

Enrichment of Soil Organic Carbon

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Abstract

Enriching soil organic carbon (SOC) through organic manures is a sustainable practice that improves soil health, fertility and carbon sequestration. Manures like farmyard manure (FYM), compost, green manure and poultry litter enhance microbial activity, form humus and promote soil aggregation, reducing erosion and improving aeration. They boost SOC levels, improve soil structure, enhance drought resilience and reduce dependency on synthetic fertilizers. Proper management is essential to address challenges like nutrient release rates and manure quality variability, ensuring effective SOC enrichment and supporting climate change mitigation.

Key Words: Soil organic carbon, FYM, Compost, Green manure, Poultry litter, Mitigation

Introduction

Enriching soil organic carbon (SOC) through the application of organic manures is a cornerstone of sustainable agriculture, offering a multifaceted approach to enhancing soil quality and productivity. SOC plays a crucial role in maintaining sustainability of cropping systems by improving soil physical (texture, structure, bulk density and water-holding capacity), chemical (nutrient availability, cation exchange capacity, reduced aluminium toxicity and allelopathy) and biological (nitrogen mineralization bacteria, dinitrogen fixation, mycorrhizae fungi and microbial biomass) properties. Organic manures, including farmyard manure (FYM), compost, green manure and poultry litter, serve as rich sources of organic matter, which is essential for building and sustaining SOC levels.

When added to the soil, these organic inputs undergo decomposition by microbial activity, releasing nutrients and carbon compounds into the soil matrix. This process not only enriches SOC but also stimulates microbial diversity, creating a more dynamic and resilient soil ecosystem. Farmyard manure, derived from animal waste mixed with bedding materials, supplies a balanced mix of nutrients and organic carbon, which helps to sustain soil fertility over time. Compost, prepared from the controlled decomposition of plant residues and organic waste, introduces well-decomposed organic matter that enhances soil texture and microbial activity. Soil microorganisms, including bacteria, fungi and archaea, play a crucial role in the decomposition of SOC and the cycling of nutrients in the soil and management practices significantly influence their composition and activity (Atoloye, 2024).

Green manure, typically grown crops like legumes that are plowed back into the soil, contributes both organic matter and nitrogen, promoting the formation of SOC and improving soil nutrient status. Poultry litter, which is rich in nitrogen, phosphorus and carbon, provides a concentrated boost to SOC levels and microbial activity, although it must be applied judiciously to prevent nutrient imbalances or environmental runoff.

By increasing SOC, organic manures improve soil structure, making it less prone to erosion and compaction while enhancing water infiltration and retention. They also contribute to carbon sequestration by stabilizing organic carbon in the soil, reducing the release of CO₂ into the atmosphere and helping to mitigate climate

change. Thus, the application of organic manures represents a holistic approach to sustainable soil management, ensuring both immediate and long-term benefits for agricultural productivity and environmental health.

1. Role of Organic Manures in Soil Organic Carbon (SOC) Enrichment

Addition of Organic Matter

Organic manures are primarily composed of decomposed plant and animal material that is rich in carbon. When these materials are applied to the soil, they decompose further through microbial activity, releasing carbon into the soil. Over time, the decomposition process leads to the formation of stable organic compounds known as humus, which significantly contributes to SOC levels.

Formation of Humus

Humus is a complex, stable form of organic carbon that resists further decomposition. It helps in improving the soil's physical properties, such as its structure, water-holding capacity and nutrient retention. The greater the humus content, the higher the SOC content in the soil.

2. Mechanisms Through Which Organic Manures Enrich SOC

Microbial Decomposition

Microorganisms in the soil break down organic matter (OM) from organic manures into simpler compounds. During this decomposition process, some of the carbon is released back into the atmosphere as CO₂, while the remaining carbon is incorporated into microbial biomass or forms stable organic carbon compounds that remain in the soil. This process not only enriches SOC but also promotes microbial diversity and activity, which are critical for soil health.

Increased Soil Aggregation

SOC, particularly in the form of humus, binds soil particles together, forming aggregates. Generally, macro-aggregates can provide physical protection against the decomposition of humus C content and are responsive to land management practices with a sense of responsiveness. Conversely, micro-aggregates can inhibit the ingress of soil microorganisms by binding to organic matter compounds, thus playing a crucial role in the long-term stability of SOM (Zhu et al., 2024). These aggregates improve soil structure, making the soil more porous, which enhances root penetration, water infiltration and aeration. Well-aggregated soils are better at retaining organic carbon, reducing erosion and improving long-term carbon sequestration.

