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Review article

Biological Fertilizers-Containing Beneficial Microorganisms in Fruit Culture[a]

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ABSTRACT

The soil, which provides both the environment and the nutritional requirements for the growth of plants, also has a significant number of microorganisms. Therefore, this ecosystem, where both living and non-living elements are together, must create an absolute balance for good growing. The natural life cycle in the soil is carried out especially by the biotic part of the soil, this part also provides the opportunity to make plant cultivation h[a]ealthier. Non-pathogenic beneficial microorganisms, which occupy an important portion in the biotic part of the soil, have taken on the task of being the biggest supporter of sustainable-organic-controlled agriculture in recent years. In this review, studies on the possibilities of using rhizobacteria and beneficial fungal forms, known as beneficial microorganisms, in fruit growing and their mechanisms of action are summarized.

Keywords: PGPR, AMF, *Trichoderma* spp., biological fertilizer

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Derleme makale

Yararlı Mikroorganizma İçerikli Biyolojik Gübrelerin Meyve Yetiştiriciliğinde Kullanımı

ÖZ

Bitkilerin yetişmesi için hem ortam hem de beslenme ihtiyaçlarını sağlayan toprak, önemli miktarda mikroorganizma içeriğine de sahiptir. Dolayısıyla hem canlı hem de cansız unsurların bir arada olduğu bu ekosistem, iyi bir yetiştiricilik için mutlak dengeyi oluşturmak zorundadır. Topraktaki doğal yaşam döngüsü, özellikle toprağın biyotik kısmı tarafından yürütülmekte, bu kısım aynı zamanda bitki yetiştiriciliğinin daha sağlıklı yapılabilmesine imkân sağlamaktadır. Toprağın biyotik kısmında önemli bir yer kaplayan patojen olmayan yararlı mikroorganizmalar, son yıllarda özellikle sürdürülebilir-organik-kontrollü tarımın en büyük destekleyicisi olma görevi üstlenmiştir. Bu derleme ile, yararlı mikroorganizmalar olarak bilinen bitki büyümesini teşvik eden rizobakteriler ve yararlı mantar formlarının meyve yetiştiriciliğinde kullanım imkanlarına yönelik yapılan çalışmalar ve etki mekanizmaları özetlenmiştir.

Anahtar Kelimeler: PGPR, AMF, *Trichoderma* spp., biyolojik gübre

Introduction

The extreme changes that have been observed in recent climate events and pose a serious threat to agricultural production can seriously affect product quality and quantity by threatening food security around the world. Abiotic stress factors caused by climatic changes also make plants more vulnerable to pathogen attacks. Especially drought and soil salinization are the most important reasons for agricultural losses caused by human-induced climate changes. Basically, these reasons result in deterioration in evapotranspiration and photosynthetic activities, which play a key role in total biomass production. This situation negatively affects the plant nutrient uptake ability both directly and indirectly.

Increasing world population and food need, and accordingly, more frequently used plant production inputs have significantly affected the health of agricultural ecosystems. In improving agricultural production, there are significant challenges, such as limited arable land, the need to reduce the use of pesticides and chemical fertilizers, and the dissemination of sustainable technologies. In order to overcome these limitations, in the last 30 years, useful microorganism-containing biological fertilizers, which are effective as plant bio-stimulants, have started to be widely used in wider areas.

Biological fertilizers containing beneficial microorganisms, which are also evaluated as plant bio-stimulants, have the capacity to increase or regulate the efficiency of other inputs used in plant production, independent of the presence of nutrients in the soil, owing to different microorganisms. As a result, these elements, which are considered as bio-stimulant, are gradually being included in plant production systems. These elements are not classical nutrients, however, they also activate mechanisms that promote the use of nutrients and protect plants against different biotic and abiotic stress conditions. Beneficial fungi and bacteria are also considered as the most promising bio-stimulants for sustainable agricultural production (Ruzzi and Aroa 2015).

Beneficial microorganisms fix atmospheric nitrogen, dissolve phosphate, chelate iron with siderephore, break down organic residues by decomposition, suppress soil pathogens, increase the availability of plant nutrients and contribute to their conversion, produce antibiotics and other bioactive substances, reduce heavy metal uptake of plants in heavy metal pollution areas. Research results have been reported in different ecosystems for many plant species that have many functions such as providing water, increasing soil aggregation with the polysaccharides they produce. These types of microorganisms that increase soil fertility and contribute to plant growth with these mechanisms are called biofertilizers.

Soil biology, which is one of the three most important components of soil fertility, is an ecosystem of organisms living in the soil and interacting with other components and has a highly complex and dynamic structure that varies greatly according to conditions. The very limited soil mass around the root, called the rhizosphere, is an environment where microorganisms are highly concentrated. Although microorganisms in this field have numerous tasks, they have an important place in terms of plant development, yield, and soil fertility. The most important microorganisms that increase plant growth are rhizobacteria, arbuscular mycorrhizal fungi (AMF), and *Trichoderma* (Jakoby et al. 2017).

Rhizobacteria, named as PGPR (Plant Growth-Promoting Rhizobacteria) by Kloepper and Schroth and discovered in 1978, provide many benefits to plants by colonizing the rhizosphere and phyllosphere of plants (Ram et al. 2013). PGPR directly support plant growth by promoting the production of plant growth regulators, facilitating the uptake of soil nutrients, contributing to disease control and increasing nitrogen fixation (Alagawadi and Gaur 1992; Antoun and Prevost 2006; Bashan and de-Bashan 2005; Çakmakçı et al. 2010; De-Ming and Alexander 1998; Podile et al. 2006; Zahir and Arshad 2004; Zhang et al. 1996). On the other hand, AMF are beneficial fungal species that occur in the root zone of 80%-90% of land plants in a symbiosis with all terrestrial plants (Abdel Latef and Chaoxing 2011a,b; 2014). The hyphae formed by the AMF in harmony with the plant roots increase the surface area of the roots, improve the mineral and nutrient uptake of the plants from the soil, and thus encourage the plants to show better growth. It is also reported that AMF contribute to the resilience of plants against environmental stresses such as soil salinity, heavy metal pollution, nutrient deficiency, and adverse soil pH conditions. (Turkmen et al. 2008). AMF, which have an important place in terms of sustainability, are in important interaction with many families in horticultural plants. *Tricoderma*, another beneficial fungus group consisting of two hundred species, are also beneficial fungi species that play an important role in plant growth and development, such as AMF, and increase the tolerance of plants to environmental stresses (salinity, drought). *Tricoderma* species are also used in seed and seedling production to provide tolerance to some root diseases (Balla et al. 2008; Bitterlich et.al. 2018; Studholme et al. 2013).

With the help of fertilizers containing microorganisms, it is normal that the successes to be obtained from cultivation in plant and root development, flower yield and stress conditions differ according to the strain used and the genotypic effect of the applied plant (Abdel-Rahman and El-Naggar 2014). For this reason, the diversification of the applications (bacteria or fungi species) and the plant species to be applied is a matter directly related to the adequacy of the knowledge to be obtained on this subject.

In this review, the results of the studies conducted to reveal the efficacy of PGPR, AMF and *Trichoderma* species, which are known as beneficial microorganisms, in fruit growing were evaluated.

2. Biological Fertilizers Containing Microorganisms and Terminology

It is observed that different terms such as bio-stimulant, microbial inoculant, or biopreparate are used in studies on biological fertilizers. The content and scope of these terms can be schematized as follows.

