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Potential of Various Organic Nutrient Management Practices for Augmenting the Growth, Yield Attributes and Yield of Finger Millet [*Eleusine coracana* (L.) Gaertn]

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Authors' contributions

This work was carried out in collaboration among all authors. Author SSM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NS and YRR managed the analyses of the study. Author FHR managed the literature searches and edited the first draft. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during *kharif*, 2016 on sandy loam soils of dry land farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University. The experiment was laid out in randomized block design with three replications. There were eight treatments *viz*., control (T_1), 100% RDF (60:30:30 kg ha^{-1} $N:P_2O_5:K_2O$) (T_2), 100% N through farm yard manure (FYM) (T_3), 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum*+ PSB) (T_4), Seedling

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treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval upto 15 days before harvest (T_5), Seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray at every 10 days interval up to 15 days before harvest (T_6), T_3 + T_5 (T_7) and T_3+ T_6 (T_8). The test variety of finger millet was 'Vakula'. The growth and yield attributing parameters *i.e.*, plant height, leaf area index, number of tillers m^{-2} and dry matter production at harvest, number of productive tillers m^{-2} and ear weight, yield and economics of finger millet crop were found to be significantly influenced by various sources of nutrients. In conclusion, the investigation revealed that higher grain yield of finger millet as well as economic returns could be realized with 100% recommended dose of nutrients through fertilizers. Among the various organic sources of nutrients tried, 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7) was proved to be the most promising integrated organic nutrient management practice for higher yield, economics of finger millet along with maintenance of soil biological activity as well as fertility for the sustenance of soil ecology in the present domain of study.

Keywords: FYM; jeevamruta; beejamruta; panchagavya; biofertiliser; yield attributes; economics; organic nutrient.

1. INTRODUCTION

Organic farming is a holistic production management system which promotes and enhances agro-ecosystem health including biodiversity, biological cycles and soil biological activities [1]. The current global scenario is firmly emphasizing the need to adopt eco-friendly agricultural practices in view of the growing demand for safe, healthy and nutritious food. In India numerous cow products based fermented liquid organic manorial formulations *viz*., beejamruta, jeevamruta, panchagavya are being widely used by the organic farming practitioners. The nature and quantity of inputs used in their preparation decides the nutrient contents of liquid manure. They are proved to contain macro, micronutrients, essential amino acids, growth promoting factors like IAA, GA and rich in microbial diversity [2]. Liquid organic manures having a variety of beneficial microorganisms may activate biological reactions to restore soil fertility, further acting as plant growth stimulants which can enhance the yield and quality. Despite the gains of the green revolution for achieving self sufficiency in food grain production, intensive cropping practices coupled with extensive chemical inputs usage made an adverse impact on natural resource base leading to a decline in crop productivity as well as food quality. Further, the farmers are being directly affected with changing climate, escalating energy crisis and exorbitant cost of agro-chemicals. At this juncture, a keen awareness has been sprung among the farming community about the adoption of sustainable agricultural practices. Finger millet [*Eleusine coracana* (L.) Gaertn.] is the third most important millet in India, next to sorghum and pearl millet, grown over an area of 1.13 Million hectares with an annual production of 1.98 Million tonnes and a productivity of 1661 kg ha^{-1}. In Andhra Pradesh, it is cultivated in an area of 44,000 hectares with a production of 36,000 tonnes having productivity of 1045 kg ha^{-1} [3]. Finger millet has much significance in Chittoor district, being grown in an area of 9,000 hectares with a production of 12,000 tonnes and a productivity of 1348 kg ha^{-1}. Finger millet being rich in calcium, iron, protein with a balanced amino acid profile and lower glycemic index offers plausible health benefits and thus referred as a miracle grain. Recently it is re-emerging as a vital dietary food crop owing to increased public awareness about its nutritional value. Finger millet is a versatile climate resilient crop with wider adaptability to adverse weather conditions with low input requirement, which made it an outstanding subsistence food crop. The organic finger millet production was mainly concentrated on the use of FYM, compost, green manure, oil cakes, bio-fertilizers *etc*. The paucity of adequate qualitative cheaper organic manures availability is limiting the adoption of inclusive organic nutrient management. Hence, there is a need to explore the diversified locally available on-farm nutrient sources. Due to the dearth of scientific data on the validation of various liquid organic formulations, it has become a major thrust area of research. In order to sustain the crop productivity and for better on-farm resource utilization, combined use of organic manures along with liquid organic formulations deserves priority as a viable alternative. Further, millet based organic farming system may ensure

