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Research
(Araştırma)

Growth promotion of apple sapling by bacterial inoculants*

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Objective: In study; it was aimed to determine the effects of *Bacillus subtilis* OSU-142 and *Bacillus megaterium* M-3 bacteria strains on growth of apple saplings.

Materials and Methods: In study was conducted at Karaman. It was used Fuji, Golden Delicious, Mondial Gala, Pink Lady, Red Chief, Scarlet Spur cultivars grafted on MM106 rootstock.

Results: Bacteria applications increased the sapling height compared to the control, the highest increase occurred in OSU-142 + M-3. In general, bacteria have increased the root length. The highest increase in root number was obtained from M-3 application in Mondial Gala, Scarlet Spur, Red Chief and Pink Lady cultivars.

Conclusion: As a result, bacteria have been confirmed to enhance development and it is suggested to use to encourage growth at apple saplings cultivation.

Keywords: Plant development, Apple sapling, Rhizobacteria

Elma fidanlarında bakteri aşılaması ile büyümenin teşviki

Öz

Amaç: Çalışmada; *Bacillus subtilis* OSU-142 ve *Bacillus megaterium* M-3 bakteri suşlarının elma fidanlarının bitki gelişimi üzerine etkilerinin tespiti amaçlanmıştır.

Materyal ve Yöntem: Araştırmada MM106 anacı üzerine aşılı Fuji, Golden Delicious, Mondial Gala, Pink Lady, Red Chief, Scarlet Spur çeşitlerinin fidanları kullanılmıştır.

Araştırma Bulguları: Bakteri uygulamaları fidan boyunu kontrole göre artırmış, en yüksek artış OSU-142 + M-3'te meydana gelmiştir. Genel olarak uygulamalar kök uzunluğunu artırmıştır. Mondial Gala, Scarlet Spur, Red Chief ve Pink Lady çeşitlerinde kök sayısında en yüksek artış M-3 uygulamasında bulunmuştur.

Sonuç: Bakteri uygulamalarının bitki gelişimini artırdığı belirlenmiş olup, elma fidanı yetiştiriciliğinde büyümeyi teşvik etmek için kullanılması önerilmektedir.

Anahtar Kelimeler: Bitki gelişimi, Elma fidanı, Rizobakteri

Introduction

The apple belongs to the Malus genus of the Rosales team, the Rosaceae family, the Pomoideae subfamily. There are more than 30 species of this genus native to Asia, Europe and North America. Its homeland is the coasts of the Caucasus and the Caspian Sea. Many Malus species are reported to occur naturally in Central Asia, China, Korea, Japan and North America (Way et al., 1991).

Apple cultivation in Turkey; It is seen in humid valleys in Central Anatolia, in low valleys in Eastern Anatolia, in areas exceeding 500 m in the Aegean

region, and in areas higher than 1000-1200 m in Southeastern Anatolia (Özbek, 1978).

World total apple production was 87.236.221 tons in 2019 (FAO, 2021). This amount was 21.323.988 tons in 1965. In the 50-year period, an approximately 4-fold increase in world apple production has been observed. The development of applications that increase efficiency in production areas causes an increase in production. The countries with the highest apple production in the world are China, USA, Turkey, Poland and Italy, respectively.

Early fruiting is an important criterion in determining yield potential in an orchard. This situation provides an economic advantage in the garden facility. Other factors affecting the yield per hectare are planting density, tree size and the applied training system (Way et al., 1991).

The use of clone rootstocks in apples has become widespread in Turkey. In fruit trees, the rootstock forms the underground part of the plant. It is effective in clinging to the soil, transferring water and nutrients from the soil to the tree, and transporting the photosynthesis products and growth regulators made in the crown to the roots. In addition, the shape and size of the varieties grafted on the rootstocks, early yield, adaptation to different soil types, resistance to cold and drought, diseases and pests are effective (Webster, 2002).

In recent years, the demand for organically produced products has been increasing rapidly in developed countries. Since the use of synthetic fertilizers is not allowed in organic farming, the yield is somewhat lower than in conventional farming. Due to the characteristics of this production method, the use of biofertilizers (microbial fertilizers) is becoming widespread in the world.

Plant growth is increased, damage to the environment is largely prevented, and soil fertility is preserved by the use of biofertilizers, which consist of beneficial microorganisms that are more compatible with nature instead of synthetic chemicals (O'connell, 1992).

