**Evaluation of Different Approaches of Fertilizer Recommendations on Yield, Nutrient Uptake And Use Efficiency of Finger Millet (*Eleusine Coracana* L. Garten).**

**ABSTRACT**

The effect of fertilizers application based on “fertilizing the soil versus fertilizing the crop” which ensures real balance between the applied and available soil nutrient is urgently needed. Hence, the present study was conducted during *Kharif* 2022 at Zonal Agricultural Research Station, Mandya to assess the effect of imbalance and balance fertilization based on initial soil test values and targeted yields, and to determine the effect of different approaches of fertilizer recommendation on yield, nutrient uptake and use efficiency of finger millet crop. The experiment was laid out in randomized complete block design comprising seven treatments. The results revealed that significantly higher grain yield (46.30 q ha‒1), straw yield (67.90 q ha‒1), total uptake of nitrogen (218.49 kg ha‒1), phosphorus (24.75 kg ha‒1) and potassium (165.74 kg ha‒1) of finger millet was observed in STCR based NPK + FYM application for the targeted yield of 45 q ha‒1 based on actual soil test values which was superior compared to general recommended dose (GRD) and soil fertility rating approach (SFR) approach. The higher apparent recovery efficiency (ARE), agronomic nutrient use efficiency (ANUE) of NPK and partial factor productivity (PFP) of N and K were recorded in STCR approach compared to SFR and GRD. Whereas PFP of phosphorus was noticed to be higher in the soil fertility rating approach and IUE of NPK was recorded as higher in absolute control. Further, the higher economics in terms of benefit cost ratio (BCR) was recorded in treatment with STCR NPK alone application for yield target of 45 q ha‒1 based on soil test value compared to other treatments, thus proving the superiority of STCR approach over other approaches of fertilizer recommendation.

**Keywords:** Soil test crop response, Finger millet, Soil fertility rating, General recommended fertilizer, Nutrient use efficiency

**INTRODUCTION**

Finger millet (*Eleusine coracana* L. Garten) is one of the oldest cultivated cereals in India, with a history dating back over 2000 years. It was a staple food in ancient Indian diets and was even mentioned in ancient Indian texts like the Yajurveda. It is India's third most important millet, besides sorghum and pearl millet. It can be cultivated under adverse soil and climatic conditions, mostly as a rainfed crop. It is rich in protein, calcium, phosphorus, iron, fibre and vitamin content (Mathyam Prabhakar *et al*., 2023). Out of the total minor millets produced, finger millet (*Eleusine coracana* L. Garten.) accounts for about 85% of production in India. The crop is cultivated over an area of 1.19 million hectares with a production of 1.98 million tons, giving an average productivity of 1661 kg ha-1. Karnataka accounts for 56.21% and 59.52% of the area and production of finger millet, followed by Tamil Nadu (9.94% and 18.27%). Unfortunately, the land area cultivated with this crop has decreased, displaced by maize and rice. Reversing this trend will involve achieving higher yields, including through improvements in crop nutrition, and synchronizing nutrient supply with crop demand is essential to maximize yield and fertilizer use efficiency.

Fertilizer nutrients are the major and important inputs in modern agriculture to fulfil the needs of the ever-increasing population of India. But Indian agriculture is operating on a net negative balance of plant nutrients to improve it, fertilizer recommendation plays an important role. It also helps in meeting crop requirements and obtaining better yields. General recommended dose, Soil fertility rating approach, Targeted yield concept and Site-Specific Nutrient Management are some approaches for fertilizer recommendation.

Achieving the potential yields of high-yielding varieties of crops requires applying optimum doses of nutrients. However, using inadequate and imbalanced fertilizers without knowledge of the inherent soil capabilities and crop requirements hinders the ability to harness the potential yield of crops, deteriorates soil health, and leads to economic losses for farmers (Krishna Murthy *et al*., 2024a). Therefore, a comprehensive approach that considers soil tests, field research, and profitability should be employed for fertilizer use. Thus, the soil test crop response (STCR) methodology can be adopted to calculate nitrogen (N), phosphorus (P), and potassium (K) requirements for crops. NPK requirements are linearly correlated with the target yield (TY), depending on the soil test values (STVs). As a result, precise fertilizer recommendations can be made using this approach, as it uses data from soil and plant analysis (Krishna Murthy *et al*., 2024b). A higher economic return and yield response are observed when nutrient application is based on crop demand, and the correction of soil nutrient imbalances can be achieved (Ramasamy Arulmani *et al*., 2025).