nutritional food and farming security in India at the present juncture of climate change. Hence, it is essential to develop a strong workable and compatible package of organic nutrient management for finger millet based on scientific facts, local conditions and economic viability.

2. MATERIALS AND METHODS

The field experiment was conducted during *kharif*, 2016 at the S.V. Agricultural College Dryland Farm, Tirupati campus of Acharya N.G. Ranga Agricultural University, on sandy clay loam soil with pH 7.1 having low organic carbon content (0.49%), low available nitrogen (154 kg ha^{-1}), low available P_2O_5 (10 kg ha^{-1}) and medium in available K_2O (166 kg ha^{-1}). The experiment was laid out in randomized block design with eight treatments replicated thrice. The treatments were T_1: Control, T_2: 100% RDF (60-30-30 kg N, P_2O_5 and K_2O ha^{-1}), T_3: 100% N through farm yard manure (FYM), T_4: 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB), T_5: Seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest, T_6: Seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to 15days before harvest, T_7: T_3+ T_5, T_8: T_3+ T_6. The test variety of finger millet used was 'Vakula'. The 21 days old seedlings of finger millet were transplanted @ one seedling per hill with a spacing of 22.5 cm x 10 cm. Seedling treatment was done by root dipping for 30 minutes in prepared beejamruta solution or biofertilizer slurry as per the treatment schedule. The entire dose of P_2O_5, K_2O and half of the N was applied as basal where as the remaining quantity of nitrogen was applied as top dressing at 30 days after transplanting. Application of panchagavya was done by diluting 3 litres of filtrate from the stock solution in 100 litres of water and sprayed with high pore size nozzle on finger millet crop at 10 days interval starting from the day of transplanting till 15 days before harvest. The prepared solution of jeevamruta was diluted in water (1:10) and applied to soil uniformly using a foot sprayer covering the total field area on the day of transplanting and at every 10 days interval until 15 days before harvest. Similarly jeevamruta was prepared for each application at 10 days interval. Two hand weeding and 3 mild irrigations were undertaken during the entire crop period. No separate plant protection measures were taken up, as the pest and disease incidence was not noticed on the crop. When the plants turned yellow and the grain to brown colour, the ear heads from border rows and net plots were harvested separately. The ear heads of each treatment were sun dried thoroughly and threshed manually. Then the grain was dried and cleaned. The straw from each net plot was harvested and sun dried.

Weather data during the crop growth period (04-06-2016 to 20-09-2016) were recorded from meteorological observatory, S.V. Agricultural College Farm, Tirupati. Weather during the crop growth period (04-06-2016 to 16-09-2016) did not deviate much from the decennial mean of the location of the study. Thus, the crop enjoyed favourable weather during different phenophases and expressed its optimal performance.

The beejamruta was prepared by mixing the microbial inoculants of *Azospirillium*, PSB, FYM and water at 1:1:5:10 ratio. Jeevamruta was prepared by mixing all the ingredients mentioned in Table 2 in 500 litres water in a plastic drum and kept for fermentation for 7 days under shade. The above solution was stirred thrice a day with a long stick. The preparation of Panchagavya was carried out by the following steps: initially the cow dung and cow ghee was added to a wide mouthed 125 litre drum and kept for 48 hours under shade by covering with a muslin cloth. The remaining ingredients were added after two days by mixing thoroughly and kept under shade. The concotion was stirred twice a day for about 20 minutes, both in the morning and evening to facilitate aerobic microbial activity. After 15 days, the contents were filtered through a clean cloth to get the clear stock solution of panchagavya. About 3 litres of Panchagavya filtrate from the stock solution was diluted in 100 litres of water.

