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Long-term effect of STCR (Soil test and crop response) based nutrient management on soil properties of a Vertisol on vertical variability under rice-wheat cropping system

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Abstract
This field experiment was established during *rabi* season of 2020-21 at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in an on-going research experiment of AICRP on STCR (Soil test and crop response) initiated during 2008, to assess the vertical variability in properties of post-harvest soil under rice-wheat cropping system. This study was consisted of six treatments of nutrient management based on STCR (T_1: Control; T_2: RDF; T_3: TY- 50 and 45 q ha^{-1} for rice and wheat; T_4: TY- 60 q ha^{-1}; T_5: TY- 50 and 45 q with FYM 5 t ha^{-1} for rice and wheat and T_6: TY- 60 q with 5 t FYM ha^{-1}) at different soil depths (0-15, 15-30 and 30-45 cm). Results revealed that STCR based nutrient management practices significantly affected the variability of physico-chemical properties of soil at different soil depths except soil pH. Highest values of EC, OC, available N, P, K and S and CEC were obtained under treatment T_6, while content in calcium carbonate of soil was obtained highest under control. It was also revealed that the values of different soil properties were decreased with increased in soil depths except soil pH, calcium carbonate and CEC of soil.

Keywords: STCR approach, rice-wheat cropping system, soil depth, soil properties

1. Introduction

A better approach for a balanced application of nutrients is to manage nutrients based on STCR (Soil Test Crop Response) fertilizer recommendations for targeted yield utilizing defined fertilizer adjustment equations for crops. The aim of this study was to determine how soil properties, under the rice-wheat cropping system changed as a result of fertilizer recommendations based on the STCR.

One of the most common cropping systems in India is the rice-wheat system, which accounts for 75% of the country's total food grain output with total acreage of 44.10 and 31.36 M ha, production of 121.03 and 107.86 Mt, and productivity of 4.10 and 3.40 t ha-1 [1]. The total area of rice and wheat in Madhya Pradesh is 2.04 and 6.03 M ha, respectively, with production of 4.12 and 18.58 Mt and productivity of 2.02 and 3.08 t ha-1, respectively [2].

The use of STCR-INM (Soil test crop response- Integrated nutrient management) based fertilizer adjustment equations has proven to be very helpful for prescribing fertilizer doses to crops grown in rice-wheat sequence in order to achieve higher productivity, improving the content of available nutrients in soil, and preventing over or under usage of fertilizer inputs [3]. Additionally, it contributes to increased soil health as well as fertilizer savings and economic growth.

Targeted yield approach (Ramamoorthy, Narasinham, and Dinesh 1967) [4] based on fertilizer Adjustment equations on soil test crop response (STCR) correlation helps in balanced fertilization and nutrient application in the soil The targeted yield approach makes the assumption that crop nutrient uptake and grain yield (economic product) have a linear relationship. Consequently, the targeted yield approach achieves a compromise between "fertilizing the crop" and "fertilizing the soil". This approach can be used for individual field situations and also as a better approximation for planning the requirement of fertilizers on area basis for a given level of crop production.

Keeping all these facts in consideration, this study (Initiated in 2008) was undertaken in the ongoing long-term experiment at Research Farm, of Department of Soil Science, JNKVV, Jabalpur, India in 2020-21 to assess the vertical variability in properties of post-harvest soil under rice-wheat cropping system.

2. Materials and Methods
2.1 Technical programme

Experimental sites	**:**	**AICRP on STCR field, Research Farm, JNKVV, Jabalpur**
Experimental design	:	Randomized Block Design (RBD)
Number of treatments	:	06
Soil depths	:	03 (0-15, 15-30 and 30-45 cm)
No. of replications	:	04
Total No. of soil samples	:	72

