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Optimizing growth, yield, and profitability in finger millet (*Eleusine coracana* L.) through diverse nutrient sources

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Abstract
A field experiment was conducted at College of Sericulture, Chintamani during late *Kharif* 2023 to study the effect of different nutrient sources on growth, yield and economics of finger millet varieties. The experiment was laid out in Factorial RCBD consisting of 2 factors *viz.*, varieties and nutrient sources with 3 levels each, and 9 treatment combinations. Among the varieties, growth and yield was found superior in ML-322 over KMR-630 and was at par with KMR-316. Application of 100 percent RDF recorded significantly higher plant height (125.6 cm), number of tillers per plant (3.93), leaf to stem ratio (0.58), number of ear heads per plant (3.04), number of fingers per earhead (7.09), finger length (7.19 cm), weight of earhead (5.09 g) and grain yield (3557 kg ha^{-1}) and was at par with 50 percent RDN + 2 foliar sprays of 4% nano urea application @ 4.0 ml per liter. However, significantly higher total dry matter accumulation, leaf area and straw yield was observed in 50 percent RDN + 2 foliar sprays of 4% nano urea (41.9 g plant^{-1}, 947.1 cm^2 and 5367 kg ha^{-1}, respectively). Among the varieties and nutrient sources ML 322 + 50 percent RDN + 2 foliar sprays of 4% nano urea recorded higher net returns and benefits cost ratio (₹ 68, 353 ha^{-1} and 2.69, respectively) followed by ML 322+ 100 percent RDF (₹ 67, 911 ha^{-1} and 2.66, respectively).

Keywords: Finger millet, nano urea, jeevamrutha, foliar application

Introduction

Small millets are increasingly recognized as ‘nutri-cereals’ due to their rich nutrient profile and are valued as ‘climate-resilient crops’ because of their ability to withstand erratic weather conditions. In the face of changing climatic scenario and the pressing need to ensure food and nutritional security for a rapidly growing population, especially in rainfed and resource limited regions, small millets play a critical role in addressing these challenges. Finger millet is one of the key small millet crops, primarily cultivated in India and several African countries. It is known by various names across regions such as Ragi and Nachni in India, Kurrakan or Koracan millet, African millet, Rapoko in South Africa, and Dagusa in Ethiopia, highlighting its broad geographic spread and cultural significance. In India alone, finger millet is grown in an area of 6.93 million hectares, producing around 8.61 million tonnes, with an average productivity of 1243 kg per hectare.

Among the millet growing states, Karnataka leads in both cultivated area (0.84 million hectares) and production (1.12 million tonnes), with an average productivity of 1332 kg per hectare (Anon, 2022) [2]. The crop performs well even with minimal inputs, especially when managed with good agronomic practices. In rainfed and resource-constraint areas, finger millet serves as a staple food grain for rural communities. Additionally, its stover provides a valuable source of dry fodder for livestock, the roughage can be converted into milk by animals and other productive outputs, making finger millet a versatile crop that supports both food and livelihood security.

India is the world’s top milk producer, yielding around 90 million tonnes annually and housing the largest cattle population at approximately 308 million. However, milk productivity remains low due to imbalanced nutrition and limited access to quality fodder. With rising population and shrinking cultivable land, improving productivity is essential to meet future demand.

Enhancing the production and nutritional quality of fodder, particularly finger millet straw, offers a promising solution. Finger millet straw contains 89-92% dry matter content, 6.5 to 8.0% crude protein, 11 to14% ash, 62 to 68% neutral detergent fiber, 38% acid detergent fiber and around 4.8% of acid detergent lignin (Backiyalakshmi *et al.* 2021) [3]. Its high in-vitro digestibility and nutrient profile make it a valuable fodder resource, highlighting its potential for improving livestock nutrition.