The observations were taken using destructive and non-destructive sampling methods. Five plants in each net plot were selected and tagged in each treatment for recording periodical observations on growth parameters at 30 days interval and yield attributes at harvest. For recording leaf area and dry matter production, destructive sampling was done by taking 5 hills each time from the border rows, leaving the extreme row of the plot. The data recorded on various parameters of crop during the course of investigation was statistically analyzed following

the analysis of variance for randomized block design as suggested by [8]. Statistical significance was tested with 'F' value at 5% level of probability. Critical Difference (CD) for the significant sources of variation was calculated at 5% level of significance.

Table 1. Nutrient content of beejamruta, jeevamruta and panchagavya stock solutions

Property	Beejamruta	Jeevamruta	Panchagavya	Methodology
Total N (%)	0.42	0.27	1.2	Alkaline potassium permanganate method [4]
Total P (%)	0.15	0.03	0.4	Olsen's method [5]
Total K (%)	0.25	0.17	1.7	Flame photometry method [6]

Source: [7]

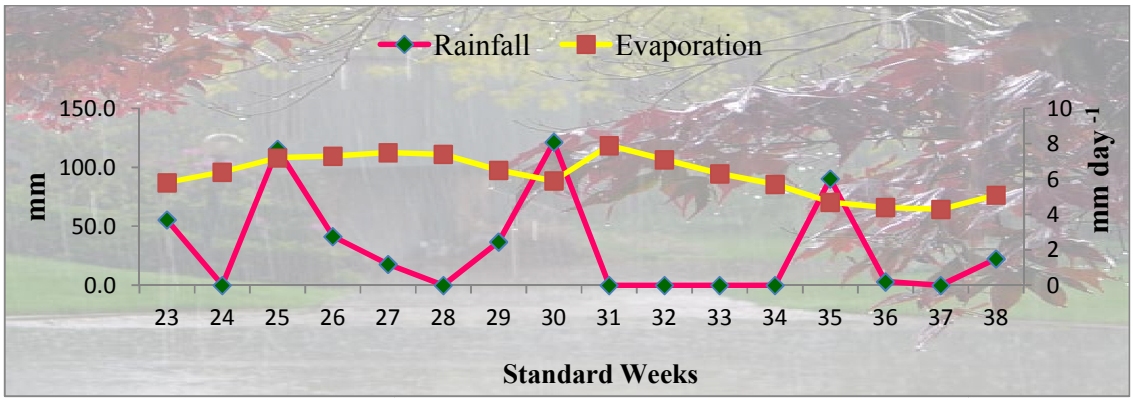

Fig. 1. Graphical representation of the rainfall (mm) and the % of Evaporation (mm day $^{-1}$) in the standard weeks through the entire crop growth period

Table 2. Ingredients and their quantities for Beejamruta, Jeevamruta and Panhagavya formulation preparation

Ingredients	Quantity		
	Beejamruta	Jeevamruta	Panchagavya
Fresh cow dung	10 kg	25 kg	5 kg
Fresh cow urine	10 lit	25 lit	3 lit
Lime	1 Kg	-	-
Jaggery	-	5 kg	-
Pulse flour (Bengal gram)	-	5 kg	-
Fertile soil	-	Two and half handful	-
Curd	-	-	2 lit
Jaggery	-	-	1 kg
Milk	-	-	2 lit
Ripened banana	-	-	12 nos.
Tender coconut water	-	-	3 lit
Ghee	-	-	500 g
Water	40 lit	500 lit	3 lit

3. RESULTS AND DISCUSSION

The growth yield attributing parameters *i.e.*, plant height, leaf area index, number of tillers m^{-2} and dry matter production at harvest, number of productive tillers m^{-2} and ear weight, yield and economics of finger millet crop were found to be significantly influenced by various sources of nutrients.