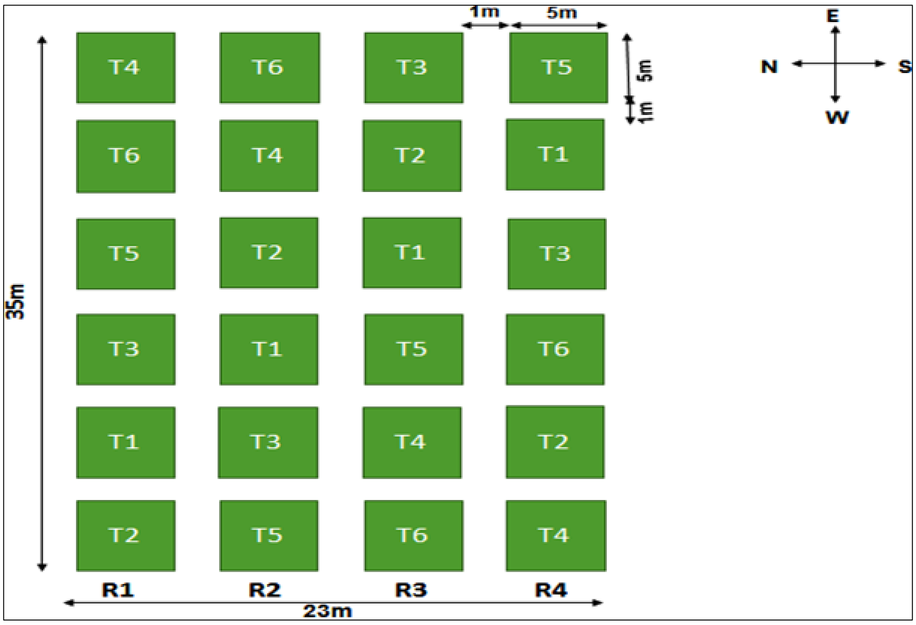

Fig 1: Layout of experimental field

2.2 Treatment details
T_1 - Control (No fertilizer)
T_2 - RDF (120:60:40 kg for rice and 120:80:60 kg for wheat)
T_3 - Targeted yield 50 q ha^{-1} for rice and 45 q ha^{-1} for wheat
T_4 - Targeted yield 60 q ha^{-1} for rice and wheat
T_5 - Targeted yield 50 and 45 q + FYM 5 t ha^{-1} for rice and wheat
T_6 - Targeted yield 60 q + FYM 5 t ha^{-1} for rice and wheat

2.3 Fertilizer Adjustment Equations

Rice		Wheat	
FN =	4.25 T – 0.45 SN	FN =	4.40 T – 0.40 SN
FP_2O_5 =	3.55 T – 4.89 SP	FP_2O_5 =	4.00 T – 5.73 SP
FK_2O =	2.10 T – 0.18 SK	FK_2O =	2.53 T – 0.16 SK

Where - FN, FP_2O_5 and FK_2O - fertilizer N, P_2O_5 and K_2O in kg ha^{-1} rates.
SN, SP and SK - Soil test values in kg ha^{-1}
T is the targeted yield of crop in Kg ha^{-1}

2.4 Physico-Chemical analysis of soil
Physico-chemical characteristics of soil, including soil pH, electrical conductivity, soil organic carbon, and available nutrients (nitrogen, phosphorus, potassium, and sulphur), calcium carbonate and cation exchange capacity, were assessed in this study at soil depths of 0–15, 15–30, and 30–45 cm were determined by using standard procedures.

Methodologies	
Soil pH	Soil pH was determined by 1:2.5 soil water suspensions and measured by pH meter at 25 ºC as described by Jakson (1973).
Electrical conductivity	Electrical conductivity was determined by using digital conductivity meter as per procedure by Jakson (1973) in deci siemens per meter (dS m^{-1}) at 25 ºC.
Organic carbon	Rapid titration method as suggested by Walkley and Black (1934) [5].
Available nitrogen	Alkaline potassium permanganate method as described by Subbiah and Asija (1956) [6].
Available phosphorus	Available phosphorus extraction procedure as described by Olsen's *et al.* (1954) and the absorbance of the developed blue colour was read on Spectrophotometer at 660 nm wavelength [7].
Available potassium	The available potassium was extracted with neutral normal ammonium acetate and estimated by using Flame photometer as described by Jakson (1973) [4].
Available sulphur	The available sulphur in soil was extracted with 0.15% $CaCl_2$ solution and estimated by turbidimetric method as suggested by Chesin and Yien (1951) [8].
Calcium carbonate	Rapid back titration method as described by (Jackson, 1973) [3].
Cation exchange capacity (CEC)	The CEC content in soil was determined by equilibrating the soil, with neutral normal ammonium acetate solution which saturates the soil surface with NH_4^+ ions. (Amma (1989) [9].
Statistical analysis	The data on different parameters were tabulated and analyzed statistically by using analysis of variance (ANOVA) the effects of STCR based nutrient management on soil properties for Randomized Block Design was worked out and the significance of treatments were tested to draw valid conclusion as described by Gomez and Gomez (1984) [10].

