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Comparative Study on Nutrient Recommendation Approaches for Optimizing Greengram Productivity in *Alfisols*

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Abstract

The Soil Test Crop Response (STCR) approach offers a scientific basis for optimal fertilizer application. In the above context a field experiment was conducted during summer, 2024 at the Zonal Agricultural Research Station, GKVK, Bengaluru to assess the impact of various nutrient recommendation approaches on the growth and yield of greengram and to validate the STCR targeted yield equations for *Alfisols* in Eastern Dry Zone of Karnataka. The experiment followed a randomized complete block design (RCBD) with twelve treatments, each replicated three times. Results showed that plant height and number of trifoliate leaves varied significantly among treatments at 60 days after sowing and harvest. The highest plant height (37.48 cm) was observed in the STCR integrated approach for a target yield of 15 q ha^{-1} based on actual soil test values (T_3), while T_4 (STCR integrated for 15 q ha^{-1} - Predicted STV) recorded the maximum number of trifoliate leaves (8 leaves per plant). Both treatments outperformed the package of practice and low-medium-high approaches. Yield parameters, including number of pods per plant, pod length, seeds per pod and test weight, were significantly higher in the STCR treatments. The highest seed yield (17.99 q ha^{-1}) was recorded in T_3, while the least (6.04 q ha^{-1}) was found in the absolute control (T_{12}). The STCR approach also showed superior yield response, response yardstick (RYS) and value-cost ratio (VCR), with T_5 (STCR inorganics, 12 q ha^{-1} - Actual STV) recording the highest VCR (49.49). The percentage deviation for yield targets of 15 and 12 q ha^{-1} through inorganic and integrated approaches, based on both actual and predicted soil test values, remained within ±10 per cent, indicating that these STCR equations are effective for determining fertilizer doses for greengram in the Eastern Dry Zone of Karnataka.

Keywords : Soil test crop response, Greengram productivity, Predicted soil test values, Actual soil test values, Package of practices

Greengram (*Vigna radiata*), commonly known as mungbean, is an important legume crop cultivated extensively in tropical and subtropical regions (Isha *et al.,* 2024). Its adaptability to various soil types, drought tolerance and ability to fix atmospheric nitrogen make it a vital component of sustainable agricultural systems (Muchomba *et al.,* 2023). However, achieving optimal yields in greengram requires effective nutrient management, which is influenced by soil fertility levels, crop requirements and external nutrient inputs.

Nutrient management in greengram has traditionally been approached through generalized fertilizer recommendations, which often prescribe a fixed dose of nutrients regardless of site-specific conditions (Dey, 2015). These blanket recommendations may not account for the inherent variability in soil nutrient availability, leading to either under- or over-application of fertilizers, which can negatively affect crop yield and soil health. To address these issues, more precise fertilizer recommendation approaches, such as Low, Medium and High (LMH) nutrient applications, have been developed. These approaches consider the crop's nutrient demand and soil nutrient supply but still lack the precision needed for site-specific nutrient management (Bhavya and Basavaraja, 2021).

In response to these limitations, Soil Test Crop Response (STCR)-based fertilizer application have emerged as a superior alternative. STCR approach tailor fertilizer recommendations based on actual soil nutrient levels and the crop's specific nutrient needs, allowing for more precise nutrient management (Ramamoorthy *et al.,* 1967). This approach not only improves crop yields but also enhances nutrient use efficiency, minimizing environmental impacts such as nutrient leaching or runoff. By taking into account the soil's nutrient status, crop requirements and target yields, STCR can offer a more sustainable and cost-effective solution compared to the blanket recommendations of low-medium-high (LMH) nutrient application strategies or generalized approaches (Rangaiah *et al.,* 2024).

The key advantage of STCR lies in its ability to create a targeted yield equation based on soil test values and crop response, optimizing fertilizer inputs to achieve a predetermined yield goal. This contrasts with the conventional LMH and generalized recommendations that apply nutrients without considering the actual soil nutrient reserves or the crop's dynamic nutrient uptake pattern throughout its growth cycle (Krishnamurthy *et al.,* 2023d). As a result, STCR-based fertilizer recommendations can potentially outperform traditional approaches by ensuring that nutrient supply matches the crop's demand during critical growth stages, improving overall productivity (Basavaraja *et al.,* 2014).