Finger millet is generally a low-input crop but, improved varieties respond well to added nutrients. The choice of finger millet variety is highly dependent on the local climate. Short-duration varieties, maturing in 90-100 days, are best suited for northern highlands, while medium to late-duration varieties (115-135 days) thrive well in southern plains. In Karnataka, it is mostly grown under rainfed conditions on marginal soils with minimal management. To boost the yields, supplying the right nutrients, especially nitrogen is crucial (Chavan *et al.*, 2018; Ramya *et al.*, 2020) [5, 12]. Nitrogen significantly enhances crop growth, but its soil application causes losses through volatilization, leaching, and denitrification, reducing its effectiveness. These losses can lead to visible deficiency symptoms that hinder crop development thus foliar application of nitrogen offers a more efficient and targeted solution to improve productivity (Liu and Lal, 2015) [10].

The introduction of nano urea by IFFCO has opened new possibilities for using nanotechnology in agriculture. Tiny particle size and large surface area, makes nano urea more readily absorbed by plants, making it ideal for foliar nitrogen application. At the same time, there is growing interest in organic nutrient sources like liquid formulations especially *jeevamrutha* and *panchagavya*. *Jeevamrutha*, is a liquid organic manure made from cow dung, cow urine, legume flour, and jaggery, rich in beneficial microbes, nutrients, vitamins, amino acids, and natural growth promoters like IAA and GA. Combining nano urea with organic inputs like *jeevamrutha* presents a sustainable way to boost crop productivity and farm income. With this potential in mind, the present study on “Effect of nutrient sources on growth, yield and economics of finger millet varieties” was undertaken.

Materials and Methods

The field experiment was conducted during late *Kharif* 2023 at College of Sericulture, Chintamani, which is geographically located at 13^0 34’N latitude and 78^0 08’ E longitude and at an altitude of 865 m above mean sea level located in Eastern Dry Zone (EDZ) of Karnataka. The soil of the experimental site is red sandy loam. To analyze the nutrient status of the soil, composite soil samples were drawn from upper 15 cm soil layer and were analyzed for chemical properties. The soil reaction was moderately acidic (5.23), normal in electrical conductivity (0.148 dS m^{-1}) and medium in organic carbon (0.55%). Initial soil nutrient status indicates low available nitrogen (236 kg ha^{-1}), medium available phosphorus (34 kg ha^{-1}) and available potassium (238 kg ha^{-1}) levels. The experiment was laid out in Factorial Randomized Complete Block Design (FRCBD) involving 2 factors *viz.*, varieties and nutrient sources, with 3 levels each and 9 treatment combinations. The varieties used in the study were ML 322, KMR 316 and KMR 630 recently released from the University of Agricultural Sciences, Bangalore besides nutrient sources *viz.*, 100 percent RDF, 50 percent RDN + 2 foliar sprays of 4% nano urea and 50 percent RDN + 2 foliar sprays of 5% jeevamrutha. The treatment combinations were, T_1: ML 322+ 100% RDF, T_2: ML 322 + N_{50}PK as basal application + 2 foliar sprays of 4% nano urea, T_3: ML 322 + N_{50}PK as basal application + 4 foliar sprays of 5% jeevamrutha, T_4: KMR 316 + 100% RDF, T_5: KMR 316 + N_{50}PK as basal application + 2 foliar sprays of 4% nano urea, T_6: KMR 316 + N_{50}PK as basal application + 4 foliar sprays of 5% jeevamrutha, T_7: KMR 630 + 100% RDF, T_8: KMR 630 + N_{50}PK as basal application+ 2 foliar sprays of 4% nano urea, T_9: KMR 630 + N_{50}PK as basal application + 4 foliar sprays of 5% jeevamrutha. Farm yard manure was applied uniformly across all plots @ 7.5 t ha^{-1} to enrich the soil two weeks prior to sowing. The fertilizers were applied as per the UAS recommendations for rainfed finger millet *viz*., 50 kg N, 37.5 kg P_2O_5 and 40 kg K_2O ha^{-1}. Full doses of phosphorus and potassium were applied at the time of sowing. They were supplied through single super phosphate and muriate of potash, respectively, along with 50% of the recommended nitrogen (*via* urea). The remaining 50% of nitrogen was applied as a top dressing based on the specific treatments. Two sprays of 4% Nanourea @ 4ml l^{-1} and 5% jeevamrutha @ 50 ml l^{-1} were given at 30 and 60 DAS.

