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Editorial: Optimizing the use of organic amendments to meet climate-smart agriculture and soil fertility goals

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Editorial on the Research Topic
Optimizing the use of organic amendments to meet climate-smart agriculture and soil fertility goals

Integrating organic amendments into cropping systems can be a powerful management tool for achieving climate-smart agriculture (CSA) goals by enhancing carbon (C) sequestration while sustainably improving long-term soil fertility and crop productivity (Li and Tasnady, 2023; Silva et al., 2024; Zhao et al., 2022). However, soil organic amendments tend to have relatively low adoption rates due in part to their high transportation and application costs as well as their inconsistent effects on crop performance (Paul et al., 2017). This Research Topic focuses on optimizing the use of organic amendments to meet CSA and soil fertility goals. Papers in this Research Topic fill in some of the existing gaps in best management practices when using organic amendments to gain the most from them. Specific focus is placed on the importance of soil properties, tightening nitrogen cycles, and maximizing the benefits of surface mulching.

The effectiveness of organic amendments in achieving CSA and soil fertility goals largely depends on soil properties, including texture, pH, organic matter, and hydrological function (Alemayehu et al.; De Lima et al.). Fine-textured, high-clay soils tend to buffer the effects of amendments and exhibit gradual improvement. In contrast, coarse or low-buffer soils display more immediate and pronounced responses, particularly in terms of fertility and microbial activity (De Lima et al.). Soils low in fertility, nutrient holding capacity, and organic matter benefit most from amendments (Hallman et al.). Breza and Grandy highlight that while some soil properties like C/N ratio and pH have only weak correlations with amendment outcomes, the quality and form of the amendment—exceptionally high C/N crop residues—primarily drive improvements in N cycling and fertility, often outweighing the effects of background soil characteristics. Thus, effective management strategies must integrate both amendment properties and soil diagnostics to

optimize fertilizer use, yield, and environmental protection. Rothardt and Kage further stress that soil texture, structure, SOM, and water-holding capacity shape decomposition rates, microbial N immobilization, and nutrient leaching. Therefore, designing amendment strategies tailored to site-specific soils and climatic conditions is essential for maximizing both immediate soil fertility gains and longer-term climate resilience.

Efficient N cycling is crucial for minimizing negative climate impacts while maximizing nutrient availability for crops. A key strategy to achieve this goal is the judicious use of organic amendments, which can significantly tighten N cycles and mitigate N losses from agricultural fields. Organic amendments, such as crop residues and animal manures, enhance soil N retention and cycling by influencing microbial processes. Breza and Grandy emphasize that these amendments accelerate N cycling through increased mineralization and immobilization rates. This dynamic interplay ensures that N is recycled between inorganic and organic forms, providing crops with continuous access to N throughout the growing season while minimizing N losses (Silva et al., 2023). Specifically, crop residues promote a tighter coupling of C and N cycles, leading to faster mineralization-immobilization processes and larger ammonium pools. This mechanism is particularly effective in reducing N losses, especially when compared to synthetic amendments that primarily increase mineralization. Rothardt and Kage further illustrate the role of organic amendments in mitigating N losses, particularly during periods of low crop N uptake, such as autumn and winter. Their research indicates that incorporating crop residues can reduce autumn net N mineralization in topsoil, thereby lessening the risk of N leaching. While the overall impact on N leaching can vary depending on the specific amendment and field conditions, amendments with a high C:N ratio (> 25) are hypothesized to promote greater retention of soil mineral N. Therefore, strategic integration of diverse organic amendments into farming practices can optimize N use efficiency, reduce environmental pollution, and foster healthier soil ecosystems.

One such organic amendment that has been not been widely investigated as a strategy to meet CSA goals is mulching. In this Research Topic, Hallman et al. used hardwood mulch to improve health indicators of sandy soils and sustain yield and fruit quality of citrus orchards in a sandy Florida soil in the United States. This study aimed to optimize nutrient availability for root uptake, while improving retention capacity of this coarse-textured soil. Effectively returning mulch to the soil annually for three years is an attractive CSA practice that can complement fertilization programs for high-value horticultural crops, such as Valencia oranges, and reduce the amount of synthetic fertilizers in the long run. This work adds substantially to our growing knowledge-base for complex effects in soil health as mulch decomposes, increases organic matter and releases macronutrients to soil solution. These changes in soil properties increased plant fitness by facilitating root foraging, which had the added benefit of ameliorating the detrimental effects of bacterial disease affecting citrus, which was not observed in the untreated control. Finally, the study underscored the importance of protecting the O horizon to facilitate water infiltration and reduce evaporation, which will reduce irrigation inputs and save resources to producers with benefits for their operations and land capacity to produce food in the long run.

In conclusion, the contributions that comprise this Research Topic further our understanding of the important role that organic amendments can play as a component of a multifaceted strategy to meet CSA and soil fertility goals. The major themes that are explored are applicable to cropping systems throughout the world, making this Research Topic highly relevant and appealing to a global audience. The conclusions drawn by the papers in this Research Topic also point to the need for additional research covering topics, including, but not limited to, 1. Investigating how different combinations of synthetic and organic N fertilizers impact mineralization and immobilization dynamics in diverse cropping systems, 2. Expanding testing of different organic amendments to immobilize excessive soil nitrate while also exploring the possibility of N remineralization from said amendments, and 3. Long-term comparisons of different organic mulches on soil fertility parameters. It is our hope that these topics, among others, will find their way into future Research Topics in *Frontiers in Agronomy*.

Author contributions

AJ: Writing – original draft, Writing – review & editing. JR: Writing – review & editing, Writing – original draft. GC: Writing – review & editing, Writing – original draft. TN: Writing – original draft, Writing – review & editing.

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