



## RESEARCH ARTICLE

### Effects of Bacteria and Iba on the Rooting of Citrange Citrus Rootstocks Cuttings

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#### ABSTRACT

In this study, the effects of *Agrobacterium rubi* A-18 and *Bacillus* OSU-142 bacterial strains alone and in combination with 1000, 2000, 4000 ppm IBA on rooting of Carrizo citrange and Troyer citrange citrus rootstock in softwood, semi-hardwood and hardwood cuttings were investigated. In the case of IBA solution, *Agrobacterium rubi* A-18 and *Bacillus* OSU-142 were prepared in solution at a concentration of  $1 \times 10^9$  bacteria / ml and applied to cuttings of citrus. Application were performed in the mist propagation system. Cuttings kept in the fogging environment for 3 months removed at the end of this period, and their rooting rates (%), callus formation rates (%) and survival rates (%) determined. Based on the results of the study, the survival rates and callus formation rates of the cuttings of citrus were generally high at the end of the rooting period. The highest rooting rates in Carrizo citrange cuttings were detected in 4000 ppm IBA and OSU-142 + A-18 (13.33%) treatments for softwood cuttings, 4000 ppm IBA + OSU-142 (20.00%) in semi-hardwood and hardwood cuttings. In the Troyer citrange, OSU-142 + A-18 (6.67%) treatments for softwood cuttings, in 1000 ppm IBA for semi-hardwood, and in 4000 ppm IBA (13.33%) and 1000 ppm IBA treatment for hardwood cuttings, 2000 ppm IBA and OSU-142 (13.33%) the highest rooting has been treatments. According to the cuttings pick-up period, the rooting rates of Carrizo citrange are not different, at the Troyer citrange in the semi-hardwood and hardwood cuttings was higher. As a result, it could be state that plant growth promoting bacteria and IBA applications have not effect on rooting in the softwood, semi-hardwood and hardwood cuttings of the Carrizo citrange and Troyer citrange citrus rootstocks.

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#### Introduction

Turkey is one of the rare countries where a combination of many types of fruit grown in world and, also one of the major producers of many fruit species (Gerçekçiöğlü et al. 2008).

Citrus group includes citrus fruits of high economic value such as citrus, orange, mandarin, bergamot, grapefruit and lemon. They are produced economically, and they are extremely important for human health. Citrus fruits, which are described as vitamins stores in winter months, are consumed

extensively as fruit juice. Citrus is cultivated between 40° north and 40° south latitude in the world, and its production is constantly increasing (Mendilcioğlu, 1999).

Citrus, whose homeland is China, Southeast Asia and India, can grow in tropical and subtropical climatic areas, and can be grown commercially in regions where the temperature does not fall below -4°C.

In Turkey, reaching about 5 million tons of citrus is done in coastal areas of the Mediterranean and Aegean regions of production. After a maximum of apples and grapes are grown

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in Turkey and also made the most exports of citrus fruits. Commercial sense in the production of Turkey is examined, as well as most types of citrus produced in the world, respectively, orange, mandarin, lemon and grapefruit.

Citrus farming, whose homeland is Southeast Asia, began in the US in the modern sense in the 19th century and spread rapidly. It is produced economically in the Northern Hemisphere, North and Central America and the Mediterranean countries, and in the Southern Hemisphere in South America, South Africa and Oceania. The world's largest citrus producing countries; Brazil, USA and China. Turkey is among the first 10 countries in the world citrus production (FAO, 2019).

Turkey is located in the northern border areas of the world citrus production. Turkey has extremely convenient to citrus growing areas in terms of ecological conditions. Turkey citrus production 4.769.772 tons in 2017(TUIK, 2019).

The prevalence of foreign fertilization has brought vegetative propagation methods to the forefront in most of the fruit species and varieties. Thus, expansions resulting from seed propagation can be prevented and all the properties of the variety can be preserved. Vegetative propagation; cutting, dipping, root and bottom shoots, or one or more of the tuber propagation methods are used, but today, especially in fruit growing method is used more widely by propagation (Rom, 1987; Hartmann et al. 1990).

