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Impact of STCR approach on productivity and profitability of cowpea-potato-cucumber cropping sequence in *Vertisols* of Chhattisgarh plains

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Abstract
A field experiment was conducted during 2022-23 and 2023-24 at the Research cum Demonstration Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, to evaluate the impact of Soil Test Crop Response (STCR)-based nutrient management on productivity and profitability in a Cowpea-Potato-Cucumber cropping system under *Vertisols*. The study followed the All India Coordinated Research Project (AICRP) on STCR guidelines and employed a fertility gradient approach to examine soil test-yield relationships. Treatments included Control ($N_0P_0K_0$), Recommended Dose of Fertilizers (RDF), and STCR-based fertilizer doses for each crop. Results revealed significant improvements in crop yields and economic returns with STCR treatments. The highest pooled yield was obtained under the STCR-based treatment applied to all three crops T8 (ST-ST-ST), with cowpea, potato and cucumber yield of 9.55, 25.78 and 5.65 t/ha respectively. Correspondingly, the highest net return (₹567,675/ha) and benefit-cost ratio (3.18) were also recorded under this treatment. Intermediate treatments, where STCR based fertilizers were applied to one or two crops T4 (R-ST-ST), T6 (ST-ST-R) and T7 (ST-R-ST), also performed better than RDF and control treatments, indicating the incremental benefits of partial STCR adoption. The findings confirm that STCR-based nutrient management enhances system productivity, improves nutrient use efficiency, and provides a profitable and sustainable nutrient management approach for intensive cropping systems in *Vertisol* regions.

Keywords: Soil Test Crop Response (STCR), cowpea-potato-cucumber cropping system, fertility gradient approach, *Vertisols*, crop yield, economic analysis, benefit-cost ratio

Introduction
Vegetable based farming system consists of appropriate crops for every season suitable for the agroclimatic condition as per the needs of farmers as well as consumer with proper allocation of available resources of a farm to the production enterprises in the manner that helps the attainment of the goals of maximization of farm income and employment. To meet the objectives of poverty reduction, nutrition and food security, competitiveness and sustainability, several researchers have suggested farming system approach including the vegetable based farming system (Anon, 2011) [2].
Cowpea (*Vigna unguiculata* L.) commonly plays an important role in nutritional aspects also the green tender pod contain moisture (84.6%), protein (4.6%), carbohydrate (8.0%), fat (0.2%) and rich source of calcium, phosphorus, iron, etc. (Aykroyd, 1963) [1].
Potato (*Solanum tuberosum* L.) is a source of carbohydrates (22.6 g/100g), starch (16.3 g/100g) and proteins (1.6 g/100g). It also contains a good amount of essential amino acids like leucine, tryptophan and isoleucine (Khurana and Naik, 2003) [4].
Cucumber (*Cucumis sativus* L.) is rich in a number of vitamins *viz.* vitamin K (16.4 mg), also known as the clotting vitamin, vitamin A (105 IU), vitamin C (2.8 mg), vitamin E (0.03 mg), riboflavin (0.033 mg), niacin (0.098 mg), pantothenic acid (0.259 mg), pyridoxine (0.040mg). Cucumbers are a rich source of a number of minerals like calcium (16 mg), potassium (147 mg), sodium (2 mg), iron (0.28 mg). Likewise, Energy (15 Kcal), carbohydrate (3.63 g), protein (0.65 g), total fat (0.11 g), cholesterol (0 g) and dietary fibre (0.5 g) per 100 g. (Source: USDA

Nutrient Database).

Fertilizer nutrient recommendations are usually given for different crops by taking into consideration the soil available nutrient status which is being categorised as low, medium and high. Among the various methods of fertilizer recommendations, the soil test crop response (STCR) approach is one of the most scientific approach of nutrient application for crops by using the soil test values and targeted yield equations. These equations are developed by considering the contribution of nutrients from soil, manures and fertilizers. (Ramamoorthy *et al.*, 1969) [7].

Cropping system refers to the principles and practices of cropping pattern followed on a farm and their interaction with farm resources, technology, other farm enterprises, aerial and edaphic environment to suit the regional or national or global needs and production strategy. In other words, a cropping system refers to a combination of crops in time and space. Combinations in time occur when crops occupy different growing periods and combinations in space occur when crops are inter-planted. When annual crops are considered, a cropping system usually means the combination of crops within a given year (Willey *et al.*, 1989) [9]. Cropping systems involving vegetable are generally practiced near urban or peri-urban areas and have higher cash flow. With higher cropping intensities higher returns are expected, but lower cropping intensity with high market value crops results in higher price than the crops of low market value with high cropping intensities (Singh *et al.*, 2013) [8].

