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Editorial

Enhancing food safety and security through organic agriculture and innovative fertilizer management

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In recent years, the global discourse on food safety and security has increasingly focused on sustainable agricultural practices (Berry *et al.*, 2015; Ala and Ridwan, 2020). As the world's population continues to rise, with projections suggesting a global population of nearly nine billion by 2050, ensuring that everyone has access to safe, nutritious, and sufficient food is a pressing challenge (Bahar *et al.*, 2020; Oluwole *et al.*, 2023). In this context, organic agriculture, the use of biostimulants, and innovative fertilizer and stress management practices emerge as pivotal elements in the pursuit of a more resilient and secure food system (Malik *et al.*, 2020; Sani and Yong, 2021).

Organic agriculture, which eschews synthetic chemicals in favor of natural processes and materials, has gained significant traction globally (Tal, 2018). This approach aligns with growing consumer demand for healthier food options and environmental sustainability (Jaeger *et al.*, 2023). Organic farming emphasizes soil health, biodiversity, and ecological balance, which collectively contribute to improved food safety and security (Underwood *et al.*, 2011; Gamage *et al.*, 2023).

The benefits of organic agriculture are multifaceted. Firstly, it promotes soil health through the use of organic fertilizers, compost, and crop rotations (Liu *et al.*, 2024). Healthy soil is rich in organic matter, which enhances its ability to retain water and nutrients, thereby increasing crop resilience to adverse weather conditions (Lal, 2020; Wolf *et al.*, 2023). This is particularly crucial in the face of climate change, which is expected to bring more frequent and severe droughts and floods. Secondly, organic farming reduces the risk of contamination from harmful pesticides and synthetic fertilizers, ensuring that the food produced is safer for consumption (Benbrook *et al.*, 2021; Ramakrishnan *et al.*, 2021). Studies have shown that organic produce generally contains lower levels of pesticide residues compared to conventionally grown produce (Barański *et al.*, 2014; Vigar *et al.*, 2019). This not only benefits consumers but also farm workers and the surrounding environment, reducing exposure to toxic chemicals.

Biostimulants represent an innovative frontier in agricultural science, offering natural solutions to enhance plant growth, productivity, and resilience (Rouphael and Colla, 2020; Rakkammal *et al.*, 2023; Tahiri *et al.*, 2024). These substances, which include seaweed extracts, humic substances, and microbial inoculants, work by stimulating natural processes in plants, thereby improving nutrient uptake, stress tolerance, and overall plant health (Kumari *et al.*, 2022; Mackiewicz-Walec and Olszewska, 2023).

The use of biostimulants in organic and conventional farming systems can significantly enhance crop performance without the negative environmental impacts associated with synthetic agrochemicals (Sani and Yong, 2021; Mandal *et al.*, 2023). For instance, seaweed extracts have been shown to improve root

development, increase nutrient uptake, and enhance resistance to environmental stressors such as drought and salinity (Ali *et al.*, 2021; Chen *et al.*, 2023). Similarly, microbial inoculants can improve soil fertility by fixing atmospheric nitrogen, solubilizing phosphorus, and decomposing organic matter (Shahwar *et al.*, 2023). In the context of food safety, biostimulants offer a way to increase crop yields and quality while maintaining or improving environmental health (Bisht and Chhabra, 2024). This is crucial for achieving sustainable intensification, where the goal is to produce more food on the same amount of land while minimizing negative environmental impacts (Petersen and Snapp, 2015; Djuric and Njegovan, 2016).

Effective fertilizer management is essential for maximizing crop productivity and ensuring food security. However, traditional fertilizer practices often lead to nutrient run-off and pollution, contributing to environmental degradation and posing risks to human health (Luna Juncal *et al.*, 2023; Penuelas *et al.*, 2023). Innovations in fertilizer management, particularly those aligned with the principles of precision agriculture, offer promising solutions (Heyl *et al.*, 2023; Easwaran *et al.*, 2024). Precision agriculture involves the use of technology to optimize the application of inputs such as fertilizers, water, and pesticides (Karunathilake *et al.*, 2023). Using GPS, sensors, and data analytics, farmers can apply fertilizers more accurately and efficiently, reducing waste and minimizing environmental impacts (Monteiro *et al.*, 2021). This approach not only enhances crop yields but also improves soil health and reduces the risk of contamination of water bodies with excess nutrients (Yadav *et al.*, 2023).