Like other fruit species, the production of citrus species does not directly involve seed propagation. As the production of cutting is not very successful in this type of production is based on the reproduction of grafting. Grafting is based on the cultivation of different plants on the same trunk, including rootstock and scion. There are two elements in grafting and reproduction, rootstock and scion. While the scion forms the crown part of the tree, the rootstock forms the subsoil part of the tree and assumes the soil to hold onto the soil and undertakes tasks such as the uptake and transport of water and nutrients. In fruit growing, rootstocks are as important as the varieties grafted on them. As a matter of fact, although a fruit rootstock is not expected to have the characteristics of a standard variety, the rootstocks should have good performance in the special relations formed under the ground and the scion. Roots are the living part that undertakes first degree responsibility in the life of trees (Gülcan, 1991).

Rootstocks used in fruit production are classified as generative and vegetative rootstocks according to their production methods. Because of the generative way, namely seed rootstock production has been opened, there has been rapid increase in the use of clone rootstocks in fruit sapling production in recent years. The use of clone rootstocks is increasingly common in the production of citrus fruit species in order to increase yield and quality and to tolerate many abiotic and biotic stresses. Among the subtropical climate fruit trees, the most common use of clonal rootstocks in the world is citrus.

The rootstocks used in fruit growing are divided into two as seedling and clone rootstocks. Most of the fruit species are

seedling rootstocks. The common drawback of almost all of these is that they show a large amount of variation. This situation adversely affects the homogeneity of the tree development. It is also known that heterogeneous depressions have different behaviors in terms of rootstock and mismatch and environmental adaptation (Gülcan, 1991).

Different rootstocks are used in the production of citrus. The most important of these are citrus and hybrids, trifoliolate orange and hybrids, mandarin and mandarin likes, lemons and their relatives, limes and relatives, oranges, citremon (trifoliolate orange X lemon), sitrumelo (trifoliolate orange X grapefruit), sweet lime, grapefruit, yuzu, volkameriana, macrophylla, citranges (orange X trifoliolate oranges). In recent years, citranges have also started to be used (Mendilcioğlu, 1999).

Citrus is used as rootstock in citrus plants are experiencing difficulties in root rooting. To solve the problem of rooting amino acid (Pedrotti et al. 1994), indole acetic acid (De Klerk et al. 1997; Ahmad et al. 2005), some vitamins (Antonopoulou et al. 2005) applications are made. In addition to these, it has been reported in many studies that it has been presented as a solution to the problem of rooting with rhizobacteria that increase plant growth, which has recently become widespread (Larraburu et al. 2007; Teixeira et al. 2007).

In this study, the effects of *Bacillus* OSU-142 and *Bacillus* A-18 bacterial strains and indole butyric acid applications on the rooting of Carrizo and Troyer citrus rootstocks were investigated.

## Materials and Methods

### Materials

This study was carried out in the heated glass greenhouse in Adana between 2017- 2018. Carrizo and Troyer citrange (*Citrus sinensis* X *Poncirus trifoliata*) rootstocks were used in the study. The cuttings used in the study were obtained from Alata Horticultural Research Institute (Mersin). Carrizo citrange resistant to drought and nematod. It can withstand pH up to 7.6. It has a positive effect on the quality of grafted mandarins. Growth force is greater than Troyer. For tristeza resistance is better than orange (Mendilcioglu, 1999). Troyer citrange very similar to trifoliolate orange. It is used as rootstock in Aegean Region. Creates 80-100% nucellar plant. It can grow at pH 8-8.5 and is resistant to dry soil, lime and cold. Development is good, especially in satsuma mandarin is very positive effect on fruit quality (Mendilcioglu, 1999). In this study *Agrobacterium rubi* A-18 and *Bacillus* OSU-142 bacterial strains which were determined to produce auxin by in vitro studies were used. Bacteria were obtained from Yeditepe University, Faculty of Engineering, Department of Genetics and Bioengineering.

