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RESEARCH PAPER

Evaluation of Different Approaches of Nutrient Recommendations on Yield, Nutrient Use Efficiency and Economics of Groundnut under Alfisols of Eastern Dry Zone of Karnataka

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ABSTRACT

A field experiment was conducted during *kharif* 2022 in Bengaluru rural district, Karnataka, to validate soil test crop response (STCR) based fertilizer prescriptions for groundnut on Alfisols. The study utilized a randomized complete block design with seven treatments, including STCR targets (30 and 25 q ha^{-1}) through inorganic and integrated approaches, General Recommended Dose (GRD), Soil Test Laboratory approach (STL/LMH), and an absolute control. The soil was sandy loam, acidic (pH5.68), with medium available nitrogen and potassium, and high phosphorus. STCR fertilizer prescription equations developed for Zone–5 were used. Results showed significantly higher pod yield with the STCR integrated approach for a 30q ha^{-1} target (30.19 q ha^{-1}), surpassing other treatments. STCR inorganic approach for 30 q ha^{-1} and 25 q ha^{-1} targets yielded 30.02 q ha^{-1} and 25.17 q ha^{-1} respectively, while the integrated approach for 25 q ha^{-1} target yielded 25.94 q ha^{-1}. These were superior to GRD (20.18 q ha^{-1}) and STL / LMH (20.56 qha^{-1}). Nutrient uptake (N, P, K) was significantly higher in STCR-integrated treatments, attributed to improved soil properties and nutrient availability. The STCR integrated approach also demonstrated higher agronomic nitrogen (1.56 kg kg^{-1}) and phosphorus (0.50kg kg^{-1}) use efficiency. The per cent deviation was within ± 10% proving the validity of the developed targeted yield equations. This study concludes that STCR targeted yield equations are highly suitable for groundnut in Zone-5 of Karnataka, promoting higher yields and encouraging the use of farmyard manure for soil sustainability despite initial higher costs.

HIGHLIGHTS

- Enhanced groundnut pod yield through soil test crop response (STCR)-based fertilizer recommendation for targeted yield.
- Validation of STCR equations for Alfisols of Eastern Dry Zone with minimal yield deviation.

Keywords: Yield, Groundnut, Soil test crop response, Nutrient uptake, Nutrient use efficiency

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Groundnut holds immense economic significance as a key cash crop for millions of farmers, contributing substantially to agricultural income and international trade. Its nutritional value is also noteworthy; groundnut seeds are rich in oil (44-56%) and protein (20-25%), making them a valuable food source for human consumption, and they also contain essential vitamins, minerals, and antioxidants (Karthu *et al*. 2025). Furthermore, as a legume, groundnut can fix atmospheric nitrogen in the soil through symbiotic association with *Rhizobium* bacteria, enhancing soil fertility and benefiting subsequent crops in rotation (Palai *et al*. 2021; Maitra *et al*. 2023). Groundnut, like other crops, requires a balanced supply of essential nutrients for optimal growth, development, and yield. However, groundnut yields are often constrained by several factors, including imbalanced nutrient management, where inadequate or excessive use of fertilizers can lead to nutrient deficiencies, toxicities, and reduced yields, as traditional blanket recommendations often fail to address the specific nutrient needs of the crop in different soil types and agro-climatic conditions (Palai *et al*. 2024). Soil variability also plays a role, as soils vary considerably in their nutrient-supplying capacity, and a uniform fertilizer application across a field can result in over-fertilization in some areas and under-fertilization in others (Singh *et al*. 2021).

To address the challenges of imbalanced nutrient use and optimize fertilizer application, soil testing is a valuable tool. Soil testing involves analyzing soil samples to determine their nutrient content and other relevant properties, providing a basis for fertilizer recommendations (Krishna Murthy *et al*. 2023a). The Soil Test Crop Response (STCR) approach is a refinement of soil test-based nutrient management. It is a more precise and scientific method of fertilizer recommendation that considers the relationship between soil nutrient availability, crop response to applied nutrients, and the yield target. Key features of STCR include targeted yield, where STCR aims to provide fertilizer recommendations to achieve a specific, predetermined yield target, aligning nutrient application with crop demand; calibration experiments, involving conducting field experiments to calibrate soil test values with crop response to applied nutrients, generating the data needed to develop fertilizer prescription equations; and fertilizer prescription equations, using equations to calculate the optimal amounts of fertilizers (N, P, K, and other nutrients) required to achieve the desired yield target, based on soil test values (Bhavya *et al*. 2023).