Integrated fertilizer management strategies, which combine organic and synthetic fertilizers, are also gaining traction. These strategies leverage the strengths of both types of fertilizers to improve soil fertility and crop performance (Graham *et al.*, 2017; Roba, 2018). For example, using organic matter to enhance soil structure and microbial activity can improve the efficiency of synthetic fertilizers, leading to better nutrient availability and uptake by plants (Bargaz *et al.*, 2018; Wei *et al.*, 2024).

Stress management in agriculture is critical to maintaining crop productivity in the face of biotic and abiotic stresses. These stresses, which include pests, diseases, drought, and extreme temperatures, can significantly impact crop yields and quality, threatening food security (Fahad *et al.*, 2017; Kopecká *et al.*, 2023). Biostimulants play a key role in stress management by enhancing the natural defense mechanisms of plants. For instance, certain biostimulants can induce the production of stress-related proteins and antioxidants in plants, improving their ability to withstand adverse conditions (Hasanuzzaman *et al.*, 2021; Martínez-Lorente *et al.*, 2024). Additionally, practices such as crop diversification, intercropping, and the use of resistant crop varieties can further enhance resilience (Lin, 2011).

Organic agriculture also contributes to stress management through its emphasis on biodiversity and ecological balance (Rani *et al.*, 2023). Diverse farming systems are generally more resilient to pests and diseases, as they create habitats for natural predators and beneficial organisms that help control pest populations (Jaworski *et al.*, 2023). Furthermore, organic practices that improve soil health can enhance the ability of crops to cope with environmental stresses (Urra *et al.*, 2019). The integration of organic agriculture, biostimulants, and advanced fertilizer and stress management practices represents a holistic approach to enhancing food safety and security (Panday *et al.*, 2024). This integration can be achieved through a combination of research, policy support, and farmer education (Stringer *et al.*, 2020; Bazzan *et al.*, 2023).

Research is needed to further understand the mechanisms through which biostimulants and organic practices influence plant health and productivity (Parađiković *et al.*, 2019; Johnson *et al.*, 2024). This includes exploring the interactions between different biostimulants, organic amendments, and soil microbes, as well as identifying the most effective combinations for different crops and environments (Martínez-Lorente *et al.*, 2024). Policy support is crucial for promoting sustainable agricultural practices. Governments can incentivize the adoption of organic farming and biostimulants through subsidies, grants, and technical assistance (Barbosa, 2024; Yang *et al.*, 2024). Additionally, policies that encourage the development and use of precision agriculture technologies can help farmers optimize their input use and reduce environmental impacts (Schieffer and Dillon, 2015). Farmer education and training are essential for the successful implementation of these practices. Extension services, farmer cooperatives, and non-governmental organizations can play a vital role in disseminating knowledge and providing hands-on training to farmers (Rasanjali *et al.*, 2021). Demonstration farms and pilot projects can also help showcase the benefits of these practices and encourage wider adoption (Aniagyei *et al.*, 2024).

The quest for food safety and security in the 21st century requires innovative and sustainable agricultural practices (Uphoff, 2012). Organic agriculture, biostimulants, and advanced fertilizer and stress management strategies offer promising solutions to enhance crop productivity, improve food safety, and protect the environment (Meddich, 2023). By integrating these approaches, we can build a more resilient and secure food system that meets the needs of present and future generations. The journey ahead is challenging, but with

concerted efforts from researchers, policymakers, and farmers, we can achieve a sustainable agricultural future. The time to act is now, and the potential rewards – a healthier planet and a more secure food supply – are well worth the effort.

Ethical approval and informed consent
Not applicable.

Data availability
Not applicable.

Conflict of interest
None to declare.

Author's contribution
Conceptualization, formal analysis, writing-original draft preparation, review and editing: Jasim Uddain. The author has read and approved the final version of the published editorial.

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