### Methods

The cuttings were prepared in July (2017) as softwood cutting, October (2017) as semi-hardwood cutting and January (2018) as hardwood cutting. The cuttings used in the research were obtained from trees from Alata Horticultural Research

Institute. The cuttings were prepared as 4-knot, 2-knot leafless, top 2-knot leaf planted. *Agrobacterium rubi* A-18 and *Bacillus* OSU-142 bacteria strains were applied to these cuttings with 1000, 2000 and 4000 ppm IBA alone and in combination. Applications to cuttings are given below.

1. Control
2. 1000 ppm IBA
3. 2000 ppm IBA
4. 4000 ppm IBA
5. Application of OSU-142
6. Application of A-18
7. Combination of OSU-142 + A-18
8. 1000 ppm combination of IBA + OSU-142
9. Combination of 2000 ppm IBA + OSU-142
10. Combination of 4000 ppm IBA + OSU-142
11. Combination of 1000 ppm IBA + A-18
12. Combination of 2000 ppm IBA + A-18
13. Combination of 4000 ppm IBA + A-18

IBA was applied to the prepared cuttings by fast dipping in solution and bacterial strains were prepared in suspension at a concentration of  $1 \times 10^9$  bacteria / ml (Pırlak and Baykal, 2011). The applied cuttings were placed in a mist propagation unit with temperature of 25°C, 90-95% relative humidity and perlite. Cuttings kept in mist propagation environment for approximately 3 months were removed at the end of this period, rooting rates (%), callus formation rates (%) and survival rates (%) were determined (Bhusal et al. 2001). While determining the survival rates of the cutted cuttings, it was examined whether the tissue under the steel shells were alive or not, and they were cross-sectioned from the eyes on the cutting.

### Statistical Analysis

Trial; two factors (applications, cuttings retrieval period) according to the completely randomized design, three replicates and 5 cutting in each repetition have been established. The data obtained were subjected to arc sinus (angle) transformation and evaluated by SPSS statistical program and Duncan Multiple Comparison Test was applied.

## Results

### The Effects of Applications on the Cutting Rooting of Carrizo Citrange

The effects of bacteria and IBA applications on the rooting of softwood, semi-hardwood and hardwood cuttings in Carrizo citrange were significant (Table 1). The viability rate of softwood cuttings was 73.33% in the control application and the viability rate was lower than the control in applications other than 1000 ppm IBA. The lowest viability rates were determined in OSU-142 + A-18 and 1000 ppm IBA + A18 (40.00%) and highest in 1000 ppm IBA application (86.67%). The callus rate, which was 66.67% in the control application, increased in 1000 ppm IBA application (86.67%). The lowest callus formation rates were found in 4000 ppm IBA + OSU-142 and

1000 ppm IBA + A-18 (26.67%). The differences between the effects of applications on rooting of green cuttings were insignificant. Rooting rates were generally low, the highest rooting applications occur with a ratio of 13.33% of 4000 ppm IBA and OSU-142 + A-18 (Table 1).

In practice, most of the Carrizo citrange semi-hardwood cuttings remained alive. The viability rate of 100.00% in the control was lower than the control in 2000 ppm IBA (93.33%) and A-18 (86.67%) applications and all the cuttings maintained their viability in other applications. In callus formation, while some of the applications were significant in the same group as control, some of them decreased significantly compared to control. The lowest callus rates were determined in 1000 ppm IBA and 4000 ppm IBA + A-18 (66.67%). Despite the high rates of viability and callus formation in Carrizo citrange semi-hardwood cuttings, the rooting rates remained below the expected level. Rooting rate of 6.67% in the control was found to be the same as the control in 6 applications, only OSU-142 + A-18 (13.33%), 1000 ppm IBA + OSU-142 (13.33%) and 2000 ppm IBA + OSU-142 (20.00%) applications increased compared to control. 3 applications (1000 ppm IBA + A-18, 2000 ppm IBA + A-18, 4000 ppm IBA + A-18) did not occur rooting (Table 1).

