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Impact of organic inputs and tillage practices on carbon fractions under cotton in Vertisols

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Abstract

A field experiment was conducted at the Research Farm of Department of Soil Science, PDKV, Akola during Kharif 2025–26 to study the effect of tillage practices and organic inputs on soil carbon dynamics in Vertisols. The experiment was conducted in Factorial Randomized Block Design with four tillage practices and four organic inputs, replicated four times. Minimum tillage recorded the highest soil organic carbon (6.00 g kg^{-1}), while zero tillage recorded the highest water-soluble carbon (1.41 g kg^{-1}) and carbohydrate carbon ($321.31 \text{ mg kg}^{-1}$). Among organic inputs, FYM recorded the highest organic carbon (6.07 g kg^{-1}). Vermicompost recorded the highest water-soluble carbon (1.42 g kg^{-1}) and carbohydrate carbon ($350.63 \text{ mg kg}^{-1}$). The interaction between tillage practices and organic inputs was non-significant for all carbon fractions. Overall, minimum tillage with FYM was beneficial for maintaining higher soil organic carbon, while zero tillage with vermicompost favoured higher labile carbon fractions.

Keywords: Tillage practices, organic inputs, carbon fractions, soil organic carbon

1. Introduction

Cotton (*Gossypium* spp.) is an important commercial crop of India and is widely known in Maharashtra as the “White Gold of Black Soil.” The crop is primarily cultivated for its natural fibre, which develops from elongated epidermal cells of the seed, and it also serves as an important source of cotton seed oil. Maintaining soil biological activity through suitable tillage, irrigation and organic biomass management is important for efficient nutrient use and sustainable cotton production (Organic Cotton Crop Guide, *FiBL*). The integration of conservation tillage and organic manures supports storing of carbon in surface and subsurface soil. Hence, the dynamics of carbon is expected to enhance. Therefore, the experiment was framed to evaluate the integrated effect of tillage and organic manures on carbon and nitrogen dynamics. FYM supplies both macro and micronutrients and improves soil physical, chemical and biological properties, including organic carbon, infiltration, water-holding capacity and aggregate stability (Benbi *et al.*, 1998) ^[1]. Minimal soil disturbance with high residue retention increased soil organic carbon, labile carbon fractions, soil microbial populations, and soil quality (Yadav *et al.*, 2021) ^[16].

2. Material and Methods

The field experiment was conducted at Research Farm, Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during Kharif 2025-26 on existing research trial started in 2023-24, sponsored by Research Institute of Organic Agriculture (FiBL) Switzerland. This trial evaluates the Suvarna Shubhra variety in black cotton soil using a $60 \text{ cm} \times 30 \text{ cm}$ spacing layout. The experimental area utilizes a plot size measuring $6 \times 3 \text{ m}^2$ gross and $4.8 \times 2.4 \text{ m}^2$ net, with isolation distances maintained at 1.5 m between replications and 1 m between treatments. Sowing is performed via the dibbling method at a seed rate of $10 - 12 \text{ kg ha}^{-1}$. To optimize crop growth, the field requires a targeted nutrient application of 60:30:30 NPK kg ha^{-1} .

Akola is positioned at an altitude of 307.4 meters above sea level, located between $22^{\circ}41'$ N latitude and $77^{\circ}02'$ E longitude. Its climate can be classified as tropical to subtropical, characterized by three distinct seasons: summer, monsoon and winter. During the summer months, from March to May, Akola experiences hot and dry weather. The monsoon season lasts from June to October, bringing warm and rainy conditions. The winter season, from November to February,

is characterized by dry and mild cold weather. Most of the rainfall in Akola is received from southwest monsoon period. The average annual precipitation is 711.1 mm. The soil of the experimental field was classified as Vertisols, particularly montmorillonitic, hyperthermic a family of Typic Haplustert. It has smectite clay minerals with swell-shrink properties.

The experiment was laid out in factorial randomized block design with eight treatments (two sets of four treatments) and each replicated four times. This study evaluates the interaction between different tillage practices and organic manures using a two-factor experimental design. Factor A focuses on tillage practices, which vary in intensity across four distinct treatments. (T₁) Conventional tillage represents the most intensive approach, combining ploughing, harrowing, hoeing, and hand weeding. (T₂) Reduced tillage lowers the intensity to a single harrowing, one hoeing, and hand weeding. (T₃) Minimum tillage further minimizes soil disturbance by relying strictly on hand weeding paired with weed residue mulching to protect the soil surface. (T₄) Zero tillage represents the absolute minimum baseline, where no mechanical farm operations are performed on the soil.

