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Shubha Shree KS

Assistant Professor (Agronomy),
Department of Agronomy, College
of Sericulture, Karnataka, India

Thimmegowda P

ZARS, V.C. Farm, Mandya, UAS,
GKVK, Bengaluru, Karnataka,
India

Raveendra HR

ZARS, V.C. Farm, Mandya, UAS,
GKVK, Bengaluru, Karnataka,
India

Suma D

Associate Professor (SS & AC),
Department of SS & AC, College of
Agriculture, Mandya, Karnataka,
India

Sushmitha G Bilur

Post graduate Student,
Department of Agronomy, College
of Sericulture, Karnataka, India

Corresponding Author:

Shubha Shree KS

Assistant Professor (Agronomy),
Department of Agronomy, College
of Sericulture, Karnataka, India

Enhancement of finger millet productivity through STCR approach under climate change scenario

Shubha Shree KS, Thimmegowda P, Raveendra HR, Suma D and
Sushmitha G Bilur

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Abstract

The field experiment was conducted at Zonal Agricultural Research Station V.C. Farm, Mandya to evaluate the effect of the STCR approach of nutrient management on the yield and nutrient uptake of finger millet during 2018 and 2019. The experiment consisted of 9 treatments laid out in RCBD and replicated thrice. Fertiliser application based on STCR equation for targeted yield of 50 and 55 q ha⁻¹ finger millet yield were compared with RDF and soil test based fertiliser application along with integration of bio-fertilisers. Application of STCR based NPK to achieve a targeted yield of 55 q ha⁻¹ along with application of *Azospirillum* and PSB recorded significantly higher plant height (98.3 cm and 98.9 cm), number of tillers plant⁻¹ (3.6 and 3.9), number of fingers ear⁻¹ (8.25 and 8.32), finger length (8.96 and 9.52 cm), grain yield (5763 and 5896 kg ha⁻¹) and straw yield (7893 and 8212 kg ha⁻¹) during 2018 and 2019, respectively, followed by application of STCR based NPK to achieve a targeted yield of 50 q ha⁻¹ along with application of *Azospirillum* and PSB. Economic analysis showed that, higher gross returns (172890 Rs. ha⁻¹, 176880 Rs. ha⁻¹), net returns (126345 Rs ha⁻¹, 130335 Rs. ha⁻¹) and BC ratio (3.71, 3.80) were obtained during the year 2018 and 2019, respectively, with application of NPK based on STCR approach to achieve a target yield of 55 q ha⁻¹ along with application of *Azospirillum* and PSB.

Keywords: Finger millet, STCR, Target yield

Introduction

Finger millet (*Eleusine coracana* L.) is an important food crop of India particularly cultivated in arid and semi-arid regions of Asia and Africa. It has gained importance due to its nutritional superiority and climate resilience nature in the era of changing climate. It is a rich source of minerals like calcium and iron along with essential amino acids, makes it a valuable crop to address malnutrition problem. Therefore, crop plays a significant role in food security and livelihood sustainability especially for small farmers. In spite of its importance, the productivity levels of finger millet in the country are below its potential, largely due to poor nutrient management practices, cultivation on low fertile soils and poor weed management practices. However, increasing population pressure has made it mandatory to enhance the productivity of crop so as to meet the growing demand for finger millet. Efficient nutrient management is crucial for maximizing crop yields and maintenance of soil health while enhancing nutrient use efficiency. But the traditional, fertilizer application methods based on the blanket recommendations doesn't take into account the soil fertility and thus results in imbalanced nutrient application and reduced yields and even some times end up in environmental issues. Hence, soil test-based fertilizer application is one such alternative to improve the productivity. Soil test-based fertilizer recommendations, based application is an approach in nutrient management which considers the initial soil nutrient status based on which the fertilizer application is done. The Soil Test Crop Response is yet another more advanced approach in nutrient management which integrates soil test values, the crop response data to articulate fertilizer recommendations tailored to achieve targeted yield. This approach aims to afford precise nutrient doses while maximizing economic returns. Bio-fertilizers *Azospirillum* which is known for its nitrogen-fixing capabilities, and Phosphorus Solubilizing Bacteria (PSB) which plays a crucial role in solubilizing insoluble soil phosphorus, making it accessible to plants are