Biometric observations on growth parameters were recorded at 30, 60, 90 DAS and at harvest from five randomly selected and tagged plants in the net plot. Days to 50 percent flowering, days to maturity and yield parameters like number of fingers $earhead^{-1}$, 1000 seed weight (g), seed yield (kg ha^{-1}), straw yield (t ha^{-1}) and harvest index were recorded at the time of harvest. Leaf to stem ratio was calculated on dry weight basis using the formula

$$\text{Leaf : stem ratio} = \frac{\text{dry weight of leaves}}{\text{dry weight of stem}}$$

The data recorded on various parameters were subjected to Fisher’s method of analysis of variance and interpretation of the data was made as given by Gomez and Gomez (1984) [6]. The level of significance used in ‘F’ and ‘t’ tests was 0.05 percent probability.

Results and Discussion

Growth parameters

The effect of different nutrient sources on growth attributes of finger millet varieties is presented in Table 1. The experimental results revealed that among the varieties ML 322 recorded significantly higher plant height (126.7 cm), total dry matter accumulation (41.8 g $plant^{-1}$), leaf area (930.3 cm^2) and leaf to stem ratio (0.56) which was on par with the variety KMR 316 (125.7 cm, 40.0 g $plant^{-1}$, 895.5 cm^2 and 0.55, respectively). Among the nutrient sources, significantly higher plant height (125.6 cm), number of tillers (3.93), number of leaves (45.1) and leaf to stem ratio (0.58) were recorded in the treatment 100 percent RDF. However, it was statistically at par with 50 percent RDN + 2 foliar sprays of 4% nano urea (122.8 cm, 3.73, 43.7 and 0.55, respectively). The, higher total dry matter accumulation and leaf area was observed in 50 percent RDN + 2 foliar sprays of 4% nano urea (41.9 g $plant^{-1}$ and 947.1 cm^2, respectively). More number of days for 50 percent flowering and maturity were recorded in the variety ML 322 (72.78 days and 110.89 days, respectively) over other varieties. Among nutrient sources, the treatment with 50 percent RDN + 2 foliar sprays of 4% nano urea recorded higher number of days for 50 percent flowering and maturity (70.78 and 109.00 days, respectively). There was no significant difference noticed among the interaction between different finger millet varieties and nutrient sources on growth parameters of finger millet.

Finger millet varieties showed diverse responses to application of nitrogen fertilizers, indicating that genetic factors influence how the crop reacts to nutrient application (Gupta *et al.*, 2012) [7]. The higher growth attributes of ML 322 variety among the tested varieties might be attributed to genetic makeup of the genotype, its ability to absorb more nutrients and superior adaptability to the local environmental conditions which might have resulted in vigorous growth of the crop. Similar observations were reported by Triveni *et al.* (2018) [20], Thapliyal *et al.* (2022) [3], Shubhashree *et al.* (2022) [18] and Shreenivasa *et al.* (2023) [17].

Nitrogen is vital for plant growth as it plays a key part of proteins and chlorophyll, supporting cell division, photosynthesis, and overall metabolism. Application of nitrogen boosts leaf area, chlorophyll content, and biomass (Zhao *et al.*, 2005) [23], it also encourages stronger root systems that improves nutrient uptake. Application of 100 percent RDF in comparison with other treatments receiving only 50 percent nitrogen through conventional urea as basal application has resulted in improved growth which might be due to steady and continuous supply of nitrogen to plants. Significantly similar results were recorded in the treatment receiving 50 percent RDN + 2 sprays of 4% nano urea despite the reduction in nitrogen by 50 percent through conventional urea. This might be due to increased nutrient use efficiency in foliar application, reduced nitrogen losses through processes like nitrate leaching, denitrification and ammonia volatilization, ensuring direct availability of nitrogen to plants. The combined effect of foliar spray of nano urea along with soil application of conventional urea enhances the height of the plant since it boosts the metabolic and meristematic activities which further increases apical growth and photosynthetic area (Samanta *et al.*, 2022) [15]. An increased supply of nitrogen to plants promotes better root growth, which enhances the plant's ability to absorb essential nutrients from the soil. This improved nutrient uptake supports various physiological processes such as photosynthesis, cell division, and cell elongation. These benefits are well-supported by studies from Triveni *et al.* (2017) [19], Beeresha (2018) [4], Uma *et al.* (2019) [21], and Radha *et al.* (2019) [11].