The availability of nutrients in soil after harvesting a crop is significantly influenced by three key factors: the initial nutrient status of the soil, the amount of fertilizer applied and the type of crop grown. In recent years, there has been a shift from monoculture to cropping sequences, which has led to the need for soil test-based fertilizer prescriptions. However, testing the soil after each crop in a sequence is not always practical. As a result, it has become essential to predict the soil test values after harvesting each crop in the sequence. To achieve this, researchers have developed equations to predict post-harvest soil test values (PHSTVs) by utilizing the initial soil test values, the amount of fertilizer applied and the crop yields or nutrient (Suresh and Santhi, 2018). This study seeks to compare the effectiveness of different fertilizer recommendation approaches, specifically the low-medium-high and general recommendation approach, against the STCR approach on growth and yield of greengram in verification trial of *Alfisols*.

Material and Methods

Soil test crop response based fertilizer prescription equations for greengram was developed as per the methodology outlined by Ramamoorthy *et al.* (1967) during *kharif* 2022 and post-harvest soil test value prediction equations were developed through multiple regression analysis. The present investigation was carried out to validate the target yield equations and post-harvest soil test value prediction equations through verification trial during summer-2024 with greengram (BGS 9) at ZARS, GKVK, Bengaluru.

In this verification experiment, different fertilizer recommendation approaches were compared to validate the equation developed in the main test crop experiment, so that this equation may be

TABLE 1
Initial soil characteristics of the verification trial

Particulars	Values	Methodology
pH (1:2.5)	5.73	Potentiometry (Jackson,1973)
Electrical conductivity (dSm^{-1})	0.043	Conductometry (Jackson,1973)
Organic carbon (%)	0.47	Wet oxidation method (Walkley and Black,1934)
Available N (kg ha^{-1})	218.97	Alkaline peramanganate method (Subbiah and Asija,1956)
Available P_2O_5 (kg ha^{-1})	196.34	Bray's method (Jackson,1973)
Available K_2O (kg ha^{-1})	271.11	Flame photometry method (Page *et al*., 1982)
Available S (mg kg^{-1})	23.41	Turbidimetry method (Jackson,1973)
Exchangeable calcium [cmol (P^+) kg^{-1}]	4.09	Versenate titration method (Jackson,1973)
Exchangeable magnesium [cmol (p^+) kg^{-1}]	1.32	
DTPA iron (mg kg^{-1})	10.26	DTPA extraction method (Lindsay and Norvell,1978)
DTPA manganese (mg kg^{-1})	6.52	
DTPA copper (mg kg^{-1})	2.55	
DTPA zinc (mg kg^{-1})	3.07	

recommended to the farmers, in addition to validation of post-harvest soil test values developed through post-harvest soil test value prediction equation in comparison with the actual soil test values. The soil at the experimental site was sandy loam in texture and acidic, with a pH of 5.73 (Table 1). The electrical conductivity measured 0.043 dS m^{-1} and the organic carbon content was 0.47 per cent. Available nitrogen was low (218.97 kg N ha^{-1}), phosphorus was high (196.34 kg P_2O_5 ha^{-1}) and potassium was medium (271.11 kg K_2O ha^{-1}). The experiment was arranged in a randomized complete block design (RCBD) with twelve treatments, each replicated three times (Table 2).

TABLE 2
Treatment details of greengram in verification trial

T_1	Nutrients applied on ASTV (Inorganics) for STCR target yield 15 q ha^{-1}
T_2	Nutrients applied on PSTV (Inorganics) for STCR target yield 15 q ha^{-1}
T_3	Nutrients applied on ASTV (Integrated) for STCR target yield 15 q ha^{-1}
T_4	Nutrients applied on PSTV (Integrated) for STCR target yield 15 q ha^{-1}
T_5	Nutrients applied on ASTV (Inorganics) for STCR target yield 12 q ha^{-1}
T_6	Nutrients applied on PSTV (Inorganics) for STCR target yield 12 q ha^{-1}
T_7	Nutrients applied on ASTV (Integrated) for STCR target yield 12 q ha^{-1}
T_8	Nutrients applied on PSTV (Integrated) for STCR target yield 12 q ha^{-1}
T_9	Package of practice (RDF + FYM)
T_{10}	LMH through ASTV
T_{11}	LMH through PSTV
T_{12}	Absolute control

ASTV : Actual soil test values,
PSTV : Predicted soil test values

The following STCR fertilizer adjustment equations were used for fertilizer application to STCR treatments.