Considering the above facts, the experiment was conducted to validate the developed soil test crop response-targeted yield equations for finger millet at various locations, along with other fertilizer recommendation approaches.

**MATERIALS AND METHODS**

Soil Test Crop Response field investigation was conducted during Kharif season 2022 at Zonal Agricultural Research Station, Vishweshwaraih Canal Farm, Mandya, located in the Southern Dry Zone of Karnataka at 12° 34' 6.58'' N latitude, 76° 49' 11.10'' E longitude with an altitude of 695 meters above mean sea level. The climate condition of this area is dry tropical savanna environment characterized by fairly hot summers and relatively cool winters. The annual precipitation level recorded at the site was 943.9 mm. The soil of the area is well-drained red soil at the research site belongs to the taxonomically defined large group known as *Typic Kandic Paleustalfs*, which is a member of the fine mixed Isohyperthermic family.

Prior to the initiation of the investigation, the EC and pH of the soil were 7.20 and 0.30 dS m−1. The textural class of soil was sandy loam with 68.00% sand, 8.00 % silt and 24.00% clay determined using the International pipette method (Black 1965). The potassium dichromate oxidizable organic carbon content in soil was 3.20 g kg–1. Soil available nitrogen, phosphorus and potassium were 232.73-286.12 kg ha−1, 38.44-57.48 kg ha−1 and 196.08-214.70 kg ha−1, respectively.

**Fertilizer prescription equations for finger millet**

Development of fertilizer prescription equations based on the STCR approach involves two consecutive field experiments *viz.*, the fertility gradient experiment and the test crop experiment. A fertility gradient experiment was conducted to create variations in soil nitrogen, phosphorus, and potassium levels within the experimental field (Ramamoorthy *et al*., 1970). After confirming the variation in soil fertility with respect to available NPK, test crop experiment was conducted to develop the targeted yield equation for finger millet. The data on basic parameters for the development of targeted yield equations *viz*., nutrient requirement, contribution of nutrients from soil, fertilizer and organic manure were computed from the main experiment. Fertilizer recommendations were given separately for the use of chemical fertilizer alone (NPK) as well as for integrated use of chemical fertilizer and organic manure (NPK + FYM) by using the following STCR fertilizer adjustment equations.

F.N = 3.29 T - 71.17 S (OC %) - 0.00281 OM

F. P2O5 = 1.798 T - 0.189 SP2O5 - 0.00173 OM

F.K2O = 1.775 T - 0.150 SK2O - 0.0015 OM.

Where, FN, FP2O5 and FK2O are fertilizer N, P2O5 and K2O in kg ha–1, respectively, OM is percent contribution of nutrients from FYM, T is the yield target in q ha–1; S(OC), SP2O5 and SK2O respectively are organic carbon, Olsen-P and NH4OAc-K in initial soil.

**Experimental design and treatments**

The field experiment consists of seven fertilization treatments along with one absolute treatment were arranged in randomized complete block design with three replications. The treatment comprised *viz.,* T1: STCR NPK TY 45 q ha–1, T2: STCR NPK + FYM TY 45 q ha–1, T3: STCR NPK TY 40 q ha–1, T4: STCR NPK + FYM TY40 q ha–1, T5: General recommended dose, T6: Soil fertility rating, and T7: Absolute control. The experimental layout was prepared, and soil samples were collected from a depth of 0-20 cm to determine the available nitrogen, phosphorus, and potassium for each plot before sowing and after harvest. Farmyard manure (FYM) was applied 15 days before sowing and it contains 0.57% N, 0.34% P and 0.51% K, and half of the nitrogen, as well as the full amount of phosphorus and potassium, were applied as a basal dose through urea, single super phosphate and muriate of potash respectively. The fertilizer dose added under each treatment is presented in Table 1. The crop was cultivated following the standard package of practices and harvested at full maturity.