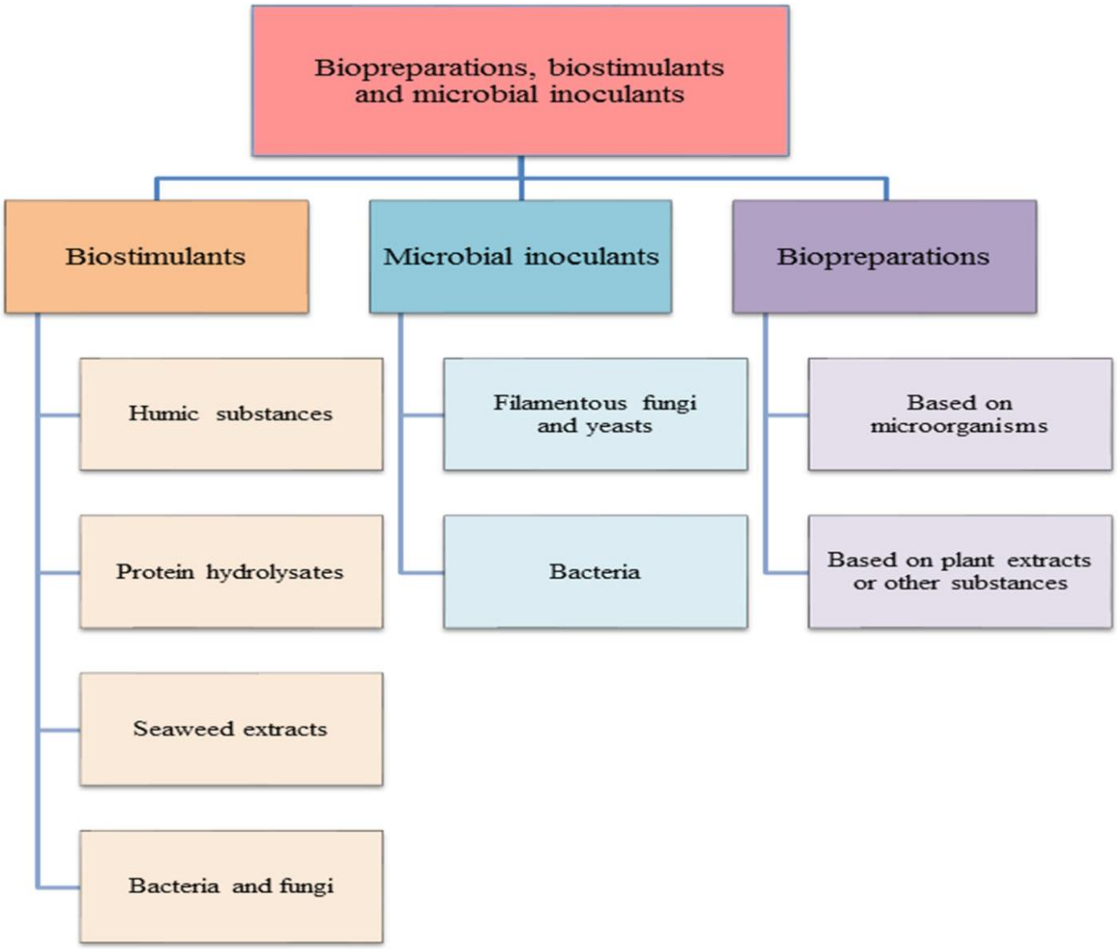

Figure 1. Scope of the terms biopreparate, microbial inoculant and biostimulant (Pylak et al. 2019).

Biopreparations are products derived from a living organism or its metabolites. They inhibit the growth of pathogenic fungi or bacteria. Their effectiveness varies and is largely dependent on ecological factors (Pačuta et al. 2018). Substances other than conventional nutrients (fertilizers) that have the ability to promote plant growth even when applied in low amounts are generally defined as bio-stimulants (du Jardin 2015). These products can be an important alternative in reducing or eliminating the low yield and quality problems in organic fruit growing. As a matter of fact, they are defined as any substance or microorganism supplied to plants, regardless of soil nutrient content, primarily to increase nutrient uptake efficiency, but also to increase abiotic stress tolerance and/or product quality characteristics. They are especially seaweed extracts, protein degraders, humic and fulvic acids, chitosan, inorganic compounds and beneficial fungi and bacteria (Ruzzi and Aroca 2015).

3. Beneficial Bacteria and Their Use in Fruit Culture

It is known that conventional agricultural techniques cannot meet the food needs of the increasing population in the world, the natural balance is disturbed as a result of these methods, and human and animal health is adversely affected by the chemicals used. In addition, these methods have led to an increase in production costs and difficulty in reaching food. Therefore, in order to reduce such problems, it is tried to adapt environmentally friendly production systems to agricultural production. One of the alternative approaches is PGPR, known as biological fertilizers. They contribute to high yield increases by contributing to the economic use of mobile nutrients in non-renewable resources, stimulating plant growth at lower costs and in a sustainable way. (Lucy et al. 2004). In this group, In addition to symbiotic species such as *Azorhizobium*, *Allorhizobium*, *Bradyrhizobium*, *Mesorhizobium*, and *Rhizobium*, there are non-symbiotic nitrogen-fixing bacteria such as *Azoospirillum*, *Azotobacter*, *Bacillus*, *Klebsilla*, and *Synorhizobium* (Hayat et al. 2010; Bhardwaj et al. 2014). The effectiveness of these species extends beyond fixing N_2 to include the ability to recycle organic matter. So that they mineralize organic nitrogen to nitrate, which can be easily taken up by plants via nitrite. The most studied genus in this group is *Azospirillum* spp. (Miransari 2011).

The effectiveness of PGPR can be by direct and indirect mechanisms. Although the mechanism of PGPR is not fully understood, their mechanism has been clarified; (1) increased root length and development, thanks to its ability to produce 1-aminocyclopropane-1-carboxylate (ACC) deaminase, an important enzyme for reducing ethylene secretion in the root of developing plants (2) auxin, indole acetic acid (IAA), abscisic ability to produce hormones such as acid (ABA), gibberellic acid (GA) and cytokinin, (3) symbiotic nitrogen fixation, (4) antagonistic to phytopathogenic bacteria by producing siderophore, ß-1, 3-glucanase, chitinase, antibiotic, color pigment and cyanide effect, (5) dissolution and mineralization of nutrients (especially phosphate compound), (6) increased resistance to drought, salinity, excess water and oxidative stress, and (7) water-soluble B group vitamins, niacin, pantothenic acid, thiamine It can be summarized as the production of riboflavin and biotin, as well as the removal of toxic substances and heavy metals for contaminated soil with plants (Hayat et al. 2010).

In addition to their contribution to soil nitrogen fixation, PGPR, such as *Bacillus circulans*, *B. megaterium*, *B. polymyxa*, *B. sircalmous*, and *B. subtilis*, are known to have the ability to dissolve phosphate rock in the soil. P in soil are also found in mineral forms such as apetite, hydroxyapetite and oxyapetite, and in organic forms such as inositol phosphate, phosphomonoesters, phosphodiesters and phosphotriesters (Khan et al. 2007). Rather than fertilizing the soil, which increases productivity and development, mineralization and dissolution of phosphorus with the help of phosphate-dissolving bacteria has become an alternative to humanity as a more sustainable way (Jeffries et al. 2003). The most important mechanism of solubilization of inorganic phosphate through PGPR applications is based on the synthesis of lower weight organic acid molecules such as glauconic acid and stric acid (Rodriquez et al. 2004). These organic acids of phosphate bind cations with carboxyl and hydroxyl groups by cleating them, which causes a decrease in soil acidity and thus the dissolution of phosphate (Tao et al. 2008). In addition, some of these bacterial groups have the ability to produce plant hormones such as abscisic acid, auxin, cytokinin, ethylene, and giberallin (Pylak et al. 2019). With this hormone production, a strong architectural structure will be formed in the roots, so the plant will be able to absorb more water and nutrients with these roots. As a matter of fact, in a study conducted, root growth increased up to 35% under irrigation conditions and up to 43% in drought conditions in *Rubus glacus* plants, where bacteria with known IAA production efficiency were applied (Rubin et al. 2017). In addition to the increase in root development and, in parallel with this, more and faster intake of nutrients, bacteria such as *B. amyloliquefacies*, *B. brevis*, *B. circulans*, *B. coagulans, B. firmus*, and *B. megterium* (PGPR) are involved in nitrate transport. It is also known that it upregulates the responsible genes (NRT1.1, NRT2 and NAR2.2), which increase nitrogen uptake (Saia et al. 2015). It was determined that the plants inoculated with *Pseudomonas mendocina*, which promotes plant growth, increased the nitrate reductase activity in the leaves and the capacity to stimulate the expression of the genes responsible for the enzymes with these applications. It has been determined that enzymes involved in nitrogen assimilation or photosynthesis are more affected by these applications (Jannin et al. 2012; Kohler et al. 2008).