The aim of this study was to grow some bacteria *(Bacillus* subtilis OSU-142 and *Bacillus megatarium* M-3) that can potentially increase plant yield and growth on saplings of apple cultivars grafted on MM106 rootstock.

Material and Methods

This research was carried out in a private commercial nursery located in the central district of Karaman province in 2016-2017. Saplings of Fuji, Golden Delicious, Mondial Gala, Pink Lady, Red Chief and Scarlet Spur apple cultivars grafted on MM106 clone rootstock were used in both years of the study. In the study, *Bacillus subtilis* OSU-142 and *Bacillus megaterium* M-3 bacterial strains were applied to stimulate growth in apple saplings.

The trial field is located at an altitude of 1022 m above sea level, at 37˚11'55" North - 33˚06'57" East coordinates and it is seen that the typical continental climate is dominant.

The trial area shows the typical features of the continental climate of Central Anatolia.

The soil analysis results of the orchard are given in Table 1. According to the results of the analysis, the amount of organic matter and nitrogen was found to be insufficient. The soil pH was slightly alkaline. The amount of soil lime was higher.

Table 1. Physical and Chemical Properties of the Orchard Soil (0-30 cm).

Soil parameters	
pH (1:2.5 s:w)	7.9
EC (µS cm^{-1}; 1:5 s:w)	0.43
Organic matter (%)	2.17
Lime (%)	27.5
Clay (%)	53
Silt (%)	46
Sand (%)	1
N (%)	0.11
P (ppm)	19.18
K (ppm)	341
Ca (ppm)	4.35
Mg (ppm)	557
Na (ppm)	185
Fe (ppm)	11.21
Zn (ppm)	3.12
Cu (ppm)	2.23
Mn (ppm)	17.77
B (ppm)	2.15

According to meteorological data, when the climatic values in the region where the research was conducted in Karaman in 2016 were examined, it was seen that the highest temperature was 37°C in July and the lowest temperature was -18°C in December. Total amount of precipitation for 2016 was 343.0 mm/m^2. In the province of Karaman, the highest temperature was 36°C in August in 2017, and the lowest temperature was -17°C in February. The total amount of precipitation in 2017 was determined as 314.0 mm/m^2 (Anonymous, 2017).

Table 2. Research Area Meteorological Data

Research Area	Year	Maximum Temperature	Minimum Temperature	Total Precipitation
KARAMAN	2016	37˚C (July)	-18˚C (December)	343.0 mm/m^2
KARAMAN	2017	36˚C (August)	-17˚C (February)	314.0 mm/m^2

Bacillus subtilis OSU-142 and *Bacillus* M-3 bacterial strains were used in the study. Bacteria were obtained from Yeditepe University. It has been stated that *Bacillus subtilis* OSU-142 is a biocontrol and plant growth regulating agent (Çakmakçı *et al*., 2001) and plays an important role in nitrogen fixation (Eşitken *et al*., 2003b). It has been determined that *Bacillus* M-3 is also effective in dissolving phosphate (Aslantaş et al., 2007).

The rootstocks used in the experiment were planted with 120 cm and 25 cm row spacing. Grafting was done with T bud graft method in August 2015 and 2016. The trial was established according to the 'Random Plots Trial Design' with 3 replications and 5 saplings in each replication. Bacterial groups were applied from the soil. A combination of these applications has also been tried. Control trees were irrigated at the time of application. The prepared bacterial suspensions were applied 3 times in April, June and August. The implementation plan is given below.

1- Control
2- OSU-142
3- M-3
4- OSU-142 + M-3

Bacterial Applications: In both years, bacterial strains were sown on Nutrient Agar and kept at 30˚C for 48 hours. At the end of this period, a suspension in 0.1 M phosphate buffer was prepared from the bacterial cultures that completed their growth. After the bacterial concentration was adjusted to 10^9 CFU/ml at 600 nm wavelength in the spectrophotometer, bacterial suspensions were applied to the root zone of the seedlings 3 times.

Measurements were made when the growth of the seedlings slowed down significantly and green shoot formation stopped when they entered the resting period. Saplings were removed on November 14, 2016 in the first year and on December 20, 2017 in the second year. The data obtained were evaluated and statistical analyzes were made using the JMP 0.8 package program.

The height of the sapling (cm) was determined by measuring the height from the root collar to the tip of the uppermost branch with the measure.

The stem diameter (mm) was measured with a caliper at the end of the growth period, 5 cm above the grafting point of the sapling stem.