The response yard stick (RYS), percent deviation and value cost ratio (VCR) were computed via the standard formulae shown below (Ramamoorthy *et al*., 1967).

$$RYS =\frac{Yield response \left(kg ha^{-1}\right)}{Total nutrient applied \left(kg ha^{-1}\right)}$$

$$Percent deviation =\frac{[Actual yield obtained \left(kg ha^{-1}\right)-Targeted yield \left(kg ha^{-1}\right)]}{ Targeted yield \left(kg ha^{-1}\right)} ×100$$

$$VCR =\frac{[Yield in treated plot \left(kg ha^{-1}\right) -Yield in control plot \left(kg ha^{-1}\right)]}{ Cost of fertilizers and FYM applied to treated plot}×Cost kg^{-1 }of seed$$

**Analysis of soil and plant samples**

The soil samples were air-dried and sieved through a 2 mm mesh. Bulk density was determined using rings with a known volume, and soil cores were dried in an oven at 105°C for 48 hours. Bulk density was calculated by dividing the weight of the dried soil by the core's volume (Veihmeyer and Hendrickson, 1948). The soil pH was measured in a 1:2.5 soil-to-water suspension using a glass electrode, and electrical conductivity was determined in the supernatant liquid of a 1:2.5 soil-to-water suspension using a conductivity meter (Jackson 1973). Soil organic carbon was determined using 1N K2Cr2O7 and back titrated with 0.5 N FAS (Walkley and Black 1934). Available nitrogen was estimated using the alkaline KMnO4 method (Subbiah and Asija, 1956), available phosphorus was extracted with Bray’s extractant (0.025 M HCl and 0.03 M NH4F) and measured colorimetrically by the ascorbic acid method (Bray and Kurtz, 1945), and available potassium was extracted with 1 N ammonium acetate (pH 7.0) and measured using a flame photometer (Page *et al*., 1982).

Plant samples were collected from each treatment, dried in shade and then in a hot air oven at 65°C, and were ground in willey mill. Nitrogen content in plant samples was determined by the micro Kjeldahl method ([Piper 1966](#twofour)). Di-acid extract was prepared out using a 9:4 mixture of HNO3:HClO4 (Jackson 1973) to determine P and K content in the plant samples. The pre-digestion of sample was done by using 10 mL of HNO3 g-1 of sample. Phosphorus was determined spectrophotometrically by vanadomolybdate phosphoric acid yellow colour method ([Jackson 1973)](#Seventeen) and potassium was estimated using flame photometer ([Jackson 1973](#Seventeen)). From the chemical analytical data, the uptake of each nutrient was calculated.

Nutrient uptake (kg ha–1) = Nutrient content (%) × dry weight in kg ha-1 / 100

***Nutrient Use Efficiency***

Nutrient (N/P/K) use efficiency parameters *viz.,* Agronomic nutrient use efficiency (AE), Recovery efficiency (RE), Partial factor productivity (PFP) and Reciprocal internal utilization efficacy (RIUE) were calculated using the following formulae, as per Singh *et al* (2021):

$$AE\left(kg kg^{-1}\right) =\frac{[Grain yield in treated plot \left(kg ha^{-1}\right)-Grain yield in control plot \left(kg ha^{-1}\right)]}{Fertilizer nutrient applied \left(kg ha^{-1}\right)}$$

$$RE\left(kg kg^{-1}\right) =\frac{[Nutrient uptake in treated plot \left(kg ha^{-1}\right)-Nutrient uptake in control plot \left(kg ha^{-1}\right)]}{Fertilizer nutrient applied \left(kg ha^{-1}\right)}$$

$$PFP \left(q ha^{-1}\right)=\frac{\left[Yield obtained in treated plot \left(q ha^{-1}\right)\right]}{Fertilizer nutrient applied \left(kg ha^{-1}\right)} $$

$$RIUE\left(\%\right) =\frac{Nutrient uptake by grain \left(kg ha^{-1}\right)}{Grain yield \left(Mg ha^{-1}\right)}$$

***Statistical Analysis***

Descriptive statistics were used for the gradient and test crop experiment using SPSS 16.0 software. Data recorded in verification experiments were analysed using the ANOVA technique (Gomez and Gomez 1984).

**RESULTS AND DISCUSSION**

 **Grain and straw yield**

The grain yield of finger millet was significantly higher in the treatment receiving fertilizers through STCR NPK + FYM application for the targeted yield of 45 q ha–1 (46.30 q ha–1) compared to STCR NPK + FYM TY 40 q ha–1 (41.23 q ha–1), and absolute control (20.00 q ha–1), respectively (Table 1). Similarly, significantly higher straw yield was recorded in STCR NPK + FYM TY 45 q ha–1 (67.90 q ha–) compared to all other treatments. The lower grain and straw yields were recorded in absolute control plots.