It has been reported that some PGPR have the ability to produce auxin, cytokinin or giberallin from plant hormones both in pure culture and in the soil, and also inhibit ethylene synthesis (Çakmakçı et al. 2008, 2010; Glick et al. 1994). Bacteria can also increase root elongation and development by reducing the amount of ethylene in plant roots with their ability to produce ACC deaminase (Penrose and Glick 2001). Especially *Enterobacter* spp., *Rhizobium* spp., *Pseudomonas* spp., *Variovorax* spp., *Alcaligenes* spp., and *Bacillus* spp. Thanks to the 1-Aminocyclopropane-1-carboxylate (ACC) deaminase enzyme activity, which is determined to be common in species, it can reduce the negative effects of ethylene caused by different stress conditions (Çakmakçı 2009; Glick et al. 1998; Safronova et al. 2006). In plants to which bacteria with this activity are applied, resistance to stress conditions is indirectly increased by proportionally more root development, especially thanks to low ethylene (Burd et al. 2000). Stress factors such as excessive water, drought, low and high temperatures, heavy metals, and salinity increase the amount of "plant stress ethylene". The most effective strategy in reducing the stress ethylene formed under abiotic stress conditions is the use of the gene that produces the ACC Deaminase activity. When bacteria showing ACC deaminase activity are applied to plants, the bacteria act as a receptor for ACC deaminase and the plant ethylene level is thus reduced (Glick et al. 1998). PGPR strains; they can also show effectiveness in resistance to abiotic stress conditions such as drought and salinity, by stimulating osmolyte regulation mechanisms that control plant cell wall integrity and induce plant tolerance to stress factors (by producing osmoprotectants such as proline, glutomat and trehalose) (Koskey et al. 2021).

Microorganisms have long been widely used as biological control agents. PGPR also have important effects on pathogenic microorganisms, insects and nematodes. Most bacterial biological control agents are of the genus *Bacillus*, and *Bacillus thuringiensis* is the most widely used bacterial biocontrol agent against many fungal pathogens and insects. Derivatives of this genus are found in more than 70% of bacterial biopesticides. These products, also called biological control agents, are easy to apply. They activate the resistance mechanisms in the plants they are applied to and increase the yield. This antagonistic effect is achieved through antibiosis, secretion of some toxic metabolites, parasitism, and competition for food. The direct antagonistic mechanisms of microbial biological agents are assisted by the agents' ability to detect enzymes that break down the cell wall (such as catalases, cellulases, chitinases, esterases, glucanases, and proteases) (Alori and Babalola 2018). These hydrolytic enzymes facilitate the penetration of the pathogen into the cell wall and insect tissues. *Bacillus thuringiensis,* one of the main entomopathogenic bacteria, produces endotoxins that disrupt insect cell structures, induce osmotic cell lysis, causing significant ion leakage and loss of functional integrity (Azizoğlu 2019; Bent 2006; Köhl et al 2019; Liu et al 2019; Melo et al 2016).

Agrobacterium, Arthrobacter, Azotobacter, Burkholderia, Pseudomonas, Rhizobium, Serratia, and *Thiobacillus* are other bacterial genera with in vitro and in vivo antibiotic properties. Bacterial biopesticides, like most bacterial control agents, are environmentally friendly, inexpensive to develop, and can be as effective as synthetic pesticides (Köhl et al. 2019). Apart from parasitism, most biological control agents directly suppress pathogens through the production of antibiotic compounds that inhibit the proliferation of target pathogens. Bassiacridin and beauvericin, produced by *Beauveria*, have insecticidal properties (McGuire and Northfield 2020). Bioactive lipopeptides produced by *B. subtilis* necrotize insect epithelial cells and cause death (Melo et al. 2016; Liu et al. 2019). In their indirect mechanisms, it is important that they inhibit the development of other pathogens through competition. Thus, most antagonist microorganisms have the ability to colonize aggressively, suppressing pathogens that prevent their establishment through competition. This mode of action is incredibly effective in controlling necrotrophic pathogens that require exogenous nutrients for their formation. Here, it is necessary to express the complexity of antagonistic mechanisms and that microbial biological agents can suppress a pathogen through several mechanisms (Tewari et al. 2019).

The use of PGPR, whose effectiveness was evaluated by these mechanisms, in perennial plants such as fruit species, has intensified in the last 20 years, and the results have been more variable than annual and herbaceous plants. Study summaries on the activities of different PGPR strains on fruit species are given in Table 1.

Table 1. The activities of beneficial bacteria in fruit growing

Fruit species	Application effects	References
Strawberry	Increase in stolon efficiency between 124-449%	Aslantaş et al. 2009
	A positive effect against *Phytophytena cacterum* and *Phytophytena fragariae* diseases	Vesteberg et al. 2004
	Yield increase up to 94.9% in salty conditions, increase in N content, decrease in Na and Cl content	Karlıdağ et al. 2011
	The cumulative yield of strawberries grown in organic conditions increased between 10.5% and 33.2% in combined applications. Titratable acid decreased, while total dry matter and sugar increased.	Eşitken et al. 2010
	All rhizobacteria applied under field conditions in Fern strawberry cultivar had a positive effect on yield factors such as fruit amount per plant, average fruit weight and first quality fruit ratio. Among these bacteria, especially RC19 (*Bacillus simplex*), RC05 (*Paenibacillus polymxa*) and RC23 (*Bacillus* spp) were identified as the prominent isolates in increasing yield in strawberry.	Erturk et al. 2012
	In San Andreas' strawberry cultivar, it was determined that with different salt concentrations (0, 30 and 60 mM/L NaCl), the growth of the strawberry decreased, and the bacteria application at 60 mM/L NaCl concentration provided the highest curative effect and provided the most effective protection against salt stress of the plant. The results revealed that the application of bacteria can have a curative effect by increasing proline and anthocyanin levels, helping it to tolerate the adverse effects of salt stress, which is an important abiotic factor in horticultural cultivation.	Koç et al. 2016
Banana	Hevenk yield, the number of fingers in each hevenk, increased the N, P, K contents in the leaf.	Kavino et al. 2010
	In yield, number of hevenk, significant increases in phosphorus uptake from the soil	Attia et al. 2009
	Hevenk yield (35-51%), root development, Ca, N and Mg uptake increased.	Mia et al. 2010
	It was determined that bacteria application did not increase stem circumference and leaf length in Cavendish bananas, but there was a significant increase in plant height, leaf number and leaf width. The effects of bacterial application on banana cluster weight and fruit development were found to be statistically significant.	Akbaş et al. 2019
Apricot	It was determined that the average yield increase was between 30% and 60%, the growth of shoot length increased significantly with the application of bacteria in both years, and the N, P, K, Ca and Mg contents of the leaves of the treated trees increased compared to the control.	Eşitken et al. 2002, 2003a; Karlıdağ et al. 2010
Hazelnut	It was determined that the root formation in cuttings increased significantly compared to the control.	Basil et al. 1991
	Increase in vegetative growth values and leaf nutrient content in seedlings	Ertürk et al. 2010b, 2011a
Cherry	Yield per unit trunk area, increase in fruit weight, shoot length, N, P, K, Fe, Zn, Mn uptake	Eşitken et al. 2006
	Increase in total yield and fruit weight	Akça et al. 2010
Sourcherry	In Kütahya sour cherry cultivar, *Bacillus mycoides* T8 and *B. subtilis* OSU-142 flower and leaf applications significantly increased the yield per tree, shoot length and leaf area compared to the control. The highest shoot length was found in T8+OSU-142 (51.74 cm) application, and the lowest value was found in the control (46.71 cm).	Arıkan and Pırlak 2016
Mulberry	Significantly increased mulberry leaf area and quality.	Sudhakar et al. 2000
Apple	Increases in yield per unit trunk area (13.3-118.5), fruit weight (4.2-7.5%), shoot thickness (9-30.1%), N, P, K, Mg, Ca, Fe, Mn, and Zn amounts.	Pırlak et al. 2007