Root length (cm) The root length was measured with a tape measure at the time of removal of the saplings.

The number of roots (pieces) of the main roots of the saplings at the time of removal were counted one by one.

Data analysis

All data in the study were subjected by analysis of variance (ANOVA) and means were separated by Duncan's multiple range tests.

Results

Sapling Height

The results of the effects of bacterial applications on sapling height are given in Table 3. Accordingly, the effects of the applications differed according to the years and cultivars. The effects of bacterial applications on sapling height in 2016 were found to be statistically insignificant in Pink Lady and Scarlet Spur cultivars, but significant in other cultivars. In 2017, the effects of applications in all varieties were found to be significant. In general, the applications increased the sapling height compared to the control.

Table 3. Effect of Rhizobacteria Applications on Sapling Length (cm)

Treatments	Pink Lady*		Mondial Gala		Golden Delicious		Fuji		Scarlet Spur		Red Chief	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	104.5	141.9 d	120.5 b	151.0 d	119.5 b	107.8 c	127.8 b	128.9 b	78.9	117.5 d	113.7 b	139.1 b
OSU-142	113.6	151.3 b	134.0 a	176.1 c	138.3 a	109.7 b	141.6 a	128.3 b	75.6	144.2 b	128.0 a	191.1 a
M-3	113.2	150.1 c	137.2 a	185.1 b	126.0 b	110.7 b	135.5ab	127.5 b	77.4	126.9 c	123.8 b	192.7 a
OSU-142+M-3	107.4	152.8 a	134.5 a	205.0 a	122.1 b	113.1 a	141.5 a	137.3 a	73.9	159.2 a	130.7 a	138.6 b
LSD	N.S.	1.10	13.33	1.63	15.39	2.37	13.66	2.88	N.S.	2.68	13.34	1.98

*The values shown with the same letter in each column are not statistically different (p≤ 0.05)

In 2016, bacterial applications of Mondial Gala cultivar increased the sapling height compared to the control, and there was no difference between the applications. In the Golden Delicious cultivar, OSU-142 application increased the sapling height compared to the control, while the effect of other applications was found to be insignificant. As a result of the applications in Fuji cultivar, the sapling height increased compared to the control, OSU-142 and OSU142+M-3 applications were statistically different from the control group. Similar to the Fuji cultivar, there was an increase in OSU 142 and OSU-142 + M3 applications compared to control in Red Chief cultivar. There was a 12.6% increase in OSU-142 application and 14.96% increase in OSU-142 + M-3 compared to the control in sapling height. Effects of bacterial applications on sapling height in 2017 were found to be statistically significant in all cultivars. In all of the treatments, there were an increase in sapling height compared to the control. In Pink Lady, Mondial Gala, Golden Delicious and Scarlet Spur cultivars, all treatments increased the sapling height compared to the control, and the highest increase was detected in OSU-142+M-3. In Fuji cultivar, only the OSU-142+M-3 application increased the sapling height compared to the control. In the Red Chief cultivar, OSU-142 and M-3 applications caused an increase in sapling height compared to the control, while in OSU-142+M-3 application, the sapling height remained at the same level as the control. In OSU-142 and M-3 applications, the sapling height increased by 37.40% compared to the control.

Stem Diameter

The results of the effects of bacterial applications on the sapling stem diameter are given in Table 4. Accordingly, the effects of the applications differed according to the years and cultivars. In 2016, the effects of bacterial applications on stem diameter were found to be statistically insignificant in Fuji and Scarlet Spur cultivars, but significant in other cultivars. In 2017, the effects of applications in all cultivars were found to be statistically significant. In 2016, bacterial applications of Pink Lady, Golden Delicious and Red Chief cultivars increased the stem diameter compared to the control, and there was no difference between the applications. As a result of the applications in Mondial Gala, the stem diameter increased compared to the control, and OSU-142 application was statistically different from the control group. In the stem diameter, there was an increase of 12.15 % in the stem diameter compared to the control. The effects of bacterial applications on stem diameter were found to be statistically significant in all cultivars in 2017. OSU-142+M-3 application increased stem diameter in Mondial Gala and Fuji cultivars compared to control. In the Mondial Gala cultivar, the stem diameter of 13.33 mm in the control increased to 16.88 mm with the application of OSU-142+M-3, and an increase of 26.63% was determined compared to the control. Applications of OSU-142 and M-3 alone reduced the stem diameter compared to the control. In the Scarlet Spur cultivar, the stem diameter was increased with the M-3 application compared to the control. An increase of 13.06% occurred in the M-3 application compared to the body-wide control. In Pink Lady and Red Chief cultivars, the applications decreased the stem diameter compared to the control

Root Length

The results of the effects of the applications on the root length Table 5. has also been given. Accordingly, the effects of the applications differed according to the years and cultivars. In 2016, the effects of bacterial applications on root length were found to be statistically insignificant in Golden Delicious and Red Chief cultivars, but significant in other cultivars..

