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Bacillus AND ANTIFUNGAL COMPOUNDS: A GREEN APPROACH TO COMBAT PLANT PATHOGENIC FUNGI

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INTRODUCTION

Plant pathogenic fungi are serious threat to crop production and food security in the world's agricultural system. Chemical fungicides are frequently used in conventional disease management approaches, although they can have negative impacts on non-target organisms, the environment, and human health. Due to such concerns, there has been a rise in interest in using Bacillus species potential for biocontrol and their ability to produce antifungal chemicals as a long-term substitute for treating plant diseases (Salazar *et al.,* 2023).

BACILLUS AS BIOCONTROL AGENTS

Numerous *Bacillus* species are commonly found in the rhizosphere and soil, where they coexist with plants in mutualistic interactions and support their development. A number of strains of Bacillus have been discovered to be effective biocontrol agents against a variety of plant diseases, including fungus. They are important allies in the battle against plant diseases because of their capacity to colonise plant roots and generate antimicrobial chemicals (Fira *et al.,* 2018).

ANTIFUNGAL COMPOUNDS PRODUCED BY *BACILLUS*

Bacillus species are renowned for their ability to synthesize a diverse array of secondary metabolites with antimicrobial properties. These compounds include lipopeptides (e.g., surfactin, iturin, and fengycin), cyclic dipeptides (e.g., bacillomycin D), polyketides (e.g., difficidin and macrolactin), and other bioactive molecules. Each of these compounds exhibits specific modes of action against fungal pathogens, making Bacillus an effective biocontrol agent against a broad spectrum of plant pathogenic fungi (Bidima *et al.,* 2022).

MECHANISMS OF ACTION

Bacillus species produce antifungal chemicals that work through a variety of pathways to achieve their biocontrol effects. Fungal cell membranes are broken down by lipopeptides like surfactin, which causes internal cell leakage and ultimately cell death. Fungal growth and development are disrupted by the inhibition of fungal cell wall formation by iturin and fengycin. Fungal cell membranes are broken by bacillomycin D, which also causes fungi to undergo programmed cell death (Tran *et al.,* 2022). Furthermore, several chemicals generated from Bacillus trigger defence responses in plants, strengthening their resistance against fungal diseases (Dimkić *et al.,* 2022).

FIELD APPLICATIONS

In field studies, Bacillus-based biocontrol solutions have demonstrated encouraging outcomes in managing a range of fungal diseases, such as damping-off, wilt, powdery mildew, and grey mould. These

compounds efficiently reduce fungal infections while boosting plant growth and health when administered as foliar sprays, soil amendments, or seed treatments. By reducing the negative effects of agriculture on the environment and encouraging sustainable crop production methods, Bacillus-based biocontrol agents provide an eco-friendly substitute for chemical fungicides (Cawoy *et al.,* 2011).

According to experiments, B. subtilis strain RB14 generates iturin A, which has a beneficial effect on tomato plants' ability to resist Rhizoctonia solani-induced damping-off. For instance, it has been shown that B. subtilis produces both iturins and fengycins, which helps to prevent Podosphaera fusca from causing powdery mildew on melon leaves (Romero *et al.* 2007). These cyclic lipopeptides have the ability to prevent *P. fusca* conidia from germinating (Cawoy *et al.* 2011). It demonstrates that the cyclic lipopeptides produced by *B. subtilis* also have the effect of reducing soilborne and foliar illnesses (Asaka and Shoda 1996). It has been found that fengycin produced by B. subtilis 9407 showed strong antifungal activity and was important to the biocontrol of apple ring rot caused by Botryosphaeria dothidea (Fan *et al.* 2017). Gray mold as postharvest disease, caused by Botrytis cinerea which results in visible decay on apple fruits effectively reduced by *B. subtilis* GA1 strain by producing three families of cyclic lipopeptides – iturins, surfactins, and fengycins (Cawoy *et al.* 2011).

CHALLENGES AND FUTURE DIRECTIONS

Although Bacillus-based biocontrol agents have great potential, their actual application is hindered by issues related to formulation stability, application method optimisation, and regulatory approval. It is recommended that future research endeavours concentrate on tackling these obstacles, refining the mechanisms of action of antifungal compounds generated from Bacillus, and maximising the effectiveness of biocontrol products based on Bacillus in field settings. Facilitating the development and commercialization of Bacillus-based biocontrol solutions for sustainable agriculture requires cooperation between researchers, industry partners, and regulatory bodies (Lahlali *et al.,* 2022).

CONCLUSION

One eco-friendly strategy that shows promise for managing plant pathogenic fungus in agriculture sustainably is the use of Bacillus species and their antifungal chemicals. Farmers may lessen their reliance on chemical fungicides, decrease environmental concerns, and create a robust and healthier agroecosystem by utilising the biocontrol capability of these beneficial bacteria. Bacillus-based biocontrol technologies have the potential to transform disease management techniques and aid in the creation of more sustainable agricultural systems with more study and innovation.