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## Effect of long-term fertilization on soil carbon pool under rice-wheat cropping system in a *Vertisol*

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### Abstract

Long-term nutrient management plays a vital role in regulating soil carbon dynamics and sustaining soil quality in intensive cropping systems. The present investigation was carried out during the *Kharif* 2024 season at the Instructional-cum-Research Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, to assess the influence of continuous fertilization on soil carbon pools in a *Vertisol* under the rice-wheat cropping system. The experiment, representing the 18th crop cycle, was conducted in a randomized block design with five nutrient management treatments and four replications. The treatments comprised an unfertilized control, the general recommended fertilizer dose (GRD), STCR-based fertilizer schedules for targeted rice yields of 5 and 6 t ha<sup>-1</sup>, and an STCR-based fertilizer schedule integrated with farmyard manure (FYM @ 5 t ha<sup>-1</sup>) for a target yield of 6 t ha<sup>-1</sup>. Continuous nutrient application markedly altered the distribution of soil organic carbon fractions. The highest contents of very labile carbon (3.17 g kg<sup>-1</sup>), labile carbon (1.63 g kg<sup>-1</sup>), less labile carbon (1.96 g kg<sup>-1</sup>), and non-labile carbon (6.08 g kg<sup>-1</sup>) were obtained under the STCR-based fertilizer treatment combined with FYM, whereas the unfertilized control recorded the lowest values. Significant treatment effects were observed for the very labile and labile carbon fractions, while variations in the less labile and non-labile fractions were statistically non-significant. The findings indicate that integrating STCR-based fertilizer recommendations with FYM is an efficient nutrient management strategy for improving active soil carbon pools and enhancing carbon storage in *Vertisols* under the rice-wheat cropping system.

**Keywords:** STCR, carbon pool, rice, farmyard manure, *Vertisol*, long-term fertilization

### Introduction

Rice (*Oryza sativa* L.) is one of the world's most important cereal crops and serves as the primary staple food for more than half of the global population. In India, rice occupies a central position in the agricultural economy, contributing significantly to food security, employment and farmers livelihoods. Sustaining rice productivity is becoming increasingly challenging due to continuous cultivation, intensive nutrient removal, and declining soil fertility. Long-term fertilizer experiments provide valuable insights into the cumulative effects of nutrient management practices on soil properties and help identify sustainable strategies for maintaining soil productivity and ensuring stable crop yields (Manna *et al.*, 2007)<sup>[4]</sup>, (Vishwanath *et al.*, 2025)<sup>[9]</sup>. Soil organic carbon (SOC) is a fundamental indicator of soil quality because it influences nutrient availability, soil aggregation, water retention, and overall soil functioning (Lal *et al.*, 2004)<sup>[3]</sup>. The distribution of SOC among different fractions, namely very labile, labile, less labile, and non-labile carbon pools, provides a better understanding of carbon dynamics than total organic carbon alone. The active carbon fractions respond rapidly to changes in nutrient management, whereas the stable fractions are important for long-term carbon storage and soil resilience. Continuous fertilizer application, particularly when integrated with organic sources such as farmyard manure (FYM), can enhance carbon inputs, improve soil organic matter accumulation, and promote sustainable soil management. (Das *et al.*, 2016)<sup>[2]</sup>.

The Soil Test Crop Response (STCR) approach offers a scientific basis for fertilizer recommendation by considering soil fertility status, crop nutrient requirements, and predetermined yield targets (Ramamoorthy *et al.*, 1967)<sup>[6]</sup>. The integration of STCR-based fertilizer recommendations with FYM has been recognized as an efficient nutrient management strategy for improving soil fertility and sustaining crop productivity (Singh *et al.*, 2014)<sup>[8]</sup>.

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Therefore, the present study was undertaken to evaluate the effect of long-term fertilization on soil carbon pools under rice in a *Vertisol* and to identify an appropriate nutrient management practice for improving soil carbon status and sustaining soil quality.

Materials and Methods

Experimental site and Treatments

The experiment was conducted at the Research-cum-Instructional Farm of the College of Agriculture, IGKV, Raipur, Chhattisgarh. The soil of the experimental field was a *Vertisol* having pH 7.65, low available nitrogen (212.20 kg ha<sup>-1</sup>), medium available phosphorus (20.44 kg ha<sup>-1</sup>), and high available potassium (483.49 kg ha<sup>-1</sup>). The trial was established using a Randomized Block Design with four replications, which included five treatment combinations viz. T<sub>1</sub> - Control (N<sub>0</sub>:P<sub>0</sub>:K<sub>0</sub>), T<sub>2</sub> - General Recommended Dose (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 100:60:40 Kg ha<sup>-1</sup>), T<sub>3</sub> - STCR Fertilizer Dose for the yield target of 5 t ha<sup>-1</sup> (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 77:12:29 Kg ha<sup>-1</sup>), T<sub>4</sub> - STCR Fertilizer Dose for the yield target of 6 t ha<sup>-1</sup> (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 113:18:44 Kg ha<sup>-1</sup>), T<sub>5</sub> - STCR Dose with FYM of 5 t ha<sup>-1</sup> for the yield target of 6 t ha<sup>-1</sup> (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 92:05:39 Kg ha<sup>-1</sup>).