Table 4. Effect of Rhizobacteria Applications on Stem Diameter (mm)

Treatments	Pink Lady*		Mondial Gala		Golden Delicious		Fuji		Scarlet Spur		Red Chief	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	10.82 b	13.05 a	11.28 b	13.33 c	9.68 b	10.08 d	11.49	13.15 b	6.19	12.71 d	9.99 b	15.98 a
OSU-142	12.82 a	12.50bc	12.65 a	14.70 b	12.64 a	12.53 a	12.58	12.46 c	6.63	13.36 c	12.18 a	13.14 d
M-3	11.56 a	12.30 c	11.79ab	14.59 b	11.27 a	10.95 c	12.00	12.20 d	7.03	14.37 a	11.55 a	14.13 c
OSU-142+M-3	11.92 a	12.81ab	12.10ab	16.68 a	12.35 a	12.18 b	12.02	13.63 a	6.17	13.97 b	11.39 a	14.37 b
LSD	1.05	0.50	1.30	0.49	1.44	0.32	N.S.	0.34	N.S.	0.21	1.24	0.28

*The values shown with the same letter in each column are not statistically different (p≤ 0.05).

In 2017, the effects of applications in all cultivars were found to be significant. In general, the applications increased the root length compared to the control.In 2016, bacterial applications of Pink Lady increased the root length compared to the control, and there was no difference between the applications. In Mondial Gala cultivar, OSU-142 application increased root length compared to control, while the effect of other applications was found to be insignificant. Root length, which was 18.73 cm in the control application, became 21.60 cm with an increase of 15.32% in the OSU-142 application. As a result of the applications, Scarlet Spur cultivar did not change much compared to the control. In Fuji cultivar, OSU-142 and M-3 applications increased compared to the control, while the effect of OSU-142+M-3 application was in the same group as the control. In 2017, the applications increased the root length in Pink Lady cultivar compared to the control, and the effects of OSU-142 and M-3 applications were found to be significant. The highest increase compared to the control was obtained in the OSU-142 application. The root length, which was 19.13 cm in the control, increased to 20.13 cm with an increase of 22.01% with this application. Similarly, root length increased in Mondial Gala as a result of applications, but the effect of only M-3 application was found to be different from the control. Root length of Golden Delicious cultivar increased in all applications compared to control and the effects of applications were found to be significant. The highest increase compared to the control was determined in the OSU-142+M-3 application. In Fuji cultivar, while root length increased in OSU-142 application compared to control, it decreased in other applications. In Scarlet Spur cultivar, M-3 and OSU-142+M-3 applications increased root length compared to control, while OSU-142 decreased. In Red Chief, root length increased as a result of OSU-142 and M-3 applications.

Table 5. Effect Rhizobacteria Applications on Root Length (cm)

Treatments	Pink Lady*		Mondial Gala		Golden Delicious		Fuji		Scarlet Spur		Red Chief	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	17.00 b	19.13c	18.20 b	18.73b	19.40	16.46 c	20.73 a	20.26 b	18.13ab	18.46c	19.60	19.46 c
OSU-142	19.33 a	23.34	21.60 a	20.26a	20.33	18.60 b	21.73 a	21.53 a	17.07ab	17.46d	18.60	20.00 b
M-3	19.27 a	21.46	17.93 b	20.86a	20.20	18.46 b	16.93 b	17.33 d	16.40 b	20.40a	19.73	22.68 a
OSU-142+M-3	19.47 a	20.13 c	18.27 b	20.13ab	20.27	19.73 a	18.20 b	17.80 c	19.13 a	19.40b	20.00	19.11 c
LSD	2.13	1.61	2.62	2.34	N.S.	0.27	2.50	0.53	2.33	0.43	N.S.	0.58

*The values shown with the same letter in each column are not statistically different (p≤ 0.05)