Materials and Methods

A field experiment was conducted based on STCR methodology on Cowpea - Potato - Cucumber cropping system with the variety Kashi Kanchan, Kufri Pukhraj and Pusa Uday at Research cum Demonstration Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur district of Chhattisgarh (India) during the *Kharif*, *Rabi* and Summer season of the year 2022-2023 and 2023-2024. The present study was carried out following the approved layout plan of the All India Coordinated Research Project (AICRP) on Soil Test-Crop Response (STCR). The experimental design was based on the field methodology developed by Ramamoorthy *et al.* (1967) [7], which involves creating fertility gradients to study soil test-crop yield relationships. The experimental field was divided into three equal strips, nominated as R-I, R-II, and R-III, to develop variations in soil fertility status. Prior to the main cropping sequence, fertility gradients were established by applying graded doses of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) fertilizers to generate differential soil test values and yield responses.

For cowpea, the fertilizer treatments included Control (0-0-0), Recommended Dose of Fertilizers (RDF) at 20:60:40 kg N: P_2O_5: K_2O ha^{-1}, and STCR-based dose (ST) at 36:78:28 kg N: P_2O_5: K_2O ha^{-1}. For potato, the corresponding treatments were Control (0-0-0), RDF (150:100:100 kg N: P_2O_5: K_2O ha^{-1}), and ST (195:130:70 kg N: P_2O_5: K_2O ha^{-1}). Similarly, for cucumber, the treatments included Control (0-0-0), RDF (70:50:50 kg N: P_2O_5: K_2O ha^{-1}), and ST (91:65:35 kg N: P_2O_5: K_2O ha^{-1}). Urea was used as the nitrogen source, single super phosphate (SSP) for phosphorus, and muriate of potash for potassium (MOP).

For all crops, 50% of the nitrogen along with the full dose of phosphorus and potassium was applied as a basal dose at the time of sowing or planting. The remaining 50% of nitrogen was top-dressed 30 days after sowing (DAS). This method allowed for evaluating crop responses under varying soil fertility levels in *vertisols* of the Chhattisgarh plains. Cost of cultivation id the total expenditure incurred for raising crop in treatment, the cost of cultivation included variable and fixed costs. Gross return is the total monetary value of economic produce obtained from the crop raised in the various treatments it is calculated based on price of local market. B:C ratio calculated by gross return divided by cost of cultivation of treatments ha^{-1}.

Results

The impact of various soil test-based nutrient management treatments on crop yields and economic returns in the Cowpea-Potato-Cucumber cropping system is presented in Table 1 and Table 2. The results revealed significant differences among treatments across two consecutive years (2022-23 and 2023-24), with the STCR-based treatment combinations consistently outperforming the recommended dose of fertilizers (RDF) and control.

Among all treatments, the ST-ST-ST (T8) treatment, where Soil Test Crop Response (STCR) recommendations were applied to all three crops, recorded the highest cowpea yield (6.60 and 12.50 t/ha in 2022-23 and 2023-24, respectively), with a pooled mean of 9.55 t/ha. Similarly, total tuber yield of potato was maximum under T8, registering 21.35 and 30.20 t/ha in the two years, with a pooled mean of 25.78 t/ha. In the case of cucumber, the same treatment also produced the highest yield (3.25 and 8.05 t/ha), with a pooled average of 5.65 t/ha. On the contrary, the lowest yields across all crops were observed under the control (T9: $N_0P_0K_0$) treatment, emphasizing the critical role of balanced and targeted fertilization. Similarly, findings by Singh *et al.* (2020) [5] in their study on STCR-based fertilizer prescriptions for potato Studies have shown that treatments under STCR not only improve tuber yield but also significantly enhance growth parameters compared to RDF and unfertilized plots. Stronger vegetative growth supports more efficient carbohydrate partitioning into the tubers during the bulking stage, which is crucial for achieving higher marketable yields. Therefore, the correlation between enhanced growth parameters and yield under STCR-based fertilizer application confirms that optimal nutrient management not only improves crop health but also directly contributes to maximizing productivity in potato cultivation.

