



Research Article (Araştırma Makalesi)

Effect of Cutting Time and IBA Application on the Rooting of Goji Berry Cuttings

Hüseyin ÇELİK^{*1}, Figen ÇETİN²

¹Ondokuz Mayıs University, Agricultural Faculty, Horticultural Department 55139, Samsun, Turkey

²DSİ Bölge Müdürlüğü, Aksaray, Turkey

¹<https://orcid.org/0000-0003-1403-7464> ²<https://orcid.org/0000-0002-7632-5042>

*huscelik@omu.edu.tr

Article Info

Received: 23.02.2021

Accepted: 24.05.2021

Online Published :30.06.2021

DOI: 10.29133/yyutbd.885250

Keywords

Cutting time,

IBA,

Rooting rate,

Sapling rate,

Wolfberry.

Abstract: This study was carried out between 2017-2018 and goji berry (*Lycium barbarum* L.) varieties were propagated with cuttings. In this study, the effects of cutting take time and indole-3-butyric acid (IBA) doses on rooting, shooting, root and shoot characteristics were investigated. Cuttings collected from Damaye and NQ7 goji berry cultivars grown in Karkin Village of Aksaray Province from the year of 2015. Cuttings collected at 4 different times (August-15, October-15, December-15 and February-15) and applied with 4 different IBA doses (0, 500, 1000 and 2000 ppm). They planted in trays with perlite medium under misting and bottom heating for rooting. The study planned with three replication and 25 cuttings for each replication under randomised complete block design under greenhouse. Cuttings were mowed after two months and alive cutting rate (%), rooting rate (%), transplantation and sapling rate (%) were determined. The highest rooting rate (88.00%) obtained from Damaye cuttings taken in August and 1000 ppm IBA dose applied. Damaye cuttings rooted good than NQ7 and August is the best cutting time and 1000 ppm IBA is the best application for all investigated characteristics.

Çelik Alma Zamanı ve IBA Uygulamalarının Goji Berry Çeliklerinde Köklenme Üzerine Etkileri

Makale Bilgileri

Geliş : 23.02.2021

Kabul : 24.05.2021

Online Yayınlanma :30.06.2021

DOI: 10.29133/yyutbd.885250

Anahtar kelimeler

Celik,

Zaman,

IBA,

Köklenme oranı,

Fidan randımanı,

Goji berry.

Öz: Bu çalışma 2017-2018 yılları arasında yapılmış ve goji berry (*Lycium barbarum* L.) çeşitleri çelik ile çoğaltılmıştır. Çalışmada, çelik alma zamanı ve Indole-3-bütirik asit (IBA) dozlarının goji berry çeliklerinde köklenme ve fidan randımanı (%) üzerine etkileri belirlenmiştir. Denemede, Aksaray İli Karkin Köyü'nde yetiştirilen 3 yaşındaki Damaye ve NQ7 goji berry çeşitlerinden 4 farklı zamanda (Ağustos-15, Ekim-15, Aralık-15 ve Şubat-15) alınan çeliklere 4 farklı IBA dozu (0, 500, 1000 ve 2000 ppm) uygulanmış ve alttan ısıtmalı tavalardaki perlit içine dikilerek mistleme sulama sistemi altındaki yüksek tünelde köklendirilmişlerdir. Tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulan denemede her tekerrürde 25 Çelik kullanılmıştır. Çelikler dikimden iki ay sonra sökülerek canlı Çelik oranı (%), köklenme oranı (%), şaşırtılan çelik oranı (%) ve fidan randımanı (%) değerleri tespit edilmiştir. En yüksek köklenme oranı (% 88.00) Ağustos ayında alınan ve 1000 ppm IBA uygulanan Damaye goji berry çeşidi çeliklerinden elde edilmiştir. İncelenen tüm özellikler bakımından Damaye çeşidi çelikleri NQ7 çeşidi Çeliklerinden daha yüksek değerler verirken çelik alma zamanı bakımından Ağustos ayında alınan çeliklerin, IBA dozu bakımından ise 1000 ppm dozunun en yüksek sonuçları verdiği saptanmıştır.