3. Results and Discussion

3.1 Soil pH

Variability in soil pH across the soil depths as affected by STCR based nutrient management was found statistically non-significant (Table 1). Results of the present study are in well agreement with those reported by Agarwal *et al.* (2010) [11]. Highest values of soil pH (7.39, 7.42 and 7.45) across the soil depths were obtained under control and lowest in T_6. Similar findings were also reported by Rawal *et al.* (2015) [12] and Kanaujia (2016) [13]. It was also found that soil pH increased with successive increase in soil depths and highest was found at 30-45 cm and lowest at 0-15 cm soil depth. These findings are corroborates with Katkar *et al.* (2014) [14].

3.2 Electrical conductivity

Electrical conductivity of soil were significantly affected by treatments of nutrient management over the soil depths with maximum under T_6 and lowest in control (Table 1). Similarly, results obtained by Kumar *et al.* (2020) [15]. It have been noted that soil EC decreased with increase in soil depths with maximum at 0-15 cm and minimum at 30-45 cm soil depths. The findings are good agreements and well supported by Porte *et al.* (2018) [16].

3.3 Organic carbon

The data clearly indicated that soil OC content was significantly affected by different doses of NPK with and without FYM where applied which brought about improvement in soil OC contents at all the soil depths (Table 1). It was indicated that content of soil OC was decreased at consecutive increase in soil depths. Earlier, similar work of Singh (2012) [17] who studied the depth wise distribution of organic carbon and reported that soil organic carbon content decreased with increase in soil depth. Highest contents (4.67, 4.51 and 4.25 g kg^{-1}) of soil OC were obtained in the treatment T_6 (TY 60 q + 5 t $FYMha^{-1}$). Similarly, results obtained by Rajput *et al.* (2016) [18] who investigated the effect of soil test based long-term fertilization on soil health and performance of rice crop in Vertisols of Central India.

3.4 Available nitrogen, phosphorus, potassium

Results showed that variability of available nitrogen, phosphorus, potassium contents in post-harvest soil of wheat crop at different soil depths were significantly affected by STCR based nutrient management treatments (Table 2). Results further revealed that the highest values of available soil nitrogen, phosphorus, potassium at respective soil depths were obtained under higher fixed yield target of 60 q along with FYM 5 t ha^{-1} (T_6), while lowest values in control at respective soil depths. Similar findings are in close agreements and well supported by Sharma and Subehia (2014) [19], Chesti *et al.* (2015) [20], Kanaujia (2016) [13] and Parminder *et al.* (2020) [21]. Results also revealed that the contents of available nitrogen, phosphorus, potassium in surface soil comparatively higher than the sub-surface soil. The findings are good agreements and well supported by Bhatt (2012) [22], Kumar *et al.* (2016) [23] and Tian (2021) [24]. Similarly, results obtained by Singh (2012) [17] studied the depth wise (0-15, 15-30, 30-60, 60-90 and 90-120 cm) distribution of important soil properties and reported that nutrients content decreased with increase in soil depth.

Table 1: Long-term impact of STCR based nutrient management on Soil pH, EC and Organic carbon under rice-wheat cropping sequence

Treatments	Soil pH			Electrical conductivity (dS m^{-1})			Organic carbon (g kg^{-1})		
	Soil depths (cm)			Soil depths (cm)			Soil depths (cm)		
	0-15	15-30	0-15	0-15	15-30	30-45	0-15	15-30	30-45
T_1	7.39	7.42	7.45	0.217	0.195	0.169	3.71	3.39	2.83
T_2	7.36	7.39	7.43	0.243	0.223	0.201	3.98	3.73	3.27
T_3	7.34	7.36	7.40	0.255	0.237	0.215	4.13	3.91	3.51
T_4	7.31	7.34	7.37	0.279	0.265	0.247	4.35	4.17	3.83
T_5	7.31	7.33	7.36	0.267	0.253	0.229	4.41	4.23	3.91
T_6	7.27	7.29	7.31	0.293	0.281	0.265	4.67	4.51	4.25
SE m ±	0.16	0.17	0.17	0.007	0.007	0.006	0.18	0.18	0.16
CD *(p=0.05)*	NS	NS	NS	0.022	0.021	0.020	0.55	0.53	0.49