Yield parameters and Yield

The yield and yield related traits of finger millet varieties as influenced by different nutrient sources are presented in Table 3 and Fig.1. Among the varieties, ML 322 performed the best recorded significantly higher values for yield parameters such as number of earheads per plant (3.02), fingers per earhead (6.93) and finger length (7.37 cm). The variety KMR 316 also showed comparable performance with respect to the above parameters (2.91, 6.85, 7.16 cm, 4.82 g, and 3.31 g, respectively). Among the nutrient treatments, 100% Recommended Dose of Fertilizer (RDF) recorded the highest yield attributes, including earheads per plant (3.04), fingers per earhead (7.09) and finger length (7.19 cm). Statistically, similar results were obtained with application of 50% RDN + two foliar sprays of 4% nano urea (2.91, 6.90, 7.03 cm, 4.90 g, and 3.26 g, respectively). The interaction between varieties and nutrient sources was not statistically significant, meaning their effects were independent of each other. Highest grain (3600 kg ha^{-1}) and straw yield (5438 kg ha^{-1}) was obtained with ML 322 closely followed by KMR 316 (3553 kg ha^{-1} grain and 5411 kg ha^{-1}straw, respectively). Among nutrient application treatments, 100% RDF gave the highest grain yield (3557 kg ha^{-1}), while 50% RDN + nano urea sprays led to the highest straw yield (5367 kg ha^{-1}). These results highlight that combining improved varieties like ML 322 with efficient nutrient strategies, such as partial nitrogen replacement with nano urea, can enhance both productivity and sustainability in finger millet cultivation.

The grain yield is largely influenced by important yield attributes, and the superior performance of the variety ML 322 can be attributed to its characters such as a high-yielding, fertilizer-responsive genotype. Its enhanced responsiveness might be due to better growth and more efficient translocation of photosynthates from source to sink, resulting in higher grain production. These findings are consistent with earlier studies by Radha *et al.* (2019) [11], Sandhya *et al.* (2017) [16], Shubhashree *et al.* (2022) [18], and Salma *et al.* (2024).

The significantly higher grain yield observed with 100% RDF can be associated to strong early growth, indicated by greater plant height and more tillers, which likely supported better root development and nutrient uptake throughout the season. This early vigour helped in efficient translocation of photosynthates to the grains. These findings are in confirmation with the findings of Radha *et al.* (2019) [11] and Salma *et al.* (2024). Similarly, the treatment with 50% RDN + two foliar sprays of 4% nano urea showed comparable results. This may be due to the controlled and sustained release of nitrogen from nano urea, which supports plant metabolism over time and improves nutrient use efficiency. Nano fertilizers also stimulate growth hormones like tryptophan and auxins which promotes root and shoot development with enhanced carbohydrate storage, directly increasing grain yield (Afshar *et al.*, 2014; Kumar *et al.*, 2020) [1, 9]. However, prolonged vegetative growth from improved nitrogen uptake might sometimes lead to a slight yield penalty (Upadhyay *et al.*, 2023) [22]. Further, the increase in straw yield with foliar application of nano urea can be attributed to its rapid absorption and efficient translocation within the plant. This enhanced nutrient availability might have boosted photosynthesis, expanded leaf area, and promoted greater dry matter accumulation, all contributing to higher straw yield. These physiological improvements highlight the positive impact of nano urea on overall crop productivity. These results are in concurrence with the findings of Khalil *et al.* (2019) [8] and Sahu *et al.* (2022) [13].

