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Role of Endophytic Bacteria in Plant Disease Management

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According to estimates, 60% more food would need to be produced by 2050 in order to feed the world's population of over 10 billion people (Fedoroff, 2015; Ristaino *et al*., 2021). To meet the demand for food, the rise in output must be sustained despite the losses brought on by agricultural pests and diseases. According to Ristaino *et al*. (2021), the average global yield losses resulting from crop diseases and pests were roughly 30.3% for rice, 21.5% for wheat, 22.6% for maize, 21.4% for soybeans, and 17.2% for potatoes. In addition to causing large losses in crop productivity, plant diseases can lower crop quality, which has an effect on human health (Savary *et al*., 2019). The great majority of plant diseases are caused by phytopathogenic fungal infections. While crops like tomatoes, bananas, and kiwifruit are important sources of human nutrition, cereal crops like rice, wheat, and maize are essential supplies of human sustenance. These crops are frequently colonized by a variety of fungal diseases. The rice blast pathogen *Magnaporthe oryzae* can result in 10–35% rice loss (Talbot, 2003). *Fusarium graminearum* is a destructive fungus that can cause root rot, foot rot, and head blight in wheat (Colombo *et al*., 2019). This fungus affects more than just yield loss. However, it can also contaminate wheat grain by generating the mycotoxins zearalenone and deoxynivalenol, which are dangerous to both human and animal health (Bennett and Inamdar, 2015).

A variety of fruits can develop gray mold due to *Botrytis cinerea*. Numerous fruits, including grapes, strawberries, raspberries, blackberries, kiwis, apples, and pears, are susceptible to infection. Additionally, it contaminates beans, carrots, broccoli, cabbage, and lettuce (Williamson *et al*., 2007). A dangerous worldwide pathogen, *Sclerotinia sclerotiorum* infects a wide variety of plants, including sunflower, rapeseed, soybean, lentil, chickpea, peanut, onion, tulip, and several vegetables, causing soft rot or stem rot (Bolton *et al*., 2006). Applying chemical pesticides to control plant pathogens or their vectors is the main method of controlling plant diseases. However, the ecosystem and human life may be negatively impacted by the use of pesticides. Thus, manufacturers and researchers are looking for environmentally friendly methods of controlling diseases. Plant growth-promoting bacteria (PGPB) are an alternate method for biocontrolling plant diseases (Kannojia *et al*., 2019). PGPB may live inside plants as well as in the rhizosphere and episphere (Santoyo *et al*., 2016).

Plant growth-promoting endophytic bacteria (PGPEB) are endophytes that live in plant tissues without producing illness (Hallmann *et al*., 1997). Some endophytes are also PGPB (Santoyo *et al*., 2016). The use of endophytes as biocontrol agents and plant growth boosters is gaining more attention (Falade *et al*., 2021). Plant diseases can be controlled by endophytic bacteria both before and after harvest. By occupying plant tissue space, generating lytic enzymes and secondary metabolites, and creating plant defenses, these bacteria can limit infections (Morales-Cedeño *et al*., 2021). The endophytic nature of strains from the bacterial genera *Bacillus*, *Paenibacillus*, *Pseudomonas*, *Burkholderia*, *Enterobacter*, *Klebsiella*, and *Arthrobacter* has been documented, and these strains have been tested for biocontrol and plant growth promotion (Khan *et al*., 2020; Bolivar-Anillo *et al*., 2021). *Bacillus* is capable of producing endospores, which are thick-walled survival structures that enable microbes to evade stress and unfavorable environmental conditions. These bacteria can stimulate plant defenses, promote plant growth, and have a broad range of biocontrol potential (Compant *et al*., 2005). The different ways that endophytic bacteria suppress phytopathogenic fungi and promote their proliferation have been covered in this article.

