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Advantages of microorganism containing biological fertilizers and evaluation of their use in ornamental plants

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Abstract

In recent years, due to issues such as irregular and unplanned urbanization and industrialization, the existing agricultural areas have been decreasing rapidly, and the decreasing agricultural areas reveal the necessity of increasing the yield obtained from the unit area. This necessity leads to the pollution of agricultural lands and indirectly groundwater due to more chemical inputs day by day. Chemical fertilizers, one of the most common of these inputs, are the leading cause of pollution. Unconscious and excessive use is one of the most important factors of pollution. In recent years, with the increasing awareness and regulations, efforts on safe and healthy food production have increased, and in this context, the use of more environmentally friendly products that are harmless to humans and other living things has become widespread. In this context, some beneficial bacteria and fungal organisms isolated from soil are the most common biological fertilizers known to improve plant and soil properties. The hyphae formed by mycorrhizae containing fungal organisms can cover the plant roots and improve the surface area of the roots and the absorption of elements by extending deep into the soil. They also support plant growth by increasing phytohormone production. PGPRs (Plant growth-promoting rhizobacteria) containing beneficial bacteria, on the other hand, enable plants to absorb nitrogen and other elements in the atmosphere more easily, and they can also contribute to the development of plants by synthesizing growth-promoting substances. Ornamental plants cultivation, which is one of the most important subjects of agriculture and is carried out in large areas around the world, is one of the sectors where agricultural inputs are used intensively. In this study, more detailed information about biological fertilizers containing microorganisms, which are environmentally friendly fertilizers, will be given and the possibilities of their use in the field of ornamental plants and the studies that have been made will be tried to be examined.

Keywords: Mycorrhiza, *Trichoderma*, Bio Fertilizer, Ornamental Plants

Introduction

Decrease in biodiversity, contamination of surface and groundwater with nitrogen and pesticides, eutrophication of surface waters, ammonia evaporation at varying rates depending on the amount of fertilization, which are the undesirable consequences of intensive agriculture, are some of the biggest threats facing modern humanity. Worldwide, this threat is getting bigger due to reasons such as increasing infrastructure activities, urbanization and the resulting waste problem reaching uncontrollable dimensions and improper forest management. Initially, this system, which is based on the philosophy of using intensive chemical inputs to increase production and efficiency; has also irreversibly deteriorated soil fertility in many areas. Thus; Soil biology, which is one of the 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 (Jakoby et al. 2017).

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Among existing organisms, non-pathogenic bacteria and fungi, which are of particular importance for plant growth and soil health and a sustainable environment, have become even more important in the last 30 years. More importantly, these organisms do not exist alone, they interact, and these interactions affect soil fertility more or less than the individual activities of the organism. Besides the soil matrix, the chemical and physical properties of soils, such as the quality and amount of soil organic matter, pH and redox conditions, have a marked effect on the dynamics of microbial community structure and function in soils (Lombard et al. 2011). Therefore, a healthy soil is the net result of ongoing conservation and degradation processes, largely dependent on the biological component of the soil ecosystem. It also affects plant health, environmental health, food safety and quality (Nielsen and Winding 2002). Soil microorganisms have been divided into three groups by scientists as having beneficial, harmful and neutral effects (Whipps 2001; Bais et al. 2006). Beneficial soil microorganisms are involved in fixing nitrogen in the atmosphere, decomposing organic waste, and residues, eliminating the harmful effects of pesticides, suppressing plant diseases and soil-borne pathogens, producing bioactive substances such as vitamins, hormones, and enzymes that increase plant growth, improving soil properties and maintaining natural balance. (Higa 1994; Fuente-Ramirez and Caballero-Mellado 2005; Gupta 2012). The future of agriculture needs to protect the soil microorganisms whose populations are reduced or depleted due to the deterioration of the ecological balance in agricultural practices or to restore the destroyed ones.

In developed countries, producer or consumer groups, who become conscious with increasing education and income levels, give more importance to the production branches called biological, ecological or organic agriculture, and prefer practices that harm the natural balance less, pollute the environment less, and are harmless to the health of other living things (Özyazıcı et al. 2010; Kodaş 2011; Çakmakçı et al. 2010; Dursun et al. 2019). In these production lines, researches are carried out on the use of many inputs in order to improve the soil structure and ensure its sustainability, and materials containing microorganisms are the leading ones.