The following STCR fertilizer adjustment equations were used for fertilizer application to STCR treatments

STCR Inorganic approach	STCR Integrated approach
F.N.=11.056 T – 0.330 SN($KMnO_4$-N)	F.N.=10.541 T – 0.305 SN ($KMnO_4$ -N) – 0.653 OM
$F.P_2O_5$=6.946 T – 0.584 SP (Bray's-P_2O_5)	$F.P_2O_5$=5.955 T – 0.461 SP (Bray's- P_2O_5) – 0.092 OM
$F.K_2O$.=7.071 T – 0.221 SK (Am.Ace.K_2O)	$F.K_2O$.=8.554 T – 0.268 SK (Am.Ace.- K_2O) – 0.843 OM

Here, FN, FP_2O_5 and FK_2O represent the amounts of fertilizer nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) in kg ha^{-1}, respectively; T denotes the yield target in q ha^{-1}; SN, SP and SK refer to available soil nutrients measured as $KMnO_4$-N, Bray's-P_2O_5 and NH_4OAc-K_2O in kg ha^{-1}, respectively and OM indicates the amount of farmyard manure applied in t ha^{-1}.

A composite soil sample was collected from each plot at a depth of 0-20 cm after setting up the experiment and prior to its commencement. Based on the soil test results, NPK fertilizers were applied to achieve specific yield targets using the STCR and LMH nutrient approaches. Fertilizer application was also guided by predicted post-harvest soil test values, which were estimated using prediction equations (Table 3) derived from the main STCR experiment for greengram.

In this context, FN, FP_2O_5 and FK_2O indicate the quantities of fertilizer nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) in kg ha^{-1}, respectively. T represents the yield target in q ha^{-1}. SN, SP and SK correspond to the available soil nutrients measured as $KMnO_4$-N, Bray's-P_2O_5 and NH_4OAc-K_2O in kg ha^{-1}, respectively. OM denotes the amount of farmyard manure applied in t ha^{-1}.

The post-harvest soil test values for nitrogen, phosphorus and potassium in kodomillet (the previous crop) were predicted using these regression equations. These predicted values were used as the initial soil test values to prescribe the fertilizer nutrient doses for the verification trial in selected treatments for greengram. Data on kodomillet yield, initial soil test values and applied fertilizer nutrients were obtained from the AICRP on STCR at UAS, GKVK, Bengaluru to predict the post-harvest soil test values.

TABLE 3

Prediction equations for post-harvest soil nutrient parameters based on yield by greengram

Inorganic	R^2 value
PHN = 60.642 + 0.649 FN + 0.703 SN - 0.020 Y	0.866 **
PHP = - 9.028 + 0.410 FP + 1.196 SP - 0.030 Y	0.939 **
PHK = 26.565 - 0.325 FK + 0.822 SK - 0.029 Y	0.881 **
Integrated	
PHN = 71.425 - 0.217 FN + 0.679 SN - 0.001 Y	0.808 **
PHP = 31.376 + 0.206 FP + 0.778 SP - 0.003 Y	0.902 **
PHK = 50.045 + 0.335 FK + 0.815 SK - 0.052 Y	0.831 **

**Significant at P = 0.01

The quantities of nutrients applied per hectare for each treatment, using various approaches, are presented in Table 4. The recommended NPK for greengram is 25:50:50 kg ha^{-1} as per UAS-B package of practices. For all treatments, 50 per cent of the recommended

TABLE 4

Fertilizer nutrient and farmyard manure application rates per hectare under different approaches based on treatments and soil test values in the verification trial

Treatments	Soil test values (kg ha^{-1})			FYM (t ha^{-1})	Fertilizer nutrient (kg ha^{-1})		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
T_1	210.93	166.44	266.96	0	96.23	6.99	47.07
T_2	225.65	163.62	282.88	0	91.37	8.64	43.55

Continued....

TABLE 4 Continued....