helpful in enhancing the nutrient availability and uptake. The combined effect of using chemical fertilizers and bio-fertilizers can lead to improvement of soil fertility, reducing reliance on synthetic fertilizers and enhancing crop productivity. In spite of the proven benefits of integration of the STCR approach and bio-fertilizers, comprehensive studies assessing their combined effect on finger millet are limited. Therefore, this study was formulated with the objective of investigating the effect of the STCR approach of nutrient management, both alone and in combination with *Azospirillum* and PSB, on the yield, nutrient uptake and economics of finger millet. The findings of this research are expected to provide valuable insights for developing sustainable and efficient nutrient management strategies for finger millet cultivation.

Materials and Methods

Field experiments were conducted at the Zonal Agricultural Research Station V.C. Farm, Mandya with the objective to evaluate the effect of the STCR approach of nutrient management on the yield and nutrient uptake of finger millet. Composite soil samples were drawn from a depth of 0-15 cm and subjected to soil analysis to determine the nutrient status. The results of soil analysis revealed that soil was neutral in pH (6.162) with electrical conductivity of 182.0 $\mu\text{S cm}^{-1}$ and organic carbon content of 0.55 per cent. The available nitrogen

content was 238.00 kg ha^{-1} , available phosphorus was 18.75 $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$ and available potassium was 164.10 $\text{kg K}_2\text{O ha}^{-1}$. The finger millet variety KMR-301 was used for sowing. The sowing of first crop was done during *Rabi* 2018 and second crop on *Rabi* 2019. Fertilizer adjustment equation developed by AICRP on STCR, UAS, Bangalore Centre for Zone-6 and validated for Zone-5 was used for calculating fertiliser to be applied for STCR treatments. The STCR equations are as follows

$$\text{FN} = 3.29 \text{ T} - 71.17 \text{ SN (O.C\%)} - 0.00281 \text{ OM}$$

$$\text{FP}_2\text{O}_5 = 1.798 \text{ T} - 0.189 \text{ SP}_2\text{O}_5 \text{ (Bray's P}_2\text{O}_5) - 0.00173 \text{ OM}$$

$$\text{FK}_2\text{O} = 1.775 \text{ T} - 0.15 \text{ SK}_2\text{O (Amm.Acetate - K}_2\text{O)} - 0.0015 \text{ OM}$$

where,

T: Targeted yield (q ha^{-1})

FN, FP_2O_5 and FK_2O : N, P_2O_5 and K_2O to be supplied through fertilizer (kg ha^{-1}), respectively.

SN, SP_2O_5 and SK_2O : initial soil test values for organic carbon (%), available P and Ammonium acetate K_2O (kg ha^{-1})

OM: Nutrient content (kg t^{-1}) in FYM $\times$ FYM to be applied (t ha^{-1}).

Based on the soil test values and the targeted yield, nutrients were applied as per the details presented in the Table 1.

Table 1: Treatment details with quantity of nutrients applied through different approaches as per the treatments.

Treatments	N: P_2O_5 : K_2O (kg ha^{-1})
T1: RDF (100-50-50 kg NPK ha^{-1})	100:50:50
T2: Soil test based fertilizer recommendations	112.5:62.5:50
T3: Based on STCR equation for 50 q ha^{-1} targeted yield	97:69:49
T4: Based on STCR equation for 55 q ha^{-1} targeted yield	114:78:58
T5: RDF (100-50-50 kg NPK ha^{-1}) + <i>Azospirillum</i> + PSB	100:50:50
T6: Soil test based fertilizer recommendation + <i>Azospirillum</i> + PSB	112.5:62.5:50
T7: Based on STCR equation for 50 q ha^{-1} targeted yield + <i>Azospirillum</i> + PSB	97:69:49
T8: Based on STCR equation for 55 q ha^{-1} targeted yield + <i>Azospirillum</i> + PSB	114:78:58
T9: Absolute Control	-