MATERIALS AND METHODS

A Field experiment entitled "Validation of soil test crop response based fertilizer prescription for groundnut on *Alfisols*" was conducted during kharif 2022 at Devanahalli village, Bengaluru rural district located in Eastern Dry Zone of Karnataka at 13° 24′ 41.1′′ N latitude, 78° 08′ 01.9′′ E longitude with an altitude of 880 meters above mean sea level (MSL). The soil of the experimental site was sandy loam in texture and acidic in reaction (pH, 5.68). Electrical conductivity was 0.18 dSm^{-1} with organic carbon content ranged from 0.46%. Available nitrogen was medium (291.25 kg ha^{-1}), phosphorus was high (95.38 kg ha^{-1}) and potassium was medium (180.56 kg ha^{-1}). The experiment was laid out in randomized complete block design (RCBD) with seven treatments replicated thrice comprising T_1 (STCR target 30 q ha^{-1} through inorganics), T_2 (STCR target 30 q ha^{-1} through integrated), T_3 (STCR target 25 q ha^{-1} through inorganics), T_4 (STCR target 25 q ha^{-1} through integrated), T_5 (GRD (25:50:25) N, P_2O_5, K_2O kg ha^{-1}+ FYM), T_6 (LMH /STL + FYM), T_7 (Absolute control).

The following STCR fertilizer prescription equation developed by AICRP on STCR, UAS, Bengaluru centre for Zone-5 was used for fertilizer application to STCR treatments.

$FN = 4.43\ T - 0.31\ SN - 0.033\ OM$

$FP_2O_5 = 8.62\ T – 2.91\ SP - 0.032\ OM$

$FK_2O = 4.92\ T - 0.58\ SK - 0.042\ OM$

where FN, FP_2O_5, and FK_2O are fertilizer N, P_2O_5, and K_2O in kg ha^{-1}, respectively; T is the yield target in q ha^{-1}; SN, SP, and SK are available soil nutrients as $KMnO_4$-N, Bray's-P_2O_5, and NH_4OAc-K_2O in kg ha^{-1}, respectively, and OM is the amount of FYM (organic manure) added in t ha^{-1}.

A composite soil sample was collected at 0-15 cm depth from each plot after laying out the plan before the start of the experiment. Based on the soil test values NPK fertilizer nutrients were applied for specific yield target in STCR and LMH/STL approach. The quantity of nutrients applied per hectare through different approaches, as per the treatments are presented in Table 1. Fifty per cent of nitrogen recommended for each treatment was applied through urea and entire quantity of phosphorus through SSP (single super phosphate) and potassium through MoP (muriate of potash) were supplied at the time of sowing as basal dose to each plot and remaining 50 per cent of nitrogen was applied at 30 days after sowing. At harvest, the yield recorded from each plot was computed and expressed in q ha^{-1}. Soil samples collected from the experimental plots after harvest were processed and analysed for available nitrogen, phosphorus and potassium.

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

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

Percent deviation =

$$\frac{[\text{Actual yield obtained }\left(\text{kg ha}^{-1}\right) - \text{Targeted yield }\left(\text{kg ha}^{-1}\right)]}{\text{Targeted yield }\left(\text{kg ha}^{-1}\right)} \times 100$$

VCR =

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

Analysis of soil and plant samples

Soil sample preparation involved air-drying and passing through a 2 mm sieve. For bulk density, known-volume rings were used to collect soil cores, which were then oven-dried at 105°C for 48 hours. Bulk density was subsequently determined by dividing the dry soil weight by the core's volume, following the methodology of Veihmeyer and Hendrickson (1948). Soil pH was assessed in a 1:2.5 soil-to-water suspension utilizing a glass electrode, while electrical conductivity was measured in the supernatant of a similar 1:2.5 soil-to-water suspension with a conductivity meter, as described by Jackson (1973). Organic carbon content in the soil was ascertained by titration with 1N $K_2Cr_2O_7$ and back titration with 0.5 N FAS, according to the Walkley and Black (1934) method. Available nitrogen was quantified using the alkaline $KMnO_4$ method (Subbiah and Asija, 1956). Available phosphorus was extracted with Bray's extractant (0.025 M HCl and 0.03 M NH_4F) and subsequently analyzed colorimetrically via the ascorbic acid method (Bray and Kurtz, 1945). Available potassium was extracted with 1 N ammonium acetate (pH 7.0) and measured using a flame photometer, a procedure outlined by 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). Di-acid extract was prepared out using a 9:4 mixture of HNO_3:$HClO_4$ (Jackson, 1973) to determine P and K content in the plant samples. The pre-digestion of sample was done by using 10 mL of HNO_3 g^{-1} of sample. Phosphorus was determined spectrophotometrically by vanadomolybdate phosphoric acid yellow colour method (Jackson, 1973) and potassium was estimated using flame photometer (Jackson, 1973). From the chemical analytical data, the uptake of each nutrient was calculated.

