitude and 78.099°E longitude with an elevation of 163 meters above mean sea level. During the *kharif* seasons of 2015, 2016 and 2017, finger millet variety CO (Ra)-14 was sown at a spacing of 30 cm × 10 cm with a seed rate of 10 kg ha^{-1}.

Initial soil analysis

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*. These samples were carefully analyzed to assess various soil reactions like pH, electrical conductivity (EC), organic carbon (OC) and available NPK.

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

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

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Climate

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 31.2°C, 25.2°C and 63% respectively (*Fig. 1*).

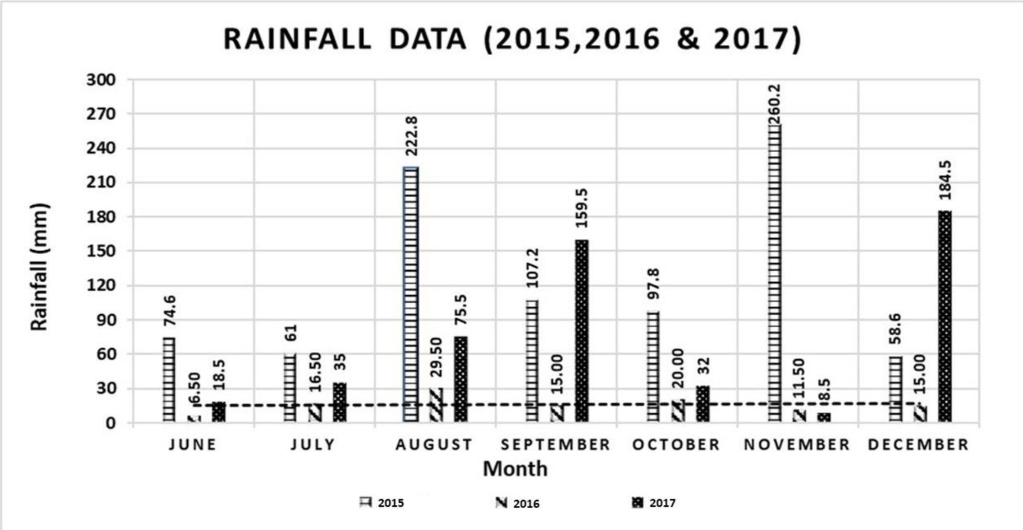

Figure 1. *Rainfall received during the cropping season*

Experimental design and treatment

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 (Days after sowing) 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. The FYM and Vermicompost 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_2O respectively and the VC included 3.00% N, 1.00% P_2O_5 and 1.50% K_2O.

Data collection and analysis

Growth parameters

Plant height

The plant height was measured from five randomly selected hills in each treatment by measuring length from the base of the plant to the tip of the longest leaf at 120 DAS and the mean values were expressed in centimeters.

Number of earheads per hill

All the earhead-bearing tillers from five randomly selected hills from each treatment were counted at harvest averaged, and expressed as numbers of productive tillers per hill.

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Number of fingers per earhead

Five earheads were selected at five randomly selected hills from each treatment at the time of harvest and the mean number of fingers earhead^{-1} was recorded

Finger length

Finger length is measured from the base of the longest finger on the main ear to the tip.

Test weight

Dried 1000 seed samples were drawn randomly from each treatment were counted and weight was recorded in grams.

Crop yield

Crops were harvested manually, leaving five centimeters above the ground. The grains and straw were separated by threshing after proper drying. The separated grains were recorded as grain yield, and the remaining straw was recorded as straw yield.

Statistical analysis

The data recorded for different parameters were analyzed with the help of the analysis of variance (ANOVA) technique for a split-plot design using MSTAT-C software. The results are presented at a 5% level of significance ($p = 0.05$). 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). Furthermore, a pooled analysis was conducted for growth and yield parameters for the years 2015 and 2017, excluding 2016, which was a drought year.

Results

Growth parameters

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 (93.03 cm), higher leaf area index (3.564 cm) and higher number of earhead hill^{-1} (6.230) and significantly superior than application of vermicompost @ 5 t ha^{-1}. This was on par with the application of RDF (60:30:30 NPK kg ha^{-1}) and FYM @ 12.5 t ha^{-1} as basal incorporation at the time of land preparation treatments.

Yield parameters

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@ 6.5 t ha^{-1} + SGM in-situ ploughing at 45 DAS resulted in the higher number of earhead hill^{-1} (6.230), number of fingers earhead^{-1} (8.367) were statistically significant than rest of the treatments. Whereas finger length (9.912 cm) was statistically similar with the application of RDF (60:30:30 NPK kg ha^{-1}) and FYM @ 12.5 t ha^{-1}. While the test weight was not influenced by various sources of basal nutrition for finger millet crop.