The viability and callus formation rates of hardwood cuttings were generally high. While the viability rate was 100.00% in 9 applications with control application, viability was found to be lower than control in 4 applications (2000 ppm IBA, OSU-142, A-18, 1000 ppm IBA + A-18). The rate of callus formation was found to be 100.00% in 5 applications (4000 ppm IBA, OSU-142 + A-18, 1000 ppm IBA + OSU-142, 2000 ppm IBA + OSU-142) with the control and decreased in the other applications compared to the control. Rooting rate of Carrizo citrange cuttings was found to be low in woody cuttings as in softwood and semi-hardwood cuttings. While rooting does not occur in the control application, rooting has occurred at different rates in 8 applications, the highest rooting was detected in 2000 ppm IBA + OSU-142 application (20.00%) (Table 1).

When the effects of bacteria and IBA applications according to cutting uptake periods are examined in Carrizo citrange rootstock, it is seen that the differences between the effects of applications on viability and callus formation are statistically significant and the effects on rooting are insignificant (Table 1). The average viability of softwood cuttings was found to be statistically lower than that of semi-hardwood and hardwood cuttings. While the viability rate of softwood cuttings was 60.59%, it was 98.46% for semi-hardwood cuttings and 96.41% for hardwood cuttings. Similarly, in callus ratios, softwood cuttings lagged behind semi-hardwood and hardwood cuttings. The ratio of callus was found to be 49.47% in softwood cuttings, 88.21% in semi-hardwood cuttings and 87.69% in hardwood cuttings. Rooting rates of the cuttings obtained in three different periods were found to be very low and no statistical difference was found between the periods.

**Table 1.** The effects of applications on the cutting rooting of Carrizo citrange

	CARRIZO CITRANGE								
	SOFTWOOD CUTTINGS			SEMI-HARDWOOD CUTTINGS			HARDWOOD CUTTINGS		
	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)
Control	73.33 b**	66.67 b	0.00	100.00 a	100.00 a	6.67 b	100.00 a	100.00 a	0.00 b
1000 ppm IBA	86.67 a	86.67 a	0.00	100.00 a	66.67 c	6.67 b	100.00 a	80.00 b	0.00 b
2000 ppm IBA	60.00 bcd	53.33 bc	6.67	93.33 b	93.33 a	6.67 b	93.33 ab	93.33 ab	6.67 ab
4000 ppm IBA	66.67 bc	53.33 bc	13.33	100.00 a	100.00 a	6.67 b	100.00 a	100.00 a	6.67 ab
OSU-142	66.67 bc	53.33 bc	6.67	100.00 a	80.00 b	6.67 b	86.67 b	80.00 b	6.67 ab
A-18	66.67 bc	66.67 b	6.67	86.67 b	80.00 b	6.67 b	86.67 b	80.00 b	6.67 ab
OSU+A-18	40.00 e	33.33 cd	13.33	100.00 a	100.00 a	13.33 ab	100.00 a	100.00 a	13.33 ab
1000 ppm IBA+OSU-142	53.33 cde	53.33 bc	6.67	100.00 a	100.00 a	13.33 ab	100.00 a	100.00 a	13.33 ab
2000 ppm IBA+OSU-142	66.67 bc	33.33 cd	6.67	100.00 a	100.00 a	20.00 a	100.00 a	100.00 a	20.00 a
4000 ppm IBA+OSU-142	60.00 bcd	26.67 d	0.00	100.00 a	100.00 a	6.67 b	100.00 a	80.00 b	6.67 ab
1000 ppm IBA+A-18	40.00 e	26.67 d	6.67	100.00 a	80.00 b	0.00 b	86.67 b	80.00 b	0.00 b
2000 ppm IBA+A-18	60.00 bcd	60.00 b	6.67	100.00 a	80.00 b	0.00 b	100.00 a	80.00 b	0.00 b
4000 ppm IBA+A-18	46.67 de	33.33 cd	0.00	100.00 a	66.67 c	0.00 b	100.00 a	66.67 b	0.00 b
LSD	16.00	18.47	N.S.	14.27	17.94	20.28	17.48	22.26	17.21
				Viability rate (%)	Callus formation rate (%)	Rooting rate (%)			
				SOFTWOOD CUTTINGS	60.59 b	49.47 b	5.64		
				SEMI-HARDWOOD CUTTINGS	98.46 a	88.21 a	7.18		
				HARDWOOD CUTTINGS	96.41 a	87.69 a	6.15		
				LSD	12.72	13.65	N.S.		

