The Role of Vermicompost and Composted Organic Residues in Sustainable Soil Management

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Context description; conceptual framework

The decline of organic matter (OM) and recurrent water scarcity in Mediterranean soils necessitates sustainable strategies that recycle local residues while improving agroecosystem functionality. Soil OM is vital for fertility, water and nutrient retention, and microbial activity, making its depletion a significant threat to long-term productivity and climate resilience. Recycling organic wastes (OW) through composting or vermicomposting aligns with the frameworks of agroecology and circular economy, offering a path to counteract soil OM depletion and enhance soil water retention. Vermicompost, in particular, has been associated with greater improvements in soil porosity, water retention, and plant growth compared to conventional composts. However, comparative assessments of different residue-derived amendments, especially vineyard prunings, are rare, and an integrated evaluation of their effects on substrate and plant physiological properties under Mediterranean conditions is needed.

Purpose; research questions

This study aimed to provide an integrated assessment of residue-derived amendments by examining their short-term effects on substrate properties and plant growth under monitored pot conditions. We hypothesized that organic amendments, especially vermicompost with its finer particle size and higher biological activity, would enhance substrate water retention and improve plant performance compared with traditionally composted materials. The research questions addressed were: How do the tested amendments (vermicompost, pruning-derived composts) impact selected Substrate Properties (SP), such as water retention capacity and salinity? Do changes in the substrate translate into enhanced Plant Growth (PP) and biomass allocation in lettuce? Do Physiological Indicators (PhP) (SPAD index, chlorophyll fluorescence, leaf colorimetry) reveal differences in nitrogen status or photosynthetic performance across treatments?

Design; methodology; approach

To address these questions, a pot experiment was conducted using soil classified as Fluventic Xerochrepts. Four organic amendments were tested against an unamended control (CTRL): Vermicompost from spent coffee grounds (VERM), Composted vine prunings without inoculant (PRUN), Pruning-derived compost with a commercial accelerator (COMM), and Pruning-derived compost inoculated with Indigenous Microorganisms (INDG). All treatments were applied at four rates: 2, 8, 16, and 32 t ha^{-1}, totaling 160 pots arranged in eight completely randomized blocks. Two cropping cycles were tested: emmer wheat (*Triticum dicoccum* Schrank, which failed) and lettuce (*Lactuca sativa* L. var. capitata 'Iceberg'). Substrate volumetric water content (VWC) and pore water electrical conductivity (ECp) were monitored during both cycles. Lettuce (second cycle) was subjected to destructive measurements (shoot/root biomass, leaf number) and non-destructive measurements (SPAD index, chlorophyll fluorescence Fv/Fm, colorimetric traits).

Data collection and analysis; evidence

Results concerning Substrate Properties (SP) demonstrated that Vermicompost (VERM) consistently and significantly increased substrate VWC compared to the control (CTRL). In the second cycle, this effect was evident even at the lowest dose of 2 t ha^{-1}, suggesting an additive effect from repeated applications, with continuous monitoring confirming that the highest VERM dose (32 t ha^{-1}) maintained VWC values on average 3.6% higher than CTRL throughout the experiment. Conversely, pruning-derived composts (PRUN, COMM, INDG) showed less evident or sporadic effects on VWC, with INDG even showing significant VWC reductions compared to CTRL in the first cycle. Electrical conductivity (ECp) showed less consistent dose responses across treatments, remaining within agronomically acceptable thresholds, and only VERM showed a significant positive relationship with dose on one sampling date in the first cycle.

Regarding Plant Growth and Physiological Parameters (PP and PhP), shoot biomass and leaf number were highest for lettuce grown in VERM amended substrates, with shoot dry weight increasing by

2.45 g plant^{-1} on average compared to CTRL ($p<0.01$) and leaf number increasing by approximately 4.5 leaves per plant ($p<0.05$). The shoot-to-root ratio was also highest in VERM-amended plants (an increase of about 5 units compared to CTRL, $p<0.01$), indicating a clear preferential allocation of biomass to aboveground tissues. COMM and INDG stimulated root development but did not significantly enhance shoot biomass or leaf number, while PRUN showed no significant effect on any Plant Growth Parameter. Importantly, Physiological Parameters (SPAD index, colorimetric traits, Fv/Fm) did not differ significantly among treatments ($p>0.05$), with Fv/Fm values consistently remaining above 0.83, confirming the absence of photo-inhibition and photosynthetic stress across all treatments.

Results and implications

The results confirm that vermicompost (VERM), even at moderate application rates (2 t ha^{-1} in the second cycle), was particularly effective in enhancing water retention and crop growth under Mediterranean conditions. The higher shoot biomass and leaf number observed in VERM-amended plants, despite non-significant differences in nutrient/physiological indicators (SPAD, Fv/Fm), suggest that the primary mechanism of growth promotion was likely improved water availability, which allowed the plants to prioritize shoot development over root investment. Pruning-derived composts showed less evident or inconsistent agronomic benefits, and their variable performance underscores the challenge of using lignin-rich residues, suggesting the need to optimize their processing for better short-term agronomic value. From an agronomic and circularity perspective, the strong and stable effects of VERM on water retention highlight its potential as a sustainable amendment for increasing resilience in Mediterranean cropping systems constrained by water scarcity. These findings emphasize that the agronomic value of recycled organic materials depends significantly on the stabilization pathway (e.g., vermicomposting vs. composting) and the resulting physical/structural properties, which directly affect substrate water dynamics. Future studies should investigate long-term effects on soil organic matter stabilization and microbial community shifts.