Economics

The data on economics of finger millet varieties as affected by different nutrient management practices is given in Fig.2. The highest gross return was recorded with ML 322+ 100 percent RDF (₹ 1, 08, 869 ha^{-1}) followed by ML 322 + 50 percent RDN + 2 foliar sprays of 4% nano urea (₹ 1, 08, 803 ha^{-1}). However, ML 322 + 50 percent RDN + 2 foliar sprays of 4% nano urea recorded higher net returns and benefits cost ratio (₹ 68, 353 ha^{-1} and 2.69, respectively) followed ML 322+ 100 percent RDF (₹ 67, 911 ha^{-1} and 2.66, respectively). The higher gross returns with ML 322+ 100 percent RDF was due to the fact that crop has not experienced nutrient stress at any growth stages and application of fertilizers improved vegetative growth and increased the yield attributes and yield. However, higher net returns and B: C ratio obtained in the treatment combination of ML 322 + 50 percent RDN + 2 foliar sprays of 4% nano urea might be due to compensation of grain yield by higher straw yield and reduced cost of cultivation as a result of replacement of 50 percent of conventional urea with nano urea. These results were in conformity with the findings of Triveni *et al.*, 2018 [20] and Radha *et al.*, 2019 [11].

Table 1: Effect of different nutrient sources on growth attributes of finger millet varieties during late *Kharif*

Parameters	Plant Height (cm)	No. of Tillers/Plant	No. of Leaves/Plant	Leaf Area (cm²/Plant)	Total Dry Matter (g/Plant)
Varieties					
V_1	126.7	3.84	44.3	930.3	41.8
V_2	125.7	3.76	42.1	895.4	40.0
V_3	111.4	3.38	38.6	801.6	34.8
S.Em.±	1.74	0.07	0.94	19.3	0.58
C.D. (p = 0.05)	5.21	0.21	2.81	57.8	1.74
Nutrient sources					
N_1	125.6	3.93	45.1	917.3	39.7
N_2	122.8	3.73	43.7	947.1	41.9
N_3	115.3	3.30	36.3	773.0	35.1
S.Em.±	1.74	0.07	0.94	19.3	0.58
C.D. (p = 0.05)	5.21	0.21	2.81	57.8	1.74
Interaction (VXN)					
V_1N_1	133.7	4.20	47.9	988.1	42.9
V_1N_2	128.5	3.87	47.1	1005.0	45.8
V_1N_3	119.2	3.44	38.0	798.0	36.8
V_2N_1	129.8	4.02	45.5	914.1	41.6
V_2N_2	128.1	3.84	43.5	955.9	42.9
V_2N_3	119.3	3.40	37.3	816.4	35.6
V_3N_1	113.4	3.58	41.9	849.9	34.5
V_3N_2	113.3	3.49	40.5	880.3	36.9
V_3N_3	107.4	3.07	33.6	704.7	32.9
S.Em.±	3.01	0.12	1.62	33.4	1.01
C.D. (p = 0.05)	NS	NS	NS	NS	NS

Note: V1-ML-322 V2-KMR-316 V3-KMR630 N1¬-RDF (100%), N2-N50PK (50% RDN as basal application +2 sprays of 4% nano urea), N3-N50PK (50% RDN as basal application +4 sprays of 5% jeevamrutha), RDF-Recommended dose of fertilizer, NS-non significant

Table 2: Effect of different nutrient sources on leaf to stem ratio, days taken for 50 percent flowering and days taken for maturity of finger millet varieties during late *Kharif*

Parameters	Leaf to stem ratio	Days taken to 50% flowering	Days taken to maturity
Varieties			
V_1	0.56	72.8	110.9
V_2	0.55	71.2	106.7
V_3	0.51	62.6	101.0
S.Em.±	0.01	0.38	0.54
C.D. (p = 0.05)	0.03	1.13	1.61
Nutrient sources			
N_1	0.58	66.8	102.6
N_2	0.55	70.8	109.0
N_3	0.49	69.0	107.0
S.Em.±	0.01	0.38	0.54
C.D. (p = 0.05)	0.03	1.13	1.61
Interaction (VXN)			
V_1N_1	0.60	69.7	106.3
V_1N_2	0.57	75.7	113.7
V_1N_3	0.52	73.0	112.7
V_2N_1	0.59	69.3	103.7
V_2N_2	0.56	73.3	109.3
V_2N_3	0.51	71.0	107.0
V_3N_1	0.55	61.3	97.7
V_3N_2	0.54	63.3	104.0
V_3N_3	0.42	63.0	101.3
S.Em.±	0.2	0.65	0.93
C.D. (p = 0.05)	NS	NS	NS

