Bacillus strains – A Promising Bio Control Agent for Post-Harvest Diseases in Fruits and Vegetables

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Nearly 45 % of yield losses occur in all fruits, roots, tubers and vegetable crops due to post-harvest diseases. There are several factors related to storage losses, including pest infestations and pathogens (bacteria, fungi, and insects), unfavourable storage conditions, water loss, scarification, and sprouting (FAO,2023). Even though chemical fungicides or food preservatives effectively prevent post-harvest decay, they are harmful to humans, animals, and the environment. The chemicals and food preservatives used against post-harvest diseases are harmful to human beings and environmental hazards and some of the European countries completely banned it (Wisniewski et al., 2016). It is highly desirable to develop effective, efficient, eco-friendly, bio-safe methods to reduce post-harvest food losses as food and environmental issues become more pressing and Bio-based technologies and organic products become more necessary. In the past, synthetic fungicides have been used to control post-harvest diseases, while biological products derived from beneficial strains of bacteria, such as plant growth-promoting bacteria (PGPB), are better alternatives to synthetic fungicides and/or food preservatives. As a result of these products altering plant metabolism, there is systemic resistance, a longer shelf life, and no adverse effects on humans, plants, or the environment on account of the use of these products (Arroyave-Toroa et al., 2017; Sarma et al., 2012). PGPBs are nonpathogenic beneficial bacteria mainly found in the rhizosphere region of the soil and phyllosphere region (endophytes) of the plant tissue. PGPB promotes plant growth, disease resistance, and tolerance to abiotic stresses. These organisms may be found living autonomously in soil or colonising the rhizosphere, phyllosphere and plant interior tissues (endophytes)

An interesting PGPB is Bacillus subtilis, a member of the genus Bacillus spp. one of the most attractive natural plant protection agents. Among the various PGPB, Bacillus subtilis belongs to the genus, Bacillus spp. is the most widely used biocontrol agent. According to the FDA, Bacillus spp. is generally considered a safe microorganism for use in food applications. Bacillus subutilis stimulates Plant metabolism without adverse effects on either the environment or human health (Sarma et al., 2012). The bio-control agent is resistant to adverse conditions and activates defence responses even under adverse stress conditions, due to the production of endospores by Bacillus spp. It produces different antibiotics and enzymes and siderophores to induce host systemic resistance response (Shafi et al., 2017).

Effect on Post Harvest diseases

The first microorganism patented for controlling post-harvest disease (brown rot of stone fruits) was Bacillus subtilis. The use of Bacillus sp. improves the post-harvest physiology of different vegetables and fruits and, in addition, increases the resistance against post-harvest diseases and adverse storage conditions, in that way prolongs shelf life and ensures nutritional quality.

A study reported that B. subtilis EXWB1 repressed ethylene production by 72.3% and reduced respiration rates by 26.1% and 71.9% of infected and non-infected melons, respectively after harvest. As a result of holding back ethylene biosynthesis, B. subtilis EXWB1 may slow down the melon fruit rot disease development (Wang et al., 2010). *B. subtilis* reduces the infection of *Monilinia fructicola* in Cherries and Peaches (Utkhede & Sholberg, 1986) and controls fungal rot in Citrus (Singh & Deverall, 1984). The other species of Bacillus namely. *B. pumilus* and *B. amyloliquefaciens* suppress the growth of Botrytis cinerea, which causes grey mold in tomato and pear crops (Miller, 2003). As well as the other Bacillus strains such as *B. pumilus* B19, B. subtilis B11, B. subtilis 1J, *B. crerus* B16 and B. cereus B17 reduce the disease incidence of Gray mold in apples and inhibited the growth of Botrytis *mali*, the causal organism for grey mold in apples (Lastochkina et al., 2017).

Mode of action

Bacillus subtilis mainly produces antibiotics and volatile organic compounds (VOCs) to reduce the growth of post-harvest pathogens such as Botrytis cinerea (gray mold), and Colletotrichum spp. (Anthracnose) and *Rhizopus stolonifer* (soft rot) (Kim et al., 2015). Another important action of B. subtilis to reduce the growth of post-harvest pathogens is entophytic activity. Bacillus spp. can survive as entophytes in the phyllosphere and rhizosphere region of the plants. This creates the competition for space and nutrients with pathogens and also the introduction of *Bacillus*

subtilis to the plants or soil before planting improves the plant growth and shelf life capacity of fruits and vegetables (Pieterse et al., 2014). B. subtilis activates the Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR) in plants by initiating the SA and JA signalling pathways. Through this, the plant showed a defence response against pathogens (Kudoyarova et al., 2014). A study reported that B. subtilis UMAF6639 activates SA and JA-dependent pathways, result of this action, the respiration in plants was reduced, through this harvest and post-harvest physiology of plants changed and showed the protective responses in melon (Zhang et al., 2016).

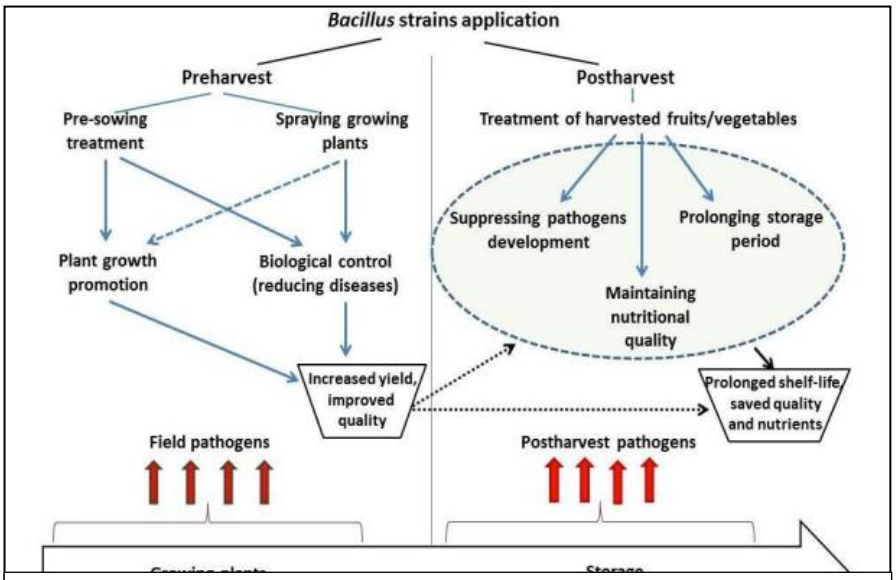
The phyto-hormone, ethylene plays an important role in the ripening and senesces of fruit and vegetables. Additionally, excess production of ethylene minimizes shelf life and speeds up senescence after harvest (Maksimov et al., 2011) various reports mentioned that PGPBs synthesize ACC-deaminase enzyme, which alters ethylene levels in plants and increase post-harvest disease tolerance (Li et al., 2015)

Post-harvest Application of Bacillus strains

The PPBs application as pre-harvest as well as post-harvest improves the plant growth and yield and reduces the disease incidence and growth of different pathogens (Kumar et al., 2023). The formulations of different Bacillus spp. can be applied through spraying, dipping and waxing. The efficacy of the bio formulations can be increased when combined with physical methods such as hot water treatment, curing or heat treatment.

Conclusion

Bacillus species are capable of improving the post-harvest physiology of fruits and vegetables by activating their resistance to different pathogens, leading to a prolonged storage period and marketing life, in addition to maintaining their nutritional value and freshness. The use of bio-based post-harvest disease management reduces disease incidence by altering plant physiology without showing adverse effects on humans and the environment.



Schematic representation of Bacillus strains applications in plant disease management

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