Table 1: Soil test values and quantity of nutrients and FYM applied for different approaches as per the treatments

Trt	Soil test values (kg ha^{-1})			FYM	Nutrients applied (kg ha^{-1})		
	N	P_2O_5	K_2O	(t ha^{-1})	N	P_2O_5	K_2O
T_1	230.56	101.56	185.56	0	61.43	36.18	49.52
T_2	235.69	94.56	190.52	10	59.51	33.86	46.20
T_3	235.63	80.56	186.36	0	37.70	39.07	48.82
T_4	236.25	84.26	191.34	10	37.18	30.64	45.79
T_5	231.58	80.45	185.79	10	25	50	25
T_6	235.67	85.69	190.45	10	31.25	37.50	25
T_7	—	—	—	—	—	—	—

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), and Reciprocal internal utilization efficacy (RIUE) were calculated using the following formulae, as per Singh *et al.* (2021):

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

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

$$PFP\ (\text{q ha}^{-1}) = \frac{[\text{Yield obtained in treatedplot }(\text{q ha}^{-1})]}{\text{Fertilizer nutrient applied }(\text{kg ha}^{-1})}$$

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

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

Pod yield

The pod yield data of groundnut in Table 2, revealed a significant difference between the treatments. The significantly higher pod yield (30.19 q ha^{-1}) was recorded in STCR target of 30 q ha^{-1} through integrated approach which was superior than all the other treatments. All the STCR targeted yield approach treatments were found to be superior over LMH (20.56 q ha^{-1}) and RDF (20.18 q ha^{-1}). The STCR-integrated approach at both the targets (30 and 25 q ha^{-1}) have recorded the pod yield more than the target fixed and was higher compared to STCR - inorganic approach. However, significantly lower yield (13.75 q ha^{-1}) was noticed in absolute control. The enhanced nutrient uptake and increased nutrient use efficiency under STCR approach over LMH and resulted in positive effect on growth and yield attributes that have enabled higher pod yield (Bhavya *et al*. 2022). Also, the favourable complementary influence of organics and inorganics on chemical, physical and biological properties of soil under STCR integrated approach would have resulted in higher yield (Krishna Murthy *et al*. 2023b)

Percent deviation, RYS and VCR

The percent deviation indicates the yield variation from the target fixed (Table 2). The percent deviation was found to be positive in STCR target of 30 q ha^{-1} and 25 q ha^{-1} through inorganics (0.07% and 0.68%, respectively) and integrated (0.63% and 3.76%, respectively) treatments where the yield obtained was higher than the fixed targets. 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) The higher value cost ratio (VCR) of 17.48 was recorded where fertilizer nutrients were applied through STCR NPK alone for a yield target of 30 q ha^{-1} followed by 12.47 in STCR target of 25 q ha^{-1} through inorganics (Table 2). The lower value cost ratio of 2.79 was recorded with the application of nutrients based on the general recommended dose. However, STCR NPK + FYM treatments recorded lower VCR than the NPK alone treatments. 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 11.78 kg kg^{-1} in STCR NPK + FYM with a yield target of 30 q ha^{-1}. The yield targeting with NPK + FYM treatments recorded relatively higher percent achievement than that aimed under their respective NPK alone treatments because of the higher yields achieved in the STCR NPK + FYM treatments (Vijayakumar *et al* 2017). The higher value cost ratio (VCR) under STCR NPK alone treatments could be mainly due to the application of required dose of NPK fertilizer without FYM associated with higher yields. Even though higher yields were recorded in STCR NPK + FYM treatments, the VCR was very low mainly due to high cost of FYM applied to these treatments. These results are in conformity with Bhavya and Basavaraja (2021) in aerobic rice.

Nutrient uptake

Nutrient uptake data (Table 3) reveal that combined application of NPK and FYM for STCR targeted yield of 30 q ha^{-1} based on soil test value recorded significantly higher nitrogen (96.79 kg ha^{-1}), phosphorous (30.79 kg ha^{-1}) and potassium (75.05 kg ha^{-1}) uptake by groundnut compared to all the treatments. The lower uptake of nutrients (N: 30.48 kg ha^{-1}, P: 10.38 kg ha^{-1}, K: 20.46 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 STL/LMH 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 (Krishna Murthy *et al.* 2024a). 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.* 2024b).