Complementing the tillage methods, Factor B evaluates four organic input treatments to assess their impact on soil health and crop productivity. These organic treatments includes (M1) Farmyard Manure @ 10 tonnes per hectare, (M2) Vermicompost @ 5 tonnes per hectare, and (M3) Phospho-compost @ 5 tonnes per hectare. Also (M4) No manure is included to establish a baseline for comparison. By combining these two factors, the experiment aims to identify the most effective integration of physical soil management and organic fertilization.

There are three carbon fractions were analyzed from soil after harvest of cotton crop. Soil organic carbon content was determined using the wet oxidation protocol described by Nelson and Sommers (1982). A weighed soil sample, passed through a 0.5 mm sieve, was reacted with a precise excess volume of

standard potassium dichromate (K₂Cr₂O₇) and concentrated sulfuric acid (H₂SO₄). The unreacted K₂Cr₂O₇ was then quantified through back-titration against standard ferrous ammonium sulfate, utilizing ferroin as an indicator. The final organic carbon value was calculated by comparing the burette measurements of the sample against a blank titration. Water soluble carbon was determined by shaking 1:2 soil water suspension followed by centrifugation. (Zhang *et al.*, 2012). Carbohydrate carbon was determined by Anthrone reagent method. Readings were taken spectrophotometrically at 625 nm (Brink *et al.*, 1958) [3].

The data will be subjected to analysis of variance (ANOVA) in Factorial randomized block design (FRBD) and interpretation will be made as suggested by Gomez and Gomez, 1984.

Soil Organic Carbon

Tillage

The impact of various tillage treatments on organic carbon in the soil was found to be significant. The significantly highest organic carbon (6.00 g kg⁻¹) was recorded in soils under minimum tillage, followed by reduced tillage (5.96 g kg⁻¹) and zero tillage (5.89 g kg⁻¹). The lowest organic carbon (5.83 g kg⁻¹) was observed in soils under conventional tillage. Higher organic carbon under minimum tillage was due to less soil disturbance, which reduced the breakdown and loss of organic matter and helped retain more carbon in soil. The minimum tillage also promotes physical entrapment of organic carbon in pore spaces. A vital mechanism where soil organic carbon (SOC) binds to clay minerals to form stable mineral-associated organic matter (MAOM), protecting carbon from microbial breakdown. Reduced or minimum tillage also helps in lowering microbial oxidation, which ultimately helps to increase organic carbon in soil.

3. Results and Discussion

Treatments	Organic carbon g kg ⁻¹	Water soluble carbon g kg ⁻¹	Carbohydrate carbon mg kg ⁻¹
a. Tillage Practices			
T ₁ - Conventional tillage	5.83	1.19	261.31
T ₂ - Reduced tillage	5.96	1.33	302.75
T ₃ - Minimum tillage	6.00	1.37	309.44
T ₄ - Zero tillage	5.89	1.41	321.31
SE (m)±	0.03	0.02	0.86
CD @ 5%	0.10	0.07	2.46
b. Organic Inputs			
M ₁ - FYM	6.07	1.35	328.31
M ₂ - Vermicompost	6.04	1.42	350.63
M ₃ - Phosphocompost	5.90	1.34	320.50
M ₄ - No manure	5.69	1.19	195.38
SE (m)±	0.03	0.02	0.86
CD @ 5%	0.10	0.07	2.46
Interaction of tillage practices and organic inputs (a X b)			
SE (m)±	0.07	0.05	1.72
CD @ 5%	NS	NS	NS

Similar results were reported by Sonune *et al.* (2012) [15], who found higher soil organic carbon under minimum tillage than conventional tillage in Vertisols. Konde *et al.* (2020) [8] also recorded the highest organic carbon content (5.28) under minimum tillage.

Organic Inputs

The effect of various organic inputs on organic carbon content in the soil was found to be significant. Significantly highest organic carbon (6.07 g kg⁻¹) was observed in soils treated with FYM,

which was at par with vermicompost (6.04 g kg⁻¹). The lowest organic carbon (5.69 g kg⁻¹) was observed with no manure. The increase in soil organic carbon with FYM may be due to its decomposed organic matter, which promotes microbial activity and carbon build-up in soil. The organic carbon also built up due to microbial conversation and its stabilization, which enhance subsoil storage of carbon.