Soil sampling

Soil samples were collected from each treatment plot after the harvest of the rice crop during 2024. Standard soil sampling procedures were followed throughout the collection process to ensure representative samples. The collected samples were placed in airtight plastic bags and transported to the laboratory for processing. In the laboratory, the soil samples were air-dried under shade, gently crushed using a wooden roller, and sieved through a 2.0 mm stainless steel sieve. The processed samples were then stored in polyethylene bags at room temperature until analysis. These prepared soil samples were subsequently used for the determination of different soil carbon fractions.

Soil analysis

Soil organic carbon (SOC) was estimated by the rapid wet oxidation method described by Walkley and Black (1934)<sup>[10]</sup>. The different fractions of SOC were determined using the modified Walkley and Black procedure outlined by Chan *et al.* (2001)<sup>[11]</sup>. In this method, varying concentrations of sulphuric acid (12 N, 18 N, and 24 N H<sub>2</sub>SO<sub>4</sub>) were used to oxidize carbon fractions with

different degrees of stability. The SOC oxidized with 12 N H<sub>2</sub>SO<sub>4</sub> was considered as the very labile carbon. The labile carbon was calculated as the difference between the carbon oxidized with 18 N and 12 N H<sub>2</sub>SO<sub>4</sub>. Similarly, the less labile carbon was obtained from the difference between the carbon oxidized with 24 N and 18 N H<sub>2</sub>SO<sub>4</sub>, while the non-labile carbon was estimated as the residual organic carbon remaining after oxidation with 24 N H<sub>2</sub>SO<sub>4</sub> relative to the total organic carbon. This fractionation approach enabled the assessment of soil carbon pools with varying degrees of oxidizability and stability.

Results and Discussion

Long-term fertilization significantly influenced the distribution of soil organic carbon fractions (Table 1). Among the carbon pools, non-labile carbon was the dominant fraction across all treatments, followed by very labile, less labile, and labile carbon. The highest values of very labile carbon (3.17 g kg<sup>-1</sup>), labile carbon (1.63 g kg<sup>-1</sup>), less labile carbon (1.96 g kg<sup>-1</sup>), and non-labile carbon (6.08 g kg<sup>-1</sup>) were recorded under T<sub>5</sub> (STCR-based fertilizer application integrated with FYM @ 5 t ha<sup>-1</sup>), while the lowest values were observed in the unfertilized control (T<sub>1</sub>). Treatment T<sub>4</sub> also recorded higher carbon fractions than T<sub>2</sub> and T<sub>3</sub>, indicating the positive influence of balanced nutrient application on soil carbon accumulation.

The treatment effect was significant for very labile and labile carbon fractions, whereas differences in the less labile and non-labile fractions were statistically non-significant. The greater response of the active carbon pools suggests that these fractions are more sensitive to long-term nutrient management than the relatively stable carbon pools. The higher carbon fractions under T<sub>5</sub> may be attributed to the continuous addition of organic matter through FYM, which supplied readily decomposable carbon and increased carbon inputs to the soil.

The predominance of non-labile carbon in all treatments reflects the greater stability of this fraction in clay-rich *Vertisols*, where organo-mineral interactions protect organic carbon from rapid decomposition. Similar results were reported by Rathod *et al.* (2025)<sup>[7]</sup>, who observed greater accumulation of soil carbon fractions under integrated nutrient management, while Parmar *et al.* (2024)<sup>[5]</sup> recorded higher soil carbon fractions under STCR-based fertilization integrated with FYM than under inorganic fertilization alone.

Table 1: Effect of long-term fertilization on Oxidizable Carbon pool (g kg<sup>-1</sup>)

| Treatment      | Treatment Details                                                                                                   | Very Labile | Labile | Less Labile | Non-Labile |
|----------------|---------------------------------------------------------------------------------------------------------------------|-------------|--------|-------------|------------|
| T <sub>1</sub> | Control                                                                                                             | 1.99        | 0.79   | 0.92        | 4.70       |
| T <sub>2</sub> | 100% Recommended Dose of Fertilizers                                                                                | 2.64        | 1.42   | 1.84        | 5.28       |
| T <sub>3</sub> | Soil Test Crop Response (STCR) dose for targeted yield (YT) of 5 t ha <sup>-1</sup>                                 | 2.60        | 1.39   | 1.84        | 5.01       |
| T <sub>4</sub> | Soil Test Crop Response (STCR) dose for targeted yield (YT) of 6 t ha <sup>-1</sup>                                 | 2.87        | 1.53   | 1.89        | 5.39       |
| T <sub>5</sub> | Soil Test Crop Response (STCR) dose with FYM @ 5 t ha <sup>-1</sup> for targeted yield (YT) of 6 t ha <sup>-1</sup> | 3.17        | 1.63   | 1.96        | 6.08       |
|                | S.Em (±)                                                                                                            | 0.21        | 0.16   | 0.26        | 0.35       |
|                | C.D. (0.05)                                                                                                         | 0.64        | 0.50   | NS          | NS         |

Conclusion

The present study demonstrated that long-term nutrient management significantly influenced the distribution of soil organic carbon fractions in a *Vertisol* under rice cultivation. The integrated application of STCR-based fertilizer recommendations with FYM (T<sub>5</sub>) recorded the highest contents of very labile, labile, less labile, and non-labile carbon fractions, whereas the unfertilized control showed the lowest values. Significant treatment effects were observed for the very labile and labile

carbon pools, indicating their greater sensitivity to long-term fertilization, while the less labile and non-labile fractions remained comparatively stable. The results suggest that integrating FYM with STCR-based fertilizer application enhances active soil carbon pools and supports the maintenance of soil carbon reserves under long-term rice cultivation.

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