1. Introduction

Goji berry or wolf berry is an alternative and super foods with its antioxidant rich healthy berries. Gojiberry (*Lycium barbarum*) included in the *Solanaceae* family and have shrubby plant with red colored and soft fruits. Goji berries are generally consumed as dried fruit and used to flavor or color agent for chocolate, cake, desserts, salads, muesli and cosmetics (Potterat, 2010; Amagase et al., 2011, Celik and Yayla Cetin, 2017). Fadiloğlu and Çoban stated that goji berry acted as a natural antioxidant and retarded lipid oxidation of common carp sausages during 28 days of storage. Goji berry can be propagated by cuttings or seed. It has been tried to determine how the most ideal plants can be produced from seeds taken from goji berries with a study by Yılmaz and Kinay (2013). Feng et al. (2000) propagated the *Lycium chinense* types with cutting and found that green wood cuttings were not rooting, and that treatment of semi-wood or lignified hard wood cuttings with 200 ppm NAA or IBA for 0.5-1.0 hours positively affected rooting. Alsup et al. (2004) stated that auxin application increased the rooting rate but also decreased the root length, and that different doses and times of cutting should be tried. As a matter of fact, Yılmaz and Yıldız (2020), who propagated some bush-type plants with cuttings, also found that the rooting in the cuttings they applied with 2000-8000 ppm IBA had a different effect on the species. They also determined that the effects of IBA doses on the rooting of cuttings taken at different times were also different. Demchak (2014), stating that goji berries are propagated as seeds or vegetatively. They stated that the plants obtained from the seed may differ in terms of phenological, morphological and fruit characteristics, and the types or varieties should be propagated by cuttings. Asanica et al. (2016), who propagated *Lycium barbarum* and *Lycium chinense* types with hard wood cuttings, found that the cutting thickness positively affected shoot length and root volume, increased peat root quality, Razormin and 1500 ppm IBA doses gave good results. Lonnee et al. (2011) stated that the cuttings of plants in shrubs are well rooted in perlite and peat (3:1 v/v) medium, appropriate moisture content, excessive water retention and bottom heating (21-25°C) in the rooting environment. It also stated that leafy cuttings taking in spring and summer can be rooted easily under the misting system. Goji berry was successfully propagated using semi-hardwood cuttings and the propagation coefficient was higher than that for hardwood cuttings. Preplanting treatment with IBA or NAA at 150, 250 or 500 p.p.m. promoted rooting, the rooting percentage being 84-96% compared with 0-5% for the control. The season of cutting preparation had little effect on rooting. When transplanted into the open field, more than 85% of the rooted cuttings survived and became established (Shen and Chen, 1990). Hartmann et al. (2014) stated that rooting is much better in reproducing the species with green leafy or semi-hard wood leafy cuttings taken from ornamentals compared to deciduous species and 1000-3000 ppm IBA application also positively affects rooting. Beyl et al. (2015) stated that the injuries to the bottom of the cuttings and etiolation are also effective on rooting, and they found that these applications accelerate rooting and the cuttings form roots more easily. On the other hand, it has been revealed by the same researchers that rooting will not occur without IBA application in species that are difficult to rooting and etiolation has more effect on rooting than wounding. Beyl et al. (2015), who determined that the auxin group hormones that encourage rooting, the cutting type and the cutting take time and the age of the mother plant are also significant in the reproduction of bush plants such as ornamentals. Beyl et al. (2015) stated that the best rooting medium is 3-4 parts perlite and 1 part of peat or peat and vermiculite mixture.

In this study, the effects of the cutting taking time and IBA doses on propagating the goji berries, which promises an important future for our country's economy and human health, were investigated. For this purpose, the effects on the rooting of the cuttings were determined by using four different IBA doses (0, 500, 1000 and 2000 ppm) from the cuttings taken in four different times from 15 August to 15 February.

2. Material and Methods

2.1. Plant Materials

In this study, hard-wood or leafy semi-hardwood cuttings of 15-20 cm length and 1 cm diameter taken from 3-year-old NQ7 and Damaye goji berry varieties grown in Aksaray Province, Kargin Village were used as plant material. Goji berry is one of the fruits with the highest nutritional value and was

used as a food source and medicine locally in East Asian countries. It has become a functional food that continues to increase in popularity in North America and Europe (Potterat, 2010). Goji berry is a common name given to *Lycium barbarum*, *Lycium chinense* and *Lycium ruthenicum* species belonging to the genus *Lycium* in the *Solanacea* family (Wang et al., 2015). Plants belonging to the *Lycium* genus are generally in the form of a thorny bush and grow up to 1-4 m. Goji berry is a deciduous perennial shrub with a developed root system. Moreover, it is highly resistant to many climatic and environmental conditions due to its high tolerance to stress factors such as salty and alkaline soil (Wei et al., 2006). The leaves are gray-green in color, small, narrow and fleshy, arranged in alternating or fascicular forms. Flowers come out of the stem singly or in clusters. Funnel or bell-shaped petals; It can be in white, green and purple colors. Fruits containing several or more seeds inside are two-part, 2 cm long, generally fleshy and juicy, and are red, orange, yellow or black (Bryan et al., 2008). Its fruits are bitter or sweet and it is estimated that the original habitat of *L. barbarum* could be the Mediterranean basin. While *Lycium* species produces fleshy fruit containing more than 10 seeds, some American varieties produce hard fruit with 2 seeds (Levin et al., 2005; Potterat, 2010).

2.2. Methods

Cuttings were taken in 4 different times (August-15, October-15, December-15 and February-15) and applied with Indole-3 butyric acid (IBA) doses (0, 500, 1000 and 2000 ppm) and rooted in perlite in bottom heated (24°C) trays. In the cuttings planted in the perlite medium in the trays established in the polyethylene covered high tunnel and under the automatic controlled misting irrigation system. The ambient humidity was kept above 70% and the temperature above 22°C, and the greenhouse was taken under control with ventilation and shading applications. In the cuttings removed three months after planting date, alive cuttings and rooting rate (%) and transplanted rooted cuttings rate (%) determined. Rooted cuttings transplanted in to the pots and grown under greenhouse conditions at the end of the vegetation periods and sapling rate (%) measurements were also determined (Figure 1 and 2).

The goji berry cuttings taken for rooting in perlite environment in bottom heated trays in the plastic greenhouse were removed two months after the planting date and the following measurements and observations were made. The rooted cuttings were taken to grow in the greenhouse environment by planting in the sapling bags.

- *Alive cutting ratio (%)*: It is determined as the ratio of alive cutting in each recurrence to the total number of the cutting.
- *Rooting rate (%)*: It was determined as the ratio of the rooting cuttings in each repeat to the total number of the cuttings.
- *Transplanted cuttings ratio (%)*: It was determined as the ratio of the number of the cuttings to the total number of cuttings among the cuttings in each repetition two months after the planting date.
- *Sapling Ratio (%)*: It was determined as the ratio of the total number of living plants to the total number of transplanted plants six months after the transplanting procedure.