	Combined use with low doses of IBA on wood cuttings resulted in increases in rooting up to 30%.	Karakurt et al. 2009
Pear	Inoculation of phosphate-dissolving bacteria in Le Cont pear significantly increased shoot length and yield.	Fawzi et al. 2010
Tea	Applications made in pots and field conditions in different tea clones caused significant increases in vegetative growth parameters, leaf nutrient content and leaf enzyme activity values.	Çakmakçı et al. 2009, 2010a, 2010b, 2011a; 2011b, 2015, 2017, Ertürk et al. 2011b, 2013
	Rooting increase of 40-76.6% in cuttings	Ertürk et al. 2008
Kiwi	It significantly increased the rooting of kiwi wood cuttings (up to 78%).	Ercişli et al. 2003
	Rooting increased by 47.50% in semi-woody cuttings and up to 42.50% in woody cuttings.	Ertürk et al. 2010a
Vine	They increased the rooting rate and the success rate of callus formation rate, grade and graft set in rootstock-pencil combinations, increases up to 93% in graft combinations.	Köse et al. 2003, 2005
Pistachios	Lateral root formation up to 7.8% in seedlings	Orhan et al. 2007
Almond	8.89-9.6% increase in lateral root formation	Orhan et al. 2006
Rosehip	It promotes rooting between 65-91% in wood cuttings.	Ercişli et al. 2004
Blueberry	Three biocontrol bacteria combination application containing *Bacillus amyloliquefaciens* JC65 and JC65 increased blueberry leaf chlorophyll content, net photosynthesis rate by 21.50%, average plant height by 13.21% at 30 days and by 2.72% at 69 days. Compared to the control, the grafted plants had a yield increase of 14.56% and an improvement in fruit quality.	Yu et al. 2020
	Increased leaf area, number of leaves, root dry weight and stem diameter, and an increase in P, Zn and Cu content in the leaf	De Silva et al. 2000
Blackberry	Application of *Pseudomonas fluorescens* N21.4 to blackberry roots (*Rubus* sp.) increased expression of some flavonoid biosynthetic genes, accompanied by an increase in the concentration of selected flavonoids in fruits.	Garci-Seco et al. 2015
	In the study carried out to determine the effect of three PGPR strains belonging to the genus *Bacillus* on the development of blackberry (*Rubus glaucus* Benth.) in semi-cover and field conditions (crop systems); In field conditions, the total number of branches (7.32), the number of productive branches (7.0), the number of flowers per cluster (26.2) and the lowest percentage of unproductive branches (6.1%) were higher than semi-covered ($P<0.001$). Significant differences ($P<0.05$) were obtained in the total number of branches over time with bacterial strains.	Roblede-Brutica et al. 2018

3. Beneficial Fungi and Its Use in Fruit Culture

Beneficial fungi, which make positive contributions to plant growth, especially in organic agriculture, have the ability to live in a symbiosis with plants. Thanks to the hyphae formed by the beneficial fungi and growing towards the plant roots, the surface area of the plant roots increases, increasing the root efficiency. In addition, siderophores, which are organic acids that chelate iron ions, are produced by these fungal groups and ensure better iron uptake. They also have the ability to secrete phosphatase and other organic compounds necessary to increase the presence of P in the soil (Rouphael et al. 2015).

Trichoderma harizanum (T22) is one of the most widely used plant pathogen antagonists in the composition of some biological preparations (its activity is fixed against pathogens such as *Armillaria, Botrytis, Demathophora, Diaportha, Fusarium, Macrophomina, Monillia, Phytophtora, Plasmophora, Phytium*). Thanks to the secretion of auxin-like hormones in the hyphae of *Trichoderma* spp, plant development is promoted due to plant root growth (Frac et al 2018). In addition to its microparasite function, it also has the ability to produce different antibiotics and growth promoting effects. In the studies, *Trichoderma* sp.; It has been determined that viriden also produces some antimicrobial compounds such as peptabol, gliotoxin, isontriles and sexterpenes. These substances are known to be toxic enzymes used by fungi to inhibit the growth of other competitors in the same ecological niche (Berg et al. 2004).

Trichoderma spp. induced resistance may contribute to plant breeding through certain mechanisms such as mycoparasitism, inactivation of pathogen enzymes, production of inhibitory compounds, and nutrient-space competition (Roco and Perez 200?; Yedidia et al. 2000).

Thanks to the antibiotic properties produced by some of the *Trichoderma* species, the development of other pathogens in the environment is prevented (*Phytoptera* pathogens are suppressed by the glovirin substance). The hyphae of this group of fungi usually grow into the hyphae of other fungi and curl around them, limiting them. Hardware such as hooks and appressorium in their hyphae facilitates attachment to fungi (Özbay and Newman 2004). In addition, many species belonging to this genus are known to produce high amounts of cell-degrading enzymes such as α-1-3 gluconases. Studies have shown that some enzymes produced by Trichoderma species also inhibit the growth of pathogenic fungal hyphae and spore germination (Szekerez et al. 2004). As a matter of fact, *Trichoderma coningii* (T21) and *Gliocladium virens* (G2 and G8) were used in strawberry cultivation, and they showed activity by providing inhibition against *Botrytis sineria* pathogen (Alizadeh et al. 2007). The contribution of this group of fungi to the inhibition of pathogen enzymes is another mechanism they use to control the growth of pathogens. Pectinase, gluconase, cutinase and chitinase secreted by pathogens; It is suppressed by the protease enzyme secreted by Trichoderma spp (Ela 2000). Some Trichoderma species colonize the roots of the plant and induce a series of biochemical and morphological changes (ISR). As a matter of fact, it has been determined that it can form systemic resistance against the powdery mildew agent *Podosphaera aphanisa* in strawberry by preventing the growth of the pathogen (Harel et al. 2011).

Arbuscular mycorrhizal fungi, which are species that can colonize 80% of terrestrial plant species, have the capacity to develop a symbiotic relationship with plants. These relationships are mutually beneficial, and fungi increase the surface area of the roots and allow them to grow, thus improving the plant's water and nutrient uptake. As a matter of fact, nitrogen, and other minerals, especially phosphorus, are taken into the plant together with water thanks to the wide hyphae network (Pylak et al. 2019).

Particularly, the effectiveness of the applications in the seedling and sapling period, and the aim of rapid and obvious seedling and sapling development make AMF an effective alternative. They can also act as biological control agents by direct or indirect mechanisms. Especially under stress conditions, the contribution of AMF to growth and development becomes clearer. Although many effects on seedlings and saplings such as high retention rate, growth, development, increases in fruit yield and quality, obtaining homogeneous fruit, increased flowering, early flowering, and induced resistance against stresses vary in different ecologies depending on the host and fungal species, fruit It has been determined by studies on species (Pylak et al. 2019).

Many fruit tree species are dependent on arbuscular mycorrhizal infection for survival and growth. Better growth of plants infected with mycorrhiza in this way is associated with a generally more efficient uptake of nutrients from the soil (Naik et al. 2018). The purpose of use of beneficial mushrooms in fruit growing and summary information about related studies are given in Table 2.

Table 2. Activities of beneficial fungi in fruit growing

Fruit species	Application effects	References
Citrus	Positive relationships were determined between AMF colonization and growth parameters in mandarins	Panja and Chaudhri 2004
	Increase in growth and ion uptake in drought and salinity conditions, improvement in fruit quality	Wu et al. 2010
	Trifoliate mycorrhizal inoculation, increases in fruit soluble sugar content and leaf chlorophyll content	Wu and Zou 2012
	Application of *Glomus macrocarpum* and *G. coledonicum* in Troyer plant increased plant height, stem diameter and total biomass.	Souza and Souza 2000
Banana	Grafting at the beginning of the weaning stage in micropropagated banana plants significantly increases growth.	Grant et al. 2005
	Increases in plant height, greener and wider leaves, more fruit clusters, higher fruit number per cluster with *Glomus fasciculatum* inoculation in dwarf Cavendish and Robusta cultivars.	Eswarappa et al. 2002
	Inoculation with AMF and Rhizobacteria alone or together (combined) resulted in higher shoot length in micropropagated banana plants than in control.	Mia et al. 2010
Vine	Growth enhancement on different rootstocks and cultivars grafted with *Gigaspora rosea* and *Glomus mosseae*	Linderman and Davis 2001
Olive	In olive plants inoculated with *Glomus mosseae*, shoot and leaf growth is at maximum levels.	Renaldelli and Mancuso 1996
	Increases in lateral root density	Vitagliano and Citernesi 1999
	Root and crown growth in grafted seedlings is maximum	Porras et al. 2002
Peach	Increase in plant height, root length, number of leaves and SSC in peach seedlings inoculated with *Glomus macrocarpum*.	Awad 1999, Sharma and Bhutani 1998
	Increases in AMF inoculation, nutrient content, and vegetative growth in Alderighi cultivar	Josec 2009
Apple	Increases in leaf area, biomass, and chlorophyll content in AMF inoculated apple seedlings under greenhouse conditions.	Mortin et al. 1994
	A positive correlation was found between AMF inoculation and shoot growth, leaf area and yield in apple seedlings.	Lovato et al. 1994
	Increases in seedling growth parameters with AMF colonization in seedling period	Wang et al. 2001
Pecans	The highest linear and radial growth internodium, number of leaves, shoot dry weight, root/shoot ratio and highest photosynthesis rates in AMF inoculation to pecan seedlings	Joolka et al. 2004
Plum	AMF applied with root inoculation in plum seedlings, vegetative growth parameters increased at different rates compared to the control.	Slawomir and Aleksander 2010
Pomegranate	Increases in fruit yield in 5-year-old pomegranate plants applied in combination with *Azotobacter chrococcum* and *Glomus mosseae.*	Aseri et al. 2008
Guava	The combined use of AMF and Bacillus megaterium provided the highest shoot length.	İbrahim et al. 2010
Strawberry	Strawberry seedlings of Camarosa, Aromas, Camino Real, Monterey, Portola, San Andreas and Albion cultivars were	Wang et al. 2012

inoculated with AMF. Increases in pH, SÇKM, titratable acidity, phenolic compounds in fruit juice, improvement in quality properties after harvest.	
Increases in fruit size and fruit strength in strawberries treated with AMF	Rivera-Chávez et al. 2012
While AMF and PGPR applications increased the sugar and anthocyanins concentration in strawberry, they decreased the pH and malic acid contents.	Todeschini et al. 2018

Conclusion

The biggest threats to conventional agriculture are high production costs of nitrogen fertilizers, decreasing natural P deposits, restrictions on pesticide use, drought and its negative impact on safe food. Increasing demand for safe food and better nutrition, developing research technologies and interest in sustainable agriculture are increasing the global interest in biological fertilizers containing microorganisms.