Table 6. Effect Rhizobacteria Applications on Root Number (pieces)

Treatments	Pink Lady*		Mondial Gala		Golden Delicious		Fuji		Scarlet Spur		Red Chief	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	5.93 b	16.00 c	6.27 b	10.23 c	8.80 a	8.33 d	6.13 b	9.93 c	3.87 b	9.60 d	5.40 b	9.53 d
OSU-142	6.07 b	27.07 a	7.30 b	18.20 b	7.06 b	12.46 c	8.07 a	17.40 b	5.00 a	17.13c	7.00 b	22.93 b
M-3	7.93 a	26.27 a	9.40 a	18.26 b	6.80 b	13.13	6.53 b	21.20 a	5.40 a	21.26b	8.01 a	21.60 c
OSU-142+M3	6.87ab	22.67 b	7.07 b	20.13 a	6.40 b	18.20 a	7.33ab	21.93 a	4.87 ab	24.46a	7.07 b	24.87 a
LSD	1.59	1.79	2.06	1.06	1.67	0.65	1.34	1.18	1.06	2.05	2.13	0.59

*The values shown with the same letter in each column are not statistically different (p≤ 0.05)

Number of Roots

The effects of bacterial applications on the number of roots in 2016 and 2017 were found to be statistically significant (Table 6).

In 2016, only M-3 application increased the number of roots in Mondial Gala, Scarlet Spur and Red Chief cultivars compared to the control. The number of roots in Mondial Gala cultivar increased from 6.27 in the control application to 7.07 with an increase of 12.76% in the M-3 application, the number of roots in the Scarlet Spur cultivar increased from 3.87 in the control application to 4.87 with an increase of 25.84% in the M-3 application, and in the Red Chief cultivar 5.40 in the control application. The number of roots increased to 7.07 with an increase of 30.93% in M-3 application. Root number of Pink Lady cultivar increased with M-3 and OSU-142+M-3 applications, and the highest increase was detected in M-3 application. There was an increase of 33.73% in the number of roots in M-3 application compared to the control. In Golden Delicious, all treatments reduced the number of roots compared to the control. There was an increase in the number of roots with applications in Fuji cultivar, and the highest increase was found in OSU-142 compared to the control. There was an increase of 31.65% in the number of roots in OSU-142 application compared to the control.

In 2017, bacterial applications increased the number of roots in all cultivars compared to control. The highest increases were obtained from OSU-142 and M-3 applications in Pink Lady, M-3 and OSU-142+M-3 in Fuji, and OSU-142+M-3 in other cultivars. In Mondial Gala cultivar, root number increased approximately 2 times in OSU-142+M-3 application compared to control. In the Golden Delicious cultivar, the increase in OSU-142+M-3 application was 118.48% compared to the control. Similarly, the number of roots in Fuji and Scarlet Spur cultivars increased by more than 100% in M-3 and OSU-142+M-3 applications compared to control. Significant increases were detected in the Red Chief variety compared to the control in all applications.

Discussion and Conclusion

When starting fruit growing, it is desirable that the saplings be too tall. Because height is an important quality feature in saplings. According to TSE apple standards, a height of 105 cm and above is required for semi-dwarf apple saplings (Yapıcı, 1992). The values we obtained are well above this value. The results show that the applications have a positive effect on the growth of saplings. The effect of these bacteria promoting plant growth on increasing the sapling height can be explained by the growth promoting substance synthesis of rhizobacteria. Aslantaş et al., (2007) reported that *Bacillus subtilis* OSU-142 and *Basillus megaterium* M-3 produce auxin and cytokinin. It is thought that the increase observed in the height of the saplings is directly related to the auxin production of *Bacillus subtilis* OSU-142 bacteria. It is seen that auxin has positive effects on shoot development as a result of stimulating cell growth with its transport from the shoot tip to the roots. In addition, nitrogen is required to support shoot growth. In this respect, nitrogen fixation of *Bacillus subtilis* OSU-142 bacterium provided a significant increase in sapling height. In previous studies on different fruit species, it was reported that these bacterial strains significantly increased vegetative growth (Eşitken et al., 2006; Aslantaş et al., 2007; Karakurt and Aslantaş, 2010; Coşkun and Pırlak, 2017; İpek et al., 2017b).