The results are in conformity with the findings of Brar *et al.* (2015) [2], who reported an increase in organic carbon with long-term application of FYM and inorganic fertilizers. Khushpuri *et*

al. (2015)^[7] recorded the highest soil organic carbon (5.95 g kg⁻¹) with FYM at 10 t ha⁻¹, while the absolute control showed the lowest value (3.33 g kg⁻¹).

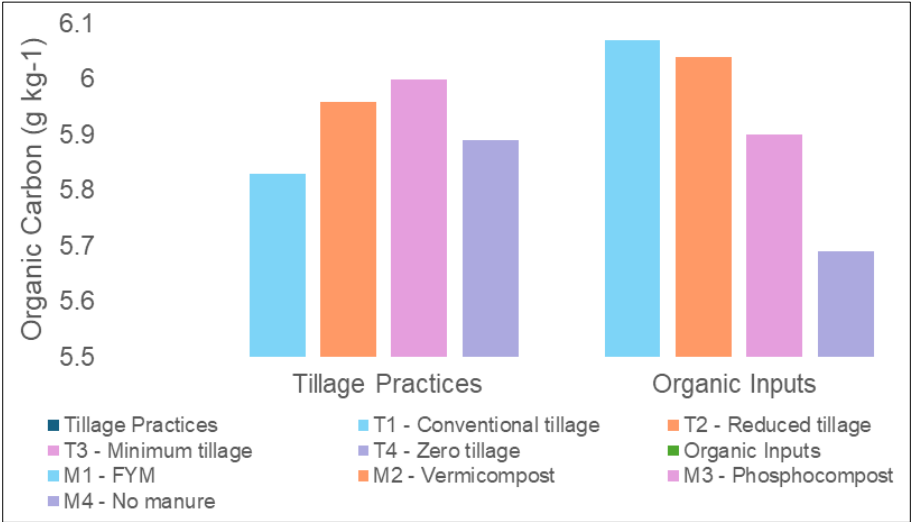


Fig 1: Effect of organic inputs & tillage practices on organic carbon content of soil

Water Soluble Carbon (WSC)

Tillage

The impact of various tillage treatments on the WSC content of soil was found to be significant. Highest WSC (1.41 g kg⁻¹) observed in zero tillage followed by minimum tillage (1.37 g kg⁻¹) and reduced tillage (1.33 g kg⁻¹). Lowest WSC (1.19 g kg⁻¹) observed in conventional tillage. The higher WSC under zero tillage was mainly due to minimum soil disturbance and better retention of crop residues, which helped to conserve WSC in soil. The findings are in conformity with the results of Lal (2004)^[10], who reported lower water-soluble carbon under conventional tillage due to repeated soil disturbance and faster decomposition of labile organic matter. Reddy *et. al.* (2024)^[13] recorded higher water-soluble carbon under zero tillage (1.10 g kg⁻¹), followed by reduced tillage (1.07 g kg⁻¹) and conventional tillage (0.97 g kg⁻¹).

Organic Inputs

The effect of various organic inputs on the WSC content of the soil was found to be significant. Highest WSC (1.42 g kg⁻¹) observed in vermicompost treated soil followed by FYM (1.35 g kg⁻¹) and phospho-compost (1.34 g kg⁻¹). Lowest WSC (1.19 g kg⁻¹) observed in no manure plots. The higher WSC under vermicompost was due to its greater supply of readily decomposable organic matter and soluble carbon compounds. The results are in conformity with the findings of Liang *et. al.* (2012)^[11], who reported that long-term FYM and vermicompost application improved soil aggregation, helping retain more water-soluble carbon. Kumar and Gupta (2017)^[9] also linked higher WSC with organic matter addition through FYM and increased sulphur accumulation.