After the layout of experiment, calculated quantities of FYM were applied @ 10 t ha^{-1} as per the treatment details 15 days before the transplanting of the crop. At the time of transplanting, 50 per cent of nitrogen (through urea) and entire quantity of phosphorus (through SSP) and potassium (through MOP) were supplied as a basal dose to each plot and remaining 50 per cent of nitrogen was applied at 30 days after transplanting. Bio-fertilizer cultures of *Azospirillum* and PSB were obtained from Department of Agricultural Microbiology, University of Agricultural Sciences, GKVK, Bangalore. The seedlings were treated using the microbial culture and treated seedlings were then transplanted in the main field as per the treatment details. The observations were recorded on the growth attributes and yield attributes and finally after the harvest of the crop, the grain yield and straw yield per plot were recorded and further subjected to statistical analysis.

Results and Discussion

Growth attributes

The data regarding the plant height and number of tillers plant^{-1} as influenced by application of nutrients based on different approach are presented in the Table 2. It is evident from the results that application of STCR based NPK to achieve a targeted yield of 55 q ha^{-1} along with application of *Azospirillum* and PSB recorded significantly higher plant height (98.3 cm and 98.9 cm), number of tillers plant^{-1} (3.6 and 3.9)

over control (72.9 cm and 79.5 cm), (2.2 and 2.6) during 2018 and 2019, respectively, followed by T7 (application of NPK based on STCR equation for 50 q ha^{-1} targeted yield along with *Azospirillum* and PSB) (94.0 and 96.1cm), (3.4 and 3.5) and T4 (Application of NPK based on STCR equation for 55 q ha^{-1} targeted yield). The mean data over two years also revealed that application of STCR based NPK to achieve a targeted yield of 55 q ha^{-1} along with application of *Azospirillum* and phosphorus solubilising bacteria has recorded significantly higher plant height and number of tillers plant^{-1} over the absolute control treatment.

Higher growth in STCR based fertilisation over the RDF, soil test based fertilisation and control might be due to the efficient supply of nutrients as per crop's needs along with contribution from soil and organic manure. The results aligning with Apoorva *et al.* (2010) [10], Satalagaon *et al.* (2014) [4] and Sandhya rani *et al.* (2017) [3]. The improvement in growth parameters due to application of fertilizers on STCR basis and application of both fertilizers and organic manures may be attributed due to the increased supply of nutrients (Duryodhana *et al.*, 2004) [2].

Yield attributes

The data on yield attributes viz., number of fingers plant and finger length as influenced by application of nutrients based on nutrient management practices are presented in the Table 3.

Significant differences were observed with respect to number of fingers ear⁻¹ and finger length of finger millet when compared to absolute control. Application of STCR based NPK to achieve a targeted yield of 55 q ha⁻¹ along with application of *Azospirillum* and phosphorus solubilising bacteria recorded significantly higher number of fingers ear⁻¹ (8.25 and 8.32), and finger length (8.96 and 9.52 cm) over control (5.33 and 5.80), (6.33 and 6.45) during 2018 and 2019 respectively. However, it was on par with T7 (application of NPK based on STCR equation for 50 q ha⁻¹ targeted yield along with *Azospirillum* and phosphorus solubilising bacteria) and T4 (application of NPK based on STCR equation for 55 q ha⁻¹ targeted yield). Pooled mean of two years also revealed similar results with respect to number of finger plant and finger length of finger millet.

Satalagaon *et al.* (2014) [4] reported that the enhanced nutrient uptake and increased nutrient use efficiency under STCR approach would have resulted in positive effect on growth and yield attributes that has enabled higher yield. also, there might be favourable complementary influence of organics and inorganics on soil properties under STCR integrated approach would have resulted in higher yield.