Irrespective of the yield targets, the yield obtained in the STCR-based NPK + FYM application was higher when compared to their corresponding STCR-NPK application. Farmyard manure contributed relatively higher contents of available forms of most of the nutrient elements and better retention of moisture in the soil during crop growing seasons, which is also linked to increased photosynthetic accumulation, higher biomass output and improved growth and yield attributes (Parvathi Sugumari *et al*., 2021). The grain yield under 45 q ha–1 fixed yield target was 9.72 and 10.34% higher than general recommendation dose and soil fertility rating approach, respectively. This might be due to balanced application of nutrients which is based on soil analysis, amount of nutrient removed by crops, initial levels of soil fertility, efficiency of nutrients present in the soil and added through fertilizers. These factors might have provided the optimum time for better uptake and ultimately resulted in higher dry matter production and yield (Suganya *et al*., 2025)

**Nutrient uptake**

Nutrient uptake data (Table 2) reveal that combined application of NPK and FYM for STCR targeted yield of 45 q ha–1 based on soil test value recorded significantly higher nitrogen (218.49 kg ha–1), phosphorous (24.75 kg ha–1) and potassium (165.74 kg ha–1) uptake by finger millet compared to all the treatments. The lower uptake of nutrients (N: 64.27 kg ha–1,P: 2.23 kg ha–1, K: 23.47 kg ha–1,respectively) was observed in the absolute control, where no fertilizer nutrients and FYM were applied. Whereas treatments receiving general recommended dose and soil fertility rating approach of fertilizer recommendation recorded lower uptake of NPK compared to STCR approach might be due to imbalanced application of fertilizer may lead to a loss of nutrients.

The greater nutrient uptake in STCR–IPNS treatments could be attributed to creation of a conducive environment for crop growth through the application of FYM by enhancing soil properties, nutrient retention and water holding capacity. This would mobilize the unavailable nutrients and also had some positive effects on root growth, ensuring improved uptake of nutrients (Sugumari *et al*., 2021). Significantly higher NPK uptake in STCR approach was recorded compared to other approaches due to the application of the required quantity of nutrients through inorganic fertilizers, results in higher uptake and high dry matter production because of higher availability of nutrients (Krishna Murthy *et al*., 2024c).

**Agronomic nutrient use efficiency**

The higher agronomic nitrogen use efficiency (28.12kg kg–1) was recorded in the treatment receiving STCR based NPK + FYM application based on soil test values for a targeted yield of 45 q ha–1, respectively (Table 3). Similarly, higher phosphorus use efficiency was also recorded in the same treatment. However, the higher potassium use efficiency was recorded in STCR-based NPK + FYM application for a targeted yield of 40 q ha–1 (87.80 kg kg–1) based on soil test values. The lower agronomic nutrient use efficiency of NPK was noticed in treatments that recorded lower yield with higher application of fertilizer nutrients

**Apparent recovery efficiency**

The higher apparent recovery efficiency in nitrogen (1.59 kg kg–1) and phosphorus (0.41 kg kg–1) was recorded in T2 STCR NPK + FYM TY 45 q ha–1, but a higher apparent recovery efficiency of potassium was recorded in STCR NPK + FYM TY 40 q ha–1 (4.37 kg kg–1). The lower apparent recovery efficiency of nitrogen (1.04 kg kg–1) and potassium (1.92 kg kg–1) was recorded in the soil fertility rating approach. While lower phosphorus recovery efficiency was recorded in absolute control (0.14 kg kg–1).

Higher agronomic nutrient use efficiency and apparent crop recovery efficiency was recorded in treatment receiving STCR based NPK + FYM due to application of fertilizers as per the crop demand along with incorporation of 10 t ha‒1 FYM which resulted in higher yield and uptake of nutrients per kg of fertilizer added, without any loss of nutrient due to excessive usage, there by increased ANUE and ARE in finger millet and it also associated with lower fertilizer rate, cultural practices meant for promoting integrated nutrient management which helped for effective saving in the amount of fertilizer nutrient applied to the crops and there by improved fertilizer use efficiency (Rangaiah *et al*., 2023a).