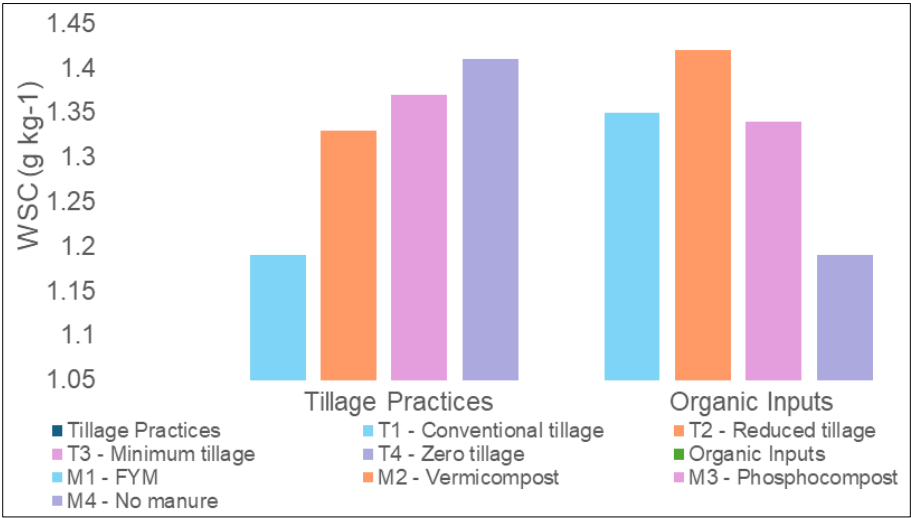


Fig 2: Effect of organic inputs & tillage practices on WSC

Carbohydrate Carbon

Tillage

The impact of various tillage practices on carbohydrate carbon content of soil was found to be significant. Highest carbohydrate carbon (321.31 mg kg⁻¹) observed in zero tillage followed by

minimum tillage (309.44 mg kg⁻¹) and reduced tillage (302.75 mg kg⁻¹). Lowest carbohydrate carbon (261.31 mg kg⁻¹) observed in conventional tillage. Higher carbohydrate carbon under zero tillage was due to less soil disturbance and better crop residue retention.

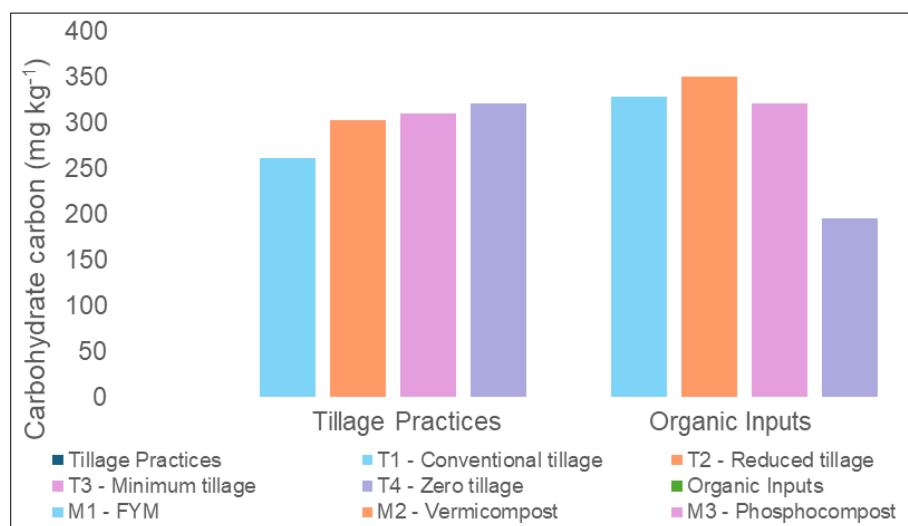


Fig 3: Effect of organic inputs & tillage practices on carbohydrate carbon

The findings are, Six *et. al.* (2000) ^[14] reported that minimum tillage increased soil carbohydrate accumulation by reducing organic matter oxidation and enhancing its physical protection. The results are align with the findings of Mina *et. al.* (2008) ^[12], they observed significantly higher soil carbohydrate content under continuous zero tillage than conventional tillage.

Organic Inputs

The effect of various organic inputs on carbohydrate carbon content in the soil was found to be significant. Highest carbohydrate carbon (350.63 mg kg⁻¹) observed in vermicompost treated soil followed by FYM (328.31 mg kg⁻¹) and phosphocompost (320.50 mg kg⁻¹). Lowest carbohydrate carbon (195.38 mg kg⁻¹) observed with no manure. The higher carbohydrate carbon under vermicompost was due to its greater supply of readily decomposable organic matter and carbon-rich compounds. Adding organic inputs like compost, manure, or crop residues increases soil carbohydrate carbon because these amendments directly supply complex carbohydrates (such as cellulose, hemicellulose, and starches) and stimulate microbial activity that synthesizes new carbon compounds.

Ghani *et. al.* (2003) ^[6] reported that application of FYM increased soil carbohydrate carbon through organic residue decomposition and microbial activity. In line with these findings, Das *et. al.* (2022) ^[4] found that vermicompost enhanced microbial activity and residue decomposition, promoting carbon accumulation in soil.

Conclusion

Therefore, based on the findings, it can be concluded that minimum tillage with FYM was found to be beneficial for maintaining higher soil organic carbon, whereas zero tillage with vermicompost favoured different carbon fractions.

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