2.3. Statistical Analyses

In the experiment, which was established in a polyethylene covered high tunnel with 3 replications according to the randomized blocks design, 25 cuttings were used for each replication. Data as percent obtained from the experiment, transformed by using $\arcsin\sqrt{x}$ transformation and the statistical analyzes were made on these transformed data. The data obtained from the experiment were subjected to variance analysis using the SPSS program (SPSS, 2017), and the differences between the averages were evaluated at the level of 1% with Duncan Multiple Range Test.



Figure 1. Collecting the goji berry shoots, preparation the cuttings and planting them into the perlite medium with bottom heated trays under high tunnel environment.



Figure 2. Removing the rooted and shooted goji berry cuttings from the benches and taking observations and measurements.

3. Results and Discussion

Goji berry could be propagated by cuttings for clonal sapling production and genetic stability. In the presented study the changes according to the cutting time, IBA dose and goji berry cultivars interaction of alive cuttings, rooting, transplanted rooted cuttings and sapling rates (%) in goji berry (*Lycium barbarum* L.) cuttings taken at different times and treated with different doses of IBA given in Table 1. It was determined that the alive cutting ratio (100.00%), rooting and transplanted rooted cuttings ratio (88.00) and sapling rate (82.67%) were found to be the highest in the cuttings taken from Damaye goji berry variety in August and applied 1000 ppm IBA dose. On the other hand, it was determined that the rate of alive cutting in Damaye variety, which was taken in December and applied with 2000 ppm IBA dose, remained at the lowest level with 2.67%, in this application there was no rooting and the sapling ratio was 0.00% (Table 1). This situation was similar for cuttings collected from the NQ7 variety in December.

According to the interaction of variety and cutting time, survival rate (90.33%), rooting and transplanting rate (67.00%) and sapling rate (47.00%) were the highest in cuttings taken from Damaye goji berry variety in August. On the other hand, survival, rooting, transplanted and sapling rate were the lowest with 23.67%, 1.50%, 3.00% and 0.67%, respectively in cuttings taken in December from NQ7 variety (Table 2).

Considering the variety and IBA doses, it was revealed that cuttings obtained from Damaye variety with 1000 ppm IBA dose gave the highest values with survival rate (62.67%), rooting and transplanted rooted cuttings ratio (34.67%) and sapling rate (29.33%). On the other hand, the survival rate (45.33%) in the cuttings belonging to the NQ7 variety applied with 2000 ppm IBA dose was the lowest, while the control cuttings of the same variety did not have any IBA in terms of rooting (9.83%), transplanted cutting (11.33%) and seedling rate (4.33%). It has also been found to give the lowest values (Table 3).

According to the cutting time and IBA dose interaction, it was determined that August x 1000 ppm IBA application gave the highest values with the ratio of surviving cuttings (90.67%), rooting and transplanted cuttings ratio (70.67%) and sapling rate (59.33%). On the other hand, it was determined that December x 2000 ppm IBA application gave the lowest alive cutting rate with 9.33%, these cuttings

were not rooted and the seedling rate was 0.00% (Table 4). Shen & Chen (1990) stated that pre-planting treatment with IBA or NAA at 150, 250 or 500 p.p.m. on green-wood cuttings of goji berry, promoted rooting, the rooting percentage being 84-96% compared with 0-5% for the control. Our findings are lower than these results and that affected from the cutting time, type and cultivars.

The survival, rooting and seedling rate of cuttings are also different according to the varieties, and the survival rate (54.25%), rooting rate (23.17%) and seedling rate (15.17%) of the cuttings belonging to the Damaye variety are better than NQ7 variety cuttings (52.08%, 15.50% and 7.42%, respectively) (Figure 3.) It was determined that August cuttings reached much higher values than other times in terms of all properties examined for cutting taking time. It was revealed that the cuttings purchased in the following months gave lower values in terms of all properties and the values especially in the cuttings purchased in December reached the lowest values (Figure 4). According to this, while 81.50% of the August cuttings remained alive during the trial, 52.83% of them were rooted and after all the rooting cuttings were transplanted, 35.01% of them turned into saplings at the end of vegetation period.

Table 1. Variation of alive cuttings ratio (%), rooting rate (%), transplanted cuttings ratio (%) and sapling ratio (%) of goji berry cuttings taken from different varieties at different times and treated with different concentrations of IBA

