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Maintaining soil organic matter quality and stability in an olive orchard sustainibly managed for 21 years: insights in local and global implications

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Among the current global challenges, the research of new practices aimed at mitigating soil impoverishment, exacerbated by the pressing climate changes, is the most urgent (Chittora et al., 2020; Kalyanasundaram et al., 2020; Gonçalves, 2021; Tan et al., 2021). Studying soil organic matter (SOM) dynamics and comparing the conventional intensive farming practices with the emerging alternative sustainable ones can represent a key indicator in soil health investigation, helping to find new guidelines for conservative agrosystems management (Doran and Zeiss, 2000; Fierer et al., 2021). Olive is an economically and socio-culturally important tree crop for the countries of the Mediterranean area. However, its management is becoming unsustainable because of the lack of young farmers, increasing soil degradation, and the high cost of mineral fertilizers (Sofo and Palese, 2021).

In this long-term study, the soil from a Mediterranean olive orchard, with both sustainable (S_{mng}) and conventional (C_{mng}) land use for 21 years, was investigated for its physicochemical properties, with particular attention to the aggregate-associated organic matter (SOM-A) and its interaction and distribution in aggregates and depths. Also, a detailed metabolomic analysis of SOM-A was carried out.

A higher amount of total carbon (+50.7%) and nitrogen (+74.9%), as well as of SOM-A aromatic component (+76.0%), was detected in the first analyzed layer (0-5 cm) in the S_{mng} soils compared to the S_{mng} ones, a sign that the organic matter from surface deeply penetrates very slowly. This evidence was highlighted especially in micro-aggregates (<0.063 mm) (C = +59.3%; N = +86.7%; SOM-A = 87.7% in the S_{mng}), likely due to their capacity to bond more easily the smaller colloidal particles with a higher specific surface. This trend was also reflected in an increase in bacterial abundance and a different accumulation of organic compounds deriving from microbial fermentation processes in S_{mng} soils, as highlighted by the SOM-A qualitative characterization by metabolomics. The soil mineralogical analysis showed that minerals maintained a higher crystallinity in the S_{mng} than in the C_{mng}, where soil tillage promoted their alteration. Moreover, Fourier-transform infrared (FTIR) spectroscopy analysis highlighted that soil disturbance due to the

C_{mng} can affect SOM distribution, creating different spatial distributions in the particle aggregates and soil depths.

In order to maximize soil health in Mediterranean orchards, living roots should be maintained, i.e., the soil needs to be covered in a mantle of diverse living plants (cover crops or spontaneous weeds) for as long as possible, while bare soil should be avoided at all times. Besides living plants and their root exudates, plant residues (e.g., stalks and leaves) and compost can also drive soil health. Distinguishing SOM quantity, quality, and interaction with mineral components can help to understand if the potential for desorption of SOM determines its degradability and the dynamics of carbon accumulation into the soil, both essential for mitigating the effects of climate change and promoting land protection (Canisares et al., 2023; Li et al., 2023).

In this scenario, the benefits of sustainable soil management involve not only the agricultural sector but also the social and ethical sphere, a prerequisite for trying to maintain the functional autonomy of agroecosystems over time and ensuring that they continue to perform their wide range of ecosystem services. Finally, the results obtained can be extended globally, considering that the olive tree is currently cultivated on 5 continents, with an area of 11.6 million hectares in 66 countries.

Keywords: Fourier-transform infrared (FTIR) spectroscopy; mineral-associated organic matter (MAOM); soil metabolomics; soil mineralogy, sustainable soil management.

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