Carbon Sequestration

The carbon in organic manures is gradually sequestered in the soil in a stable form, increasing the soil's ability to store carbon over long periods. This process is known as carbon sequestration and it helps mitigate the effects of climate change by reducing the amount of CO₂ in the atmosphere.

3. Types of Organic Manures and Their Impact on SOC

Farmyard Manure (FYM)

FYM is made from the waste of farm animals and contains a mix of animal dung, urine and bedding materials (straw or hay). It is rich in nutrients and organic carbon. When applied to soil, FYM not only boosts SOC but also enhances microbial activity, promotes soil fertility and improves soil structure. FYM is one of the most commonly used organic manures for increasing SOC.

Compost

Composting is a vital technology for disposing the organic wastes economically. It is a biochemical process, in which, aerobic and anaerobic microbes break down the organic material to create compost, a beneficial form

of manure. Organic material is transformed into a nutrients' rich dark substance via a natural process (Taneja et al., 2024). Compost is a rich source of organic matter and provides significant amounts of carbon. Compost application enhances SOC, improves soil texture and increases microbial diversity, which boosts nutrient cycling in the soil.

Green Manure

Green manures are plants (usually legumes or fast-growing grasses) that are grown specifically to be incorporated into the soil. When these plants decompose, they add organic carbon to the soil. Leguminous green manures, in particular, fix nitrogen in the soil, which supports the growth of subsequent crops and indirectly contributes to SOC enrichment by enhancing plant biomass production.

Poultry Litter

Poultry litter is the waste produced by chickens, consisting of droppings, bedding materials and feed residues. It is high in nitrogen, phosphorus and organic carbon. Applying poultry litter to the soil increases SOC and promotes microbial activity, but care must be taken to avoid excessive application, which could lead to nutrient imbalances or environmental pollution.

4. Benefits of Organic Manures for Soil Organic Carbon Enrichment

Improved Soil Fertility

The carbon from organic manures contributes to the creation of humus, which increases the soil's cation exchange capacity (CEC). This means the soil can hold onto more nutrients, making them available for plants and enhancing overall soil fertility.

Enhanced Soil Structure

SOC improves the soil's physical structure, making it less prone to erosion and compaction. Soils with higher organic carbon content are better able to retain water, reducing the need for irrigation and improving drought resilience.

Increased Soil Biological Activity

The presence of organic carbon stimulates the activity of soil organisms such as earthworms, fungi and bacteria. These organisms play a crucial role in nutrient cycling and the maintenance of soil health.

Sustainability and Carbon Sequestration

By continuously adding organic manures to the soil, agricultural systems can sequester more carbon over time. The sequestration of SOC depends on the equilibrium between C inputs and outputs, provided that other nutrients are present at concentrations that do not limit crop growth (Song et al., 2024). This helps mitigate climate change by reducing atmospheric CO₂ levels and enhances the sustainability of farming systems by maintaining or increasing SOC.

Reduced Dependency on Synthetic Fertilizers

Organic manures not only contribute to SOC but also provide essential nutrients for plants, reducing the need for chemical fertilizers. This can lead to cost savings and lower environmental impact from synthetic fertilizer production and use.

5. Challenges and Considerations

Balance Between Application and Decomposition

While organic manures enrich SOC, there must be a balance between the rate of application and the capacity

of the soil to decompose the organic matter. Excessive application of organic matter can lead to nutrient imbalances or pollution of water sources due to leaching of excess nitrogen or phosphorus.

Nutrient Release Rates

The nutrient release rate from organic manures is slower than from synthetic fertilizers, so it is important to plan their use carefully to meet crop nutrient needs without overloading the soil with excess organic material.

Variation in Quality

The quality and carbon content of organic manures can vary greatly depending on the source. For example, poultry litter is generally higher in nutrients and organic carbon than FYM or compost, so it may have a more significant effect on SOC.

Conclusion

The application of organic manures is an effective method for enriching soil organic carbon, improving soil fertility and contributing to sustainable agricultural practices. Organic manures enhance microbial activity, increase SOC levels, improve soil structure and promote nutrient cycling. Over time, they help sequester carbon in the soil, providing long-term environmental benefits and improving soil resilience to climate change. However, proper management is crucial to ensure balanced nutrient supply and prevent environmental degradation.

Referances

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