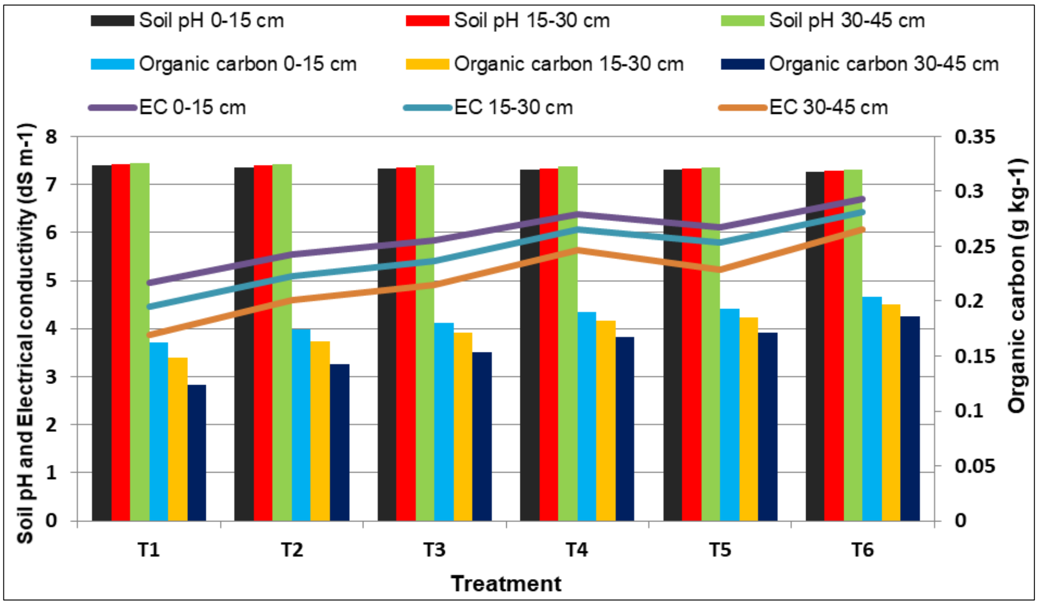

Fig 2: Long-term impact of STCR based nutrient management on Soil pH, EC and Organic carbon under rice-wheat cropping sequence

Table 2: Long-term impact of STCR based nutrient management on available Nitrogen, Phosphorus, Potassium under rice-wheat cropping sequence

Treatments	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	Soil depths (cm)			Soil depths (cm)			Soil depths (cm)		
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T_1	109.57	91.33	67.95	13.21	8.89	4.15	168.93	151.67	123.19
T_2	126.93	110.67	91.43	18.93	14.11	7.28	187.51	169.25	135.43
T_3	132.68	117.45	99.21	25.39	19.67	11.41	199.27	177.93	145.95
T_4	139.75	125.91	109.55	30.17	23.39	14.15	212.85	189.41	155.73
T_5	137.41	122.75	105.27	28.23	22.15	12.57	207.33	185.68	158.15
T_6	145.13	132.87	117.39	33.45	25.27	15.21	221.97	201.85	175.58
SE m ±	5.98	5.51	4.63	1.11	0.83	0.49	8.91	8.38	6.95
CD $(p=0.05)$	17.81	16.13	13.77	3.35	2.41	1.47	27.45	24.81	20.73