The highest plant height, leaf area index, number of tillers m^{-2} and dry matter production of finger millet was noticed with 100% recommended dose of nutrients through fertilizers (T_2), which was significantly superior to the organic sources tested (Table 3). Among the various organic sources of nutrients tried, application of 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7) recorded highest growth parameter values followed by 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB) (T_4) and 100% N through FYM + seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to 15 days before harvest (T_8), which were statistically at par with each other. This might be attributed to the quick release and availability of nutrients and especially nitrogen, which is an important constituent of protoplasm playing a positive role in cell division and elongation resulting in vigorous crop growth with effective interception of light and higher rate of photosynthesis. The higher leaf area in the organic treatments might be due to the synergistic effect of organic sources which might have facilitated in faster release of nutrients with a favorable effect on producing of more number of larger leaves. These findings are in support of [9,10]. Tillering has a significant effect on canopy development and resource capture. The increase in number of tillers m^{-2} might be due to ready availability of nutrients and their role in cytokinin synthesis. Dry matter accumulation is the prerequisite for higher yields, which is an indication of the biosynthetic processes associated with the crop growth and development. The soil application of jeevamruta might have accelerated the soil microbial activities, which might have helped in the continuous mineralization of applied FYM leading to better availability of nutrients, particularly nitrogen as well as growth promoting hormones *viz*., IAA and GA_3 in jeevamruta might have favoured rapid cell division and multiplication leading enhanced biological efficiency in terms of plant height and dry matter accumulation. Further, seedling treatment with beejamruta with cow dung as an integral component rich in several genera of bacteria and fungi might have enhanced the availability of soil native nutrients. The lowest values recorded with control might be due to non-availability of sufficient quantity of nutrients to produce even a moderate stature of finger millet crop. Similar results were perceived by [9,10,11,12,13,14].

Days to 50 per cent flowering and days to maturity of finger millet were not significantly influenced by various nutrient management practices. Application of organic and inorganic sources of nutrients failed to exert significant influence on in finger millet (Table 4).

The prominence of yield attributes on yield is a composite intricate development altered by harmonizing interaction of source with sink. Thus the favorable effect of adequate quantity of readily available nutrients with 100% recommended dose of nutrients through fertilizers (T_2) is evident with higher dry matter accumulation and effective translocation of photosynthates to the sink, which resulted in improved stature of yield attributes *i.e*. number of productive tillers m^{-2}, ear length, grain weight ear^{-1} (g) and test weight (g) (Table 5). Among the organic sources of nutrients tried, application of 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7) exerted a synergistic effect of FYM, jeevamruta and beejamruta on the yield attributes of finger millet. Jeevamruta, a cow dung based formulation is a rich source of naturally occurring beneficial microorganisms, which put forth a direct influence on production of plant growth promoting hormones *viz*., auxins, gibberlins and cytokinins in addition to the supply of biologically fixed nitrogen, solubilization of the insoluble phosphates and better release of potassium into available pool [15]. Hence the regular soil application of jeevamruta might have enhanced the conversion of organically bound nutrients in the soil as well as FYM to inorganic forms, thereby making them concurrently available synchronizing with peak period of crop requirement *i.e.* panicle initiation, flowering and grain filling stages. This is in accordance with the results reported by [9,10,11,12,13]. The deflated stature of yield attributes noticed with control might be ascribed to the fact that the inherent soil fertility status (154-10-166 kg N, P_2O_5 and K_2O

ha^{-1}) was insufficient to meet the crop requirement for supporting normal growth and development.