Treatments	Soil test values (kg ha^{-1})			FYM ($t\ ha^{-1}$)	Fertilizer nutrient (kg ha^{-1})		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
T_3	207.95	180.99	275.49	7.5	89.79	5.20	48.16
T_4	227.49	220.62	263.01	7.5	83.83	0.00	51.50
T_5	206.45	190.89	272.23	0	64.54	0.00	24.69
T_6	231.70	183.70	262.96	0	56.21	0.00	26.74
T_7	210.56	195.52	263.89	7.5	57.37	0.00	25.60
T_8	219.92	231.29	262.95	7.5	54.52	0.00	25.85
T_9	216.91	208.14	284.71	7.5	25.00	50.00	50.00
T_{10}	212.05	197.97	275.59	7.5	37.50	37.50	50.00
T_{11}	242.18	202.91	300.02	7.5	37.50	37.50	45.83
T_{12}	215.79	213.98	242.63	0	0.00	0.00	0.00

T_1 : STCR through inorganics (15 q ha^{-1}) - Actual STV; T_2 : STCR through inorganics (15 q ha^{-1}) - Predicted STV
T_3 : STCR through integrated (15 q ha^{-1}) - Actual STV ; T_4 : STCR through integrated (15 q ha^{-1}) - Predicted STV
T_5 : STCR through inorganics (12 q ha^{-1}) - Actual STV; T_6 : STCR through inorganics (12 q ha^{-1}) - Predicted STV
T_7 : STCR through integrated (12 q ha^{-1}) - Actual STV; T_8 : STCR through integrated (12 q ha^{-1}) - Predicted STV
T_9 : Package of practice (as per UASB); T_{10} : LMH (STL) - Actual STV;
T_{11} : LMH (STL) - Predicted STV T_{12} : Absolute control

nitrogen was applied through urea, while the full dose of phosphorus and potassium was supplied at sowing as a basal application using single super phosphate (SSP) and muriate of potash (MoP), respectively. The remaining 50 per cent of nitrogen was applied 30 days after sowing (DAS). Biometric observations on the growth and yield parameters of greengram were recorded from five randomly selected plants per plot, with the results averaged. At harvest, the seed and haulm yields were determined from the net plot and expressed in quintals per hectare (q ha^{-1}).

The Response Yard Stick (RYS), per cent deviation and Value Cost Ratio (VCR) were computed by using the standard formulae as shown below.

$$\text{Yield response} = \text{Treated yield (Kg ha}^{-1}\text{)} - \text{Control yield (Kg ha}^{-1}\text{)}$$

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

$$\text{Per cent deviation} = \frac{[\text{Actual yield obtained (Kg ha}^{-1}\text{)} - \text{Targeted yield (Kg ha}^{-1}\text{)}]}{\text{Targeted yield (Kg ha}^{-1}\text{)}}$$

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

RESULTS AND DISCUSSION

Influence of different Approaches of Nutrient Application on Growth Parameters of Greengram

Data pertaining to plant height (cm) and number of trifoliate leaves per plant of greengram at 30 DAS, 60 DAS and at harvest as influenced by different approaches of nutrient application based on actual and predicted soil test values are presented in Table 5.

Plant height differed significantly at all the growth stages among the treatments except at 30 DAS. Significantly higher plant height of 26.72 cm and 37.48 cm was recorded in treatment T_3 (STCR integrated for the target 15 q ha^{-1} - Actual STV) at 60 DAS and at harvest, respectively compared to treatment T_{10} (LMH - Actual STV), T_{11} (LMH - predicted STV) and T_{12} (Absolute control). However, it was on par with treatment T_8 (STCR integrated for

TABLE 5

Influence of different approaches of nutrient application on plant height and number of trifoliate leaves of green gram at different intervals of crop growth

	Treatment details	Plant height (cm)			Number of trifoliate leaves per plant		
		30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	STCR inorganics (15q ha^{-1})-Actual STV	9.72	24.87	33.93	4	7	7
T_2	STCR inorganics (15q ha^{-1})-Predicted STV	9.56	24.17	33.33	4	7	7
T_3	STCR integrated (15q ha^{-1})-Actual STV	10.14	26.72	37.48	4	7	6
T_4	STCR integrated (15q ha^{-1})-Predicted STV	9.13	24.47	33.27	5	7	8
T_5	STCR inorganics (12q ha^{-1})-Actual STV	9.68	23.94	32.33	4	6	6
T_6	STCR inorganics (12q ha^{-1})-Predicted STV	8.47	23.89	32.67	4	6	6
T_7	STCR integrated (12q ha^{-1})-Actual STV	9.03	24.23	33.24	4	6	6
T_8	STCR integrated (12q ha^{-1})-Predicted STV	10.06	26.26	36.88	4	6	7
T_9	Package of practice	8.52	23.00	31.33	4	5	6
T_{10}	LMH (STL) - Actual STV	9.10	21.51	30.91	4	5	6
T_{11}	LMH (STL) - Predicted STV	8.29	20.39	29.11	4	5	6
T_{12}	Absolute control	7.09	17.61	21.93	3	5	5
	S.Em.±	0.74	0.82	1.15	0.25	0.22	0.71
	C.D.@5%	NS	2.386	3.371	NS	0.643	2.071