Ornamental plants sector is an important production category with high added value in plant production. The ornamental plants sector, which is grouped as cut flowers, indoor plants, outdoor plants, and bulbs, emerges as an agricultural activity area where interest is increasing day by day due to its worldwide export potential. The production of ornamental plants, which started to gain value at the beginning of the 20th century, is made in more than 50 countries around the world and on a total area of 749.200 hectares. In this production field, where a substantial agricultural area is used, it is important to research, use and disseminate the application of environmentally friendly inputs, as in other production lines (Anonymous 2020).

In this evaluation; microbial fertilizers' types, properties and capabilities will be mentioned and information about the studies in the field of ornamental plants will be gathered under one roof and the possibilities of using these fertilizers in this field will be discussed.

Effects Of Microorganism Fertilizers On Ornamental Plants Growıng

The soil mass around the root, called the rhizosphere, is a very common environment for microorganisms. Although microorganisms have numerous tasks, they have an important place in terms of plant development, yield and soil fertility (İmriz et al. 2014, Koç et al. 2015). Rhizobacteria, AMFs and Tricodermas are the leading microorganisms that increase plant growth.

Rhizobacteria, named PGPR (plant growth-promoting rhizobacteria) by Kloepper and Scroth and discovered in 1978, colonize the rhizosphere and phyllosphere of plants and provide many benefits to plants (Ram et al. 2013). PGPRs 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, Zhang et al. 1996, De-Ming and Alexander 1998; Zahir and Arshad 2004, Bashan and de-Bashan 2005; Antoun and Prevost 2006; Podile et al. 2006; Çakmakçı et al. 2010). AMFs, on the other hand, are beneficial fungi species that live in symbiosis with all terrestrial plants and occur in the root zone of 80%-90% of land plants (Newman and Reddell 1987; Abdel Latef and Chaoxing 2011a,b; 2014). The hyphae formed by the arbuscular mycorrhizal fungi in harmony with the plant roots increase the surface area of the roots and improve the mineral and nutrient uptake of the plants from the soil, thus encouraging better development of the plants. It is reported that thanks to the hyphae formed by AMFs, they help the uptake of water and nutrients from the points that the plant roots cannot reach, and provide resistance to environmental stresses such as soil salinity, heavy metal pollution, nutrient deficiency and adverse soil pH conditions (Balla et al. 2008; Turkmen et al. 2008). Arbuscular mycorrhizal fungi, which have an important place in terms of sustainability, are in important interaction with many families in horticultural plants especially ornamental plants and herbal products such as basil, thyme, rosemary, etc. (Smith and Read 2008). Trichoderma, which are composed of nearly two hundred species, are also beneficial fungal species that play an important role in plant growth and development, such as AMFs, and increase the tolerance of plants to environmental stresses (salinity, drought). Trichoderma species are also used in seed and seedling production to provide tolerance to some root diseases (Chang et al. 2008; Hermosa et al. 2012; Atanasova et al. 2013; Studholme et al. 2013; Bitterlich et al. 2018).

The effects of beneficial microorganisms have been studied on different species, but studies in the field of ornamental plants have been limited. The idea of making the production of ornamental plants, which have an important place in the world, in a more practical and faster way, as well as in a more environmentally friendly way, has been one of the main reasons for the studies. With the help of fertilizers containing microorganisms, it is normal for the success to be obtained from cultivation in plant and root development, flower yield and stress conditions to differ according to the strain used and the genotypic effect of the applied plant (Abdel-Rahman and El-Naggar 2014). For this reason, diversification of applications (bacteria and fungi species) and plant species to be applied is a matter directly related to the adequacy of the knowledge to be obtained on this subject.