Cultivar	Cutting Time	IBA	Alive Cutting Ratio (%)	Rooting Rate (%)	Transplanted cuttings ratio (%)	Sapling Ratio (%)
Damaye	August	0	90.67 b*	49.33cd	49.33 cd*	24.00 cde
		500	90.67 b	72.00 b	72.00 b	48.00 b
		1000	100.00 a	88.00 a	88.00 a	82.67 a
		2000	80.00 b-c	58.67 bc	58.67 bc	33.33 bc
	October	0	37.33 g-k	0.00 j	0.00 j	0.00 i
		500	50.67 fgh	18.67 ef	18.67 ef	9.33 efg
		1000	86.67 bc	40.00 cd	40.00 cd	32.00 bcd
		2000	66.67 def	10.67 fgh	10.67 fgh	2.67 ghi
	December	0	32.00 h-l	0.00 j	0.00 j	0.00 i
		500	30.67 h-l	5.33 hij	5.33 hi	1.33 i
		1000	24.00 jkl	5.33 g-j	5.33 g-j	0.00 i
		2000	2.67 m	0.00 j	0.00 j	0.00 i
	February	0	50.67 fgh	5.33 g-j	5.33 g-j	4.00 f-i
		500	26.67 i-l	5.33 f-i	5.33 f-i	0.00 i
		1000	40.00 g-k	5.33 f-i	5.33 f-i	2.67 ghi
		2000	58.67 efg	6.67 f-i	6.67 gi	2.67ghi
NQ7	August	0	58.67 efg	12.00 fgh	12.00 fgh	9.33 efg
		500	58.67 c-f	32.00 de	32.00 de	13.33 def
		1000	60.00 bcd	53.33 c	53.33 c	36.00 bc
		2000	42.67 b-e	57.33 bc	57.33 bc	33.33 bcd
	October	0	24.00 efg	8.00 f-i	8.00 f-i	5.33 f-i
		500	22.67 efg	12.00 fgh	12.00 fgh	6.67 fgh
		1000	32.00 d-g	2.67 ij	2.67 ij	2.67 ghi
		2000	16.00 g-j	9.33 f-i	9.33 f-i	2.67 ghi
	December	0	69.33 jkl	3.33 hij	9.33 hij	2.67 ghi
		500	68.00 kl	2.67 hij	2.67 hij	0.00 i
		1000	48.00 h-l	0.00 j	0.00 j	0.00 i
		2000	16.00 l	0.00 j	0.00 j	0.00 i
February	0	69.33 def	16.00 fg	16.00 fg	0.00 i	
	500	68.00 def	14.67 fg	14.67 fg	5.33 f-i	
	1000	48.00 f-i	9.33 f-i	9.33 f-i	1.33 i	
	2000	42.7 g-j	9.33 f-i	9.33 f-i	0.00 i	

* There is no difference according to 1% between the averages in the same column and marked with the same letter.

Table 2. The variation of alive cuttings ratio (%), rooting rate (%), transplanted cuttings ratio (%) and sapling ratio (%) of goji berry cuttings according to cultivar and cutting taking time interaction

Cultivar	Cutting Time	Alive Cutting Ratio (%)	Rooting Rate (%)	Transplanted Cuttings Ratio (%)	Sapling Ratio (%)
Damaye	August	90.33 a*	67.00 a*	67.00 a*	47.00 a*
	October	60.33 bc	17.33 c	17.33 c	11.00 c
	December	22.33 e	2.68 d	2.67 d	0.33 d
	February	44.00 d	5.68 c	5.67 c	2.33 d
NQ7	August	72.67 b	38.69 b	38.67 b	23.00 b
	October	55.00 cd	8.00 c	8.00 c	4.33 cd
	December	23.67 e	1.50 d	3.00 d	0.67 d
	February	57.00 cd	12.33 c	12.33 c	1.67 d

*There is no difference according to 1% between the averages in the same column and marked with the same letter.

Table 3. The variation of alive cuttings ratio (%), rooting rate (%), transplanted cuttings ratio (%) and sapling ratio (%) of goji berry cuttings according to cultivar and IBA concentration interaction

Cultivar	Cutting Time	Alive Ratio (%)	Cutting	Rooting Rate (%)	Transplanted cuttings ratio (%)	Sapling Ratio (%)
Damaye	0	52.67		13.67 b*	13.67 b*	7.00 b*
	500	49.67		25.33 ab	25.33 ab	14.67 ab
	1000	62.67		34.67 a	34.67 a	29.33 a
	2000	52.00		19.00 ab	19.00 ab	9.67 b
NQ7	0	52.67		9.83 ab	11.33 ab	4.33 b
	500	55.00		15.33 ab	15.33 ab	6.33 b
	1000	55.33		16.33 ab	16.33 ab	10.00 b
	2000	45.33		19.00 ab	19.00 ab	9.00 b

*There is no difference according to 1% between the averages in the same column and marked with the same letter.

Table 4. The variatoin of alive cuttings ratio (%), rooting rate (%), transplanted cuttings ratio (%) and sapling ratio (%) of goji berry cuttings according to cutting taking time and IBA concentration interaction

Cutting Time	IBA	Alive Ratio (%)	Cutting	Rooting Rate (%)	Transplanted cuttings ratio (%)	Sapling Ratio (%)
August	0	74.67 bc*		30.67 c*	30.67 c	16.67 cd*
	500	80.67 b		52.00 b	52.00 b	30.67 bc
	1000	90.67 a		70.67 a	70.67 a	59.33 a
	2000	80.00 b		58.00 ab	58.00 ab	33.33 b
October	0	48.00 de		4.00 efg	4.00 efg	2.67 ef
	500	54.67 d		15.33 cd	15.33 cd	8.00 de
	1000	73.33 bc		21.33 cd	21.33 cd	17.33 d
	2000	54.67 d		10.00 def	10.00 def	2.67 ef
December	0	28.00 ef		1.67 efg	4.67 fg	1.33 f
	500	26.67 f		4.00 efg	4.00 efg	0.67 f
	1000	28.00 ef		2.67 efg	2.67 efg	0.00 f
	2000	9.33 g		0.00 g	0.00 g	0.00 f
February	0	60.00 cd		10.67 def	10.67 def	2.00 ef
	500	47.33 de		10.00 de	10.00 de	2.67 ef
	1000	44.00 def		7.33 def	7.33 def	2.00 ef
	2000	50.67 d		8.00 def	8.00 def	1.33 f

*There is no difference according to 1% between the averages in the same column and marked with the same letter.