the target 12 q ha^{-1} - Predicted STV) and superior over LMH approach at 60 DAS and at harvest. The number of trifoliate leaves varied significantly at 60 DAS and at harvest, but not at 30 DAS. Treatment T_4 (STCR integrated for the target of 15 q ha^{-1} - Predicted STV) recorded significantly higher numbers of trifoliate leaves, with 7 leaves per plant at 60 DAS and 8 leaves per plant at harvest, followed by treatment T_3 (STCR integrated for the target of 15 q ha^{-1} - Actual STV). These treatments out performed T_{10} (LMH - Actual STV) and T_{11} (LMH - Predicted STV), while the least number of trifoliate leaves was observed in T_{12} (Absolute control).

The increased plant height and number of trifoliate leaves per plant in STCR approach was mainly due to application of higher dose of nitrogenous fertilizer in STCR treatment when compared to other treatments (LMH and package of practice). Abhirami *et al.* (2023) have also reported that increase in plant height in greengram through the STCR approach is attributed to the sufficient levels of NPK provided, which are essential for the formation of nucleic acids responsible for growth and development. The enhanced availability and better utilization of these nutrients by the crop are due to the conjunctive use of organic and inorganic fertilizers, which together promote vigorous vegetative growth in plants. The results of the present study are in accordance with Ravi *et al.* (2020) in soybean and Singh *et al.* (2021) in chickpea. Rath and Gulati (2020) recorded higher vegetative growth of greengram under STCR approach compared to the farmers practice and opined that the enhanced growth observed was due to the efficient utilization of nutrients from both organic manure and inorganic fertilizers. Targeted yield-based fertilizer application ensures a balanced and optimal supply of NPK, fostering synergistic interactions within the crop production system.

Influence of different Approaches of Nutrient Application on Yield Parameters of Green Gram

The data pertaining to number of pods per plant, pod length (cm), number of seeds per pod and test weight (g) as influenced by different approaches of fertilizer recommendations by considering actual and predicted soil test values are presented in Table 6. A significantly higher number of pods was recorded in the STCR target of 15 q ha^{-1} using the integrated approach, where fertilizer nutrients were applied based on actual soil test values (T_3), with an average of 19 pods. The lowest number of pods (9) was observed in the absolute control (T_{12}), which received no organic or inorganic fertilizers and this was on par with the STCR target of 15 q ha^{-1} using the inorganic approach, where nutrients were applied based on actual STV. Significantly, the maximum pod length (9.15 cm) was recorded in the STCR target of 15 q ha^{-1} using the integrated approach, where fertilizers were applied based on predicted soil test values (T_4), while the shortest pod length (7.15 cm) was noted in the absolute control (T_{12}). This was comparable to all other STCR treatments. The highest number of seeds per pod (13 seeds) was found in the STCR target of 15 q ha^{-1} with the integrated approach and actual soil test values (T_3), while the lowest (8 seeds) was recorded in the absolute control (T_{12}), which was on par with other STCR treatments, except for those following the LMH approach. Test weight (100 seeds) ranged from 3.88 g in the absolute control (T_{12}) to 4.26 g in the STCR integrated approach targeting 15 q ha^{-1} with predicted STV (T_4). Although there was no significant difference between treatments, numerically higher test weight (4.26 g) was observed in T_4. The increase in test weight may be attributed to better seed filling due to improved nutrient availability.

The data on yield parameters and yield clearly indicates that STCR inorganic and integrated approach of fertilizer recommendation for both the targets based on actual and predicted soil test values were superior compared to LMH approach and package of practice. These findings are in close accordance with those reported by Isha *et al.* (2024) who opined that nitrogen application during the early growth stages of plants has been found to stimulate vegetative growth, creating favorable conditions for achieving high yields. It plays a crucial role in chlorophyll formation and protein synthesis, directly contributing to increased plant protein content and consequently,

TABLE 6

Influence of different approaches of nutrient application on yield parameters of green gram