\*Statistical analysis have been carried out using arc sin values.

\*\*Values shown in different letters in the same column are different at 0.05 (Duncan test)

### **The Effects of Applications on the Cutting Rooting of Troyer Citrange**

Plant growth-promoting bacteria and IBA applications on effects of rooting of Troyer citrange rootstock softwood, semi-hardwood and hardwood cuttings are given in Table 2. The effects of the applications on the viability, callus formation and rooting of the steels were found to be statistically significant.

Most of the Troyer citrange softwood cuttings remained viable at the end of the rooting period. In the control, the viability rate increased from 66.67%, but the effects of OSU-142 + A-18 and 4000 ppm IBA + OSU-142 applications where only the highest viability rates were determined (93.33%) were statistically different from the control group (Table 2). The callus forming cuttings ratios were lower than the viability, except that OSU-142 + A-18 had no effect on callus formation compared to control. The highest callus formation with 93.33% OSU-142 + A-18 application, the lowest occurred with 40.00% A-18 application (Table 2). Although most of the Troyer citrange softwood cuttings maintained their viability and formed callus, rooting did not occur except OSU-142 + A-18 application, and the rooting rate was as low as 6.67%.

The viability rates of the semi-hardwood cuttings were found to be high, and the application of 1000 ppm IBA + A-18, where only 80.00% viability was determined, was statistically different from the other group. Similarly, callus formation was

found to be high in semi-hardwood cuttings. Callus rate of 80.00% in control was found to be close to control in IBA and bacterial applications, and 1000 ppm IBA application with the highest rate of callus formation with only 100.00% rate was statistically different from other applications. Similar to softwood cuttings, semi-hardwood cuttings have high viability and callus formation rates, but rooting rates are well below satisfactory levels. Only 4 applications were rooting with the control. They are 6.67% control and 2000 ppm IBA and 13.33% with 1000 ppm and 4000 ppm IBA applications (Table 2).

Viability ratios were also high in hardwood cuttings. Applications generally had a positive effect on viability. The viability rate of 80.00% in control was found to be the same as control in OSU-142 and 1000 ppm IBA + A-18 applications, but higher in control in other applications. Callus formation is also high in hardwood cuttings. In general, no effect on callus formation was observed, and only 1000 ppm IBA (100%) and 4000 ppm IBA (93.33%) increased callus rates compared to control. As with Troyer citrange green and semi-hardwood cuttings, the positive effects of applications on rooting have not been determined. The rooting rates were low in 5 applications with the control, while the rooting rates in other applications were 0.00%. Rooting occurred in applications with 6.67% control and 4000 ppm IBA and 13.33% with 1000 ppm IBA, 2000 ppm IBA and OSU-142 (Table 2).