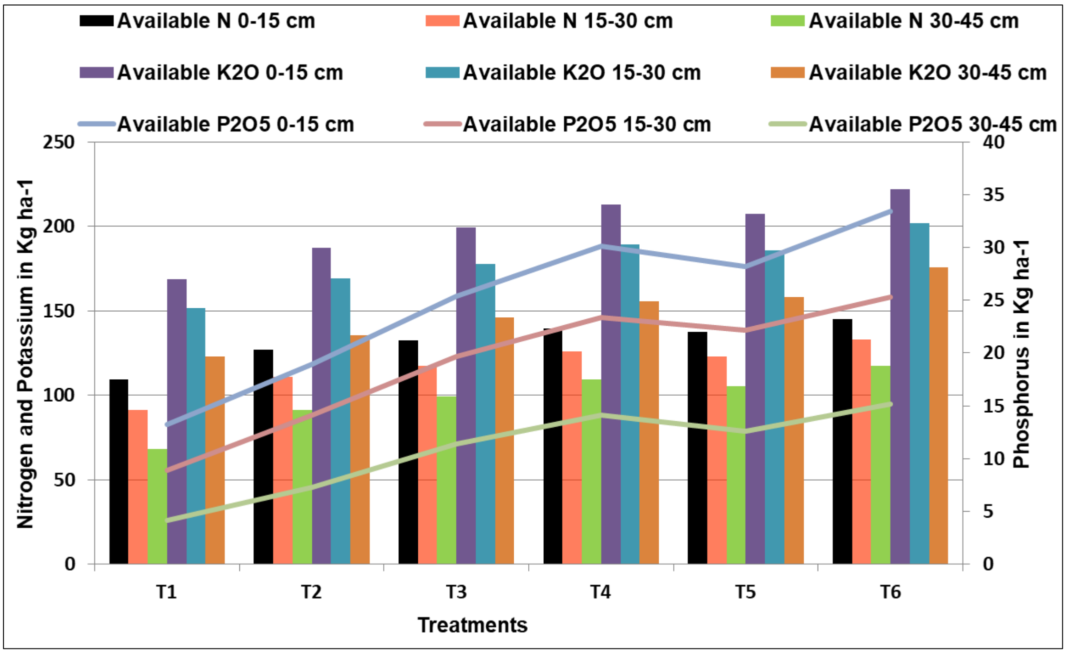

Fig 3: Long-term impact of STCR based nutrient management on available Nitrogen, Phosphorus, Potassium under rice-wheat cropping sequence

3.5 Available sulphur

It is clearly evident from the data, the content of available soil Sulphur was significantly influenced by nutrient management practices based on STCR at various soil depths (Table 3). Similar findings are in close agreements and well supported by Sharma and Subehia (2014) [19], Chesti *et al*. (2015) [20], Kanaujia (2016) [13] and Parminder *et al*. (2020) [21]. Data further observed that the content of available soil sulphur in surface soil (0-15 cm depth) comparatively higher than the sub-surface soils. The findings are good agreements and well supported by Bhatt (2012) [22], Kumar *et al*. (2016) [23] and Tian (2021) [24]. It was also revealed that contents of available soil sulphur at different soil depths under different treatments were minimum in control (T_1) at 30-45 cm and maximum in treatment T_6 at 0-15 cm soil depth.

3.6 Calcium carbonate

It is clearly evident from the data that the contents of calcium carbonate in soil across the soil depths were significantly affected by different treatments of nutrient management based on STCR (Table 3). Findings of the present investigation are well supported by Parminder *et al*. (2020) [21] and data further showed that calcium carbonate contents in soil were increased with successive increase in soil depths. The findings are good agreements and well supported by Sarkar *et al*. (2006) [25] and Patangray *et al*. (2018) [26]. Data also revealed that the contents of residual calcium carbonate across the soil depths (45.71, 46.57 and 46.89 g kg^{-1}, respectively) under control which was significantly higher over rest of the treatments but was found at par with treatments T_2, T_3 and T_4 at 0-15 and15-30 cm depth and T_2 and T_3 at 30-45 cm soil depth. However, the lowest contents of calcium carbonate in soil were obtained under T_6 at 0-15 cm and T_5 at 15-30 and 30-45 cm soil depths.

3.7 Cation exchange capacity

Changes in cation exchange capacity of soil across the soil depths was also found significant with maximum values under T_6 and minimum in control at respective soil depths (Table 3). It have been noted that CEC of soil gradually increased with consecutive increase in soil depths and maximum was found at 30-45 cm and minimum at 0-15 cm soil depths. Findings of the present investigation are well supported by those reported by Ingle *et al*. (2018) [27], Patangray *et al*. (2018) [26] and Parminder *et al*. (2020) [21].