Economic analysis repeated the yield trends, with the T8 (ST-ST-ST) treatment again showing superiority. It recorded the highest net returns of ₹485,750 and ₹519,938 in 2022-23 and 2023-24, respectively, with a pooled mean net return of ₹567,675. The corresponding benefit-cost (B:C) ratio was also the highest under this treatment, recorded at 2.35 in 2022-23, 4.01 in 2023-24, and a pooled average of 3.18. In contrast, the control treatment (T9) exhibited the lowest economic performance with a pooled B:C ratio of only 1.14, confirming the uneconomical nature of nutrient-deficient cropping systems.

Treatments where STCR was applied to one or two crops *e.g.*, T4 (R-ST-ST), T6 (ST-ST-R) and T7 (ST-R-ST) also showed considerable improvements in yield and profitability compared to RDF and Unfertilized Control treatments. For instance, T6 (ST-ST-R) achieved a pooled cowpea yield of 8.41 t/ha, potato yield of 24.62 t/ha, and cucumber yield of 4.67 t/ha, alongside a net return of ₹520,665 and a B:C ratio of 2.85, T4 (R-ST-ST) produced a pooled cowpea yield of 7.63 t/ha, potato yield of 23.87 t/ha, and cucumber yield of 5.23 t/ha, accompanied by a net return of ₹511,335 and B:C ratio of 2.78. Similarly, T7 (ST-R-ST) achieved pooled yields of 8.93 t/ha (cowpea), 22.04 t/ha (potato), and 5.05 t/ha (cucumber), with a net return of ₹494,405 and a B:C ratio of 2. 75. These findings align with the work of Jena *et al.* (2022) [3], who demonstrated that STCR-based fertilizer application in a rice-vegetable cropping system significantly improved crop productivity and economic returns. STCR leads to optimal crop response, lower input costs per unit yield, and better nutrient recovery, all of which contribute to maximum profitability.

Table 1: Effect of various treatments on, Total tuber yield of potato (t/ha), Cowpea Yield (t/ha) and Cucumber Yield (t/ha).

Treatments	Cowpea Yield t/ha			Total tuber yield of potat (t/ha)			Cucumber Yield t/ha		
	2022-23	2023-24	Pooled mean	2022-23	2023-24	Pooled mean	2022-23	2023-24	Pooled mean
T_1 (R-R-R)	5.32	9.24	7.28	17.13	20.35	18.74	2.17	6.11	4.14
T2 (R-R-ST)	5.37	9.69	7.53	17.30	23.12	20.21	2.41	7.27	4.84
T3 (R-ST-R)	5.14	9.58	7.36	19.26	26.34	22.80	2.25	6.55	4.40
T4 (R-ST-ST)	5.55	9.71	7.63	19.35	28.38	23.87	2.63	7.82	5.23
T5 (ST-R-R)	5.99	10.26	8.13	18.11	23.09	20.60	2.20	6.29	4.25
T6 (ST-ST-R)	5.90	10.92	8.41	20.75	28.49	24.62	2.28	7.06	4.67
T7 (ST-R-ST)	6.09	11.77	8.93	18.99	25.09	22.04	2.60	7.50	5.05
T8 (ST-ST-ST)	6.60	12.50	9.55	21.35	30.20	25.78	3.25	8.05	5.65
T9 (N0P0K0)	2.55	6.32	4.44	10.44	11.57	11.01	0.71	3.42	2.07
CD	0.52	1.65	0.85	4.03	5.45	4.74	0.54	1.44	1.03

Table 2: Economics of cropping system influenced by different treatments

Treatments	Economics of cropping system											
	2022-23				2023-24				Pooled mean			
	cost	Gross return	Net return	B:C ratio	cost	Gross return	Net return	B:C ratio	cost	Gross return	Net return	B:C ratio
T 1 (R-R-R)	139938	239252	379190	1.71	125232	452490	327258	2.61	132585	283255	415840	2.16
T2 (R-R-ST)	140353	248017	388370	1.77	125646	511560	385914	3.07	133000	316965.5	449965	2.42
T3 (R-ST-R)	143954	264176	408130	1.84	129248	550340	421092	3.26	136601	342634	479235	2.55
T4 (R-ST-ST)	144369	281081	425450	1.95	129662	597220	467558	3.61	137016	374319.5	511335	2.78
T5 (ST-R-R)	140377	264003	404380	1.88	125232	503910	378678	3.02	132805	321340.5	454145	2.45
T6 (ST-ST-R)	144393	297507	441900	2.06	129248	599430	470182	3.64	136821	383844.5	520665	2.85
T7 (ST-R-ST)	140792	287508	428300	2.04	125646	560510	434864	3.46	133219	361186	494405	2.75
T8 (ST-ST-ST)	144808	340942	485750	2.35	129662	649600	519938	4.01	137235	430440	567675	3.18
T9 (N0 P0 K0)	122234	98476	204710	0.81	107529	265150	157621	1.47	114882	128048.5	234930	1.14