It has been reported that microorganism-containing (PGPR, AMF and T-22) fertilizers can provide positive effects in many stages of plant development and growth in both perennial woody and annual herbaceous plant species such as Strawberry (Aslantaş et al. 2009; Ertürk et al. 2012; Koç et al. 2016; Balcı et al., 2021), raspberry (Orhan et al. 2006; Balcı et al. 2020), kiwi (Ertürk et al. 2010), cherry (Eşitken et al. 2006; Akça and Ercişli 2010), apple (Pırlak et al. 2007), tea (Ertürk et al. 2008; 2013, Çakmakçı et al. 2010, 2013; 2015; 2017; Bhattacharyya et al. 2020, Ertürk et al., 2021), rosehip (Ercişli et al. 2004), hazelnut (Bassil et al. 1991; Ertürk et al. 2011), pistachio (Orhan et al. 2007), plum (Karakurt et al. 2010), apricot (Eşitken et al. 2003), banana (Kavino et al. 2010), corn (Dobbelaere et al. 2002; Yazdani et al. 2009), wheat (Turan et al. 2010), sorghum (Baghiae and Aghilizefeei 2019), mint (Kaymak et al. 2008), okra, spinach and tomatoes (Adesemoye et al. 2008; Öztekin et al. 2015). Similarly, in the field of ornamental plants, a study was conducted to determine the effects of mycorrhizal fungi on factors such as the number of buds, the number of flowers and their development, and the N, PK concentrations accumulated in the shoots of the gum geranium (*Pelargonium peltatum*). In the study, compost at two different rates, 20% and 40%, and 3 different AMF applications were made. It was reported that a statistically significant increase was observed in the number of buds, the number of flowers and development, and the accumulation of P and K in the shoots when compared to the control group in all AMF applications. However, dry matter accumulation and N concentration increase in shoots were not found to be statistically significant (Perner et al. 2007).

In another study, the effects of Trichoderma (T-22) and mycorrhizal fungus on the growth characteristics of willow (*Salix fragilis* L.) plant, shoot length, shoot and root formation and increase in plant biomass parameters were investigated. It was determined that T22 and mycorrhizal applications increased in all parameters compared to the control group, and T-22 application encouraged 20% longer shoot and root formation compared to mycorrhizal fungus application and 40% longer than the control application in terms of shoot length. In addition, when the biomass of the plant was examined, it was determined that the T-22 application produced more than 50% extra biomass compared to the mycorrhiza application and more than twice that of the control. As a result of the study, it was reported that T-22 and mycorrhiza application were beneficial for plant growth in willow (*Salix fragilis* L.) plant, but T-22 application performed better than mycorrhiza application in individual evaluation (Adams et al. 2007).

PGPRs can have a positive effect on the rooting properties of plants by promoting the production of plant growth regulators and at the same time supporting the uptake of nutrients (Antoun and Prevost 2006). Mycorrhizal fungi, on the other hand, facilitate nutrient and water uptake by forming hyphae on the roots and can help root development (Türkmen et al. 2008; Abdel Latef and Chaoxing 2011a,b). In the light of this information, Scagel (2001) investigated the effect of AMF application on rooting amount and quality of rooted cuttings at the time of cutting of 5 different miniature rose (*Rosa* spp.) varieties. In the study, it was reported that an increase in the number of rooted cuttings was observed in two varieties that took longer to root four weeks after the cuttings were planted. It was also determined that the combined use of growth regulators (IBA and NAA) and AMF increased the number of rooted cuttings and the number of roots per cutting compared to hormone application alone.

Also, Sezen et al. (2014) investigated the effects of PGPRs on the propagation and rooting ability of cuttings taken from *Ficus benjamina* L., which is an important ornamental plant and known as Benjamin Flower. In the study where *Agrobacterium rubi* (A1 and A18), *Pseudomonas putida* (BA-8) and *Bacillius subtilus* (BA-142) bacteria were used as rooting agents, the rooting percentage was reported as 100% in all applications. The lowest rooting percentage was found in the control group with 86.7%. In the research, in which root length, fresh root weight and new leaf number parameters were examined besides rooting percentages, BA-142 strain gave high results in all parameters and according to these results, it was reported that BA-142 strain containing *Bacillus subtilis* had a high potential for propagation and rooting studies for *Ficus benjamina*. In another study, it was reported that *Bacillus subtilis* (MA-2 strain) and *Pseudomonas fluorescens* (MA-4 strain) applications had a positive effect on vegetative growth parameters of Geranium (Mishra et al. 2010). In a similar study, Rahman et al. (2014) investigated the effect of rooting-promoting hormones together with PGPR and AMF applications on the rooting of cuttings in Bougainvilleas species. As a result of their study, they determined that the combination of PGPR and AMF together with IBA, which is used as a hormone, significantly increased rooting compared to the use of IBA alone. Researchers have reported that this may have occurred as a result of stimulation of growth hormone production (such as IAA) by PGPR and AMF.

In another study, Aalipour et al. (2021) examined the effect of used arbuscular mycorrhizal fungi and plant growth promoting rhizobacteria against to Cd-contaminated soil in Arizona cypress. As a result of the research, they reported that either co-inoculation with AMF and P. fluorescens or individual inoculation with AMF could potentially ameliorate harmful effects of Cd on Arizona cypress growth.