The highest grain yields (Table 5), straw yields and harvest index of finger millet was recorded with 100% recommended dose of nutrients through fertilizers (T_2), might be due to the cumulative effect of elevated growth stature as well as yield attributes under the condition of adequate nutrient supply, favouring the production of photosynthates coupled with better partitioning to the sink. Application of recommended dose of fertilizers recorded 27.5% higher grain yield over the next best treatment of 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7). Supplementation of FYM with beejamruta and jeevamruta (T_7) registered 45.1% higher yield over 100% N through FYM alone (T_3) where as 53.1% higher grain yield over only beejamruta and jeevamruta (T_5). Further it is noticed that application of either beejamruta and jeevamruta (1076 kg ha^{-1}) or FYM alone (1135 kg ha^{-1}) have resulted in comparative yield. Provision of required carbon substrate through FYM and microorganisms through fermented liquid organic sources might have maintained a steady rhizosphere with enzymatic and biological activity for the favorable biochemical reactions, thereby creating congenial environment for mineralization and continuous supply of essential macro and micro nutrients. Further, application of FYM along with jeevamruta might have enhanced the activity of dehydrogenase, phosphatase and urease in the soil as reported by [9,16,17,18]. Hence, the positive effect of combined application of FYM, beejamruta and jeevamruta was reflected with higher grain and straw yields. These results are in accordance with the findings of [9,10,11,12,13,14,19].

Gross returns, net returns and benefit: cost ratio of finger millet were significantly influenced by various organic sources of nutrients (Fig. 3). The highest gross returns of finger millet were obtained with 100% recommended dose of nutrients through fertilizers (T_2), which was significantly superior to all other treatments. The next higher gross returns were noticed with 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7). Application of 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB) (T_4) was noticed to be at par with 100% N through FYM + seedling treatment with beejamruta + foliar application of panchagavya @ 3% just after transplanting and at every 10 days interval up to 15 days before harvest (T_8), followed by application of 100% N through FYM (T_3) and seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_5) which maintained parity between them. The seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to

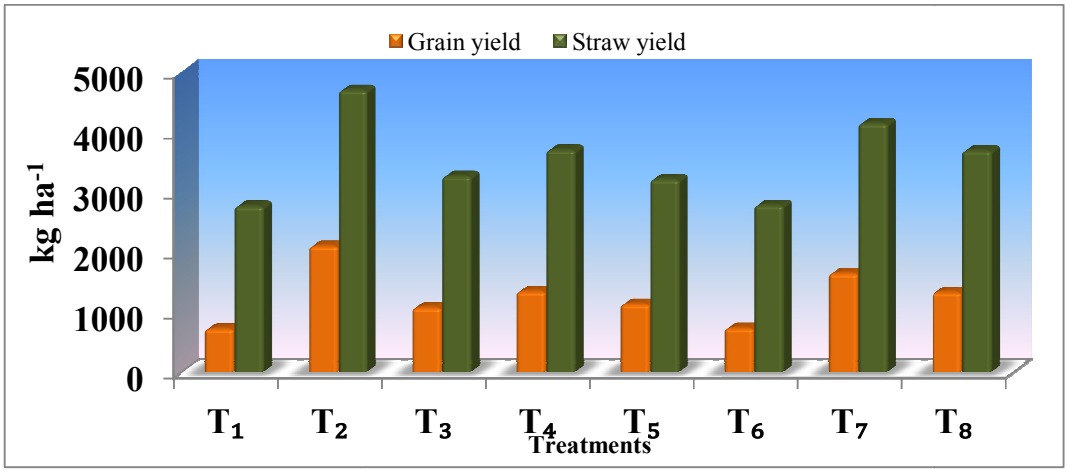

Fig. 2. Grain yield and straw yield (kg ha^{-1}) of finger millet as influenced by various organic sources of nutrients with CD value at 0.05 probability as 186 and 421 respectively

Table 3. Effect of various organic sources of nutrients on plant height, leaf area index, tillers m^{-2} and dry matter of finger millet crop at harvest