Grain yield and straw yield

The impact of application of nutrients based on different nutrient management practices are illustrated in Table 4. Significant differences were observed with grain yield and straw yield of finger millet when compared to no application of fertilizers that is absolute control. Grain yield and straw yield of finger millet differed significantly over the control treatment. Significantly higher grain yield (5763 and 5896 kg ha⁻¹) and straw yield (7893 and 8212 kg ha⁻¹) was recorded with application of STCR based NPK to achieve a targeted yield of 55 q ha⁻¹ along with application of *Azospirillum* and phosphorus solubilising over control (2342 and 2034 kg ha⁻¹ grain yield and 3562 and 3452 kg ha⁻¹ of straw yield during 2018 and 2019 respectively. However, it was on par with T7 (application of NPK based on STCR equation for 50 q ha⁻¹ targeted yield along with *Azospirillum* and phosphorus solubilising bacteria) (5012 and 5213 kg ha⁻¹ grain yield and 7563 and 7741 kg ha⁻¹ straw yield) and T4 (application of NPK based on STCR equation for 55 quintal ha⁻¹ targeted yield) (5412 and 5789 kg ha⁻¹ grain yield and 8569 and 8563 kg ha⁻¹ straw yield). Similarly, pooled mean of two years also revealed that application of STCR based NPK to achieve a targeted yield of 55 quintal ha⁻¹ along with application of *Azospirillum* and phosphorus solubilising recorded significantly higher grain yield (5830 kg ha⁻¹) and straw yield (8053 kg ha⁻¹) over control (2188 and 3507 kg ha ha⁻¹, respectively).

The improvement in the yield due to application of fertilizers based on STCR approach was attributed to the increase in growth attributes as a consequent of improved nutrient supply and efficiency of applied nutrients in the soil. The higher grain yield in STCR treatments could also be attributed to the ability of targeted yield approach to supply the nutrient demand of crop more efficiently as it considers the nutrient requirement of the crop and contribution of nutrients from soil, fertilizers (Regar and Singh, 2014) [6] and organic manures and it discourages lop sized application of nutrient or over fertiliation (Manish *et al.*, 2014) [5]. The results are also in conformity with Manish *et al.* (2017) [5], Saraswathi *et al.* (2018) [9] and Sandhya rani *et al.*, (2017) [3] who reported that the higher productivity of finger millet may be attributed to improved root growth, nutrient uptake, simulation of many different enzymes related to photosynthesis, improved soil properties and increased nutrient

use efficiency of applied nutrients under integrated STCR based fertilisation treatment.

Nutrient Uptake

Uptake of nitrogen, phosphorus and potassium by finger millet differed significantly when compared to absolute control treatment (Figure 1). The Pooled data of two years revealed that significantly higher uptake of nitrogen (165.6 kg N ha⁻¹), phosphorus (45.53 kg P ha⁻¹) and potassium (152.01 kg K ha⁻¹) was observed in the treatments receiving nutrients based on STCR equation for 55q/ha targeted yield along with application of *Azospirillum* and phosphorus solubilizing bacteria over control. The next best treatment was nutrient application based on STCR equation for 55q ha⁻¹ targeted yield. Application of fertilizers as per STCR treatments using both organic and inorganic nutrient sources increases the NPK content in plant parts because of balanced fertilization that might have improved nutrient status in the soil and hence improved uptake by the crop. Similar findings were obtained by Bhavya (2018) [7] that, increased NPK concentration were obtained in the root and shoot of carrot in treatment receiving nutrients as per STCR NPK + FYM approach. The findings of the experiment are also in line with Jagathjothi *et al.* (2010) [12] and Basavaraja *et al.* (2017) [8].

Available nutrient status after harvest of the crop

The effect of different nutrient management practices on availability of major nutrients in soil after the harvest of finger millet variety KMR 301 is presented in Figure 2. Significant differences were observed with respect to available nitrogen, phosphorus and potassium in the soil as influenced by different treatments. Significantly higher available nitrogen values were observed during both the years (278.9 and 281.9 kg N ha⁻¹ during 2018 and 2019 respectively) when the nutrients were applied based on STCR equation for 55 q ha⁻¹ targeted yield along with *Azospirillum* and Phosphorus solubilizing bacteria when compared to absolute control (165.3 and 185.3 kg N ha⁻¹ respectively). Significantly higher soil available phosphorus values were registered with the same treatment during both the years (59.78 and 51.81 kg P₂O₅ ha⁻¹ during 2018 and 2019 respectively). Similarly, the available soil potassium values were significantly higher in the T8 treatment. The Pooled data of two years revealed that significantly higher available nitrogen (175.3 kg N ha⁻¹), phosphorus (28.2 kg P₂O₅ ha⁻¹) and potassium (121.4 kg K₂O ha⁻¹) was observed in the treatments receiving nutrients based on STCR equation for 55 q ha⁻¹ targeted yield along with *Azospirillum* and phosphorus solubilizing bacteria over control. The next best treatment was nutrient application based on STCR equation for 55 q ha⁻¹ targeted yield. Similar results are observed by Basavaraja *et al.* (2017) [8].