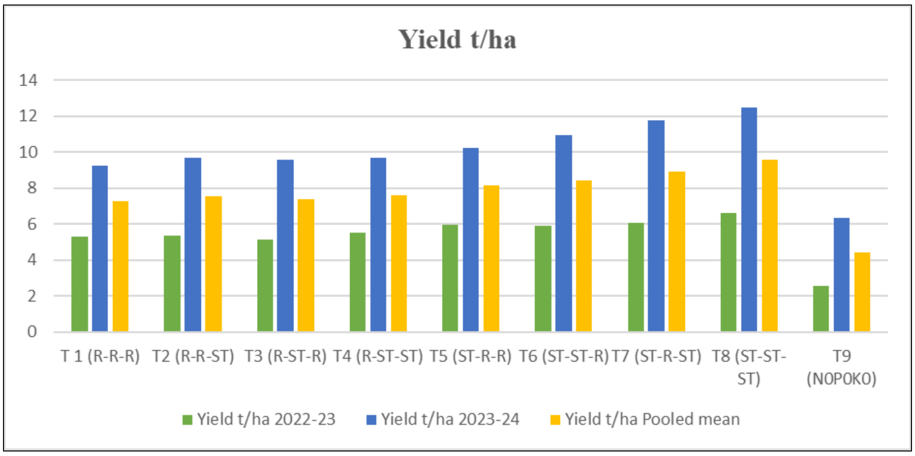

Fig 1: Effect of different fertilizer treatments on cowpea yield (t/ha)

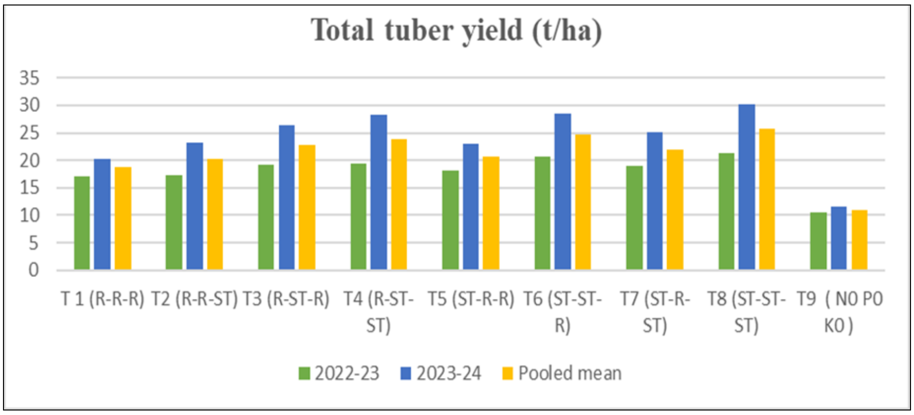

Fig 2: Effect of different fertilizer treatments on potato yield (t/ha)

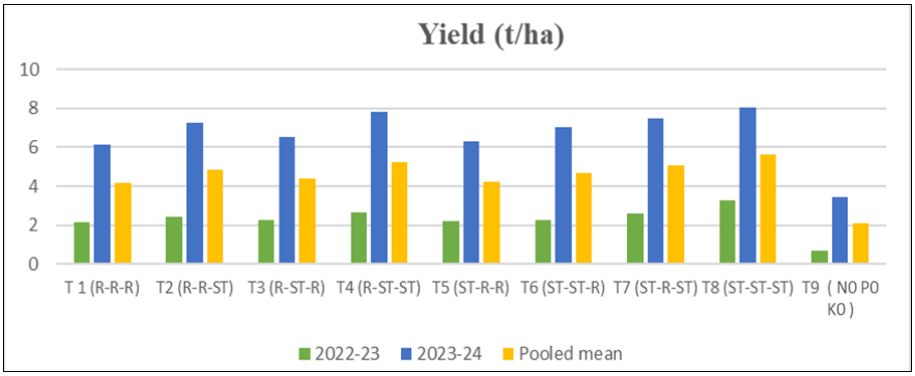

Fig 3: Effect of different fertilizer treatments on cucumber yield (t/ha)