**Table 2.** The effects of applications on the cutting rooting of Troyer citrange

	TROYER CITRANGE								
	SOFTWOOD CUTTINGS			SEMI-HARDWOOD CUTTINGS			HARDWOOD CUTTINGS		
	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)	Viability rate (%)*	Callus formation rate (%)	Rooting rate (%)
Control	66.67 b**	66.67 bc	0.00 b	100.00 a	80.00 bc	6.67 ab	80.00 c	80.00 c	6.67 ab
1000 ppm IBA	73.33 b	66.67 bc	0.00 b	100.00 a	100.00 a	13.33 a	100.00 a	100.00 a	13.33 a
2000 ppm IBA	73.33 b	73.33 bc	0.00 b	100.00 a	80.00 bc	6.67 ab	100.00 a	80.00 c	13.33 a
4000 ppm IBA	73.33 b	73.33 bc	0.00 b	100.00 a	93.33 ab	13.33 a	100.00 a	93.33 ab	6.67 ab
OSU-142	80.00 b	53.33 cd	0.00 b	100.00 a	66.67 c	0.00 c	80.00 c	66.67 c	13.33 a
A-18	66.67 b	40.00 c	0.00 b	93.33 a	73.33 bc	0.00 c	93.33 b	73.33 c	0.00 b
OSU+A-18	93.33 a	93.33 a	6.67 a	100.00 a	80.00 bc	0.00 c	100.00 a	80.00 c	0.00 b
1000 ppm IBA +OSU-142	80.00 b	66.67 bc	0.00 b	100.00 a	80.00 bc	0.00 c	100.00 a	80.00 c	0.00 b
2000 ppm IBA +OSU-142	73.33 b	66.67 bc	0.00 b	100.00 a	80.00 bc	0.00 c	100.00 a	80.00 c	0.00 b
4000 ppm IBA +OSU-142	93.33 a	73.33 bc	0.00 b	100.00 a	80.00 bc	0.00 c	100.00 a	73.33 c	0.00 b
1000 ppm IBA +A-18	73.33 b	66.67 bc	0.00 b	80.00 b	66.67 c	0.00 c	80.00 c	66.67 c	0.00 b
2000 ppm IBA +A-18	66.67 b	53.33 cd	0.00 b	100.00 a	93.33 ab	0.00 c	100.00 a	86.67 bc	0.00 b
4000 ppm IBA +A-18	86.67 ab	80.00 b	0.00 b	100.00 a	80.00 bc	0.00 c	100.00 a	80.00 c	0.00 b
LSD	22.16	18.25	10.09	18.00	29.03	20.18	10.09	21.68	22.57
				Viability rate (%)	Callus formation rate (%)	Rooting rate (%)			
				SOFTWOOD CUTTINGS	76.92 b	67.18 b	0.51 b		
				SEMI-HARDWOOD CUTTINGS	97.95 a	81.03 a	3.08 a		
				HARDWOOD CUTTINGS	93.33 a	80.00 a	4.10 a		
				LSD	11.93	5.07	2.51		

\*Statistical analysis have been carried out using arc sin values.

\*\* Values shown in different letters in the same column are different at 0.05 (Duncan test)

The effects of treatments on viability, callus formation and rooting were found to be statistically significant compared to the cutting uptake periods in the Troyer citrange rootstock. The viability, callus formation and rooting rates were higher in the semi-hardwood and hardwood cuttings than the softwood cuttings. The average viability was 76.92% for softwood cuttings, 97.95% for semi-hardwood cuttings and 93.33% for hardwood cuttings; callus formation rates were 67.18% for softwood cuttings, 81.03% for semi-hardwood cuttings, 80.00% for hardwood cuttings; rooting rates were 0.51%, 3.08% and 4.10% respectively.

## Discussion

In this study, the effects of plant growth promoting rizobacteria and IBA applications on rooting, callus formation and survival rates of Carrizo citrange and Troyer citrange rootstocks in softwood, semi-hardwood and hardwood cuttings were investigated. The highest rooting rates were 4000 ppm IBA and OSU-142 + A-18 (13.33%) in Carrizo citrange softwood cuttings, 4000 ppm IBA + OSU-142 (20.00%) in semi-hardwood and hardwood cuttings; Troyer citrange softwood OSU-142 + A-18 (6.67%), 1000 ppm IBA and 4000 ppm IBA (13.33%) and 1000 ppm IBA, 2000 ppm IBA and OSU-142 applications in semi-hardwood cuttings (13.33%) was determined (Table 1, 2). Similar results were obtained in a study conducted on M9 apple rootstock cuttings, while bacterial and IBA applications increased the viability and callus formation rates of the