Note: V1-ML-322 V2-KMR-316 V3-KMR630 N1¬-RDF (100%), N2-N50PK (50% RDN as basal application +2 sprays of 4% nano urea), N3-N50PK (50% RDN as basal application +4 sprays of 5% jeevamrutha), RDF-Recommended dose of fertilizer, NS-non significant

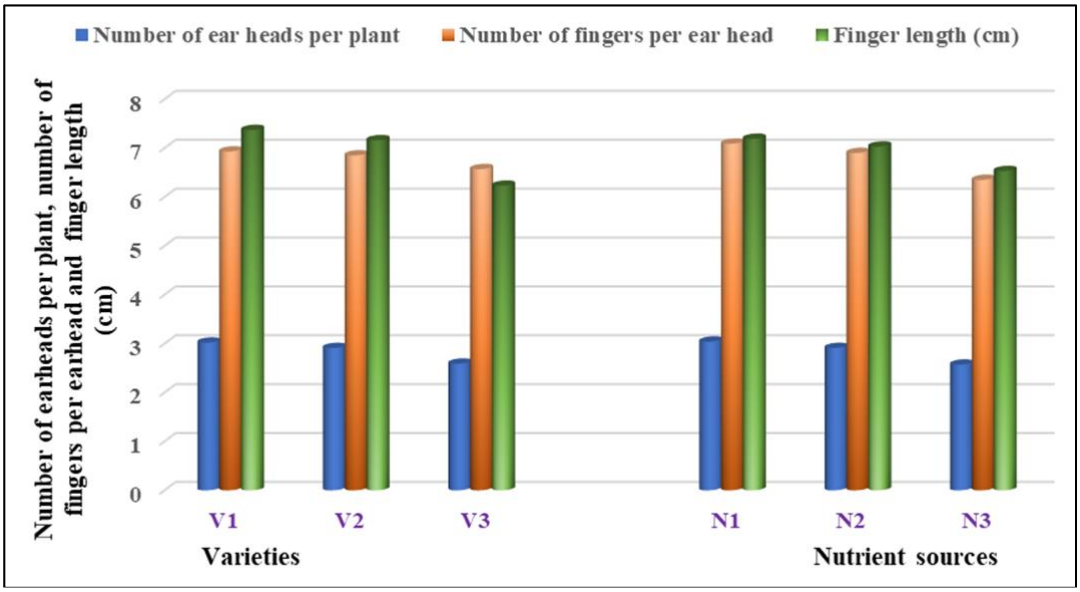

Fig 1: Yield parameters of finger millet as influenced by varieties and nutrient sources during late *Kharif*

Legend

V1-ML-322	N1¬-RDF (100%)
V2-KMR-316	N2-N50PK (50% RDN as basal application +2 sprays of 4% nano urea)
V3-KMR630	N3-N50PK (50% RDN as basal application +4 sprays of 5% jeevamrutha)
	RDF-Recommended dose of fertilizer, NS-non significant

Table 3: Effect of different nutrient sources on grain yield, straw yield of finger millet varieties during late *Kharif*

Parameters	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index (%)
Varieties			
V_1	3600	5438	39.69
V_2	3553	5411	39.56
V_3	2936	4647	38.67
S.Em.±	96.6	62.5	0.11
C.D. (p = 0.05)	289.5	187.4	NS
Nutrient sources			
N_1	3557	5146	40.78
N_2	3539	5367	39.70
N_3	2993	4982	37.45
S.Em.±	96.6	62.5	0.11
C.D. (p = 0.05)	289.5	187.4	0.33
Interaction (VXN)			
V_1N_1	3830	5467	41.09
V_1N_2	3819	5695	40.15
V_1N_3	3151	5152	37.85
V_2N_1	3757	5341	41.27
V_2N_2	3735	5599	40.02
V_2N_3	3167	5294	37.39
V_3N_1	3085	4631	39.97
V_3N_2	3062	4807	38.92
V_3N_3	2659	4502	37.13
S.Em.±	167.2	108.3	0.19
C.D. (p = 0.05)	NS	NS	NS