**Partial factor productivity**

The higher partial factor productivity of nitrogen and potassium was recorded in STCR NPK + FYM TY 40 q ha–1 (51.07 kg kg–1). However, the higher partial factor productivity of phosphorus was recorded in the soil fertility rating approach (111.89 kg kg–1), which recorded a higher yield (41.96 q ha–1) with a lower dose of phosphorous fertilizer (37.50 kg ha–1) application.

Partial factor productivity was higher in the treatment showing higher yield with respect to a lower application rate of fertilizer (Karthika *et al*., 2024).

**Internal utilization efficiency**

The internal utilization efficiency of nitrogen, phosphorous and potassium recorded higher value in absolute control plot compared to all the treatments (Table 3). It may be attributed to the higher utilization efficiency of NPK recorded with no fertilizer application compared to fertilized treatments. This signifies the deficiency of nutrients in control plot (Krishna Murthy *et al*., 2023b).

**Response Yard Stick**

The response yard stick (RYS) indicates the yield obtained in kg per kg of NPK applied in that particular ratio of each treatment. The response yard stick was recorded higher 14.10 kg kg‒1 in STCR NPK + FYM with a yield target of 40 q ha‒1 based on soil test values.

Response yard stick recorded higher in STCR based NPK + FYM application than compared general recommended dose and soil fertility rating approach it may be attributed to that fertilizers were applied along with FYM to crop in balanced manner by considering soil test values and nutrient requirement of the crop which was effectively utilized by the crop to achieve the target as compared to all other treatments (Bhavya *et al*., 2023) and organic manures also contain both micro and macronutrients, unlike NPK fertilizer that contains only N, P and K which contributed to the higher grain yield in crop (Spoorthishankar *et al*., 2025).

**Per cent Deviation**

The percent deviation indicated the yield variation from the targeted yield (Table 4). In the present study it was found to be higher in STCR based NPK + FYM application for target of 40 q ha-1 based on soil test values (6.20%) where the yield obtained was higher than the fixed targets and remaining all treatments found positive deviation from fixed target. Here, the higher negative deviation indicates that the crop could not achieve the genetic potential yield in these treatments. The per cent deviation of ± 10.00 will be generally considered as the best equation; otherwise, the equations will be modified (Patel *et al*., 2001).

**Benefit Cost Ratio**

The higher benefit cost ratio (BCR) of 2.93 was recorded where fertilizer nutrients were applied through STCR NPK alone for yield target of 45 q ha‒1 based on soil test values followed by 2.81 in STCR NPK TY 40 q ha–1. The lower benefit cost ratio of 1.39 was recorded in absolute control plot, where fertilizers and FYM were not applied.

The benefit-cost ratio was found to be highest in STCR treatments with purely inorganic approach compared to any other treatments. The highest BCR could be mainly due to lower levels of NPK fertilizer application associated with higher yield (46.07 q ha‒1) production compared to all other treatments. Even though higher yields were recorded in STCR integrated approach the BCR was lower, mainly due to the high cost of FYM (Krishna Murthy *et al*., 2023c). BCR was found to be 36.92 and 38.21% higher in fertilizer treatments based on STCR methodology as compared to the general recommended dose and soil fertility rating approach at both locations respectively, it may be attributed to the balanced application of nutrients based on crop requirement and contribution from soil, fertilizer and organic matter had reduced excess application of fertilizers thereby reduced cost of fertilizer application (Spoorthishankar *et al*., 2025).

**CONCLUSION**

Based on this study, it can be concluded that the STCR targeted yield equations developed for finger millet crop is most suitable for Zone-6 of Karnataka and Dhartimitra software can be used to prescribe fertilizer dose for finger millet where frequent soil testing could be avoided for getting higher grain and straw yield compared to all other different approaches of fertilizer recommendation. Even though BCR was recorded lower in STCR based NPK + FYM application due to high cost of FYM, these treatments should be recommended for applying balanced dose of fertilizer nutrients in order to encourage farmers to utilize their own compost/FYM to reduce the cost of production and maintain soil sustainability.

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**Originality and Plagiarism**:

We hereby declare that the work presented in this manuscript is original and has not been published elsewhere, nor is it currently under consideration for publication by any other journal. All sources that have been used or quoted are properly cited and acknowledged. We affirm that the manuscript is free from any form of plagiarism, including self-plagiarism, and complies with the ethical standards for academic publishing.

**Data availability statement:** The data that support this study will be shared upon reasonable request to the corresponding author.

**Conflict of interest:** The author reported no potential conflicts of interest.

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