Different studies are needed to use beneficial microorganisms effectively in different processes of sustainable commercial fruit growing. A better understanding of the application principles and benefits of beneficial microorganisms will bring great benefits to sustainable agriculture. Understanding the complex plant X microorganism interactions, responses to stress tolerance and adaptations influenced by different soil and climatic factors is an important key here. In order to identify potential microbial candidates conferring resilience to abiotic stresses, their effectiveness in small-scale agro-ecosystems should be tested by employing advanced biotechnological tools.

Inoculation of beneficial microorganisms; Contribution to safe and adequate food production and environmental sustainability can be an important pillar. However, more information is needed on the effects of climate change and the effects of agricultural practices on the biofunctionality of microorganisms in multiple agrosystems.

References

Abdel Latef A A and Chaoxing H (2011a). Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition, antioxidant enzymes activity and fruit yield of tomato grown under salinity stress. Sci. Hort. 127, 228–233. doi: 10.1016/j. scienta.2010.09.020.

Abdel Latef A A and Chaoxing H (2011b). Arbuscular mycorrhizal influence on growth, photosynthetic pigments, osmotic adjustment and oxidative stress in tomato plants subjected to low temperature stress. Acta Physiol. Plant. 33, 1217–1225. doi: 10.1007/s11738-010-0650-3

Abdel Latef A A and Chaoxing H J (2014). Does the inoculation with *Glomus mosseae* improve salt tolerance in pepper plants? Plant Grow. Regul. 33, 644– 653. doi: 10.1007/s00344-014-9414-4

Abdel-Rahman S S, El-Naggar A I (2014). Promotion of rooting and growth of some types of *Bougainvillea*s cutting by plant growth promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF) in combination with indole-3-butyric acid (IBA). Inter. J. Sci. and Res, 3(11), 97-108.

Akbaş Y, Pirlak L, Dönmez M F (2019). *Bacillus atrophaeus* MFDV2 Rhizobacteria Isolate Increases Vegetative Growth, Yield, and Fruit Size of Banana Plant. *Indonesian* Journal of Agricultural Science Vol. 20 No. 2: 55–60. DOI: http//dx.doi.org/10.21082/ijas.v.20.n2.2019.p.55–60

Akça, Y, Ercişli S (2010). Effect of plant growth promoting rhizobacteria inoculation on fruit quality in sweetcherry (*Prunus avium* L) cv. 0900 Ziraat. J. Food Agr. And Biology, 8(2):769-771.

Alagawadi A R, Gaur A C (1992). Inoculation of Azospirillum brasilense and phosphate-solubilizing bacteria on yield of sorghum (*Sorghum bicolor* L. Moench) in dry land. Trop. Agric. 69, 347–350.

Alizadeh H, Sharifi-Tehrani A, Hedjaroude G (2007). Evaluation of the effects of chemical versus biological control on *Botrytis cinerea* agent of gray mould disease of strawberry. Commun Agric Appl Biol Sci 72:795–800

Alori E T and Babalola O O (2018). Microbial Inoculants for Improving Crop Quality and Human Health in Africa. Front. Microbiol. 9:2213. doi: 10.3389/fmicb.2018.02213

Antoun H, Prevost D (2006). Ecology of plant growth promoting rhizobacteria. PGPR: biocontrol and biofertilization. Edited by Zaki A. Sıddıqui, S 1-38.

Arıkan Ş, Pırlak L (2016). Effects of Plant Growth Promoting Rhizobacteria (PGPR) on Growth, Yield and Fruit Quality of Sour Cherry (*Prunus cerasus* L.). Erwerbs-Obstbau (2016) 58:221–226.

Aseri, G K, Jain N, Panwar J, Rao A V, Meghwal P R (2008). Biofertilizers improve plant growth, fruit yield, nutrition, and metabolism and rhizosphere enzyme activities of pomegranate (*Punica granatum* L.) in Indian Thar Desert. Scientia Horticulturae. 117: 130-135

Aslantas R, Karakurt H, Kose M, Ozkan G, Cakmakci R (2009). Influences of some bacteria strains on runner plant production on strawberry. Proc III. National Berry Fruit Symposium 50–58

Attia M, Ahmed M A, El-Sonbaty M R (2009). Use of biotechnologies to increase growth, productivity and fruit quality of maghrabi banana under different rates of phosphorus. World J Agric Sci 5:211–220

Awad S M (1999). Response of flame grape transplant to mycorrhizal inoculation and phosphorus fertilization. Egyptian Journal of Horticulture. 26(3): 421-423

Azizoglu U (2019). Bacillus thuringiensis as a biofertilizer and biostimulator: a mini-review of the little-known plant growth-promoting properties of Bt. Curr. Microbiol. 76, 1379–1385. doi: 10.1007/s00284-019-01705-9

Balla I Szucs E, Borkowska B, Michalczuk B (2008). Evaluation the response of micropropagated peach and apple rootstocks to different mycorrhizal inocula. Mycorrhiza Works, eds F. Feldmann, Y. Kapulnik, and J. Baar (Braunschweig: Deutsche Phytomedizinische Gesellschaft), 126–134

Bassil N V, Proebsting W M, Moore L W, Lightfoot D A (1991). Propagation of hazelnut stem cuttings using *Agrobacterium rhizogenes*. Hort Sci 26:1058–1060

Bashan Y, De-Bashan L E (2005). Plant growth-promoting. Encyclopedia of soils in the environment, 1, 103-115.

Bent E (2006). Induced systemic resistance mediated by plant growth-promoting rhizobacteria (PGPR) and fungi (PGPF). In: Tuzun S, Bent E (eds) Multigenic and induced systemic resistance in plants. Springer, New York, pp 225–258

Berg A, Kemami Wangun H V, Nkengfack A E, Schlegel B (2004) Lignoren, a new sesquiterpenoid metabolite from Trichoderma lignorum HKI 0257. J Basic Microbiol 44:317–319. https://doi.org/10.1002/jobm.200410383

Bhardwaj D, Ansari M W, Sahoo R K, Tuteja N (2014) Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microb Cell Fact 13:1–10. https://doi.org/10.1186/1475-2859-13-66

Bitterlich M, Sandmann M, Graefe J (2018). Arbuscular mycorrhiza alleviates restrictions to substrate water flow and delays transpiration limitation to stronger drought in tomato. Front.Plant Sci. 9:154. doi: 10.3389/fpls.2018. 00154.

Burd G I, Dixon D G, Glick B R (2000). Plant Growth Promoting Bacteria that decrease heavy metal toxity in Plants. Can J. Microbiol, 46:237-245.