On the other hand, it was determined that only 23.00% of the cuttings taken in December could survive, 2.08% of them were rooted and only 1.17% of them turned into saplings (Figure 4). Shen & Chen (1990) found 84-96% rooting for auxin application compared with 0-5% for the control. When transplanted them into the open field, more than 85% of the rooted cuttings survived and became

established. Our survived transplants is lower than this results and this may effect by cultivar, cutting time and auxins. Jian-Feng (2010) also found that 750 mg/L of IBA was the best for goji berry survival rate.

It was determined that there is a statistically significantly difference between the IBA doses used in the experiment and applied to goji berry cuttings in order to promote rooting in terms of all the properties examined. Accordingly, 1000 ppm IBA application gave the highest results in terms of the ratio of surviving cuttings (59.00%), rooting and transplanted rooted cuttings ratio (25.50%) and sapling ratio (19.67%). The lowest values were determined at the rate of surviving cutting at 2000 ppm (48.67%) application, while rooting rate was 11.75% and seedling yield was 5.67% from control (without IBA) application (Figure 5). Shen and Chen (1990) stated that pre-planting treatment with IBA or NAA at 150, 250 or 500 p.p.m. on green-wood cuttings of goji berry, promoted rooting, the rooting percentage being 84-96% compared with 0-5% for the control. Our findings are lower than this result and this could be affected by the cultivar, cutting time and auxin doses.

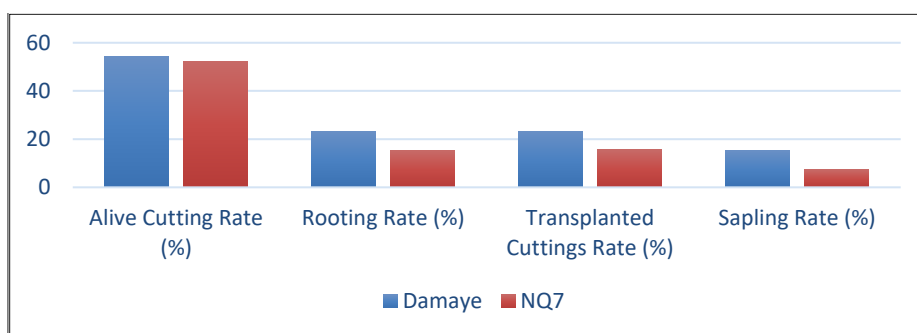


Figure 3. Variation in alive cutting, rooting, transplanted cuttings and sapling rate (%) in goji berry cuttings according to the varieties.

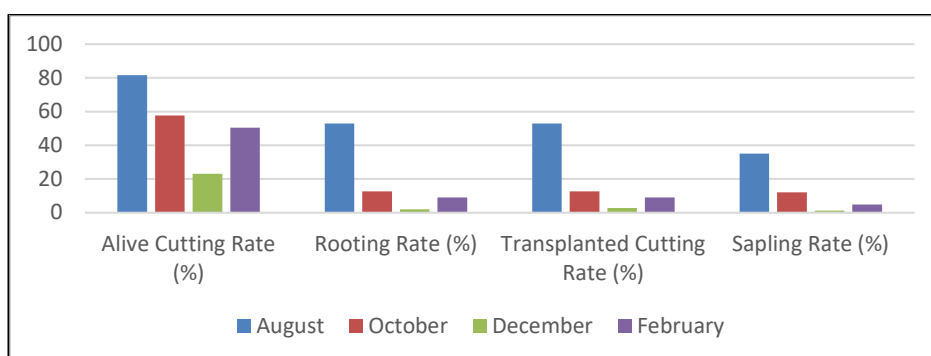


Figure 4. Variation in alive cutting, rooting, transplanted cuttings and sapling rate (%) in goji berry cuttings according to the cutting collecting time.

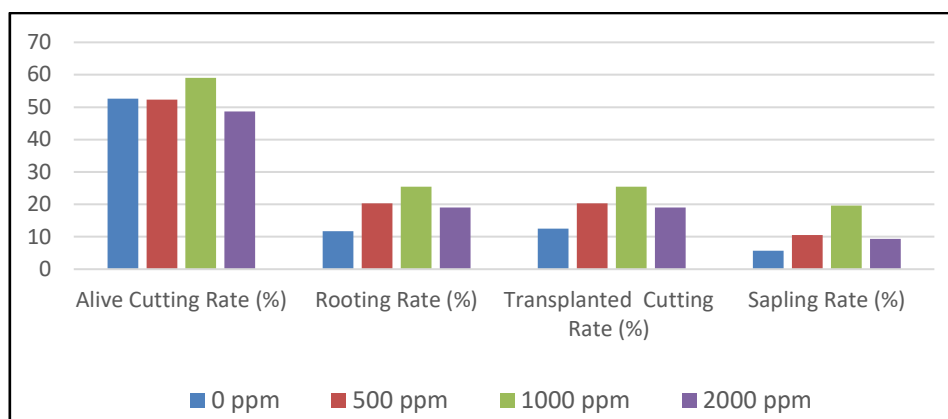


Figure 5. Variation in alive cutting, rooting, transplanted cuttings and sapling rate (%) in goji berry cuttings according to the IBA doses.

