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Original Article

FARMYARD MANURE-INDUCED CHANGES IN SOIL CARBON SEQUESTRATION AND ORGANIC MATTER STABILITY

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ABSTRACT

This trial appraised the impact of fluctuating levels of farmyard manure (FYM) on soil carbon sequestration and organic matter constancy under controlled conditions at Ayub Agricultural Research Institute, Faisalabad. Four treatments were applied: 0, 10, 20, and 30 t/ha FYM. Outcomes signposted that FYM application expressively enhanced soil organic matter fractions. The highest level of FYM (30 t/ha) resulted in maximum total organic carbon (TOC) at 1.08 ± 0.04%, followed by 0.89 ± 0.03% and 0.74 ± 0.03% under 20 and 10 t/ha, respectively, compared to the control (0.58 ± 0.02%). Particulate organic matter carbon (POM-C) also amplified with FYM, getting 0.54 ± 0.02% under 30 t/ha, approximately triple the control (0.19 ± 0.01%). Similarly, mineral-associated organic carbon (MAOC) emaciated at 0.67 ± 0.02% in the premier FYM treatment. These outcomes recommend that FYM, particularly at 30 t/ha, can play a momentous role in augmenting soil organic carbon pools, promoting carbon constancy and causative to sustainable soil fertility management. The study accentuates the significance of organic amendments in cultivating soil health and backings the adoption of FYM as a feasible strategy for carbon sequestration in agricultural soils.

INTRODUCTION

Soil organic matter (SOM) plays an essential role in supporting soil fertility, increasing water retention and sustaining ecological equilibrium in agricultural ecosystems. Its class and magnitude are critical indicators of soil health and productivity. Among the apparatuses of SOM, labile and recalcitrant carbon fractions fluctuate in their turnover rates and functions, manipulating nutrient cycling, carbon sequestration and microbial activity [1].

Farmyard manure is a readily accessible, economical organic input that recovers soil physical properties, increases microbial biomass and provisions of indispensable macro- and micronutrients [2]. Contrasting synthetic fertilizers that chiefly support short-term nutrient supply, FYM underwrites to long-term enhancements in soil structure and organic carbon content. The application of FYM augments both labile carbon fractions, which are proximately available to soil microbes, and more stable fractions that are crucial to long-term carbon sequestration [3]. These enhancements in SOM fractions are closely associated to enhance soil aggregation and reduced erosion fatalities, contributing to improved crop yields and environmental resilience.

Carbon sequestration in soils is now widely recognized as a viable strategy to mitigate climate change by storing atmospheric CO_2 in more stable organic forms. The use of FYM can substantially increase the carbon sequestration potential of agricultural soils by enriching microbial-derived organic compounds and humic substances [4]. Several studies have documented significant increases in soil total organic carbon and its particulate and mineral-associated fractions under continuous organic manure application [5,6]. However, the magnitude of such benefits can vary with factors such as soil type, manure quality, and duration of application.

Despite growing evidence, the mechanistic understanding of how FYM influences different SOM fractions, particularly in arid and semi-arid regions, remains limited. Evaluating the dynamics of SOM pools under FYM management can help optimize organic amendments for better soil carbon storage and fertility management. This study targets to evaluate the changes in soil organic carbon fractions and overall SOM constancy induced by FYM application under controlled conditions.

Materials and Methods

An exploratory trial was conducted during the 2024–2025 growing season at the Soil Chemistry Section of Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan. The study intended to appraise the impact of farmyard manure (FYM) on soil organic matter fractions and soil carbon sequestration in a sandy loam soil under meticulous conditions.

Soil Sampling and Characterization

Bulk soil samples were collected from the exterior layer (0–15 cm) of a cultivated field at AARI. The soil was air-dried, crumpled, and filtered through a 2 mm mesh for homogenization. Baseline physico-chemical analysis discovered that the soil was sandy loam in texture, with a pH of 7.8, electrical conductivity (EC) of 1.2 dS m^{-1}, organic matter content of 0.58%, total nitrogen of 0.034%, and available phosphorus and potassium at 6.5 and 115 mg kg^{-1}, correspondingly.