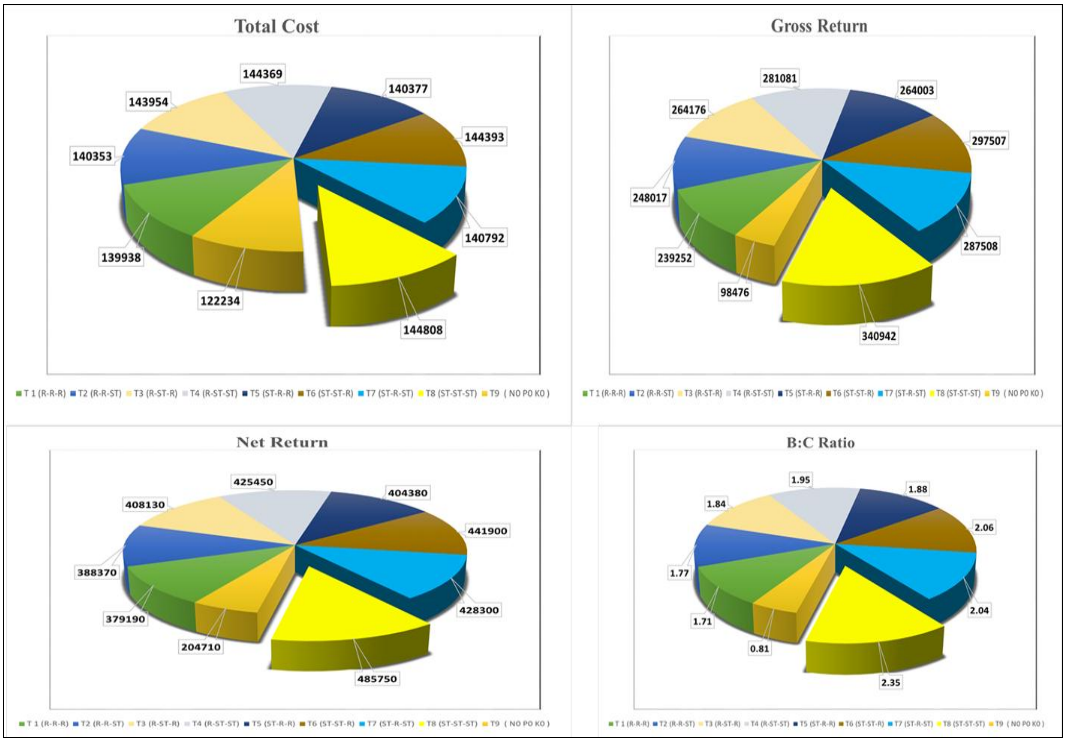

Fig 4: Effect of different fertilizer treatments on total cost, gross return and net return of cropping system of 2023

