Bacillus subtilis: A Potential Plant Growth Promoting Rhizobacteria that Impacts Plant Disease

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Bacillus subtilis is a gram-positive, rod shaped, spore-forming bacterium which is extensively present in the environment. B. subtilis develops endospores that can withstand stress. Its sequenced genome have 4 214 630 base pairs which encoded about 4100 proteins. It is used as a model organism for research on sporulation and the behaviour of Gram-positive bacteria with low GC levels. It is not infectious. Proteases and amylases are two of the products it produces. Due to its commercial importance and simplicity for genetic manipulation B. subtilis has undergone extensive research. It has low GC content of 43.5%. It lacks an exterior membrane, as is typical of Gram-positive organisms, but it does have a cytoplasmic membrane and a strong cell wall.

Table 1: List of antibiotics produced by several strains of *B. subtilis*

B. subtilis strains	Plant pathogen	Disease in plant	Antibiotics produced
B. subtilis RB14	*Rhizoctonia solani*	Damping off of tomato	Iturin A and surfactin
B. subtilis	*F. oxysporum* f.sp. *ciceris*	Fusarium wilt of chickpea	Subtilin
B. subtilis AU195	*Aspergillus flavus*	Aflatoxin contamination	Bacillomycin D
B. subtilis QST713	*Botrytis cinerea* and *R. solani*	Damping off	Iturin A
B. subtilis BBG100	*Pythium aphanidermatum*	Damping off	Mycosubtili
B. subtilis UW85	*Phytophthora medicagins*	Damping off	Zwittermycin A, kanosamine
B. subtils fmbj	*Aspergillus flavous*	Aflatoxin contamination	Bacillomycin D
B. subtilis B47	*Bipolaris maydis*	Southern corn leaf blight	Iturin A2
B. subtilis SQR9	*F. oxysporum* f.sp. *cucumerinum*	Wilt disease of cucurbits	Fengycin and Bacillomycin
B. subtilis CMB 32	*Colletotrichum gleosporioides*	Anthracnose	Iturin A, Fengycin and surfactin A
B. subtilis PCL1608	*Fusarium oxysporum*	Wilt	Iturin A
B. subtilis PCL1612	*Rosellinia necatrix*	White root rot	Iturin A

Systemic position of the bacterium

The genus was first discovered as Vibrio subtilis by Christian Gottfried Ehrenberg in 1835. It was renamed by Ferdinand Cohn in 1872. The Bacillus genus was first reported by Cohn in 1872. Currently, the genus includes over 377 species.

Domain: Bacteria

Phylum: Firmicute

Class: Bacilli

Order: Bacillales

Family: Bacilliaceae

Genus: Bacillus

Species: Subtilis

Mechanism of B. subtilis in plant disease control

Competition for nutritients and colonizing sites

Root exudates such as amino acids, fatty acids, polyamines, sterols, phenolics, organic acids, nucleotides, organic acids and vitamins. Competition for these nutrients is fundamental key of B. subtilis for management of plant disease. Chemotaxis was suggested as the essential characteristic for colonisation. Colonization of plant roots by B. subtilis directly contributes to plant disease management. On

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chir pine seedlings, B. subtilis BN1 showed excellent root colonization.

Plant growth promotion

B. subtilis produce several phytohormones including auxins, cytokinins, gibberellins and ethylene as well as enzymes like 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase that helps to regulate the growth and development of plants. Additionally, this encourages nitrogen fixation, enhanced root growth, nutrient mineralization (such as phosphate, potassium, and zinc solubilization) and enhance absorption ability of roots. Application of B. subtilis GB03 and B. amyloliquefaciens IN937 mixture helps to enhance the growth of Arabidopsis mutants deficient in IAA. Cucumber seedling growth was stimulated by B. subtilis B579 through phosphate solubilization, IAA and siderophore production.

Production of cell wall hydrolytic enzymes

Various strains of B. subtilis synthesize a wide range of hydrolytic enzymes i.e. cellulases, proteases, and β-glucanases. The diminished growth of the Rhizopus stolonifer fungus on B. cereus AR156 and B. subtilis SM21 treated peach fruit was due to over expression of the genes for 1,3-glucanase, chitinase, and phenylalanine-ammonium-protein lyases.

Antibiotics production

B. subtilis produces several antibiotics that are very helpful in suppressing the growth and multiplication of the pathogens.

Induction of plant disease resistance

The use of PGPR such as B. subtilis may activate host defense mechanisms which results changes in ultrastructure and cytochemical alteration (ISR) against the pathogen. One of the main mechanisms of B. subtilis was the elicitation of ISR for controlling plant diseases. It is well accepted that signal transduction pathways elicited by B. subtilis are dependent on production of Jasmonic acid (JA), ethylene, and the regulatory gene NPR1, but independent of salicylic acid (SA), a signal of systemic acquired resistance elicited by pathogens.

Table 2: Commercially available formulations of B. subtilis

Commercial product	Active biological agent
Kodiak	B. subtilis GB03
Gallipro	B. subtilis DSM 17299
Calsporin	B. subtilis C-3102
Clostat	B. subtilis PB6
Biotop	B. subtilis CCT 7611
Natto powder- 710	B. subtilis Natto
Fertitacto	B. subtilis PBRS-1
Fertitacto	B. subtilis PBRS-2
Serenade	B. subtilis QST 713
Integral	B. subtilis MBI 600
Companion	B. subtilis GB03
Green Dual	B. subtilis
Quantum-400	B. subtilis GB03
YIB	B. subtilis QST 713

Production of Bacteriocins

Ribosomal synthesized peptides which are produced by numerous bacteria and might be useful against pathogenic bacteria are known as Bacteriocins (Zou et al., 2018). Bacteriocins interfere with the cell wall synthesis or by forming pores in the cell membrane acts against target pathogen. Bacillus spp. exhibits a broad-spectrum of antibacterial activity due to the production of bacteriocins. Some bacteriocins and bacteriocin-like substances (BLSs) such as amylolysin, amysin, subtilin, subtilosin A, subtilosin B and thuricin were isolated from various Bacillus spp.

Production of siderophores

Siderophores are Fe-chelating, low molecular weight, non-ribosomal peptides which are produced by some microorganisms and plants under iron starvation conditions. Siderophores chelate with Fe, allowing its solubilization and extraction from minerals and organic compounds by making Fe unavailable for pathogens., Bacillus spp. produce a wide variety of siderophores such as bacillibactin, pyoverdine, pyochelin, schizokinen, petrobactin etc. For example, B. subtilis acts as promising biological control agent against Bipolaris sorokiniana due to siderophores, chitinase and cellulase production of (Villa-Rodríguez et al., 2019).

Some of commercially available products are listed along with their Trade name and biologically active strain of B. subtilis.

Conclusion

B. subtilis represent an eco-friendly approach to improving crop productivity through various mechanisms of biological control, biofertilization and biostimulation processes. Although it helps to boost crop output and reduce disease incidence. The interaction of bacteria with plants, potential pathogens, and the environment determines whether B. subtilis can display advantageous characteristics. B. subtilis play a significant role in both economic and ecological processes, so more practically significant species must be discovered together with advanced approaches for rapid and comprehensive study and effective application.

References

Villa-Rodriguez, E., Parra-Cota, F., Castro-Longoria, E., López-Cervantes, J. and de los Santos-Villalobos, S. (2019). B. subtilis TE3: a promising biological control agent against Bipolaris sorokiniana, the causal agent of spot blotch in wheat (Triticum turgidum L. subsp. durum). Biological control, 132, 135-143.

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