Although the propagation of goji berries by seed and tissue culture in *in-vitro* conditions is not practically preferred, the most preferred propagation method is reproduction by cutting. It is stated that fully green cuttings are not preferred for goji berries, which can be reproduced with semi hard-wood and/or hard-wood cuttings taken in summer or winter time. In addition, it has been determined that the application of auxin group growth regulators that increase rooting in cuttings also increases the rooting success (Feng et al., 2000, Celik et al., 2015; Asanica et al., 2016). In the present study, which investigated the effects of cutting taking time and IBA application on rooting in the reproduction of goji berries, 4 different doses of IBA (0, 500, 1000 and 2000 ppm), planted in perlite medium in bottom heated trays and they rooted under high tunnel conditions with misting. The highest results in terms of rooting rate of goji berry cuttings rooted under misting irrigation were obtained from cuttings (88.00%) with 1000 ppm IBA dose, which were taken from Damaye goji berry in August. While the best rooting result (67.00%) in terms of cultivar x cutting time interaction was obtained from the cuttings taking from the Damaye goji berry variety in August, the lowest rooting results (1.50%) were obtained from the cuttings obtained from the NQ7 variety in December (Table 1). According to these results, it is seen that the rooting rate can be very high when three factors in the experiment (Variety x Cuttings time x IBA dose) are taken into account. Considering only the cutting time, it was determined that the highest rooting rate was obtained from the cuttings taken in August with 52.83%, and when the rooting rate was evaluated only in terms of variety, Damaye variety had a higher rooting rate with 23.17% (Figures 3 and 4). According to Celik et al. (2015) semi hardwood cuttings taken in the end of the growing period, roots better than fully dormant cuttings. On the other hand, the cuttings that were taken from Damaye goji berry variety in October and the control group cuttings that did not apply IBA and the cuttings that were taken in December with the dose of 0 (control) or 2000 ppm IBA and the cuttings that were taken from the NQ7 variety in December and applied 1000 or 2000 ppm IBA dose could not be rooting obtained (Table 1). These findings are the same with Celik et al. (2015) results. Again, only 2.67% of the cuttings taken from Damaye variety in December could be transplanted and this value was recorded as the lowest level (Table 2). According to the literature, the rooting rate could be affected by cutting time (Celik et al., 2015), mother plant age and growing conditions (Celik and Celik, 2017), auxins rate and types (Hartmann et al., 2014; Beyl et al., 2015) and cutting growing environment (Asanica et al., 2016). At the end of six months after the transplanting process, it was determined that the rate of alive plants also varied according to the time of taking the cuttings, the IBA dose and the variety of the cuttings. It was determined that there were significant differences between the rate of transplanted rooted cuttings and the rate of alive saplings. Celik et al. (2015) also stated that cutting taking time and IBA doses could have positive affection on alive cuttings rate. Jian-Feng (2010) also found that IBA and the NAA treatments had the positive effects on the survival rate, height of seedlings, the average numbers and the average root length of goji berry. In the present study it has been determined that there are statistically significant differences between sapling rates in terms of variety x cutting time x IBA dose interaction. Cuttings from Damaye goji berry variety taken in August, and applied 1000 ppm IBA dose, reached the highest sapling rate as 82.67%. On the other hand, since there are no alive plants in many application groups and the seedling rate was recorded as 0.00% (Table 1). It is obvious that the goji berry cuttings

taken during active dormant period like winter time, they could not root well unless external auxin spraying (Celik et al., 2015). Markovic et al. (2018) also found that pH value of substrate and substrate type had positive affection on rooting performance. They stated that the rooting percentage was the highest (66%), and the length of primary roots, number and length of shoots were higher in sand compared to other mediums. According to Shen and Chen (1990), the season of cutting preparation had little effect on rooting. But we found cutting time is dramatically affected to the both rooting and transplanting ratio. Shen and Chen (1990) also pointed out that the daily mean temperature (20-30°C), a relative humidity (90-100%), a soil moisture content (<15%) and a 50% reduction in light transmission by shading in the plastic film-covered nursery provided the optimum conditions for rooting of goji berry cuttings. This means that rooting of goji berry cutting may affected to the soil and environmental conditions.

In the present study, when the variety and the cutting taking time were examined, cuttings taken from Damaye and in August reached the highest value with a sapling rate of 47.00% at the end of the research. However, the living plant ratio of cuttings taken from Damaye goji berry variety in December and rooting remained at the lowest level with 0.33% (Table 2). The number or ratio of rooted cuttings obtained after the cultivation of other higher plants such as ornamental plants with cuttings and which can be confused depends on the ambient temperature (Ball, 1998), rooting medium and auxin type and concentration (Alsup et al., 2004; Hartmann et al., 2014). Celik and Karasakal (2018), the highest living plant rate was obtained in July from the spreading mountain medlar cuttings planted in the peat environment without IBA and were obtained as 86.68%. They were also determined that the rate of living plants in the cuttings take in August and planted in perlite medium after 1000 ppm IBA application was at the lowest level with 23.33%. It is believed that the survival rate of the transplanted rooted cuttings can vary depending on the containers used, ambient conditions, transplanting time, irrigation, fertilization, light and temperature (Toogood, 1999; Hartman et al., 2014; Osburn et al., 2015) and cutting type (Toogood, 1999, Beyl et al., 2015, Osburn et al., 2015, Markovic et al., 2018). However, only when IBA doses are examined, it is seen that 1000 ppm IBA dose application reached the highest rooting rate (25.50%) (Figure 5). Studies show that the rate of rooting in cuttings may vary depending on the time the cuttings are taken, the IBA dose applied and rooting environments (Hartmann et al., 2014). As a matter of fact, Celik and Celik (2017) applied different doses of IBA to the autumn olive berry cuttings they bought at different times and achieved 97.33% rooting success by applying 500 or 1000 ppm IBA to the leafy semi-hardwood cuttings taken on May 15 or July 15. This shows that rooting is affected by many factors such as cutting taking time, cutting type and auxin dose. The obtained results showed significant affection on rooting of goji berry with cuttings taking during different periods and spraying auxins. As Feng et al. (2000) found that greenwood, cuttings, i.e. tender shoots with green leaves, were not suitable for cutting propagation of *Lycium chinense*. Lignified or semi-lignified hardwood cuttings, treated with NAA or IBA at 200 mg/kg for 0.5~1.0 h., or with H 3BO 3 at 500 mg/kg for 0.5 h., rooted readily. The auxin treatments increased rooting rate and root number, but decreased root length. Qiong (2011) also stated that the use of plant growth regulators (PGRs) is necessary for successful propagation of this plant. Asanica et al. (2016) obtained 60% rooted goji cuttings (0.4 - 0.8 cm diameter) in a control treatment in a peat and sand (1: 1) mixture, 50% rooted cuttings after treatment with 1500 ppm IBA, and only 40% rooted after treatment with 500 ppm IBA. However, their results with thinner cuttings (0.1 - 0.3 cm) were significantly different, reaching 90% rooting of cuttings treated with 500 ppm IBA, rooted in a same substrate mixture. Gehlot et al. (2015) showed that success of hardwood cuttings rooting depends of several factors and their interactions, including cuttings diameter, PGRs type and concentration and a rooting medium. Genotype is also important factor, and each clone could have a different response to a treatment, and the rooting rate can vary from 30% to 100% depending on genotype (Asanica et al., 2016). Zong-Cai et al. (2012) used IAA and ABT plant growth regulators and their 4 concentrations for hardwood cuttings of Ningqi-1 goji berry. They proved that the survival rate of hardwood cuttings were developed and the growth of the roots, stems and leaves of cutting seedlings were promoted best when the hardwood cuttings of Ningqi-1 *Licium barbarum* L.were soaked in IAA or ABT with 100 mg/L.