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Table 2. *Influence of organic manures and organic foliar application on growth and yield attributes of irrigated finger millet (pooled 2015 and 2017 excluding 2016)*

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^{ab}	3.327^{b}	4.721^{c}	7.032^{b}	9.702^{ab}	3.092
Vermicompost @ 5 tha^{-1}	81.84^{b}	2.336^{c}	4.562^{c}	5.123^{d}	9.136^{c}	3.123
FYM @6.5 tha^{-1} + SGM	93.03^{a}	3.564^{a}	6.230^{a}	8.367^{a}	9.912^{a}	3.128
RDF(60:30:30 kg NPK kgha^{-1})	83.73^{ab}	2.423^{c}	4.852^{b}	5.915^{c}	9.636 ^{ab}	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	NS
Organic foliar sprays						
Panchakavya @3.00%	91.30^{a}	3.123^{a}	5.803^{a}	7.525^{a}	10.02^{a}	3.143
Vermiwash @3.00%	88.06^{ab}	3.037^{ab}	5.417^{b}	6.965^{b}	9.701^{ab}	3.126
Jeevamruth @3.00%	86.24^{ab}	2.815^{c}	5.254^{bc}	6.584^{c}	9.636^{abc}	3.108
Coconut water @5.00%	83.23^{bc}	2.762^{cd}	4.526^{d}	5.791^{e}	9.278^{de}	3.071
Water spray (Control)	80.31^{cd}	2.673^{e}	4.531^{d}	6.263^{d}	9.464^{bcd}	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	NS

Yield

The results shows (*Fig. 2*) 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. 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.

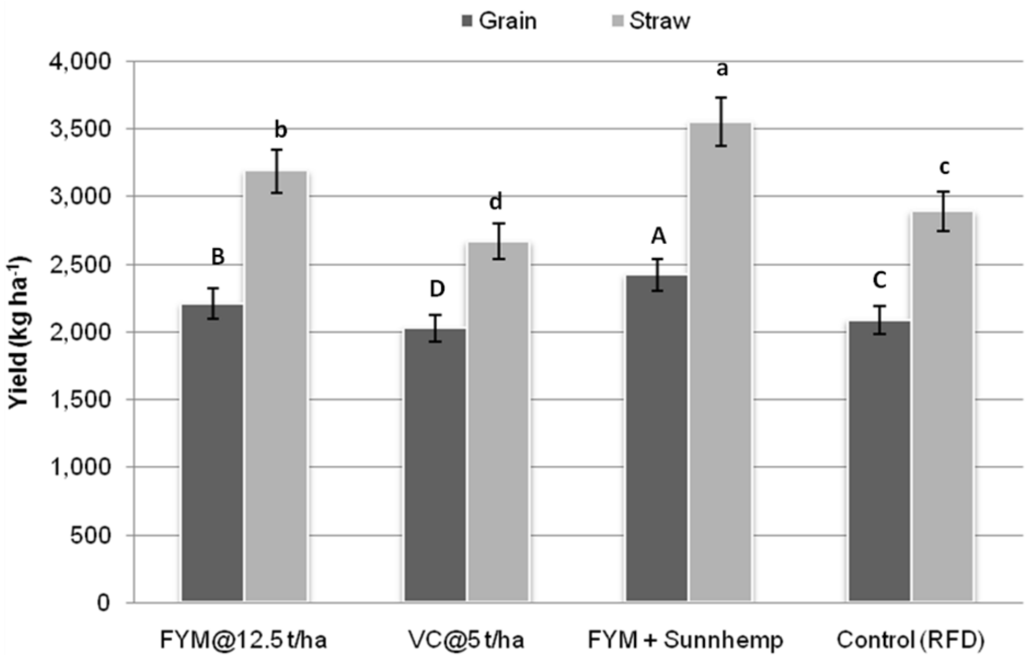

Figure 2. *Performance of finger millet for various sources of organics for basal nutrition*

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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. 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.43,534ha^{-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 (*Table 3*).

Table 3. *Influence of organic manures and organic foliar application on economics of rain-fed finger millet (pooled kharif 2015 to 2017)*

Treatments	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
Basal nutrition			
FYM @ 12.5 tha^{-1}	77336	45984	2.43
Vermicompost @ 5 tha^{-1}	70612	- 4490	0.91
FYM @ 6.5 tha^{-1} + SGM	84724	55372	2.84
RDF (60:30:30 kg NPK $kgha^{-1}$)	72997	44645	2.54
S.Ed	-	-	-
CD (P = 0.05%)	-	-	-
Organic foliar sprays			
Panchakavya @3.00%	84478	43534	2.36
Vermiwash @3.00%	78359	36289	2.07
Jeevamruth @3.00%	76535	35890	2.14
Coconut water @5.00%	69102	28833	1.92
Water spray (Control)	73612	32343	2.01
S.Ed	-	-	-
CD (P = 0.05%)	-	-	-

The economics were worked out based on the prevailing market prices during the period of study

Discussion

Growth parameters

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

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facilitated better rooting that helped in better absorption of water and nutrients resulting in taller plants. Similar findings were also reported by Praveenkumar (2019) and Sivagamy et al. (2020).