cuttings, it was determined that they had no effect on rooting (Pirlak and Baykal, 2009). When the cuttings are placed in a suitable environment for rooting, callus layer forms at the bottom of the cuttings. Conductive tissue cambium and callus tissue formed in the adjacent phloem region may in some cases consist of various cells in the cortex and core. The protective layer formed by the callus tissue delays the decay of the cutting from the bottom. In some cases, it is shown that the callus layer helps the cutting to absorb water (Hartmann et al. 1990). However, there are different views on the relationship between callus tissue and root formation. According to Girouard (1967), xylem elements that differ in the dense callus tissue generally seen in the cuttings of hard-rooted plants determine the starting point of root formation. Hartmann et al. (1990) states that callus formation and root formation are independent events. Again, Tayfun (1995) in a study made by kiwifruit, while a low rooting in the wood cuttings, a high callus formation occurred in the same conditions. The researcher interpreted this situation as inhibiting rooting and root development due to excessive callus formation.

Due to its many advantages, cutting propagation is widely used in fruit growing as in most plant species. These advantages include a small body part and a large number of homogeneous plants in a small area, being cheap, quick and easy. In addition, this propagation method is less likely to cause soilborne diseases into plants. In spite of all the positive properties of cutting propagation, the biggest obstacle that restricts its use is that the cutting cannot be rooted due to the

low regeneration ability of some species (Rugini and Fedeli, 1990; Webster and Looney, 1996).

The low rooting rates in the citrus rootstock cuttings examined are related to the species characteristics. The rooting ability of cuttings in fruit species shows great differences even between different species and varieties within these species. Accordingly, species are classified as very easy-rooted, hard-rooted and very hard-rooted. Citrus species in this grouping is often included in the hard-rooted (Hartmann et al., 1990). As a matter of fact, positive results have been obtained in studies investigating the effects of bacterial applications on genetically rooting species (Nagarajan et al., 1989; Bassil et al., 1991; Jacob and Hamdam, 1992; Hatta et al., 1996; Sarmast et al., 2012; Arıkan et al., 2015; Kinik and Celikel, 2017).

In general, in citrus fruits propagated by grafting, very good results except for lemon have not been obtained in steel propagation so far (Cooper, 1935). In the study examining the effects of IBA and Paclobutrazol on steel rooting in Valencia orange cultivar, the highest steel rooting (19.6%) was obtained from 500 ppm IBA + Paclobutrazol (Habermann et al., 2006). In the study which investigated the effects of IBA applications on cutting rooting in different citrus rootstocks, trifoliolate orange, Carrizo citrange, Cleopatra mandarin, Citrumelo 1452 rootstocks control and different rooting applications could not be detected (Uzun and Seday, 2011). In the study examining the effects of IBA and cycloposphamide applications on rooting of Citrus jambhiri cuttings, the highest rooting rate (8.2%) was obtained by using IBA and cycloposphamide together (Singh et al., 1987).

Although the rooting rate of the cuttings is very low, it is seen that the rooting of the semi-hardwood and hardwood cuttings is higher than the softwood cuttings. It is stated that rooting is better if cutting is taken in a certain season or month of each plant species grown with cutting (Gülyüz, 1987). In a study conducted by Pırlak (1997) cranberry, it was determined that the rooting rates of cuttings taken at different periods were different.

## Conclusion

In conclusion, in this study, the effects of IBA and bacterial applications on cutting rooting in Carrizo citrange and Troyer citrange rootstocks were not sufficient. This study mainly focuses on the effects of plant growth enhancing bacteria which are used as an alternative in cutting rooting studies in recent years. In different studies, it can be investigated whether there will be an increase in rooting rates by experimenting with different breeds of these bacteria and their combinations with different growth regulators.

In addition, the viability and callus rates in the cuttings are quite high, suggesting that the rooting rates may increase if the 3-month period generally used in cutting rooting applications is increased slightly.

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