Goji berry is a deciduous shrub that has been used for centuries in China as a traditional medicinal and food supplement. Today, it is widely grown as a fruit as well as a landscape ornamental species, including some ornamental varieties. It is easily grown plant, suitable for hedges, and it endures pruning. Goji has well developed root system and it can be planted for erosion control or to stabilize

sandy soils. It can be propagated by seed, cuttings, layering and division. Propagation by cuttings is the most convenient method for mass production of uniform plants. In vegetative propagation of horticultural plants, rooting rate, root quality, sprout and shoot quality, as well as the ratio of plants that can survive and turn into seedlings that can survive by reaching the appropriate quality after being transplanted to the pots, and which can be put up for sale, is also very significant. Therefore, the rate of plants that were transplanted to the pots and the rate of sapling rate at the end of the research, after six-seven months, were also calculated.

4. Conclusion

In conclusion, the increasing interest of consumers for goji fruits and plants and the opportunity seized for growers to deliver valuable and profitable products on the local market raise the need of producing new plants of *Lycium* sp. In this respect, the present work reveals some particularities in semihardwood and hardwood cuttings propagation for two goji berry cultivars. In the experiment, 88.00% rooting and 82.67% sapling rate were obtained in cuttings taken from Damaye goji berry variety in August and applied 1000 ppm IBA dose. December cuttings for both cultivars were not profitable. It was found that auxin (IBA) application generally increased the number of both rooting, alive cutting rate and sampling rate. We know goji berry is a promising medicinal and aromatic plant for the agriculture of our country. It is extremely important that goji berries are promoted to the farmers of our country, encouraged by the Ministry of Agriculture and Forestry, evaluated in terms of the added value it will provide to our economy. For this reason, it will be possible to propagate good types or varieties vegetatively by using the results of this study on the reproduction of goji berries.

5. Acknowledgement

We would like to thank to the owner of HZR Fidan, Tarım A.Ş., Mr. Mehmet CEKIL, who presented the goji berry garden to us, provided the trial materials and established the rooting environment by setting up the high tunnel and bottom heated trays, pans, and rooting medium.

References

- Alsop, C. M., Cole, J. C. & Claypool, P.L. (2004). Stem cuttings from caddo sugar maple trees differ in their rooting potential. *Acta Horticulturae*. 630, 263-269.
- Amagase, H. A. & Farnsworth, N.R. (2011). A review of botanical characteristics, phytochemistry, clinical relevance in efficacy and safety of *Lycium barbarum* fruit (Goji). *Food Research International* 44(7), 1702-1717.
- Anonymous. (2015). Goji berry nasıl yetiştirilir. <http://gojiberryorganik.com/index.php?s=icerik&id=26> (Date of Access: 02.09.2019)
- Asanica, A., Tudor, V., Teodorescu, R.I., Iacob, A., Zolotoi, V. & Tudor, A.D. (2016). Results on hardwood cuttings propagation of some *Lycium* sp. genotypes. *Fruit Growing Research*, 32: 63-70.
- Ball, V. & Zylstra, A. (1998). More Efficient Greenhouse Heating. In V. Ball (Eds.) *Ball RedBook*, (pp. 35-54). Ball Publishing, Batavia, Illinois, USA.
- Beyl, C.A., Burger, D.W. & Cheng Z. M. (2015). Plant Growth Substances Used in Propagation. In C.A. Beyl & R.N. Trigiano (Eds.), *Introduction to Plant Propagation and Laboratory Exercises*, (pp. 47-63). CRC Press, Taylor & Francis.
- Bryan, J. K., Costa, D., Giese, N., Nummy, K., Rapp, C. & Seamon, E. (2008). Goji (*Lycium spp*) in natural standardmonograph. *Natural Standard*. USA
- Celik, H. & Celik, D. (2017). Güzyemişi (*Elaeagnus umbellata* Thunb.) Celiklerinde köklenme üzerine Celik alma zamanı ve IBA dozlarının etkisi. *BAHÇE 46 (Özel Sayı 1)*, 155-162.
- Celik, H. & Karasakal, Ö. (2018). *Yayılcı dağ muşmulası'nın (Cotoneaster horizontalis dnce.) tohum ve Celikle çoğaltılması*. OMÜ Fen Bil. Enst. Bahçe Bitkileri Anabilim Dalı, Yüksek Lisans Tezi, Samsun.
- Celik, H. & Yayla Cetin F. (2017). Süper meyve gojiberry (kurt üzümü). *Köyüm Bitkisel Üretim ve Hayvancılık Dergisi*. 2(20), 76-80