Treatments	Plant Height	Leaf area index	Number of tillers m^{-2}	Dry matter production
T_1 : Control	43.3	2.18	43.3	3751
T_2 : 100% RDF (60-30-30 kg N, P_2O_5 and K_2O ha^{-1})	71.0	5.20	71.0	6865
T_3 : 100% N through farm yard manure (FYM)	53.0	2.96	53.0	4863
T_4: 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB)	59.3	3.77	59.3	5769
T_5: Seedling treatment with beejamruta + soil application of jeevamrutha @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest	51.3	2.88	51.3	4707
T_6: Seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to 15 days before harvest	44.0	2.32	44.0	4004
T_7 : 100% N through FYM + T_5	64.7	4.49	64.7	6384
T_8 : 100% N through FYM + T_6	58.3	3.74	58.3	5692
SEm (±)	0.64	0.16		157.2
CD (P=0.05)	1.93	0.49		477

Table 4. Effect various organic sources of nutrients on Days to 50 per cent flowering and maturity of finger millet crop

Treatments	Days to 50 per cent flowering	Days to maturity
T_1 : Control	54.7	108.0
T_2 : 100% RDF (60-30-30 kg N, P_2O_5 and K_2O ha^{-1})	52.7	105.0
T_3 : 100% N through farm yard manure (FYM)	55.0	106.7
T_4: 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB)	53.0	105.3
T_5: Seedling treatment with beejamruta + soil application of jeevamrutha @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest	54.7	106.7
T_6: Seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to 15 days before harvest	55.0	108.0
T_7 : 100% N through FYM + T_5	53.0	105.3
T_8 : 100% N through FYM + T_6	53.3	105.3
SEm±	1.02	1.11
CD (P=0.05)	NS	NS

15 days before harvest (T_6) was noticed to be comparable with control (T_1),which in turn recorded the lowest gross returns. Similar trend in results was also observed for net returns and B: C Ratio. The highest gross and net returns as well as B:C Ratio realized with complete usage of inorganic fertilizers might be due to the yield compensation in comparison to organic sources. Application of panchagavya was noticed to be lesser remunerative due to the increased cost of its ingredients compared to jeevamruta. However, the economic returns with usage of panchagavya and jeevamruta were found to be lesser due to the higher cost of cultivation involved in their frequent preparation and application throughout the crop growth period. Favorable premium prices for the organic produce can offset reduced yields and make organic farms equally or more profitable than conventional farms. Similar results were perceived by [10,11], [20].

Table 5. Effect of various organic sources of nutrients on yield and yield attributing characters of finger millet crop

Treatments	Number of productive tillers m^{-2}	Ear length (cm)	Grain weight ear^{-1} (g)	Test weight (g)	Grain yield (kg ha^{-1})	Harvest Index (%)
T_1: Control	41.0	6.6	1.76	1.55	722	26.4
T_2: 100% RDF (60-30-30 kg N, P_2O_5 and K_2O ha^{-1})	67.3	10.8	3.15	2.62	2102	44.7
T_3 : 100% N through farm yard manure (FYM)	52.0	8.2	2.11	1.87	1135	33.3
T_4: 100% N through FYM + seedling treatment with biofertilizers (*Azospirillum* + PSB)	57.0	9.2	2.46	2.10	1347	36.4
T_5: Seedling treatment with beejamruta + soil application of jeevamrutha @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest	51.3	8.1	2.10	1.84	1076	35.3
T_6: Seedling treatment with beejamruta + foliar application of panchagavya @ 3% foliar spray just after transplanting and at every 10 days interval up to 15 days before harvest	42.3	6.7	1.78	1.59	734	26.7
T_7: 100% N through FYM + T_5	61.0	9.9	2.81	2.31	1648	39.8
T_8: 100% N through FYM + T_6	56.0	9.1	2.42	2.08	1333	36.0
SEm (±)	0.95	0.25	0.092	0.065	61.6	1.04
CD (P=0.05)	2.8	0.7	0.28	0.20	186	3.2