Experimental Design and Treatments

The experiment was laid out in a completely randomized design (CRD) with four treatments and three replications. Each treatment was applied to 5 kg of processed soil placed in plastic pots under ambient laboratory conditions. The treatments were as follows:

- T_0: Control (No FYM)
- T_1: FYM at 10 tons ha^{-1} equivalent
- T_2: FYM at 20 tons ha^{-1} equivalent
- T_3: FYM at 30 tons ha^{-1} equivalent

Well-decomposed farmyard manure was collected from the AARI livestock farm, analyzed for nutrient composition (total N: 0.69%, P: 0.22%, K: 0.95%), and thoroughly mixed with the soil according to the respective treatment rates. Moisture was maintained at 60% of field capacity throughout the incubation period of 90 days.

Soil Organic Matter Fractionation

After 90 days, soil samples were collected from each pot and subjected to SOM fractionation using the standard method, which separates total organic carbon (TOC), particulate organic matter carbon (POM-C), and mineral-associated organic carbon (MAOC). The Walkley-Black method was used for TOC determination, while POM was isolated by wet sieving and MAOC by density separation using sodium polytungstate solution.

Statistical Analysis

Data were analyzed using Statistix 10.0 software. One-way analysis of variance (ANOVA) was performed to determine the significance of treatment effects on SOM fractions. Means were separated using the Least Significant Difference (LSD) test at a 5% probability level.

Results

Total Organic Carbon (TOC)

The application of farmyard manure (FYM) had a significant influence on the total organic carbon content in the soil. As shown in Figure 1, the TOC content increased progressively with higher FYM levels. The control treatment (T_0) recorded the lowest TOC value (0.58 ± 0.02%), while the highest TOC content (1.08 ± 0.04%) was observed in the 30 t/ha FYM treatment (T_3). Statistically, the TOC values in all treatments differed significantly from each other ($T_0 < T_1 < T_2 < T_3$), indicating a dose-dependent response of TOC to manure application. The enhancement of TOC under FYM treatments can be attributed to the input of organic residues that enrich the soil with carbonaceous material. These findings are consistent with earlier studies by Chaudhary et al. [7] and Kumar et al. [8], which also reported elevated TOC levels in soils treated with organic amendments.

Particulate Organic Matter Carbon (POM-C)

Particulate organic matter carbon is an important indicator of labile carbon pools and a driver of microbial activity. The results (Figure 1) show that FYM significantly improved the POM-C content of soil. The control treatment had a POM-C of 0.19 ± 0.01%, whereas application of 30 t/ha FYM led to the highest value (0.54 ± 0.02%). Treatments T_1 (0.31 ± 0.02%) and T_2 (0.42 ± 0.01%) also showed intermediate increases. Statistical analysis indicated that each treatment was significantly different from the others, reflecting a consistent increase in labile carbon with FYM dosage. The accumulation of POM-C in FYM-treated soils can be ascribed to the partial decomposition of organic residues and the subsequent formation of stable aggregates, as noted by Singh and Benbi [9]. This also suggests improved microbial habitat and nutrient cycling.

Mineral-Associated Organic Carbon (MAOC)

MAOC represents the more stable and recalcitrant fraction of soil organic matter. The data in Figure 1 reveal that MAOC content also increased significantly with the addition of FYM. The lowest MAOC was in the control (0.39 ± 0.01%), while the highest was recorded at the 30 t/ha FYM rate (0.67 ± 0.02%). Intermediate values were seen at T_1 (0.48 ± 0.02%) and T_2 (0.58 ± 0.01%). All treatments were statistically distinct, and the trend was similar to that observed for TOC and POM-C. The increase in MAOC may be due to heightened microbial processing of organic inputs, leading to the establishment of stable organo-mineral complexes. This outcome is in agreement with Anandakumar et al. [10], who accentuated the role of organic inputs in alleviating carbon through microbial byproducts that bind to mineral surfaces.