Economics

Table 5 presents impact of different nutrient management approaches on the economic performance of the finger millet variety KMR 301. Economic analysis revealed that a gross return of 70256 Rs. ha⁻¹ and 61026 Rs. ha⁻¹ was realized from absolute control during the year 2018 and 2019 respectively. Among the different nutrient management practices, higher gross returns (172890 Rs. ha⁻¹, 176880 Rs. ha⁻¹), net returns (126345 Rs. ha⁻¹, 130335 Rs. ha⁻¹) and BC ratio (3.71, 3.80) was recorded with application of NPK based on STCR approach to achieve a target yield of 55 q ha⁻¹ along with application of *Azospirillum* and PSB during the year 2018 and 2019 respectively and also pooled mean also followed similar trend. The next best treatment was application of NPK based on STCR

equation for 50 q ha⁻¹ targeted yield along with *Azospirillum* and PSB. Improvement in growth parameters such as plant height and number of tillers per plant might be due to application of fertilizers based on STCR approach along with application of *Azospirillum* and phosphorus solubilising bacteria which might have led to the increased supply of nutrients both by fixation of atmospheric Nitrogen by *Azospirillum* and also by solubilization of available phosphorus in the soil. Results are backed by Apoorva et al. (2010)^[10], Rai et al. (2016)^[13] and Shetty et al. (2016)^[11]. STCR is a fertiliser recommendation method that helps farmers

apply the right amount of fertiliser to achieve the targeted yields with improved efficiency. The study revealed that application of NPK based on STCR approach to achieve a target yield of 55 q ha⁻¹ along with application of *Azospirillum* and PSB shown superior growth, yield and nutrient uptake and also improved the soil nutrient status when compared RDF, soil test based fertilisation and control. The same treatment has also recorded higher gross returns, net returns and BC ratio. The next best treatment was application of NPK based on STCR approach to achieve a target yield of 50 q ha⁻¹ along with application of *Azospirillum* and PSB.

Table 2: Growth attributes of finger millet variety KMR-301 as influenced by different nutrient management practices

Treatments	Plant height (cm)			No. of tillers plant ⁻¹		
	2018	2019	Mean	2018	2019	Mean
T1: RDF (100-50-50 kg NPK ha ⁻¹)	84.2	80.2	82.2	3.1	3.4	3.2
T2: Soil test-based fertilizer recommendations	88.7	83.6	86.2	3.3	3.4	3.4
T3: Based on STCR equation for 50 q ha ⁻¹ targeted yield	83.5	95.0	89.2	3.5	3.3	3.4
T4: Based on STCR equation for 55 q ha ⁻¹ targeted yield	87.9	99.9	93.9	3.7	3.8	3.7
T5: RDF (100-50-50 kg NPK ha ⁻¹) + <i>Azospirillum</i> + PSB	84.1	82.4	83.2	3.1	3.6	3.4
T6: Soil test-based fertilizer recommendations + <i>Azospirillum</i> + PSB	83.6	82.5	83.0	3.5	3.4	3.4
T7: Based on STCR equation for 50 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	94.0	96.1	95.0	3.4	3.5	3.5
T8: Based on STCR equation for 55 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	98.3	98.9	98.6	3.6	3.9	3.7
T9: Absolute Control	72.9	79.5	76.2	2.2	2.6	2.4
S.Em (±)	2.2	2.2	2.0	0.1	0.2	0.1
C.D. (p= 0.05)	6.4	6.5	5.7	0.3	0.7	0.4

Table 3: Yield attributes of finger millet variety KMR-301 as influenced by different nutrient management practices