Biocontrol mechanisms of endophytic bacteria

Because endophytic bacteria may create a variety of antimicrobial chemicals and enzymes to regulate fungal growth, they may prevent plant diseases. By inducing plant systemic resistance, endophytic bacteria can also boost defense mechanisms (Pérez-Montaño *et al*., 2014). Plant diseases can be reduced by the colonization of beneficial bacteria and the ensuing competition for nutrients and space (Glick, 2012). Direct biocontrol mechanisms of endophytic bacteria

Antibiosis

By creating antimicrobial substances, bacteria can inhibit other microorganisms through a process known as antibiosis. By producing secondary compounds with antifungal and antibacterial properties, endophytic bacteria prevent the proliferation of phytopathogenic microorganisms. The antimicrobial properties of secondary metabolites such as surfactin, iturin, fengycin, bacillaene, subtilosin A, fusaricidin, polymyxin, 2,4-diacetylephloroglucinol (DAPG), phenazine-1-carboxylic acid, 2-hydroxyphenazine, pyrrolnitrine, viscosinamide, and Orfamide are widely recognized (Ma *et al*., 2016). For instance, in apple fruits, *B. subtilis* inhibits *B. cinerea* and generates fengycin.

Hydrolytic enzymes

Different polymeric components, such as cellulose, chitin, proteins, and lipids, can be broken down by the hydrolytic enzymes of endophytic bacteria (Liu *et al*., 2017). Fungal cell walls can be broken down by these enzymes. Protease, cellulase, β-1,3-glucanase, and chitinase are the enzymes for biocontrol that have been extensively documented. These enzymes have the ability to harm pathogen cell walls. For example, it has been found that *Xanthomonas campestris*, which causes black rot disease in cruciferous crops, can be controlled by *Pseudomonas aeruginosa*'s extracellular chitinase (Mishra and Arora, 2012).

Volatile compounds

Additionally, endophytic bacteria release volatile organic compounds (VOCs), which have been shown to suppress nematodes, bacteria, and phytopathogenic fungi. *Pseudomonas putida*, which was isolated from black pepper root, used its volatile organic compounds (VOCs) to suppress *Phytopthora capsici*, *Athelia rolfsii*, *Giberella moniliformis*, *R. solani*, *Pythium myriotylum*, and *Colletotrichum gloeosporioides* (Sheoran *et al*., 2015).

Siderophores

Certain endophytes, such as *Bacillus*, *Paenibacillus*, and *Pseudomonas*, are capable of producing active low molecular weight compounds that have the ability to chelate iron (Fe), deliver it in a form that plants can use, and deprive pathogens of iron. According to Rajkumar *et al*. (2010), endophyte-produced siderophores such hydroxymate, phenolate, catecholate, and pyoverdine have demonstrated biocontrol activity.

Quorum sensing

Crosstalk between cells, biofilm formation, reproduction, mutualism, adaptation, and disease are all regulated by quorum sensing. By quenching quorum sensing, certain endophytes have been found to disrupt phytopathogenic signaling pathways (Kusari *et al*., 2014).

Competition for nutrients and space

By competing with diseases for resources and space, endophytic bacteria can also inhibit them. According to Lastochkina *et al*. (2020), *B. subtilis* successfully competed for nutrients and space inside the potato tubers, suppressing *Phytopthora infestans* and *F. oxysporum*. Indirect biocontrol mechanisms of endophytic bacteria.

The indirect biocontrol mechanism

It entails the stimulation of microbe-related plant defenses. Based on the hormonal implications and the type of elicitor, two types of induced defenses have been proposed: induced systemic resistance (ISR) and systemic acquired resistance (SAR). *Rhizobacteria* and other non-pathogenic microbes cause ISR, whereas chemicals or pathogenic germs cause SAR. The ethylene (ET) or jasmonic acid (JA) pathways control ISR, while the salicylic acid (SA)-dependent signaling pathways control SAR after pathogenesis-related (PRs) protein gene expression (Van Oosten *et al.*, 2008). Nevertheless, SA and JA/ET signaling mechanisms may also be necessary for ISR. B. cereus strain AR156's ISR was dependent on NPR1 and the SA and JA/ET signaling pathways. Another study revealed that endophytic *B. subtilis* triggered PR genes (PR-1 and PR-4) in maize and protected it from *F. moniliforme* by creating antifungal lipopeptides (fengycin and iturin).