	Treatment details	No. of pods per plant	Pod length (cm)	No. of seeds per pod	Test weight (g)
T_1	STCR inorganics (15q ha^{-1})-Actual STV	18	8.71	13	4.23
T_2	STCR inorganics (15q ha^{-1})-Predicted STV	17	8.43	12	4.10
T_3	STCR integrated (15q ha^{-1})-Actual STV	19	8.92	13	4.20
T_4	STCR integrated (15q ha^{-1})-Predicted STV	19	9.15	13	4.26
T_5	STCR inorganics (12q ha^{-1})-Actual STV	16	8.47	12	4.16
T_6	STCR inorganics (12q ha^{-1})-Predicted STV	16	8.66	12	4.22
T_7	STCR integrated (12q ha^{-1})-Actual STV	17	8.63	13	4.17
T_8	STCR integrated (12q ha^{-1})-Predicted STV	17	8.70	13	4.22
T_9	Package of practice	14	8.32	13	4.22
T_{10}	LMH (STL)-Actual STV	13	8.03	12	4.11
T_{11}	LMH (STL)-Predicted STV	13	8.47	11	4.05
T_{12}	Absolute control	9	7.15	8	3.88
	S.Em.±	0.57	0.23	0.65	0.10
	C.D.@5%	1.672	0.691	1.893	NS

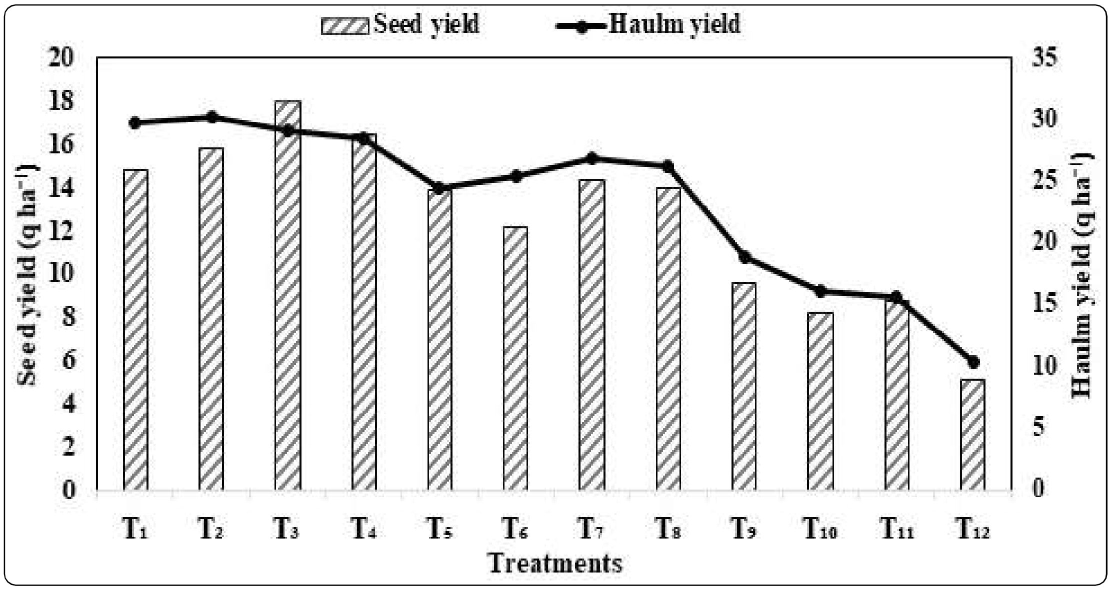

Fig. 1 : Influence of different approaches of fertilizer recommendation on seed and haulm yield of greengram

enhancing the overall yield. Phosphorus plays a significant role in various metabolic processes and energy producing reactions in plants and promotes blooming and seed formation, ultimately leading to increased yield. The application of potassium had both quantitative and qualitative improvements in green gram. The combination of chemical fertilizers with FYM created a favorable soil environment and provided essential nourishment for improved yield parameters.

The data on seed yield and haulm yield influenced by different fertilizer recommendation approaches, considering both actual and predicted soil test values, are presented in Fig. 1. A significantly higher seed yield of 17.99 q ha^{-1} was recorded in the STCR approach targeting 15 q ha^{-1}, where nutrients were applied using an integrated approach based on actual soil test values (T_3). The lowest seed yield (6.04 q ha^{-1}) was observed in the absolute control (T_{12}). However, the seed yield in T_3 was on par with treatments T_1 (14.77 q ha^{-1}), T_2 (15.78 q ha^{-1}), T_4 (16.49 q ha^{-1}) and T_7 (14.37 q ha^{-1}). Similarly, a significantly higher haulm yield of 30.25 q ha^{-1} was recorded in T_2 [STCR in organics (15 q ha^{-1}) - Predicted STV], which was comparable to T_1 (29.79 q ha^{-1}), T_3 (29.13 q ha^{-1}) and T_4 (28.48 q ha^{-1}), all targeting a yield of 15 q ha^{-1}. The lowest haulm yield (10.29 q ha^{-1}) was recorded in the absolute control (T_{12}).