- Celik, H., İslam, A. & Kalkışım, Ö. (2015). Effect of cutting time and IBA application on rooting of edible cherry laurel (*Prunus laurocerasus* cv. 'Kiraz') cuttings. *Anadolu Journal of Agricultural Sciences*, 30(3), 215-220.
- Demchak, K. (2014). Goji Berry Culture. *New York Berry News*, 12(9), 27-28
- Fadiloğlu, E.E. & Çoban, M.Z. (2019). The Effects of Goji Berry (*Lycium barbarum* L.) Extract on Some Chemical, Microbiological and Sensory Characteristics of Liquid Smoked Common Carp (*Cyprinus carpio* L., 1758) Sausages. *Yuzuncu Yil University Journal of Agricultural Science* 29(4),702-710.
- Feng, F., HongBo L. & JianYing X. (2000). Propagation of Chinese wolf-berry (*Lycium chinense*) by cuttings. *Journal of Southwest Agricultural University*, 22(3), 251-253.
- Gehlot, A., Tripathi A., Arya, I. & Arya S. (2015). Influence of cutting diameter, auxin and rooting substrate on adventitious rooting from hardwood cuttings of *Azadirachta indica* A. Juss (*Neem*). 2(3), 49-61.
- Hartmann, H.T., Kester, D.E., Davies, F.T. & Geneva, R.T. (2014). *Plant Propagation. Principles and Practices*. Pearson New Int. Ed. England, Eight Ed., USA.
- Jian-Feng, W. (2010). Effects of different concentrations IBA and NAA on tender branch cottage of *Lycium barbarum* L. en.cnki.com.cn/Article_en/CJFDTOTAL-HBLY201003008.htm Date of Access: 05.09.2019.
- Levin, R. A. & Miller, S. A. (2005). Relationships within tribe *Lycieae* (*Solanaceae*): paraphyly of *Lycium* and multiple origins of gender dimorphism. *American Journal of Botany* 92(12): 2044-2053.
- Lonnee, D., Rose, D., Selinger, D. & Whitman, J. (2011). *Growing Shrubs and Small Trees in Cold Climates*. Univ. Of Minnesota Press., USA.
- Markovic, M., Grbic, M., Skocajic, D., Djukic, M. & Bojovic, D.D. (2018). The influence of the substrate composition on rooting of hardwood cuttings of *Lycium barbarum* L. IX International Agricultural Symposium, Proceeding Book, 343-347.
- Osburn, L.D., Cheng, Z.M. & Trigiano, R. (2015). Adventitious Rooting of Woody and Herbaceous Plants. In C.A. Beyl & R.N. Trigiano (Eds.), *Plant Propagation Concepts and Laboratory Exercises* (pp: 231-240), CRC Press, Taylor & Francis.
- Potterat, O. (2010). Goji (*Lycium barbarum* and *L. chinense*): Phytochemistry, Pharmacology and Safety in the perspective of traditional uses and recent popularity. *Planta Med*, 76, 7-19.
- Qiong D. (2011). Effects on plant growth regulator on survival rate and growth of wolfberry cuttings. en.cnki.com.cn/Article_en/CJFDTOTAL-QHXZ201103019.htm. Date of Access: 07.09.2019.
- SPSS, (2017). IBM SPSS Statistics 25.0 for Windows. Armonk, NY.
- Toogood, A. (1999). *Plant Propagation*. The American Horticultural Society, DK Publishing, New York. USA.
- Wang, Y., Chen, H., Wu, M., Zeng, S., Liu, Y. & Dong, J. (2015). Chemical and genetic diversity of wolfberry. In: R.C.C Chang & K.F. So (Eds.), *Lycium barbarum and Human Health* (pp. 1-27), Springer Press.
- Wei, Y.Q., Xu, X., Tao, H. & Wang, P. (2006). Growth performance and physiological response in the halophyte *Lycium barbarum* grown at salt-affected soil. *Annals of Applied Biology*, 149, 263–269.
- Yılmaz, G. & Kınay, A. (2016). Goji beri (*Lycium barbarum* L.) fidesi üretimine farklı ortamların etkileri. *GOP Ziraat Fakültesi Dergisi*, 33(1), 111-115.
- Yılmaz, G. & Yıldız, K. (2020). Bazı önemli dış mekan süs bitkilerine ait yeşil çeliklerin köklenme performansı. *Akademik Ziraat Dergisi*, 9(2), 373-380
- Zong-Cai XU., Ming-ceng MA., Feng T., Feng C. & Feng T. (2012). Effects of plant growth regulators on wolfberry hardwood cuttings root and growth. *Journal of Fujian Forestry Science and Technology*, en.cnki.com.cn/Article_en/CJFDTOTAL-FJLK201203025.htm. Date of Access: 02.09.2019.