Future perspectives

Bacteria that live inside plant systems are known as endophytic bacteria. Thus, this is a fantastic chance to choose the most promising bacteria from this diversity for use in sustainable agriculture. In addition to the antifungal action, research into endophytic bacteria's efficacy, perspectives, and implications for their use in biological control is essential. Numerous endophytic bacteria have been chosen for plant growth enhancement and biocontrol. Nevertheless, the majority of them were assessed in vitro, and additional operational assessment had to be verified in field settings. When these bacteria are shown to be effective, they can take the place of agrochemicals in agriculture to provide natural biocontrol capability.

Conclusion

An efficient and practical biological substitute for agrochemicals is endophytic bacteria. Without having a detrimental effect on the agroecosystem, they can suppress phytopathogenic fungi and encourage plant growth. Lipopeptides and polyketides are primarily involved in the underlying antifungal processes. In the case of endophytic *Bacillus*, *Paenibacillus*, and *Pseudomonas*, fengycin, fusaricidins, and DAPG are important metabolites for antifungal action with dual biocontrol and plant-growth promotion capabilities. It is essential to properly screen for these endophytic bacteria. The majority of research on plant growth promotion and endophytic bacteria-driven biocontrol is done in lab settings. In order to use them in the development of sustainable agriculture, more endophytic bacteria should be first screened in the lab and then tested under practical and realistic conditions (such as at the farm level).

References

1. Bennett, J.W. and Inamdar, A.A. (2015). Are some fungal volatile organic compounds (VOCs) mycotoxins?. *Toxins*, **7**(9): 3785-3804.
2. Bolivar-Anillo, H.J., González-Rodríguez, V.E., Cantoral, J.M., García-Sánchez, D., Collado, I.G. and Garrido, C. (2021). Endophytic bacteria *Bacillus subtilis*, isolated from *Zea mays*, as potential biocontrol agent against *Botrytis cinerea*. *Biology*, **10**(6): 492.
3. Bolton, M.D., Thomma, B.P. and Nelson, B.D. (2006). *Sclerotinia sclerotiorum* (Lib.) de Bary: biology and molecular traits of a cosmopolitan pathogen. *Molecular plant pathology*, **7**(1): 1-16.
4. Colombo, E.M., Kunova, A., Pizzatti, C., Saracchi, M., Cortesi, P. and Pasquali, M. (2019). Selection of an endophytic Streptomyces sp. strain DEF09 from wheat roots as a biocontrol agent against *Fusarium graminearum*. *Frontiers in Microbiology*, **10**: 2356.
5. Compant, S., Duffy, B., Nowak, J., Clément, C. and Barka, E.A. (2005). Use of plant growth-promoting bacteria for biocontrol of plant diseases: principles, mechanisms of action, and future prospects. *Applied and environmental microbiology*, **71**(9): 4951-4959.
6. Falade, A.O., Adewole, K.E. and Ekundayo, T.C. (2021). Aptitude of endophytic microbes for production of novel biocontrol agents and industrial enzymes towards agro-

industrial sustainability. *Beni-Suef University Journal of Basic and Applied Sciences*, **10**(1): 61.