Cakmakci R, Erdogan U, Kotan R, Oral B, Donmez M F (2008). Cultivable heterotrophic N2-fixing bacterial diversity in wild red raspberries soils in the coruh valley. In: Proceedings of IV. National Plant Nutrition and Fertilizer Congress 706–717

Çakmakçı R (2009a). Stres Koşullarında ACC Deaminaze Üretici Bakteriler Tarafından Bitki Gelişiminin Teşvik Edilmesi. Atatürk Üniv. Ziraat Fak. Derg. 40(1):109-125

Çakmakçı R, Ertürk Y, Dönmez F, Erat M, Haznedar A, Sekban R (2009b). Organik çay yetiştiriciliği için biyolojik gübre araştırmaları. I. GAP Organik Tarım Kong. 17-20 Kasım 2009 Şanlıurfa. s, 193-201

Çakmakçı R, Ertürk Y, Dönmez F, Erat M, Sekban R (2010 a). Organik çay üretiminin geliştirilmesi için biyolojik gübre olarak kullanılabilecek bitki gelişimini teşvik edici bakteri araştırması. International Conference on Organic Agriculture in Scope of Environmental Problems 03-07 February 2010 in Famagusta, p:371-376

Çakmakçı R, Dönmez M F, Ertürk Y, Erat M, Haznedar A, Sekban R (2010 b). Diversity and metabolic potential of culturable bacteria from the rhizosphere of Turkish tea grown in acidic soils. Plant and Soil,332:299-318

Çakmakçı R, Ertürk Y, Atasever A, Ercişli S, Şentürk M, Haznedar A, Sekban R (2011a). The Use of Plant Growth Promoting Rhizobacteria for Organic Tea Production in Turkey. Proceeding of Tea Organic Low Carbon International Symposium. Guangyuan, Chına, 2011, June 6-9, 89-97pp.

Çakmakçı R, Ertürk Y, Dönmez M F, Turan M, Sekban R, Haznedar A (2011b). Bitki Gelişimini Teşvik Edici Bakterilerin Tuğlalı Çay Klonunda Gelişme, Verim, Besin Alımı Üzerine Etkisi. Uluslararası Katılımlı I. Ali Numan Kıraç Tarım Kongresi ve Fuarı, 27-30 Nisan, s:571-581.

Çakmakçı R, Ertürk Y, Varmazyari A, Atasever A, Kotan R, Erat M, Turkyılmaz K, Sekban R, Haznedar A (2015). The effect of mixed cultures of plant growth promoting bacteria and mineral fertilizers on tea (*Camellia sinensis* L.) growth, yield, nutrient uptake, and enzyme activities. International Congress on "Soil Science in International Year of Soils" 19-23 October 2015 Sohi, Russia. Vol:1, pp:67-71.

Çakmakçı R, Ertürk Y, Varmazyari A, Atasever A, Kotan R, Haliloğlu K, Erat M, Türkyılmaz K, Sekban R, Haznedar A (2017). The effect of bacteria-based formulations on tea (*Camellia sinensis* L.) growth, yield, and enzyme activities. Annals of Warsaw University of Life Sciences – SGGW Horticulture and Landscape Architecture No 38, 2017: 5–18 (Ann. Warsaw Univ. of Life Sci. – SGGW, Horticult. Landsc. Architect. 38

De-Ming L I, Alexander M (1988) Co-inoculation with antibiotic producing bacteria to increase colonization and nodulation by rhizobia. Plant Soil 108, 211–219

De Silva A, Patterson K, Rothrock C, Moore J (2000). Growth Promoting of Highbush Blueberry by fungal and Bacterial Inoculants. HortSci. 35(7): 1228-1230.

du Jardin P (2015) Plant biostimulants: definition, concept, main categories and regulation. Sci Hortic 196:3–14. https://doi.org/10.1016/j.scienta.2015.09.021

Ercisli S, Esitken A, Cangi R, Sahin F (2003). Adventitious root formation of kiwifruit in relation to sampling date, IBA and *Agrobacterium rubi* inoculation. Plant Growth Regul 41:133–137

Ercisli S, Esitken A, Sahin F (2004). Application of exogenous IBA and inoculation with *Agrobacterium rubi* stimulate adventitious root formation among stem cuttings of two Rose genotypes. HortSci 39:533–534

Ertürk Y, Ercisli S, Sekban R, Haznedar A, Donmez M F (2008). The effect of plant growth promoting rhizobacteria (PGPR) on rooting and root growth of tea (*Camellia sinensis var. Sinensis*) cuttings. Roum Biotech Lett 13:3747– 3756

Ertürk Y, Ercişli S, Haznedar A, Çakmakçı R (2010a). Effects of plant growth promoting rhizobacteria(PGPR) on rooting and root growth of kiwifruit (*Actinidia deliciosa*) stem cuttings. *Biol Res 43:* 91-98

Ertürk Y, Çakmakçı R, Duyar Ö, Turan M (2010b). Fındık bitkisinde PGPR uygulamalarının bitki gelişimi ve yapraktaki bitki besin elementi içeriğine etkilerinin belirlenmesi. Türkiye IV. Organik Tarım Sempozyumu, 28 Haziran-01 Temmuz 2010, Erzurum, s 511-516

Ertürk Y, Çakmakçı R, Duyar Ö, Turan M (2011a). The Effects of Plant Growth-Promoting Rhizobacteria on Vegetative Growth and Leaf Nutrient Contents of Hazelnut Seedlings (Turkish hazelnut cv. Tombul and Sivri). Int. J. Soil Sci. 6(3):188-198.

Ertürk Y, Çakmakçı R, Dönmez M F, Sekban R, Haznedar A (2011b). Fener-3 Çay klonu Fidanlarında Enjeksiyon ve Daldırma Metotları ile PGPR Uygulamalarının Verim Üzerine Etkilerinin İncelenmesi. GAP VI. Tarım Kongresi 9-12 Mayıs 2011, s: 29-34.

Ertürk Y, Ercisli S, Çakmakçı R (2012). Yield and growth response of strawberry to plant growth promoting rhizobacteria inoculation. Journal Plant Nutrition 35:817-826.

Ertürk Y, Çakmakçı R, Sekban R, Haznedar A (2013). Çay yetiştiriciliğinde bitki büyümesini teşvik edici bakteri uygulamaları alternatif olabilir mi? Türkiye V. Organik Tarım Sempozyumu 25-27 Eylül 2013. Samsun, cilt 1, s:47-51.

Eswarappa H, Sukhada M, Gowda K N, Mohandas S (2002). Effect of VAM fungi on banana. Current Research 31(5-6): 69-70

Esitken A, Karlidag H, Ercisli S, Sahin F (2002). Effects of foliar application of *Bacillus subtilis* OSU-142 on the yield, growth and control of shot-hole disease (*Coryneum* Blight) of Apricot. Gartenbau 67:139–142

Esitken A, Karlidag H, Ercisli S, Turan M, Sahin F (2003). The effect of spraying a growth promoting bacterium on the yield, growth and nutrient element composition of leaves of apricot (*Prunus armeniaca* L. cv. Hacihaliloglu). Aust. J. Agric. Res. 54, 377–380

Esitken A, Pirlak L, Turan M, Sahin F (2006) Effects of floral and foliar application of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrition of sweet cherry. Sci Hortic 110:324–327

Esitken A, Pirlak L, Ipek M, Donmez M F, Cakmakci R, Sahin F (2009). Fruit bio-thinning by plant growth promoting bacteria (PGPB) in apple cvs. Golden Delicious Braeburn. Biol Agric Hort 26:379–390

Eşitken, A, Yıldız E H, Ercişli S, Dönmez M F, Turan M, Güneş A (2010). Effects of plant growth promoting bacteria PGPB) on yield, growth and nutrient contents of organically grown starwberry. Scientia Hort. 124:62-66.

Fawzi F M, Shahin E, Daood A, and Kandil E A (2010). Effect of organic and biofertilizers and magnesium sulphate on growth yield, chemical composition and fruit quality of "Le-Conte" pear trees. Nature and Science 8(12):273-280]. (ISSN: 1545-0740).

Fra̧c M, Hannula SE, Bełka M, Jȩdryczka M (2018). Fungal biodiversity and their role in soil health. Front Microbiol 9:707. https://doi.org/10.3389/fmicb.2018.00707

Jacoby R, Peukert M, Succurro A, Koprivova A, Kopriva S (2017). The Role of Soil Microorganisms in Plant Mineral Nutrition—Current Knowledge and Future Directions. Frontiers in Plant Science V:8. doi:10.3389/fpls.2017.01617.

Garcia-Seco D, Zhang Y, Gutierrez-Mañero F J, Martin C, Ramos-Solano B (2015). Application of Pseudomonas fluorescens to Blackberry under Field Conditions Improves Fruit Quality by Modifying Flavonoid Metabolism. PLoS ONE 10(11): e0142639. Doi:10.1371/journal.pone.0142639

Glick B R, Jacobson C B, Schwarze M M K, Pasternak J J (1994). 1-Aminocyclopropane-1-acid deaminase mutants of the plant growth promoting rhizobacterium *Pseudomonas putida* GR12-2 do not stimulate canola root elongation. Can J Microbiol 40:911–915

Glick B R, Penrose D M, Li J (1998). A model for the Lowering of Plant Ethylene Concentrations by Plant Growth Promoting Bacteria . J. Theor Biol, 190:63-68.