The higher yield in STCR treatments could be attributed to the ability of targeted yield approaches to satisfy the nutrient demand of crop more efficiently. The combination of chemical fertilizers with FYM created a favorable soil environment and provided essential nourishment for improved yield parameters and ultimately resulting in maximum seed yield (Krishna Murthy *et al.,* 2023a). Indeed, the absolute control exhibited poor yield attributes and the lowest seed yield because it did not receive any fertilization, neither chemical nor organic. The absence of nutrient supplementation in this treatment resulted in limited plant growth and productivity (Abhirami *et al.,* 2024).

The improved nutrient uptake and increased nutrient use efficiency under the STCR approach, compared to the LMH and POP methods, positively impacted growth and yield attributes, leading to a higher greengram yield. Additionally, the synergistic effect of combining organic and inorganic inputs in the STCR integrated approach likely enhanced the soil's chemical, physical and biological properties, contributing to the increased yield (Singh *et al.,* 2021). The results are in accordance with the findings of Raghav *et al.* (2019) who have reported that the increase in yield attributes of soybean in STCR approach compared to LMH, RDF and Farmer's practice was ascribed to the balanced application of nutrients by considering the soil test values and nutrient requirement by the crop for producing certain fixed yield target.

It is important to notice that application of nutrients based on predicted soil test values for the targets of 15 and 12 q ha^{-1} in both inorganic and integrated approach have recorded higher yield and yield attributes over LMH and POP approaches which was mainly due to increased fertilizer nutrient application. However, there was no significant difference between actual and predicted soil test values indicating the accuracy of soil test values which were predicted making use of data on initial soil test values, fertilizer dose and yield of kodo millet (previous crop in the experimental site) by adopting post-harvest soil test values prediction equations that were developed during the main experiment. Thus, the predicted soil test values could be used with confidence to prescribe the fertilizer nutrient dose in a cropping sequence and therefore testing the soil after each crop to recommend the fertilizers can be avoided. Similar results were recorded by Coumaravel *et al.* (2016) for maize and Gangola *et al.* (2017) for maize-chickpea sequence.

Yield Response and Economics of Greengram as Influenced by Different Approaches of Nutrient Application

The data on yield response and cost economics of greengram cultivation under different nutrient recommendation approaches, based on actual and predicted soil test values are presented in Table 7. Yield response refers to the additional yield obtained over the control plot due to the application of fertilizer nutrients. The highest yield response of 12.87 q ha^{-1} was observed when NPK fertilizers, along with 7.5 t ha^{-1} farmyard manure, were applied using the STCR integrated approach for a target yield of 15 q ha^{-1} based on actual soil test values (T_3). This was followed by 11.37 q ha^{-1} for the same target yield using the integrated approach based on predicted soil test values (T_4). In contrast, the lowest yield response of 3.12 q ha^{-1} was recorded in the LMH approach, where nutrients were applied based on actual soil test values

TABLE 7

Yield response, response yardstick, per cent deviation and value cost ratio of greengram production as influenced by different approaches of nutrient application in summer

	Treatments	Seed Yield\	Yield response	RYS	Per cent deviation	VCR
		q ha^{-1}		kg kg^{-1}	%	
T_1	STCR inorganics (15q ha^{-1})-Actual STV	14.77	9.65	6.42	-1.52	27.58
T_2	STCR inorganics (15q ha^{-1})-Predicted STV	15.78	10.66	7.43	5.23	31.09
T_3	STCR integrated (15q ha^{-1})-Actual STV	17.99	12.87	8.99	19.91	7.91
T_4	STCR integrated (15q ha^{-1})-Predicted STV	16.49	11.37	8.40	9.93	7.14
T_5	STCR inorganics (12q ha^{-1})-Actual STV	13.85	8.73	9.79	15.44	49.49
T_6	STCR inorganics (12q ha^{-1})-Predicted STV	12.15	7.03	8.48	1.25	40.90
T_7	STCR integrated (12q ha^{-1})-Actual STV	14.37	9.25	11.15	19.76	6.31
T_8	STCR integrated (12q ha^{-1})-Predicted STV	13.95	8.83	10.98	16.22	6.04
T_9	Package of practice	9.58	4.46	3.57	-20.14	2.39
T_{10}	LMH (STL)-Actual STV	8.24	3.12	2.50	-31.30	1.74
T_{11}	LMH (STL)-predicted STV	8.80	3.68	3.05	-26.67	2.06
T_{12}	Absolute control	5.12	-	-	-57.31	-

