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Editorial

Biological Control of Plant Diseases in Changing Environment

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Excessive pesticide application for plant disease control can result in environmental and health-related problems. This has led to a demand for pesticide-free food products and for a sustainable alternative to chemical pesticide application for plant disease control. Biological control, which is a reliance on living agents to combat pathogens for human good [1], promised to be a sustainable alternative to chemical pesticide application, and has the potential to play an important role in future integrated pest management-based strategies for plant disease control. However, the rapid demand for a biologically based pest management strategy in recent years has led to a broadening of the biocontrol concept to include plant growth-promoting agents, and biologically derived substances with non-living active ingredients, such as semiochemicals, plant extracts and essential oils [1]. Although there is growing interest world-wide regarding the use of BCAs, there are still several bottlenecks: for example, variations in biocontrol efficacy under field conditions, and in the adoption of biological control products due to legislative barriers [2]. Therefore, understanding the mode of action of BCAs is crucial for optimizing their biocontrol efficacy under field conditions and for assessing possible risks to public health and the environment. The mode of action of BCAs include their direct and/or indirect interactions with plant pathogens. Direct interactions constitute competition for food and space, interference competition through antibiosis, and direct parasitism of pathogens. BCAs can act indirectly by suppressing plant pathogens through the activation of plant defense responses, leading to induced resistance without any direct interaction with the targeted pathogen [1]. The papers published in this Special Issue, entitled "Biological Control of Plant Disease", cover a diverse area of biocontrol research, including the identification of new BCAs, insights into their mode of action, product formulation, and their application to control plant disease at pre- and-post harvest stages [3–6]. The biocontrol effect of plant organic extracts [7] and phytohormones [8] has also been considered in this Special Issue.

The paper by Hasan et al. [3] demonstrated the biocontrol effect of a native papaya yeast *Trichosporon asahii* against postharvest anthracnose disease on papaya fruit caused by *Colletotrichum gloeosporioides*. They showed that *T. asahii* acted through competition for space and nutrition, interference competition by producing diffusible antifungal substances, and direct parasitism by attachment to *C. gloeosporioides* hyphae. Similarly, Cao et al. [4] isolated several strains of the bacterium *Bacillus velezensis* from rice plants, and evaluated their potential application in controlling rice seedling blight caused by the fungus *Fusarium oxysporum*. Furthermore, the article provided insight into the mode of action of *B. velezensis* by highlighting the role of secondary metabolites, such as organic acids and terpenes in the biocontrol of *F. oxysporum*.

Leiva et al. [5] isolated and characterized 199 strains of *Trichoderma* native to Bagua Province in the Amazonas region of Peru. They used both in vitro and in vivo methods to investigate their potential as BCAs against frosty pod rot (FRR) on cocoa caused by the fungus *Moniliophthora roreri*. Strain CP24-6 showed the most effective biocontrol of FRR under field conditions. The findings presented in this article highlight the importance of both in vitro and in vivo evaluation procedures in the selection of a BCA with optimum biocontrol effects. Developing a biocontrol product is one of the major obstacles for the commercialization of BCAs. Developing a formulation that provides an abundant and effective form of the BCA with a long shelf-life is the primary step in biocontrol product development. Naeimi et al. [6] used a low-cost solid-state fermentation process, and screened 13 inexpensive and locally available substrates to develop *Trichoderma harzianum*-based biocontrol products. They found that the production and shelf-life of *T. harzianum* colony-forming units was higher on five substrates (i.e., broom sorghum grain, rice husk, rice straw, sugar beet pulp, and cow dung). In addition, *T. harzianum* produced on these five substrates significantly reduced the sheath blight caused by *Rhizoctonia solani* and, thus, were suggested it for use in the large-scale production of a *T. harzianum*-based biocontrol product.

Morales-Ubaldo and co-authors [7] used organic extracts from *Larrea tridentata*, a well-known plant in Mexican and American traditional medicine, to investigate its antibacterial activity against several plant pathogenic bacteria. *L. tridentata* organic extracts showed a bactericidal effect against *Clavibacter michiganensis* subsp. *michiganensis*, *Pseudomonas syringae*, and *Xanthomonas campestris*. Kim et al. [8] investigated whether exogenously applying wheat with phytohormones salicylic acid (SA) or jasmonic acid (JA) affected the resistance of common wheat to leaf rust caused by *Puccinia triticina*. The application of SA or JA induces different defense response mechanisms in wheat. The expression of chitinase-related genes was increased in SA-treated wheat leaves, while the expression of peroxidase-related genes was higher in JA-treated wheat leaves. Furthermore, metabolomics analysis revealed the induction of the phenylalanine pathway by SA, while levels of primary metabolites, including amino acids such as glutamate, alanine, and aspartate, were induced in wheat leaves by JA treatment.

Overall, this Special Issue showcases a broad range of articles from different parts of the world, illustrating the growing interest in the use of biocontrol as a solution for plant disease control. These articles make a significant contribution to biocontrol research and highlight the importance of using native strains in biocontrol applications.

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