Grant C, Bittman S, Montreal M, Plenchette C, Morel C (2005). Soil and fertilizer phosphorus: Effects on plant P supply and mycorrhizal development. Can. J. Plant Sci. 85: 3-14

Hayat R, Ali S, Amara U, Khalid R, Ahmed I (2010). Soil beneficial bacteria and their role in plant growth promotion: a review. Ann Microbiol 60:579–598. https://doi.org/ 10.1007/s13213-010-0117-1

Harel Y M, Kolton M, Elad Y, Rav-david D, Cytryn E, Borenstein M, Shulchani R, Graber E R (2011) Induced systemic resistance in strawberry (*Fragaria ananassa*) to powdery mildew using various control agents. IOBC/Wprs Bull 71:47–51

Ibrahim H I M, Zaglol M M A, Hammad A M M (2010). Response of Baldy guava trees cultivated in sandy calcareous soil to biofertilization with phosphate dissolving bacteria and /or VAM fungi. Journal of American Science 6(9): 399- 404.

Jannin L, Arkoun M, Ourry A, Laıˆne´ P, Goux D, Garnica M, Fuentes M, Francisco S S, Baigorri R, Cruz F, Houdusse F, Garcia-Mina J M, Yvin J C, Etienne P (2012). Microarray analysis of humic acid effects on Brassica napus growth: involvement of N, C and S metabolisms. Plant Soil 359:297–319. https://doi.org/10.1007/s11104-012-1191-x

Jeffries P, Gianinazzi S, Perotto S, Turnau K (2003). The contribution of arbuscular mycorrhizal 706.

Joolka N K, Singh R R, Sharma M K (2004). Influence of biofertilizers, GA_3 and their combinations on the growth of pecan seedlings. Indian Journal of Horticulture. 61(3): 226-228

Josec B F (2009). Effeciency of Arbuscular mycorrhizalfungi on growth of aldrighi peach tree rootstock. Bragantia. 68(4): 931-940

Karakurt H, Aslantas R, Ozkan G, Guleryuz M (2009). Effects of indol-3-butyric acid (IBA), plant growth promoting rhizobacteria (PGPR) and carbohydrates on rooting of hardwood cutting of MM106 Apple rootstock. Afr J Agric Res 4:60–64

Karlidag H, Esitken A, Yildirim E, Donmez M F, Turan M (2011). Effects of plant growth promoting bacteria (PGPB) on yield, growth, leaf water content, membrane permeability and ionic composition of strawberry under saline conditions. J Plant Nutr 34:34–45

Kavino M, Harish S, Kumar S, Saravanakumar D, Samiyappan R (2010). Effect of chitinolytic PGPR on growth, yield and physiological attributes of banana *(Musa spp.)* under field conditions. Applied Soil Ecology 45:71-77.

Khan M S, Zaidi A, Wani P A (2007). Role of phosphate-solubilizing microorganisms in sustainable agriculture – a review. Agron Sustain Dev 27:29–43

Koç A, Balcı G, Ertürk Y, Keles H, Bakoglu N, Ercisli S (2016). Influence of arbuscular mycorrhizae and plant growth promoting rhizobacteria on proline content, membrane permeability and growth of strawberry (*FragariaXananassa* Duch.) under salt stress. Journal of Applied Botany and Food Quality 89:89 – 97.

Köhl J, Kolnaar R, Ravensberg W J (2019). Mode of action of microbial biological control agents against plant diseases: relevance beyond efficacy. Front. Plant Sci. 10:845. doi: 10.3389/fpls.2019.00845

Kohler J, Caravaca J A H F, Roldan A (2008). Plant-growth-promoting rhizobacteria and arbuscular mycorrhizal fungi modify alleviation biochemical mechanisms in water stressed plants Josef. Funct Plant Biol 35:141–151. https:// doi.org/10.1074/jbc.272.16.10639

Köse C, Guleryuz M, Sahin F, Demirtas I (2005). Effects of some plant growth promotion rhizobacteria (PGPR) on graft union of grapevine. J Sustain Agric 26:139–147

Koskey G, Mburu S W, Awino R, Njeru E M, Maingi J M (2021). Potential Use of Beneficial Microorganisms for Soil Amelioration, Phytopathogen Biocontrol, and Sustainable Crop Production in Smallholder Agroecosystems. Front. Sustain. Food Syst. 5:606308. doi: 10.3389/fsufs.2021.606308

Linderman R G, Davis E A (2001). Comparative response of selected grapevine rootstocks and cultivars to inoculation with different mycorrhizal fungi. American Journal of Enology and Viticulture. 52(1): 8-11

Liu X, Cao A, Yan D, Ouyang C, Wang Q, Li Y (2019). Overview of mechanisms and uses of biopesticides. Int. J. Pest Manage. 24, 1–8. doi: 10.1080/09670874.2019.1664789

Lovato P E, Hammatt N, Gianinazzi Pearson V, Gianinazzi S (1994). Mycorrhization of micropropagated mature wild cherry and common ash. Agriculture Science in Finland 3(3): 297- 302

Lucy M, Reed E, Glick B R (2004). Applications of free-living plant growth-promoting rhizobacteria. Antonie van Leewenhoock, 86:1-25

Melo A L, de A, Soccol V T, Soccol C R (2016). *Bacillus thuringiensis*: mechanism of action, resistance, and new applications: a review. Crit. Rev. Biotechnol. 36, 317–326. doi: 10.3109/07388551.2014.960793

McGuire A V, Northfield T D (2020). Tropical occurrence and agricultural importance of *Beauveria bassiana* and *Metarhizium anisopliae*. Front. Sust. Food Syst. 4:6. doi: 10.3389/fsufs.2020.00006

Mia M A B, Shamsuddin Z H, Wahab Z, Marziah M (2010). Rhizobacteria as bioenhancer and biofertilizer for growth and yield of banana (*Musa spp*. cv. 'Berangan').Scientia Hort. 126:80-87.

Miransari M (2011). Arbuscular mycorrhizal fungi and nitrogen uptake. Arch Microbiol 193:77–81. https://doi.org/10.1007/s00203-010-0657-6

Mortin F, Fortin J A, Hamel C, Granger R L, Smith D L (1994). Apple rootstock response to VA-mycorrhizal fungi in a high P soil. Journal of American Society of Horticultural Science. 119(3): 578-583

Naik S M R , Nandini M L N, Jameel Md A, Venkataramana K T, Mukundalakshmi L (2018). Role of Arbuscular Mycorrhiza in Fruit Crops Production. Int. J. Pure App. Biosci. 6 (5): 1126-1133.

Orhan E, Ercisli S, Esitken A, Sahin F (2006). Lateral root induction by bacteria, radicle cut off and IBA treatments of almond cv. "Texas" and "Nonpareil" seedlings. Sodininkyste ir darzininkyste 25:71–76

Orhan E, Esitken A, Ercisli S, Sahin F (2007). Effects of indole-3-butyric acid (IBA), bacteria and radicle tip cutting on lateral root induction in *Pistacia vera*. J Hort Sci Biotechnol 82:2–4

Ozbay N, Newman S E (2004) Biological control with *Trichoderma* spp. with emphasis on *T. harzianum*. Pak J Biol Sci 7:478–484. https://doi.org/10.3923/pjbs.2004.478.484

Pačuta V, Rašovský M, Černý I, Klimczak B, Wyszynski Z, Lesniewska J, Buday M (2018). Influence of weather conditions, variety and sea algae-based biopreparations on root yield, sugar content and polarized sugar yield of sugar beet. Listy Cukrovarnicke a Reparske 134(11): 368.

Panja B N, Chaudhuri S (2004). Exploitation of soil arbuscular mycorrhizal potential for AM-dependent mandarin orange plants by the cropping with mycotropic crops. Applied Soil Ecology. 26(3): 249-255

Penrose D M, Glick B R (2001). Levels of 1- aminocyclopropane- 1-carboxylic acid (ACC) in exudates and extracts of canola seeds treated with plant growth-promoting bacteria. Can J Microbiol, 47:368–372

Pirlak L, Turan M, Sahin F, Esitken A (2007). Floral and foliar application of plant growth promoting rhizobacteria (PGPR) to apples increases yield, growth, and nutrient element contents of leaves. J Sustain Agric 30:145–155

Podile A R, Kishore G K, Manjula K (2006). Achievements in biological control of diseases with antagonistic organisms at University of Hyderabad, Hyderabad. In Current status of biological control of plant diseases using antagonistic organisms in India. Proceedings of the group meeting on antagonistic organisms in plant disease management held at Project Directorate of Biological Control, Bangalore, India on 10-11th July 2003 (pp. 340-349). Project Directorate of Biological Control, Indian Council of Agricultural Research.