Poinsettia is an ornamental plant that has been extensively studied with different PGPR isolates. As a matter of fact, FCA-8, FCA-60 and FCA-56 isolates belonging to the Pseudomonas putida species showed positive effects on development and growth parameters compared to the control (Silva and Iveth 2011). The published information on the ability of fertilizers with microbial content to help plants take in nutrients has led to the idea of reducing the use of artificial fertilizers, which is the most important chemical input in plant cultivation, through the effective use of microbial fertilizers. For this purpose; In a study conducted with 3 different *Pseudomonas putida* isolates and mixtures on the poinsettia plant; It has been reported that applications increase plant growth, have positive effects on anthocyanin pigmentation, and provide positive effects on development criteria such as leaf number and leaf area compared to control (Zulueta Rodriguez et al. 2014). In another study of the same cv, the effects of 4 different bacterial formulations (BI, BII, BIII and BIV) and chemical fertilization (KG) application, as well as the combined use of chemical fertilizers (50% reduced) and bacterial combinations on growth parameters were investigated. In the study, in which parameters such as plant height, main stem diameter, root number, root length and diameter, fresh and dry weight of the plant were examined, bacterial formulations and half of the chemical fertilizer dose were used. As a result of the study, it was determined that BIV+KG, BIII+KG, BIV and BII applications were applications that had a significant positive effect on plant growth parameters. As a result of the research; It has been reported that bacterial formulations can be used in the production of poinsettia, thus reducing the use of chemical fertilizers and producing quality flowers at a lower cost (Parlakova and Dursun 2019). In studies on the same species; It has been determined that different strains contribute to the formation of balance within the scope of plant characteristic nutrients, improve color formation, and increase heavy metal and boron accumulation depending on the characteristics of the isolates (Parlakova and Dursun 2020a,b). In another similar study, Meenakshi et al. (2014) evaluated the effect of three different bio-fertilizers such as *Azotobacter*, KSB and PSB and various levels of inorganic fertilizers (applied both alone and in combination) . In the application of 1/2 N, P and K + Azotobacter + PSB + KSB, the maximum number of flowers opened per spike and the available P content in the soil were reported. Maximum fresh and dry spike weight was determined in applications containing 3 / 4th N, P and K + *Azotobacter* + KSB. Among all applications, the longest vase life was observed in 3 / 4th N, P and K + PSB + STM applications.

Azotobacter and *Azosprillum* species have positive effects on development and flowering in gladiolus (Dalve et al. 2009), some isolates of *Pseudomonas* and *Bacillus* genera in chrysanthemum plants improve growth and chemical composition compared to control (Arab et al., 2015), different bacterial strains in cyclamen have similarly been reported to make positive contributions to developmental parameters (Girgin 2019). In the rooting study carried out in lavenders; It has been reported that *Azosprillum brasilence* Sp245 isolate applications have positive effects on root growth parameters (Zulfitri, 2012). In another study, PGPR's used with zeolitites for optimised fertilisation and this study shown that PGPR's can significantly improve the agronomic and physiological quality of buttercup plants. Zeolites can improve the uptake of water and fertilizer by the roots and the study shown that PGPR's can increase the properties of the zeolites by working together (Domenico, 2020).

Plants infected with mycorrhizal fungi are affected by drought (Reid and Bowen, 1979; Auge, 2001), nutrient deficiencies (McArthur and Knowles, 1993; Moora and Zobel 1998), heavy metal (Schutzendubel and Polle 2002), and low temperature (Zak et al. 1998) can show higher resistance to abiotic stress conditions. It is reported that this effect is due to the better nutrient uptake capacity of the plants in which mycorrhizal fungi colonize their roots (Sylvia et al. 1993; Subramanian and Charest 1999). In ornamental plants, some studies have been carried out to optimize aquaculture performance under stress conditions. Zuccarini and Okurowska (2008) investigated the effects of mycorrhizal fungus (AMF) inoculation and fertilization at different levels under salt stress conditions in a greenhouse study on Sweet Basil (Ocimum basilicum L.), an important ornamental plant with aromatic properties that can be used for different purposes. In their study, eight different applications were compared with the combination of Glomus intraradices Schenck and Smith's inoculum and two different fertilization doses, two salinity levels of irrigation water, and the formation or absence of mycorrhizal colonization in the study, as well as all factors. Salt stress applied in the study significantly reduced plant growth and fluorescence levels, resulting in higher sodium (Na) and chloride (Cl) content in both roots and shoots, while potassium (K) decreased. However, both mycorrhizal inoculation and high fertilization had positive effects on plant growth and fluorescence, and symptoms caused by salt stress were reduced. Inoculation with mycorrhiza showed more pronounced effects than fertilizer application, but co-administration of colonization and high fertilization provided a higher tolerance to salinity stress than a single factor. As a result of the study, it was concluded that fertilization with mycorrhizal fungus applications had positive effects against salt therapy, whereas the colonization rate was significantly reduced with both saline irrigation and high fertilization.