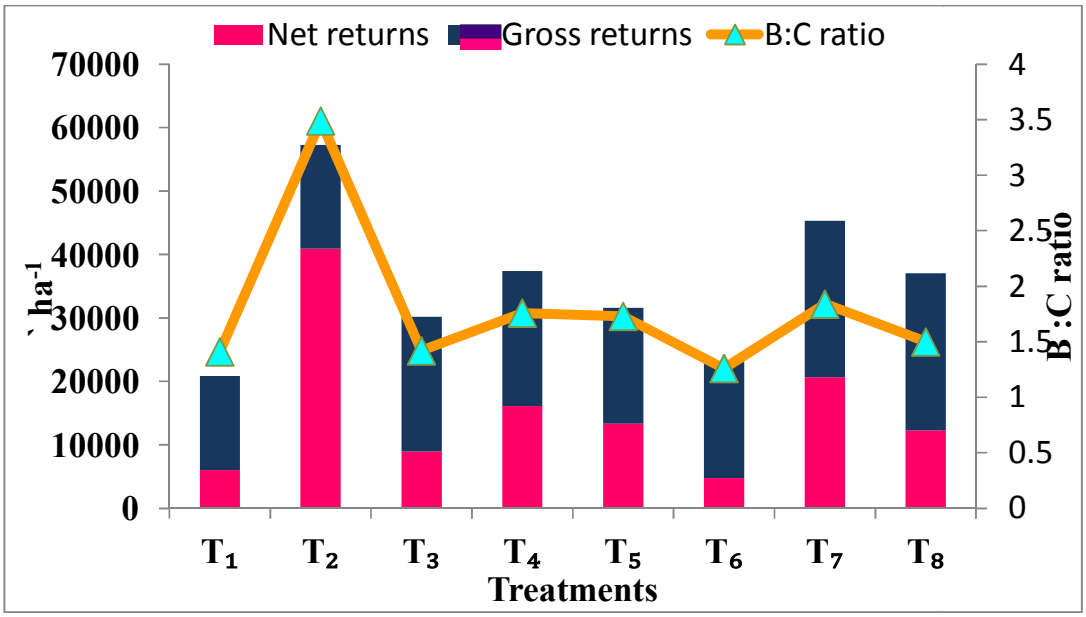

Fig. 3. Gross returns, net returns (` ha^{-1}) and B: C ratio of finger millet as influenced by various organic sources of nutrients with CD value at 0.05 probability as 4562 and 0.23 respectively

5. CONCLUSION

Thus it can be concluded that performance of finger millet in terms of productivity and economic returns were found at their best with the application of 100% recommended dose of nutrients through fertilizers *i.e.* 60-30-30 kg N, P_2O_5 and K_2O ha^{-1}. However among the various organic sources of nutrients tried, 100% N through FYM + seedling treatment with beejamruta + soil application of jeevamruta @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest (T_7) was found to be the most promising, feasible and economically viable organic nutrient management practice for higher yield, economics of finger millet along with maintenance of soil biological activity and fertility for the sustenance of soil ecology. Conjunctive use of 100% N through FYM, seedling treatment with beejamruta along with either soil application of jeevamruta or foliar application of panchagavya at regular intervals up to 15 days before harvest was confirmed to be the most effective and successful means with higher magnitude of response compared to their sole application. The idea of using mineral fertilizers and organic and biological fertilizers together is a good idea that deserves to be studied and supported because the farmer is afraid of organic farming because he believes that the yield will be small and the costs are high compared to mineral fertilizers. But this is a wrong concept, because this will happen in the short run only, while the long run will bring high yields and economic profit. Mixing organic fertilizers with mineral fertilizers can be done to reduce the chemical degradation and improvise the soil quality. On the other hand, the mixing is useful with maintenance of soil biological activity and fertility for the sustenance of soil ecology. Finally, it produces healthy food free of pollutants.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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