Agronomic nutrient use efficiency

The higher agronomic nitrogen use efficiency (1.56 kg kg^{-1}) was recorded in the treatment receiving STCR based NPK + FYM application based on soil test values for a targeted yield of 25 q ha^{-1}, respectively (Table 4). Similarly, higher phosphorus

Table 2: Influence of different approaches of nutrient application on yield, % deviation, RYS and VCR of groundnut

Treatments	Pod Yield (q ha^{-1})	% deviation	RYS (kg kg^{-1})	VCR
T_1: STCR target 30 q ha^{-1} through inorganics	30.02	0.07	11.06	17.48
T_2: STCR target 30 q ha^{-1} through integrated	30.19	0.63	11.78	6.95
T_3: STCR target 25 q ha^{-1} through inorganics	25.17	0.68	9.09	12.47
T_4: STCR target 25 q ha^{-1} through integrated	25.94	3.76	10.73	5.33
T_5: General recommended dose (GRD)	20.18	-19.28	6.43	2.79
T_6: Soil Test laboratory approach (STL/LMH)	20.56	-17.76	7.26	3.13
T_7: Absolute Control	13.75	-45.00	—	—
SEm±	**0.45**	—	—	—
CD@5%	**1.39**	—	—	—

Table 3: Influence of different approaches of nutrient application on NPK uptake of groundnut

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1: STCR target 30 q ha^{-1} through inorganics	93.00	26.20	71.51
T_2: STCR target 30 q ha^{-1} through integrated	96.79	30.79	75.05
T_3: STCR target 25 q ha^{-1} through inorganics	80.27	24.28	66.19
T_4: STCR target 25 q ha^{-1} through integrated	88.52	25.61	68.93
T_5: General recommended dose (GRD)	73.26	20.70	55.93
T_6: Soil Test laboratory approach (STL/LMH)	70.15	20.51	51.70
T_7: Absolute Control	30.48	10.38	20.46
SEm±	1.25	1.04	2.16
CD@5%	3.80	3.12	6.58

Table 4: Influence of different approaches of nutrient application on nutrient use efficiency of groundnut

Treatment	Nitrogen use efficiency			Phosphorus use efficiency			Potassium use efficiency		
	AE (kg kg^{-1})	RE	RIUE kg q^{-1}	AE (kg kg^{-1})	RE	RIUE kg q^{-1}	AE (kg kg^{-1})	RE	RIUE kg q^{-1}
T_1	1.12	26.49	3.10	0.44	44.97	0.87	1.03	32.86	2.38
T_2	1.11	27.63	3.21	0.60	48.55	1.02	1.18	35.58	2.49
T_3	1.32	30.29	3.19	0.36	29.23	0.96	0.94	23.39	2.63
T_4	1.56	32.79	3.41	0.50	49.78	0.99	1.06	26.62	2.66
T_5	1.01	25.72	3.63	0.21	12.86	1.03	1.42	25.72	2.77
T_6	1.27	21.79	3.41	0.27	11.16	1.00	1.25	27.24	2.51
T_7			2.22			0.75			1.49

use efficiency was also recorded in the STCR integrated approach for the yield target of 30 q ha^{-1}. However, the higher potassium use efficiency was recorded LMH / STL approach (1.42 kg kg^{-1}). 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 (32.79 kg kg^{-1}) and phosphorus (49.78 kg kg^{-1}) was recorded in T_4 STCR integrated approach for the yield target of 25 q ha$^{-1,}$ but a higher apparent recovery efficiency of potassium was recorded in STCR NPK + FYM for the yield target of 30 q ha^{-1} (35.58 kg kg^{-1}). The lower apparent recovery efficiency of nitrogen (21.79 kg kg^{-1}) and phosphorus (11.16 kg kg^{-1}) was recorded in the soil fertility rating approach. While lower potassium recovery efficiency was recorded in STCR inorganic approach for the yield target of 25 q ha^{-1} (23.39 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 (Krishna Murthy *et al*. 2024c).

Reciprocal internal utilization efficiency

The reciprocal internal utilization efficiency of nitrogen, phosphorous and potassium recorded higher value in general recommended dose treatment compared to all the treatments (Table 4). It may be attributed to the higher utilization efficiency of NPK recorded with less fertilizer application compared to other treatments. This signifies the deficiency of nutrients (Krishna Murthy *et al*. 2024d).

CONCLUSION

The STCR targeted yield equations developed for groundnut crop are most suitable for Zone-5 of Karnataka for getting higher yield compared to all other different approaches of fertilizer recommendation. Even though VCR 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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