Note: V1-ML-322 V2-KMR-316 V3-KMR630 N1¬-RDF (100%), N2-N50PK (50% RDN as basal application +2 sprays of 4% nano urea), N3-N50PK (50% RDN as basal application +4 sprays of 5% jeevamrutha), RDF-Recommended dose of fertilizer, NS-non significant

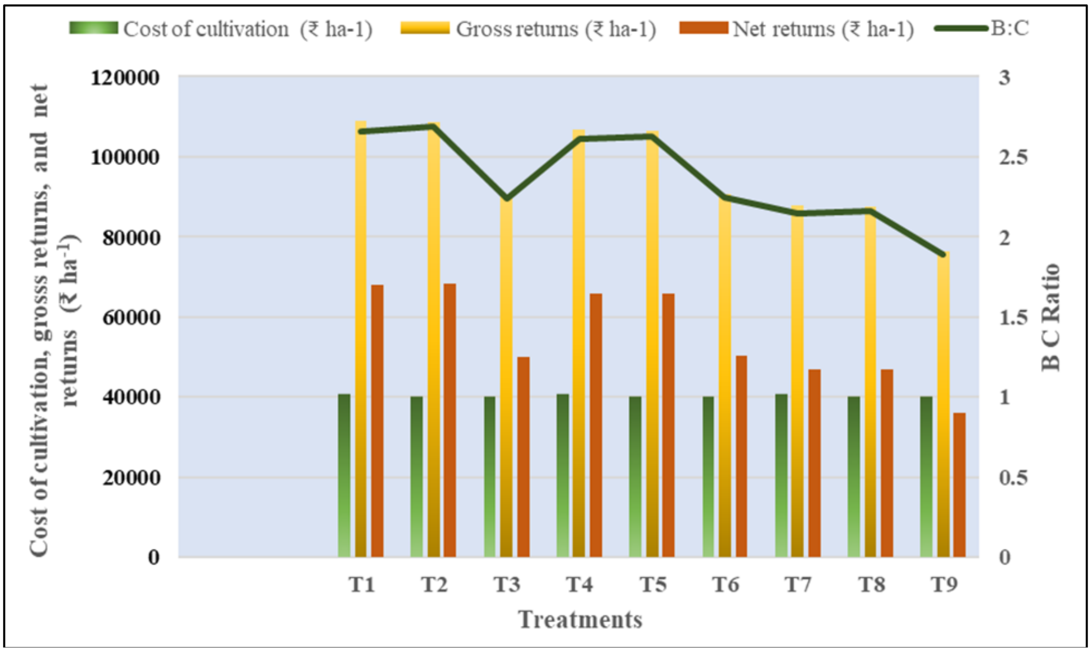

Fig 2: Economics of finger millet as influenced by different varieties and nutrient sources

Legend:

T_1: ML 322+ 100% RDF
T_2: ML 322 + N_{50}PK as basal application+ 2 foliar sprays of 4% nano urea
T_3: ML 322 + N_{50}PK as basal application + 2 foliar sprays of 5% jeevamrutha
T_4: KMR 316 + 100% RDF
T_5: KMR 316 + N_{50}PK as basal application+ 2 foliar sprays of 4% nano urea
T_6: KMR 316 + N_{50}PK as basal application + 2 foliar sprays of 5% jeevamrutha
T_7: KMR 630 + 100% RDF
T_8: KMR 630 + N_{50}PK as basal application+ 2 foliar sprays of 4% nano urea
T_9: KMR 630 + N_{50}PK as basal application + 2 foliar sprays of 5% jeevamrutha

Conclusion

The results indicated among the varieties evaluated, ML 322 demonstrated significantly higher growth parameters, yield parameters and yield, over KMR-630 and on par with KMR-316. Whereas among nutrient sources, application of 100 percent RDF recorded significantly higher growth and yield parameters however, it is equivalent with application of 50 percent RDN + 2 foliar sprays of 4% nano urea. Cultivation of ML 322 with 50 percent RDN along with 2 foliar sprays of 4% nano urea recorded higher net returns and benefit cost ratio indicating the benefit of nano urea.

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