Treatments	No. of fingers ear ⁻¹			Finger length (cm)		
	2018	2019	Mean	2018	2019	Mean
T1: RDF (100-50-50 kg NPK ha ⁻¹)	6.87	7.07	6.97	7.93	6.58	6.87
T2: Soil test-based fertilizer recommendations	7.37	7.42	7.39	7.12	7.85	7.37
T3: Based on STCR equation for 50 q ha ⁻¹ targeted yield	7.25	7.85	7.55	7.87	8.03	7.25
T4: Based on STCR equation for 55 q ha ⁻¹ targeted yield	7.85	8.02	7.94	8.33	8.77	7.85
T5: RDF (100-50-50 kg NPK ha ⁻¹) + <i>Azospirillum</i> + PSB	7.07	7.20	7.13	8.20	8.57	7.07
T6: Soil test-based fertilizer recommendations + <i>Azospirillum</i> + PSB	8.20	8.40	8.30	8.67	8.45	8.20
T7: Based on STCR equation for 50 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	8.02	7.96	7.99	8.56	8.85	8.02
T8: Based on STCR equation for 55 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	8.25	8.32	8.29	8.96	9.52	8.25
T9: Absolute Control	5.33	5.80	5.57	6.33	6.45	5.33
S.Em (±)	0.35	0.29	0.25	0.18	0.28	0.35
C.D. (p= 0.05)	1.04	0.85	0.73	0.52	0.83	1.04

Table 4: Grain yield and straw yield of finger millet variety KMR-301 as influenced by different nutrient management practices

Treatments	Grain yield (kg ha ⁻¹)			Straw yield (kg ha ⁻¹)		
	2018	2019	Mean	2018	2019	Mean
T1: RDF (100-50-50 kg NPK ha ⁻¹)	4012	4103	4057	6212	6521	6367
T2: Soil test-based fertilizer recommendations	4785	4829	4807	7456	7852	7654
T3: Based on STCR equation for 50 q ha ⁻¹ targeted yield	4896	5062	4979	7745	7812	7779
T4: Based on STCR equation for 55 q ha ⁻¹ targeted yield	5412	5789	5601	8569	8563	8566
T5: RDF (100-50-50 kg NPK ha ⁻¹) + <i>Azospirillum</i> + PSB	4896	4248	4572	7185	7323	7254
T6: Soil test-based fertilizer recommendations + <i>Azospirillum</i> + PSB	5081	5026	5053	7463	7716	7590
T7: Based on STCR equation for 50 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	5012	5213	5113	7563	7741	7652
T8: Based on STCR equation for 55 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	5763	5896	5830	7893	8212	8053
T9: Absolute Control	2342	2034	2188	3562	3452	3507
S.Em (±)	243.3	27.4	153.3	192.4	436.2	258.55
C.D. (p= 0.05)	713.7	799.0	449.6	564.3	1279.4	758.31

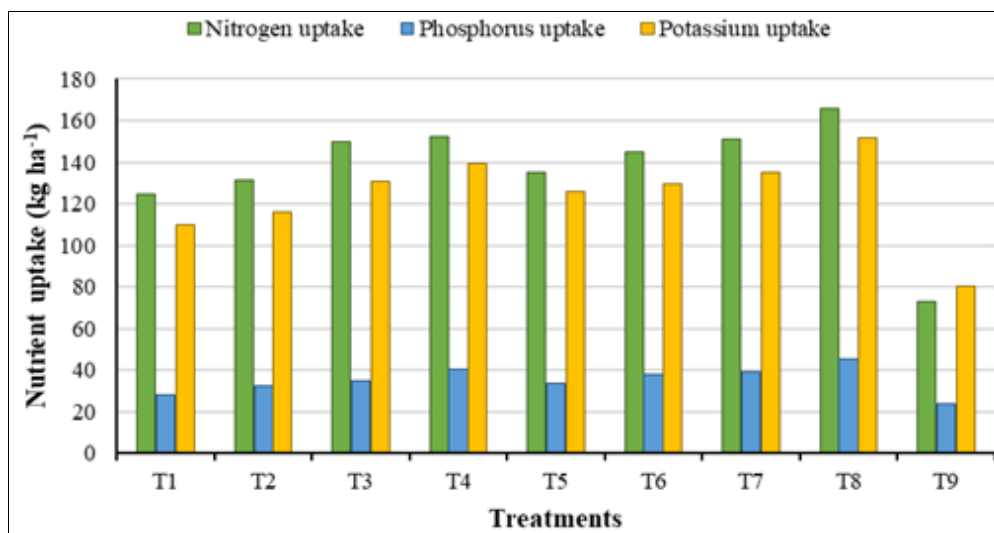


Fig 1: Effect of different nutrient management practices on major nutrients uptake by finger millet.