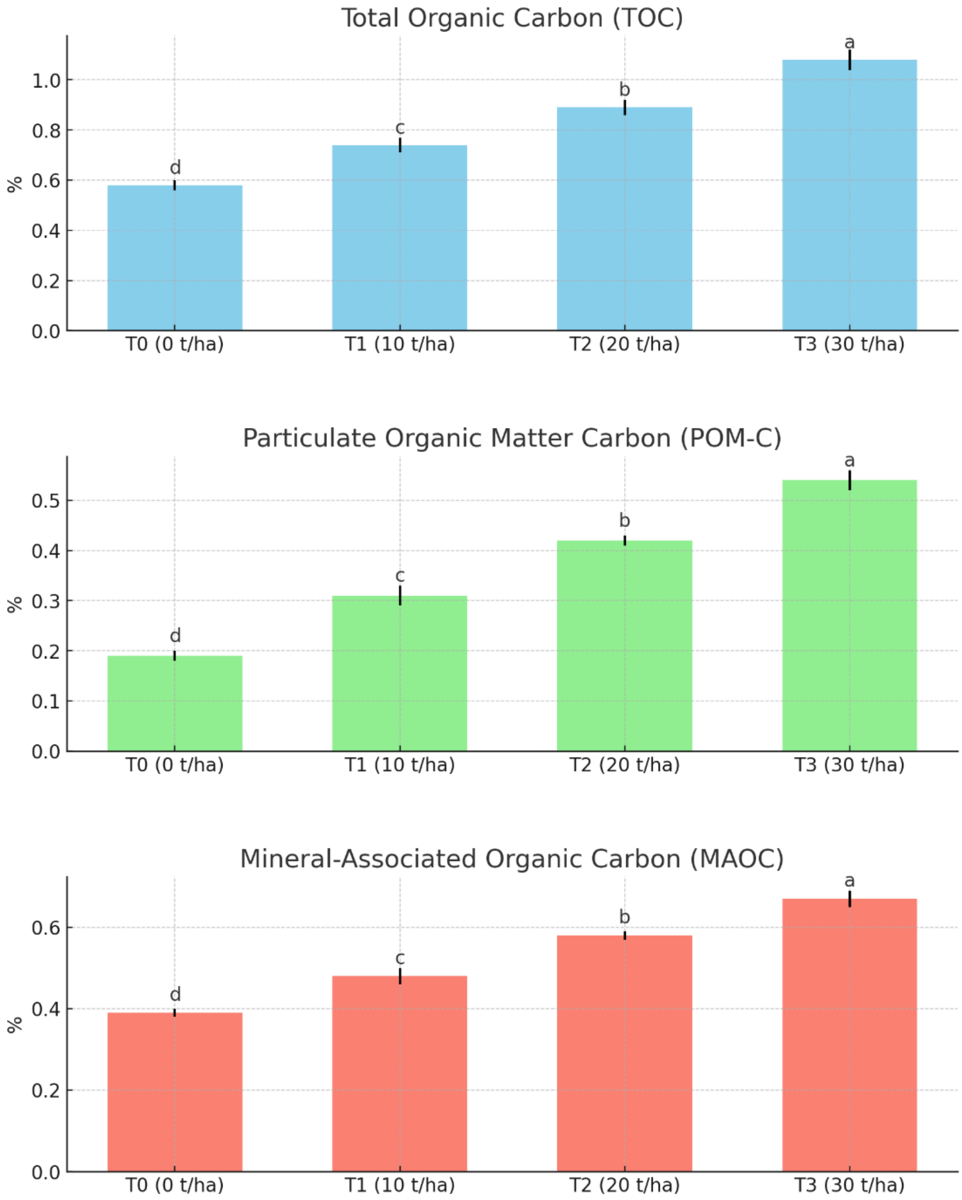

Figure: Effect of FYM on Total Organic Carbon (TOC), Particulate Organic Matter Carbon (POM-C) and Mineral-Associated Organic Carbon (MAOC)

The application of farmyard manure suggestively enhanced soil organic carbon fractions, including TOC, POM-C, and MAOC. The rejoinder was positively associated with the application rate of FYM, with the most noticeable effects observed at 30 t/ha. The consequences indicate both short-term and long-term benefits of FYM: POM-C enrichment suggests immediate nutrient availability and microbial stimulation, while amplified MAOC points to improved soil carbon sequestration and structural stability. These outcomes underscore the potential of FYM not only to increase soil fertility but also to underwrite to climate-resilient agriculture by stowing carbon in stable soil fractions.

Conclusion

The application of farmyard manure (FYM) significantly enhanced soil organic carbon fractions, including total organic carbon, particulate organic matter carbon, and mineral-associated organic carbon. Among the treatments, 30 t/ha FYM resulted in the highest carbon accumulation across all fractions, indicating improved soil carbon sequestration and organic matter stability. These improvements are essential for enhancing soil health, fertility, and long-term sustainability of agricultural systems. The results highlight the importance of integrating organic amendments like FYM into soil management practices for maintaining productive and resilient agroecosystems. Continued research is recommended to explore long-term impacts under field conditions and diverse cropping systems.

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