Trunk diameter is another factor affecting the quality of fruit saplings. In 2016, a positive effect of bacterial applications on sapling diameter was determined, except for Fuji and Scarlet Spur cultivars. While the 2017 applications decreased the stem diameter in Pink Lady and Red Chief cultivars, the stem diameter increased in other cultivars compared to the control (Table 4.2.). In previous studies on this subject, it has been reported that these growth-promoting bacteria significantly increase shoot diameter (Pırlak et al., 2007; Coşkun and Pırlak, 2017; İpek et al., 2017b).

Plant root development is an important factor in fruit growing. Plants take most of their nutrients through their roots. A plant whose roots are not well formed and underdeveloped cannot develop as it should. This affects yield and quality. In 2016, the effects of bacterial applications on root length in Golden Delicious and Red Chief cultivars were found to be insignificant, but significant in other cultivars and an increase occurred. When the number of roots was evaluated in the same year, an increase was observed in Mondial Gala, Scarlet Spur and Red Chief cultivars with M-3 application. With the bacterial applications in 2017, root length showed significant increases compared to the control. In the root count evaluations, it was determined that the combination of OSU-142+M-3 bacteria provided significant

increases in Mondial Gala, Golden Delicious, Scarlet Spur and Red Chief cultivars. OSU-142 and M-3 applications increased in Pink Lady compared to control. Auxin and cytokinin production of the applied bacterial strains were effective in the increase in root length and root number. Auxins are transported from the shoot tips to the root, stimulating the division of the cells there, and thus provides lateral root formation. As a result of the maturation of these cells and their ability to divide again, they were effective in the formation of adventitious roots. Cytokinins were also transported from the root tips to the shoot, and together with auxins, they stimulated cell division and growth, resulting in significant increases in root development. In a study, it was reported that bacteria promoting plant growth in Şekerpare apricot saplings significantly increased the number of lateral roots (Karakurt et al., 2010). In previous studies, it has been reported that bacterial strains have positive results on plant and root growth due to their ability to synthesize plant hormones that stimulate plant growth (Zahir et al., 2003; Şahin et al., 2004; Canbolat et al., 2006).

The reason for the difference between the years in the sapling height, stem diameter, root length and root number evaluated in the study; It is thought that it is due to the fact that apple cultivars were in different parcels in both years in the land where the study was conducted. It was observed that some of the land remained in a more pitted area and the saplings in this area showed slower growth. It is also thought that as a result of flooding due to heavy snow and rain seen in the first year, it affects plant growth negatively. In addition to this, soil fatigue may have occurred as a result of constantly growing saplings in the field and not applying alternation.

According to the results obtained, significant increases in vegetative growth were observed in saplings with root application of the bacterial strains used.

Rhizobacteria promoting plant growth; It has been reported to promote vegetative growth in different plant species such as apple, apricot, barley, lettuce and tomato, broccoli, blueberry, hazelnut, grape and cherry (Bassil et al., 1991; Rodríguez and Fraga, 1999; De Silva et al., 2000; Şahin et al., 2004; Aslantaş et al., 2007; Pırlak et al., 2007).

Bacillus subtilis OSU-142 used in the study is a biocontrol and plant growth regulating agent (Çakmakçı et al., 2001; Şahin et al., 2004; Aslantaş et al., 2007) and in nitrogen fixation plays an important role (Eşitken et al., 2003b). It has been determined that *Bacillus* M-3 is also effective in dissolving phosphate (Aslantaş et al., 2007). In addition, it has been reported that *Bacillus* OSU-142 and M-3 produce auxin and cytokinin (Aslantaş et al., 2007). Auxin and cytokinin amounts appear to be directly related to plant growth and development. The vegetative growth-enhancing effects of the bacteria used in this study on apple saplings can be explained by their nitrogen fixation capacity, IAA production and phosphate dissolution.

Bacterial strains, applied to test their effectiveness on above-ground and root growth in apple cultivars grafted on MM106 rootstock generally increased the parameters examined compared to the control. In order to better understand the effects of bacteria, it is thought that it will be useful to try different kinds of bacteria, to examine the use and frequency of use of different bacteria. As a result of the exact determination of the mechanisms of these bacterial strains after detailed studies to be carried out in the future, it is thought that commercial formulations can be prepared and used as biofertilizers in the cultivation of fruit saplings in sustainable agriculture.

Conflicts of interest

The authors declare no conflicts of interest

Authors' Contributions

ZA, LP: Contributed to the procurement of materials required for the study, the establishment and execution of the trials.

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