Porras Soriano A, Domenech Menor B, Castillo Rubio J, Sorian Martin M L, Porras Piedra A (2002). Influence of vesicular arbuscular mycorrhizae on growth of mist propagated olive cuttings. Olivae. 92: 33- 37

Pylak M, Oszust K, Frac M (2019). Review report on the role of bioproducts, biopreparations, biostimulants and microbial inoculants in organic production of fruit. Rev Environ Sci Biotechnol (2019) 18:597–616. https://doi.org/10.1007/s11157-019-09500-5.

Ram R L, Maji C, Bindroo B B (2013). Role of PGPR in different crops-an overview. Indian J. Seric. 52(1):1-13.

Renaldelli E, Mancuso S (1996). Response of young mycorrhizal and nonmycorrhizal plants of olive tree to saline condition. Short term electrophysiological and long term vegetative salt effects. Agrochimica. 44(3-4): 151- 159

Rivera-Chavez F H, Vasquez-Galvez G, Castillejo-Álvarez L H, Angoa-Perez M V, Oyoque-Salcedo G, Mena-Violante H G (2012). Efecto de hongos micorrícicos arbusculares y extracto acuoso de vermicompost sobre calidad de fresa. Ra Ximhai 8: 119-130.

Robledo-Buriticá J, Aristizábal-Loaiza J C, Ceballos-Aguirre N, Cabra-Cendales T (2018). Influence of plant growth-promoting rhizobacteria (PGPR) on blackberry (Rubus glaucus Benth. cv. thornless) growth under semi-cover and field conditions. *Acta Agron*. 67 (2) 258-263 ISSN 0120-2812 | e-ISSN 2323-0118. https://doi.org/10.15446/acag.v67n2.62572

Roco A, Pe´rez L M (2001) In vitro biocontrol activity of *Trichoderma harzianum* on Alternaria alternata in the presence of growth regulators. Electron J Biotechnol 4:68–73. https://doi.org/10.2225/vol4-issue2-fulltext-1

Rodriguez H, Gonzalez T, Goire I, Bashan Y (2004). Gluconic acid production and phosphate solubilization by the plant growth-promoting bacterium *Azospirillum* spp. Naturwissenschaften 91:552–555

Rouphael Y, Franken P, Schneider C, Schwarz D, Giovannetti M, Agnolucci M, De Pascale S, Bonini P, Colla G (2015). 123 614 Rev Environ Sci Biotechnol (2019) 18:597–616 Arbuscular mycorrhizal fungi act as biostimulants in horticultural crops. Sci Hortic 196:91–108. https://doi.org/10. 1016/j.scienta.2015.09.002

Ruzzi M and Aroca R (2015). Plant growth-promoting rhizobacteria act as biostimulants in horticulture. Sci. Hort. 196, 124–134.

Safronova V I, Stepanok V V, Engqvist G L, Alekseyev Y V, Belimov A A (2006). Root associated bacteria containing 1- aminocylclopropane-1-carboxylate deaminase improve growth and nutrient uptake by pea genoytypes cultivated in cadmium supplemented soil. Biol. Fertil. Soils, 42:267-272.

Saia S, Rappa V, Ruisi P, Abenavoli M R, Sunseri F, Giambalvo D, Frenda A S, Martinelli F (2015). Soil inoculation with symbiotic microorganisms promotes plant growth and nutrient transporter genes expression in durum wheat. Front Plant Sci 6:1–10. https://doi.org/10.3389/fpls.2015. 00815

Sharma S D, Bhutani V P (1998). Response of apple seedling to VAM, Azotobacter and inorganic fertilizers. Horticulture Journal. 11(1): 1-8

Slawomir S, Aleksander S (2010). The influence of mycorrhizal fungi on the growth and yield of plum and sour cherry trees. Journal of Fruit and Ornamental Plant Research 18(2): 71-77

Szekeres A, Kredics L, Antal Z, Kevei F, Manczinger L (2004). Isolation and characterization of protease overproducing mutants of *Trichoderma harzianum*. FEMS Microbiol Lett 233:215–222. https://doi.org/10.1016/j.femsle.2004.02. 012

Studholme D J, Harris B, Le Cocq K, Winsbury R, Perera V, Ryder L, Grant M (2013). Investigating the beneficial traits of *Trichoderma hamatum* GD12 for sustainable agriculture—insights from genomics. Frontiers in plant science, 4, 258.

Souza PV D-de, Souza de P V D (2000). Effect of arbuscular mycorrhizae and gibberellic acid interactions on vegetative growth of Carrizo citrange seedlings. Cienicia Rural 30(5): 783-787

Sudhakar P, Chattopadhyay G N, Gangwar S K, Ghosh J K (2000). Effect of foliar application of *Azotobacter; Azospirillum* and *Beijerinckia* on leaf yield and quality of mulberry (*Morus alba*). J. Agric. Sci. 134, 227–234

Tao G C, Tian S J, Cai M Y, Xie G H (2008). Phosphate-solubilizing and –mineralizing abilities of bacteria isolated from soils. Pedosphere 18:515–523

Tewari S, Shrivas V L, Hariprasad P, and Sharma S (2019). “Harnessing endophytes as biocontrol agents,” in Plant Health Under Biotic Stress (Sigapore: Springer), 189–218. doi: 10.1007/978-981-13-6040-4_10

Todeschini V, Aitlahmidi N, Mazzucco E, Marsano F, Gosetti F, Robotti E, Bona E, Massa N, Bonneau L, Marengo E, Wipf D, Berta G, Lingua G (2018). Impact of beneficial microorganisms on strawberry growth, fruit production, nutritional quality, and volatilome. Frontiers in Plant Science 9: 1611-1611.

Turkmen O, Sensoy S, Demir S, Erdinc C (2008). Effects of two different AMF species on growth and nutrient content of pepper seedlings grown under moderate salt stres. African Journal of Biotechnology Vol. 7 (4), pp. 392-396

Yedidia I, Benhamou N, Kapulnik Y, Chet I (2000). Induction and accumulation of PR proteins activityduring early stages of root colonizationby the mycoparasite *Trichoderma harzianum* strain T-203. Plant Physiol Biochem 38(11):863–873. https://doi.org/10.1016/S0981-9428(00)01198-0

Yu Y Y, Xu J D, Huang T X, Zhong J, Yu H, Qui J P, Guo J H (2020). Combination of beneficial bacteria improves blueberry production and soil quality. *Food Sci Nutr*. 8:5776–5784. https://doi.org/10.1002/fsn3.1772

Wang C M, Han Z H, Li X L, Xu X F (2001). Effects of phosphorus levels and VA mycorrhizae on growth and nutrient contents of apple seedlings. Acta Horticulturae Sinica. 28(1): 1-6

Wang P, Zhang J J, Shu B, Xia R X (2012). Arbuscular mycorrhizal fungi associated with citrus orchards under different types of soil management, southern China. Plant Soil Environ. 58, (7): 302–308

Wu Q S, Zou Y N, He X H (2010). Exogenous putrescine, not spermine or spermidine, enhances root mycorrhizal development and plant growth of trifoliate orange (Poncirus trifoliata) seedlings. Int. J. Agric. Biol., 12: 576-580

Wu Q S, Zou Y N (2012). Evaluating Effectiveness of Four Inoculation Methods with Arbuscular Mycorrhizal Fungi on Trifoliate Orange Seedlings. Int. J Agric. Biol. 14: 266-270

Verterberg M, Kukkonen S, Sari K, Parikka P, Huttunen J, Tainino L, Devos N, Weekers F, Kevers C, Thonart P, Lemoine M C, Cordier C, Alabouvette C, Gianinazzi S (2004). Microbial inoculation for Improving the Growth and Health of Micropropagated Strawberry. Appl. Soil Ecol 27:243-258.

Vitagliano C, Citernesi A S (1999). Plant growth of *Olea europaea* L. as influenced by arbuscular mycorrhizal fungi. Acta Horticulturae 474: 357-361

Zahir Z A, Arshad M (2004). Perspectives in agriculture. Advances in agronomy, 81, 97.

Zhang F, Dashti N, Hynes R K and Smith D L (1996). Plant growth promoting rhizobacteria and soybean (*Glycine max* L. Merr.) nodulation and nitrogen fixation at suboptimal root zone temperatures. Ann. Bot. 77, 453–459.