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Enhancing Abiotic and Biotic Stress Tolerance in Crops through Endophytes

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Introduction

Abiotic and biotic stresses severely affect crop productivity, soil fertility, and health. These stresses may have significant financial repercussions, compelling a practical, cost-effective, and eco-friendly approach to reduce their negative impacts on crop growth and productivity. Several agrochemicals, such as insecticides, fertilizers, and, pesticides are being used to protect the crop plants; however, these chemicals have detrimental effects on human health and environment. Plants are sessile and cannot move or escape to avoid stress. Therefore, they have evolved to develop highly beneficial interactions with endophytes.

Endophytes are the microorganisms that lives inside the plant cells without harming the plants. It will help detoxify harmful substances, defend against foreign microorganisms, and hormone synthesis, which is just a few of the ways endophytes are known to benefit in the development of host plants. (Chitnis et al.,2020) Endophytes are also known for antibacterial and anticancer activities. Moreover, they also help in nutrient recycling and act as bio- transformers for many compounds. Endophytes are widely distributed and typically little understood by researchers, but as our understanding of plant-microbe interactions expands, more endophytes with a wider range of functions are being found. (Kamran et al., 2022.). The targeted use of beneficial plant endophytes and their role in combating abiotic and biotic stresses are gaining lot of attention now a days.

Role of endophytes in enhancing biotic stress tolerance

Endophytes help in protection of crop plants against pathogens either by directly or indirectly. In direct mechanism, endophytes are involved in the production and release of secondary metabolites or compounds with antimicrobial properties, such as siderophores, antibiotics, and hydrolytic enzymes, which can help in culminating or reducing the invading pathogens.

In indirect mechanisms, endophytes compete with the pathogen for space and available nutrients. Endophytes are also known to play a role in systemic acquired resistance (SAR) against plant pathogens (Kloepper and Ryu., 2006). List of endophytes associated with defense against various plant pathogens along with the host plants and mode of action is summarized in the below table.

Table: List of endophytes associated with Biotic stress tolerance in crop plants

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Sl no.	Endophyte	Host Plant	Plant-Pathogen	Target Pathway	Refernce
1	*Bacillus spp*	*Oryza sativa*	*Pyricularia oryzae*	Induce systemic resistance, Antioxidant defense activities	Morelli et al., 2020, Rais et al.,2017
2	*Paenibacillus*	*Triticum aestivum*	*Mycosphaerella graminicola*	Defense pathway	Samain et al., 2019
3	*Streptomyces strain, DEF09*	*Triticum aestivum*	*Fusarium graminearum*	Chitinase production	Colombo et al.,2019
4	*Paenibacillus sp. strain B2*	*Triticum aestivum*	*Zymoseptoria tritici*	Induce flavonoid and phytohormonal pathways	Samain et al.,2017
5	*Fusarium solani*	*Solanum lycopersicum*	*Septoria lycopersici*	SA-dependent PR gene pathway	Kavroulakis et al.,2007
6	*Penicillium citrinum*	*Helianthus annus L*	*Sclerotium rolfsii*	SA, JA pathway	Waqas et al.,2015
7	*Flavobacterium*	*Beta vulgaris*	*Rhizoctonia solani*	Chitinase, nonribosomal peptide synthetases (NRPSs), and polyketide synthases (PKSc)	Carrión et al.,2019
8	*Bacillus aryabhattai*	*Nicotiana tabacum, A.thaliana*	*Botrytus cinerea*	SA, JA	Portieles et al.,2021

Role of endophytes in enhancing Abiotic stress tolerance

Global crop production is facing an increasing challenge from abiotic stresses. The most common abiotic stressors include moisture stress, high and low temperatures, salinity, and nutrient deficiency. These stresses may cause alterations in metabolomics and transcriptomics, which change the exudates from the roots and leaves and, in turn, influence the microbial community associated with plants (Liu et al.,2020). In the rhizosphere, microbes associated with plants triggers the signal transduction pathways and activates the stress responsive genes responsible for imparting tolerance against several abiotic stresses like drought, salinity, high and low temperature stresses. In this direction, many endophytes have been identified which can enhance the plant's abiotic stress tolerance and are being used in different formulations for different crops to improve the abiotic stress tolerance. Below table summarizes the several examples of different endophytes used to enhance the different abiotic stress tolerance in different crops.

Table: List of endophytes associated with Abiotic stress tolerance in crop plants

Sl no.	Endophyte	Host Plant	Abiotic stress	Mechanism of stress tolerance	Refernce
1	*Trichoderma harzianum TH-56*	*Oryza sativa*	Drought	Upregulation of aquaporin, dehydrin, and malonialdehyde genes	Pandey et al.,2016
2	*Embellisia chlamydospora, and Cladosporium oxysporum*	*Zea mays*	Drought	Altered root development	Li et al.,2019
3	*Bacillus cereus, Pseudomonas otitidis and Pseudomonas sp.*	*Glycine max*	Drought	Improving plant growth, membrane integrity, water status, accumulation of compatible solutes, and osmolytes	Dubey et al.,2021
4	*Pseudomonas putida*	*Cicer arietinum*	Drought	miRNAs and their target genes indicated the involvement in the stress regulatory pathways, which control/regulate drought stress response	Jatan et al.,2019
5	*Gluconacetobacter diazotrophicus*	*Saccharum officinarum*	Drought	IAA and proline production	Vargas et al .,2014
6	*Bacillus amyloliquefaciens subsp. plantarum UCMB511*	*T. aestivum*	High temperature	By molecular modifications in wheat leaf transcript patterns of proteins related to stress defense and energy supply	Abd El-Daim et al.,2018
7	*Pseudomonas aeruginosa strain 2CpS1*	*T. aestivum*	High temperature	Reducing heat and drought–induced oxidative stress	Meena et al.,2015
8	*Burkholderia phytofirmans PsJN*	*A. thaliana*	Cold	Pigment accumulation and cold response pathway induction	Su et al.,2015
9	*Alternaria chlamydospora*	*Triticum aestivum*	Salinity	Inducing the physiological and biochemical responses	Bouzouina et al.,2021
10	*Pantoea agglomerans*	*Zea mays*	Salinity	Upregulation of aquaporins, enhancing the expression of genes responsible for water, potassium ion uptake, carotenoid biosynthesis, phenylalanine metabolism	Gond et al.,2015

Conclusion

Research in the field of microbial endophyte biology is expanding. Researchers' interest in studying endophytes has grown over the past 25 years, as seen by the rise in the number of research articles published in this field. Over the years, a substantial amount of information regarding endophytes and their effects on plants has been gathered. A sustainable and environmentally acceptable way to bestow abiotic stress tolerance in crop plants would be by endophyte-mediated activation of abiotic stress tolerance traits. Several studies have shown that endophyte treatment can give tolerance to multiple abiotic stresses, and that it can sustain productivity under adverse conditions by activating basic physiological processes like photosynthesis. Current and future research must concentrate on microbial endophytes to increase plant/crop productivity and build a more sustainable agricultural system where environmental degradation from excessive use of agrochemicals is avoided.

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