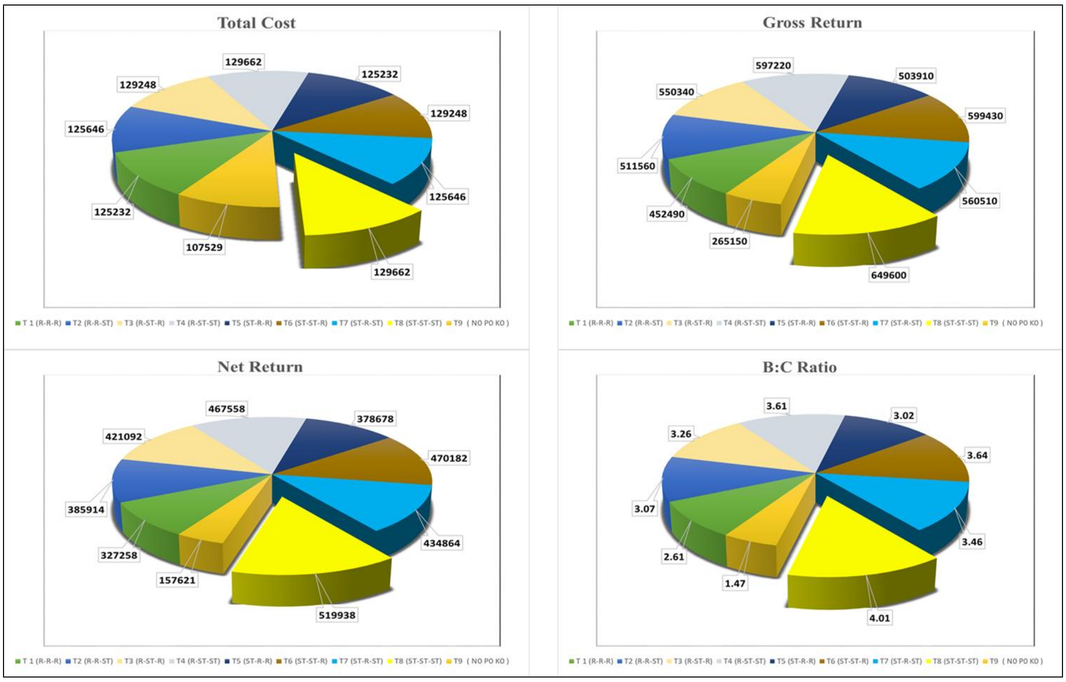

Fig 5: Effect of different fertilizer treatments on total cost, gross return and net return of cropping system of 2024

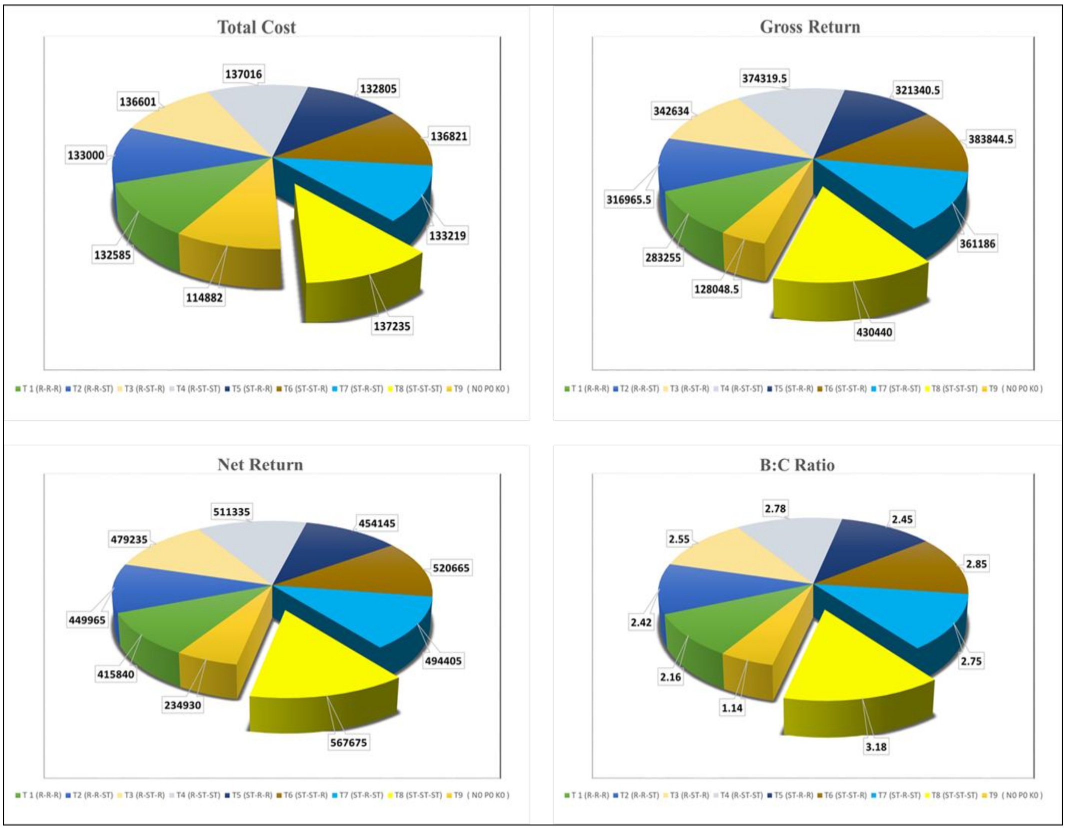

Fig 6: Effect of different fertilizer treatments on total cost, gross return and net return of cropping system on pooled basis

Summary

The findings from this study underscore the effectiveness of the STCR (Soil Test Crop Response) approach in optimizing yield and profitability in the Cowpea-Potato-Cucumber cropping system on vertisols of the Chhattisgarh plains. The STCR-managed cropping system (T8: ST-ST-ST), where nutrient recommendations were applied to all three crops based on soil test values, resulted in the highest yields and economic returns, validating the efficiency of site-specific nutrient management. Intermediate treatments such as T4 and T7, where STCR was applied to two crops, also showed significantly improved system performance over RDF and control. Overall, the adoption of STCR-based nutrient management enhances productivity, maximizes resource use efficiency, and provides a sustainable pathway for improving farmer incomes in intensive cropping systems.

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