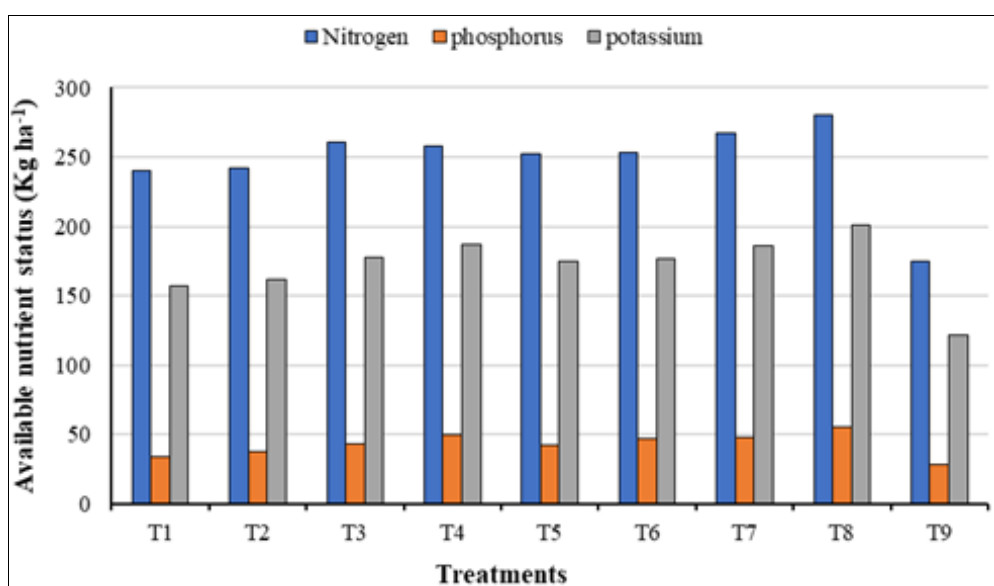


Fig 2: Effect of different nutrient management practices on major nutrients available in the soil after harvest of finger millet

Table 5: Economics of finger millet variety KMR-301 as influenced by different nutrient management practices

Treatments	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)			Net returns (Rs./ha)			B: C ratio		
		2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T1: RDF (100-50-50 kg NPK ha ⁻¹)	45322	120346	123077	75024	75024	77755	76389	2.66	2.72	2.69
T2: Soil test-based fertilizer recommendations	46034	143550	144872	97516	97516	98837	98176	3.12	3.15	3.13
T3: Based on STCR equation for 50 q ha ⁻¹ targeted yield	46227	146880	151860	100653	100653	105633	103143	3.18	3.29	3.23
T4: Based on STCR equation for 55 q ha ⁻¹ targeted yield	46545	162360	173670	115815	115815	127125	121470	3.49	3.73	3.61
T5: RDF (100-50-50 kg NPK ha ⁻¹) + <i>Azospirillum</i> + PSB	45322	146880	127436	101558	101558	82114	91836	3.24	2.81	3.03
T6: Soil test-based fertilizer recommendations + <i>Azospirillum</i> + PSB	46034	152423	150769	106389	106389	104735	105562	3.31	3.28	3.29
T7: Based on STCR equation for 50 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	46227	150360	156390	104133	104133	110163	107148	3.25	3.38	3.32
T8: Based on STCR equation for 55 q ha ⁻¹ targeted yield + <i>Azospirillum</i> + PSB	46545	172890	176880	126345	126345	130335	128340	3.71	3.80	3.76
T9: Absolute Control	43499	70256	61026	65641	26757	17527	22142	1.62	1.40	1.51

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