Among the organic foliar sprays, the application of Panchakavya at a 3% concentration during flowering (40-45 DAS) recorded higher plant height (91.30 cm), leaf area index (3.123 cm), and the number of earhead hill^{-1} (5.803). The increased growth attributes due to the application of vermiwash @ 3% concentration are in line with the findings of Lalitha *et al*. (2002), Kanimozhi (2003), Yadav and Lourduraj (2006). The overall improvement in the growth attributes may be attributed to the beneficial effects of vermiwash on plant growth, possibly due to the presence of several macronutrients and micronutrients in vermicast and their secretions in considerable quantities, as reported by Surya (2012).

Yield parameters

Farm yard 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 have a positive impact on crop yields and overall soil health (Tadesse et al., 2013). Some studies suggest that this positive effect may be due to the steady release of both NH_4-N and NH_3-N throughout the active growth phase of the crop period, potentially enhancing higher crop yields (Kumara et al., 2007).

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). The 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 materials, enhancing nutrient mineralization and availability, stimulating the production of plant growth hormones, and acting as biocontrol agents against plant pests, parasites, or diseases (Jacoby et al., 2017). The foliar spray of Panchakavya at a 3% concentration showed a higher number of earheads per hill (5.803), the number of fingers per earhead (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 promotes the development of an extensive root system. This allows the plants to extract nutrients more efficiently from the soil, resulting in improved yield components (Vimalendran and Wahab, 2013).

Yield

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 led to lower yields (1984 kg ha^{-1} grain and 2750 kg ha^{-1} straw) (*Fig. 3*). These treatments can be used to supply nutrients, enhance plant growth, mitigate nutrient deficiencies or improve overall crop performance.

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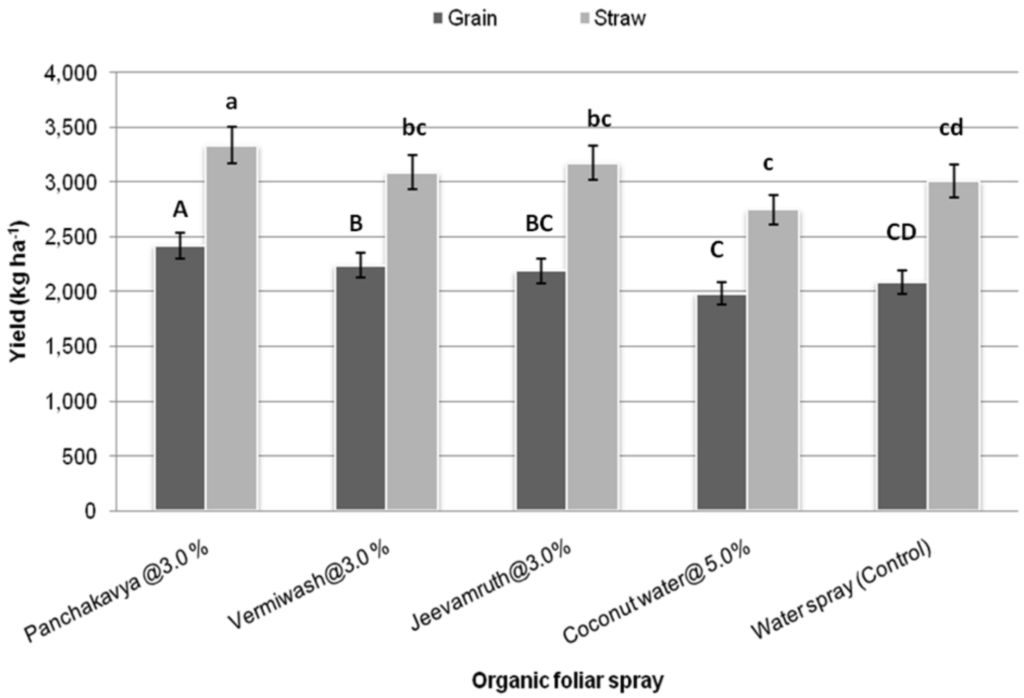

Figure 3. *Performance of finger millet for various sources of organic foliar spray*

Conclusion

The application of FYM @ 6.5 t ha^{-1} as basal and sunhemp green manuring (SGM) in-situ incorporation cum foliar spray of Panchakavya @ 3% concentration, on 45 DAS can maximize the productivity and profitability of finger millet cultivation. By adopting this technology, farmers can improve their farming practices and achieve better results through organic methods. This approach not only addresses the nutritional requirements of the crop but also promotes sustainable and organic farming practices that provide long-term benefits for both farmers and the environment.

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Conflict of interest. We declare no known conflict of interest that could have appeared to influence the work reported in this paper.

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