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Research Article

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Enhancing Soil Organic Carbon and Soil Quality through Double-Cropping, Conservation Tillage, and Optimized Nitrogen Management under Mediterranean Conditions

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ABSTRACT
In Mediterranean agroecosystems, conventional agricultural practices have historically led to a marked depletion of soil organic carbon (SOC), compromising soil health and sustainability. This study aimed to assess the combined effects of legume-maize double-cropping (DC), tillage systems, and mineral nitrogen (N) fertilization rates on SOC and its fractions—particulate organic matter carbon (POM-C), mineral-associated organic matter carbon (Min-C), and permanganate-oxidizable carbon (POxC)—as well as on soil enzymatic activities related to the carbon cycle. A field experiment was conducted comparing monocropped maize (MC) with legume-maize DC across two tillage systems (conventional tillage, CT; and no-tillage, NT) and three N fertilization regimes (0, medium, and high). The legumes used included pea for grain (2019), vetch for green manure (2020), and vetch for forage (2021).

Results showed that DC increased SOC compared to MC, primarily through the accumulation of POM-C. DC maintained SOC levels over time, while MC led to a decline relative to initial values. NT significantly enhanced SOC, POM-C, and Min-C in the topsoil (0–10 cm), whereas CT resulted in SOC depletion. Although N fertilization initially increased SOC and its fractions, high N inputs ultimately caused a decline in SOC by the end of the study. Furthermore, DC and NT practices stimulated key soil enzymatic activities, particularly dehydrogenase and β-glucosidase, indicating improved biological functioning.

These findings underscore the potential of legume-maize double-cropping, conservation tillage, and reduced N fertilization as synergistic strategies to preserve SOC and enhance soil biological quality in irrigated Mediterranean cropping systems.

Keywords: Soil Organic Carbon, Mediterranean Agroecosystems, Soil Quality, Double-Cropping

Introduction

Mediterranean soils managed under long-term no-tillage may reach a steady state in soil organic carbon, limiting further carbon sequestration and potentially leading to SOC decline. Integrating legume–cereal double cropping has emerged as a promising strategy to enhance carbon inputs and improve soil quality in these systems. This study aimed to evaluate the effect of introducing a legume before corn on SOC content and enzymatic activities involved in the carbon cycle

Material and Methods

Location

Ebro Valley, NE Spain.

Background

A long-term tillage field experiment established in 1996 under rainfed conditions was transformed into irrigation with corn

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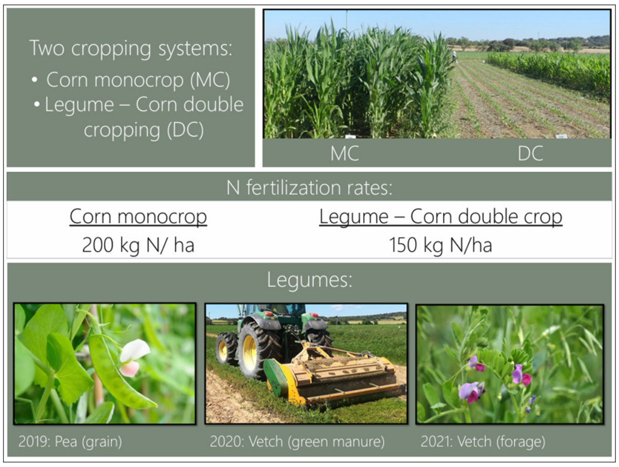
monocrop as cropping system in 2015, and into a diversification experiment in 2018.

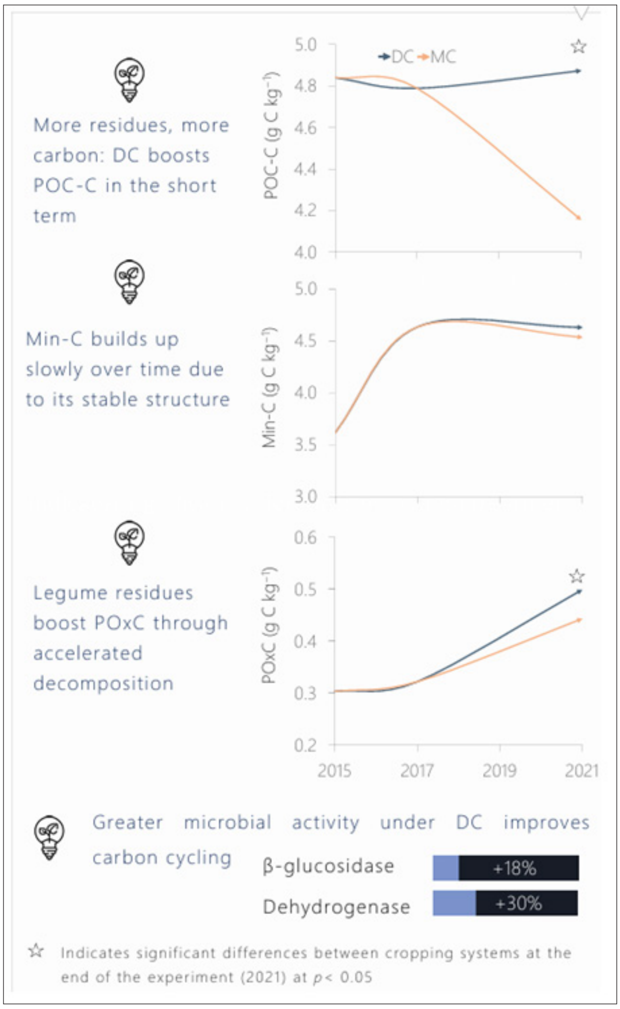


Measurements

Corn and legumes crop residues after harvest. Soil organic carbon (SOC) and its fractions (particulate organic carbon, POC; mineral-associated C, C-Min; and permanganate-oxidizable organic C, POxC). β-glucosidase and dehydrogenase activity.

Conclusions

Long-term no-tillage alone was insufficient to preserve soil organic carbon levels. However, introducing a legume crop prior to corn effectively maintained SOC, particularly by increasing labile carbon fractions such as POC and POxC. Additionally, the system enhanced soil biological quality, as evidenced by greater β-glucosidase and dehydrogenase activity, indicating improved carbon cycling and stabilization under DC systems.



Results