7. Fedoroff, N.V. (2015). Food in a future of 10 billion. *Agriculture & Food Security*, **4(**1): 11.
8. Glick, B.R. (2012). Plant growth-promoting bacteria: mechanisms and applications. *Scientifica*, **2012**(1): 963401.
9. Hallmann, J., Quadt-Hallmann, A., Mahaffee, W.F. and Kloepper, J.W. (1997). Bacterial endophytes in agricultural crops. *Canadian journal of microbiology*, **43**(10): 895-914.
10. Khan, M.A., Asaf, S., Khan, A.L., Adhikari, A., Jan, R., Ali, S. and Lee, I.J. (2020). Plant growth-promoting endophytic bacteria augment growth and salinity tolerance in rice plants. *Plant Biology*, **22**(5): 850-862.
11. Kannojia, P., Choudhary, K.K., Srivastava, A.K. and Singh, A.K. (2019). PGPR bioelicitors: induced systemic resistance (ISR) and proteomic perspective on biocontrol. In *PGPR amelioration in sustainable agriculture* (pp. 67-84). Woodhead Publishing.
12. Kusari, P., Kusari, S., Lamshöft, M., Sezgin, S., Spiteller, M. and Kayser, O. (2014). Quorum quenching is an antivirulence strategy employed by endophytic bacteria. *Applied microbiology and biotechnology*, **98**(16): 7173-7183.
13. Lastochkina, O., Baymiev, A., Shayahmetova, A., Garshina, D., Koryakov, I., Shpirnaya, I. and Palamutoglu, R. (2020). Effects of endophytic Bacillus subtilis and salicylic acid on postharvest diseases (*Phytophthora infestans*, *Fusarium oxysporum*) development in stored potato tubers. *Plants*, **9**(1): 76.
14. Liu, H., Carvalhais, L.C., Crawford, M., Singh, E., Dennis, P.G., Pieterse, C.M. and Schenk, P.M. (2017). Inner plant values: diversity, colonization and benefits from endophytic bacteria. *Frontiers in microbiology*, **8**: 2552.
15. Ma, Z., Geudens, N., Kieu, N.P., Sinnaeve, D., Ongena, M., Martins, J.C. and Höfte, M. (2016). Biosynthesis, chemical structure, and structure-activity relationship of orfamide lipopeptides produced by *Pseudomonas protegens* and related species. *Frontiers in Microbiology*, **7**: 382.
16. Mishra, S., and Arora, N.K. (2012). Evaluation of rhizospheric *Pseudomonas* and *Bacillus* as biocontrol tool for *Xanthomonas campestris* pv *campestris*. *World Journal of Microbiology and Biotechnology*, **28**(2): 693-702.
17. Morales-Cedeño, L.R., del Carmen Orozco-Mosqueda, M., Loeza-Lara, P.D., Parra-Cota, F. I., de Los Santos-Villalobos, S. and Santoyo, G. (2021). Plant growth-promoting bacterial endophytes as biocontrol agents of pre-and post-harvest diseases: Fundamentals, methods of application and future perspectives. *Microbiological Research*, **242**: 126612.
18. Pérez-Montaño, F., Alías-Villegas, C., Bellogín, R.A., Del Cerro, P., Espuny, M.R., Jiménez-Guerrero, I. and Cubo, T. (2014). Plant growth promotion in cereal and leguminous agricultural important plants: from microorganism capacities to crop production. *Microbiological research*, **169**(5-6): 325-336.
19. Rajkumar, M., Ae, N., Prasad, M.N.V. and Freitas, H. (2010). Potential of siderophore-producing bacteria for improving heavy metal phytoextraction. *Trends in biotechnology*, **28**(3): 142-149.
20. Ristaino, J.B., Anderson, P.K., Bebber, D.P., Brauman, K.A., Cunniffe, N.J., Fedoroff, N. V. and Wei, Q. (2021). The persistent threat of emerging plant disease pandemics to global food security. *Proceedings of the National Academy of Sciences*, **118**(23): e2022239118.
21. Santoyo, G., Moreno-Hagelsieb, G., del Carmen Orozco-Mosqueda, M. and Glick, B. R. (2016). Plant growth-promoting bacterial endophytes. *Microbiological research*, **183**: 92-99.
22. Savary, S., Willocquet, L., Pethybridge, S.J., Esker, P., McRoberts, N. and Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nature ecology & evolution*, **3**(3): 430-439.

23. Sheoran, N., Nadakkakath, A.V., Munjal, V., Kundu, A., Subaharan, K., Venugopal, V. and Kumar, A. (2015). Genetic analysis of plant endophytic *Pseudomonas putida* BP25 and chemo-profiling of its antimicrobial volatile organic compounds. *Microbiological research*, **173**: 66-78.
24. Talbot, N.J. (2003). On the trail of a cereal killer: exploring the biology of *Magnaporthe grisea*. *Annual Reviews in Microbiology*, **57**(1): 177-202.
25. Van Oosten, V.R., Bodenhausen, N., Reymond, P., Van Pelt, J.A., Van Loon, L.C., Dicke, M. and Pieterse, C.M. (2008). Differential effectiveness of microbially induced resistance against herbivorous insects in Arabidopsis. *Molecular Plant-Microbe Interactions*, **21**(7): 919-930.
26. Williamson, B., Tudzynski, B., Tudzynski, P. and Van Kan, J.A. (2007). *Botrytis cinerea*: the cause of grey mould disease. *Molecular plant pathology*, **8**(5): 561-580.