In a study on the plant velvet (*Tagetes erecta* L.), the effects of three arbuscular mycorrhizal fungi, including *Glomus intraradices*, *Glomus constrictum* and *Glomus mosseae*, on growth, root colonization and Cd (cadmium) accumulation under Cd stress were investigated. In the study, physiological properties of *Tagetes erecta* L. such as chlorophyll content, soluble sugar content and antioxidant enzyme activity were evaluated. Under Cd stress, the symbiotic relationship between plants and mycorrhizal fungi is well established, and shoot and root biomass in velvet plants are significantly higher, 15.2-47.5% and 47.8-130.1%, respectively, compared to ungrafted velvet plants. In addition, it was determined that antioxidant enzyme activities were generally higher in plants inoculated with three AMFs under Cd stress than in plants that were not inoculated. In this study, the researchers concluded that antioxidant enzymes have a significant effect on plant biomass and increase the scavenging capacity of reactive oxygen species (ROS) of AMFs, thus helping to reduce Cd concentrations in plants under Cd stress (Ling-Zhi et al. 2011). In another study, which was established under water stress conditions, researchers evaluated the effects of mycorrhizal fungi (AMF) on plant growth, nutrient uptake, flower yield, water relations, chlorophyll contents and water use efficiency in two groups of snapdragon (*Anthirhinum majus*) well-watered and water-stressed. The applied water stress significantly decreased the growth parameters, nutrient contents, flower yield, water relations and chlorophyll pigment contents compared to the normally irrigated group, and increased electrolyte leakage from the cells. However, despite water stress, snapdragon plants inoculated with mycorrhizal fungi in both well-watered and water-stressed groups had higher shoot and root dry weight, water use efficiency, flower yield, nutrient content, (P, N, K, Mg and Ca) and chlorophyll content compared to the group without mycorrhizal inoculation. At the same time, it was determined that water stress increased the accumulation of proline in plant leaves, this increase was significantly higher in the group without mycorrhizal fungus application, therefore, AMF colonization improved tolerance to water stress in the host plant, snapdragon (Asrar et al. 2012). In another study of clove (*Dianthus caryophyllus* L.), the effects of different *Glomus strains* on growth, quality and mineral concentrations of plants grown under salt stress (1, 3 and 6 dS m-1) were investigated. A moderate dose of salt stress (3 dS m-1) in irrigation water and inoculation with *G. intraradices* have been reported to produce the best clove plant quality. As a result of the research, it was observed that the salt tolerance in cloves increased with the colonization of plant roots by *G. intraradices*. In addition, an increase was observed in the growth of the clove plant, the number and size of flowers, leaves and flower color. Although it was reported that the best results were obtained from moderate salt stress and *G. intraradices* inoculation, it was found that mycorrhizal inoculation provided positive results against salt stress in all doses and plants compared to control (Navarro et al. 2012).

Conclusion

The use of chemical inputs, which initially contributed significantly to the growth of plants, over time seriously threatens both soil biology and human life through the food chain. In particular, the increase in soil and environmental pollution contributed by conventional agricultural activities, deterioration of soil microbiota and changes in climatic conditions appear as a problem in a significant part of agricultural lands. The introduction of microorganisms at this stage will be an important step in re-establishing the soil ecosystem, using lower chemical inputs, and environmentally friendly sustainable agricultural production. In studies carried out in many annual and perennial plant species for the last thirty years, it has been determined that beneficial microorganisms interact with each other and with the plant, they can have different effects depending on the strain and the host, and their activities may vary depending on the soil ecology.

In this context; For ornamental plants, which are less studied than other plant species, determination of appropriate microorganismic associations according to species, and the creation of commercial biological fertilizer formulations suitable for different purposes and species can be important target points for this cultivation. Also; Studies on the biochemical and genetic mechanisms of the effects of microorganisms on the growth and quality criteria of ornamental plants may be the most interesting areas in this subject.

Conflict of Interest

The authors are declared that they have no conflict for this research article.

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