Table 3: Long-term impact of STCR based nutrient management on Available Sulphur, Calcium carbonate, CEC under rice-wheat cropping sequence

Treatments	Available sulphur (kg ha^{-1})			Calcium carbonate (g kg^{-1})			Cation exchange capacity [Cmol (P$^+$) kg^{-1}]		
	Soil depths (cm)			Soil depths (cm)			Soil depths (cm)		
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T_1	7.91	5.65	2.37	45.71	46.57	46.89	36.45	36.91	37.13
T_2	12.57	10.13	5.25	43.95	44.87	45.23	38.21	38.85	39.11
T_3	13.75	10.41	5.93	42.39	43.21	43.67	38.97	39.63	39.95
T_4	16.43	12.25	7.21	40.63	41.27	41.71	40.13	40.88	41.27
T_5	15.89	11.78	6.93	39.89	40.75	41.38	39.71	40.56	40.98
T_6	17.63	13.56	8.41	39.37	40.93	41.65	41.37	42.35	42.83
S.Em ±	0.65	0.48	0.27	1.91	1.85	1.73	1.63	1.67	1.75
CD *(p=0.05)*	1.87	1.43	0.81	5.75	5.41	5.15	4.81	4.99	5.13

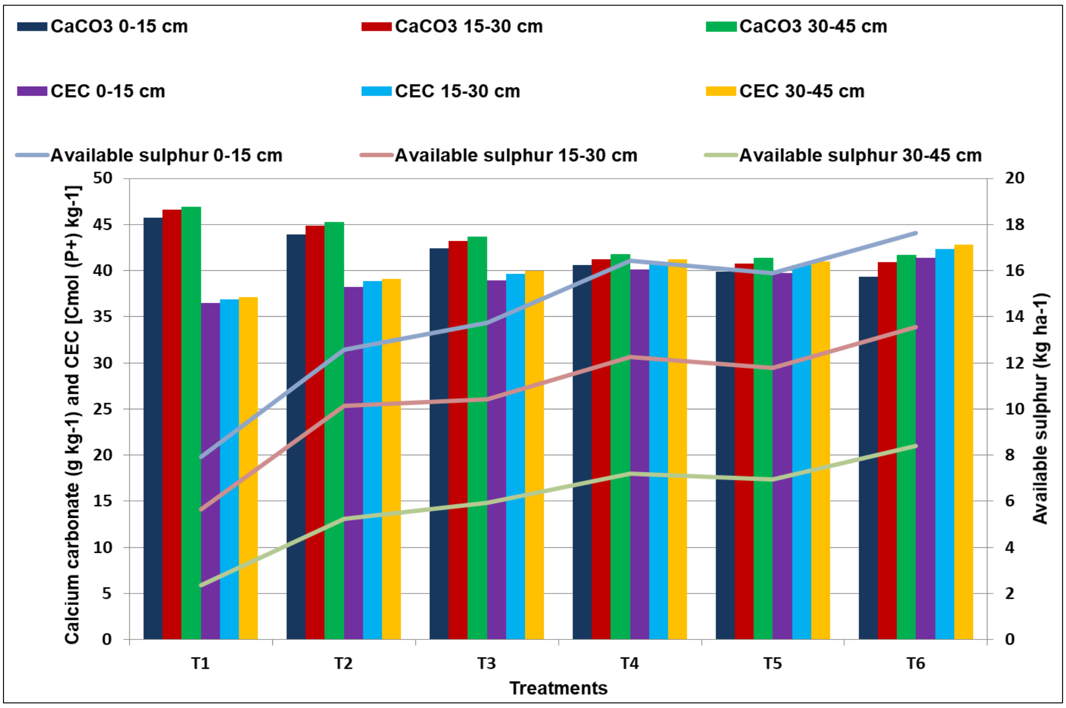

Fig 4: Long-term impact of STCR based nutrient management on Available Sulphur, Calcium carbonate and CEC under rice-wheat cropping sequence

4. Conclusion

STCR (Soil test and crop response) based nutrient management significantly affected the physico-chemical properties of soil at different depths except the soil pH. Highest values of different soil parameters were obtained under treatment T_6 having highest yield target of 60 q along with FYM 5 t ha^{-1} except soil pH and $CaCO_3$. The values of different soil parameters were decreased with increased soil depths except soil pH, calcium carbonate and cation exchange capacity of soil.

5. Conflict of Interest Statement

The authors have no conflict of interest to declare.

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