(T_{10}). The response yardstick (RYS), which indicates the yield obtained in kg per kg of NPK applied in each treatment, was highest in the STCR integrated approach targeting 12 q ha^{-1} with nutrients applied based on actual soil test values (11.15 kg kg^{-1}), followed by 10.98 kg kg^{-1} for the same target using predicted soil test values. The lowest RYS was recorded in the LMH approach using actual soil test values (2.50 kg kg^{-1}). The percentage deviation measures the yield variation from the fixed target or genetic potential of the crop. Positive deviations were observed in the STCR target of 15 q ha^{-1}, based on both actual (19.91%) and predicted (9.93%) soil test values, using the integrated approach. Similarly, positive deviations were noted for the STCR target of 12 q ha^{-1}, based on actual (19.76%) and predicted (16.22%) soil test values using the integrated approach. The lowest deviation was observed in the STCR inorganic approach for a 15 q ha^{-1} target based on actual soil test values (-1.52%) and in the package of practice (-20.14%). However, larger negative deviations were recorded in the LMH approach using actual (-31.30%) and predicted (-26.67%) soil test values, as well as in the absolute control (-57.31%), indicating the crop did not achieve its genetic yield potential in these treatments. A higher value cost ratio (VCR) of 49.49 was recorded in the STCR inorganic approach targeting 12 q ha^{-1} with nutrients applied based on actual soil test values (T_5), followed by 40.90 in the same target using predicted soil test values (T_6). The lowest VCR of 1.74 was recorded in the LMH approach using actual soil test values (T_{10}).

The higher yield response obtained in STCR approach compared to LMH approach and package of practice was due to higher seed yield of greengram obtained in STCR treatments over control plot. Higher RYS in STCR targets with integrated approach indicated that the NPK fertilizer nutrients were applied in a balanced way by taking into consideration of the nutrient requirement of the crop and was effectively utilized by the crop to achieve the target as compared to other treatments. Whereas LMH approach recorded lower RYS because here nutrient requirement of the crop is not considered and just based on low, medium and high nutrient status the fertilizers were applied. Even though negative deviation was observed in STCR integrated approach for the targeted yield of 15 q ha^{-1}, the variation was within ± 10.00 per cent. The per cent deviation of ± 10.00 will be generally considered as a best equation otherwise the equations will be modified (Krishnamurthy *et al.,* 2023b). Hence, this equation is suitable for recommending fertilizer dose for greengram to farmers.

Value-cost ratio (VCR) worked out was found to be higher in STCR inorganic approach for the target yield of 12 q ha^{-1} followed by STCR inorganic approach for the target yield of 15 q ha^{-1}. However, STCR integrated treatments recorded lower VCR than the inorganic treatments. The higher VCR in inorganic treatments could be mainly due to lower levels of NPK fertilizer, no phosphatic fertilizer and no farmyard manure where applied in both the seasons compared to integrated approach. Even though higher yields were recorded in STCR integrated approach, the VCR was very low mainly due to high cost of phosphatic fertilizer and farmyard manure applied to these treatments. These results are in conformity with Krishnamurthy *et al.* (2023c).

Based on the study, it can be concluded that the STCR-targeted yield equations developed for greengram are highly suitable for the *Alfisols* of the Eastern Dry Zone of Karnataka to achieve higher yields. The STCR approach, with a target of 15 q ha^{-1} based on predicted soil test values using an integrated nutrient management strategy, outperformed the LMH approach and the POP. Although the VCR was lower in the STCR integrated approach due to the high cost of farmyard manure and phosphatic fertilizers, these treatments should still be recommended for applying balanced fertilizer doses. This approach can encourage farmers to use their own compost or FYM to reduce production costs and enhance benefits, while also maintaining soil health. Additionally, the use of predicted soil test values for fertilizer recommendations can be relied upon in a cropping sequence, as no significant difference in yield was observed between recommendations based on actual versus predicted soil test values. This can help avoid the need for soil testing after every crop in the sequence.

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