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Araştırma
(Research)

The Effect of Collection Time, IBA and Putrescine Treatments on the Rooting Potential of Foşa Hazelnut Cultivar

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Abstract

Objective: The aim of the research was to determine how collection time, IBA, and putrescine treatments affected the rooting potential of the Foşa hazelnut cultivar (*Corylus avellana* L.).

Material and Methods: Cuttings were taken from 1-year-old root suckers of Foşa hazelnut cultivar on 4 different dates (June 15, July 10, August 4 and August 28; in 2021 year). 3 different treatments [Control, IBA (2000 ppm) and IBA+putrescine (2000 ppm+1600 ppm)] were performed to the prepared cuttings. Rooting, callusing, survived cutting ratio, dead cutting ratio, root number, root length, rooting level, number of cutting with buds, number of cutting with shoot, and number of cutting with leaves properties were investigated in cuttings removed from the rooting medium.

Results: The collection time and treatments had a significant effect on the rooting ability of Foşa hazelnut cuttings. Depending on the collection time and treatments interaction, the callusing ranged from 1.7 (in IBA+putrescine treatment in the June 15) to 96.7% (in IBA treatment in the July 10). Rooting was determined between 0 (in control in the August 3, in control and IBA+putrescine treatments in the August 28) and 26.7% (in IBA treatment in the July 10). The root number was determined from 0 (in control in the August 3, in control and IBA+putrescine treatments in the August 28) to 13.1 (in IBA treatment in the July 10). Root length was measured between 0 (in control in the August 3, in control and IBA+putrescine treatments in the August 28) and 7.4 cm (in IBA treatment in the July 10). The best rooting scale was determined in (2.5) cuttings collected in July 10 and treated with IBA. It was followed by (2.3) cuttings treated IBA collected in June 15.

Conclusion: It was determined that the rooting ability of IBA-treated semi-hardwood cuttings collected in the early period from Foşa hazelnut cultivar was higher.

Keywords: Cutting, rooting, callusing, survived cutting, root number

Çelik Alma Zamanı, IBA ve Putresin Uygulamalarının Foşa Fındık Çeşidinin Köklenme Potansiyeli Üzerine Etkisi

Öz

Amaç: Araştırmanın amacı, Foşa fındık çeşidinin (*Corylus avellana* L.) köklenme potansiyeli üzerine çelik alma zamanı, IBA ve putresin uygulamalarının etkisini belirlemektir.

Materyal ve Yöntem: Çelikler, Foşa fındık çeşidinin 1 yaşlı dip sürgünlerden 4 farklı tarihte (2021 yılı 15 Haziran, 10 Temmuz, 4 Ağustos ve 28 Ağustos tarihlerinde) alınmıştır. Hazırlanan çeliklere 3 farklı uygulama [Kontrol, IBA (2000 ppm) ve IBA+putresin (2000 ppm+1600 ppm)] yapılmıştır. Köklendirme ortamından sökülen çeliklerde köklenme oranı, kallüslenme oranı, canlı çelik oranı, ölü çelik oranı, kök sayısı, kök uzunluğu, köklenme düzeyi, tomurcuk veren çelik sayısı, sürgün veren çelik sayısı ve yapraklı çelik sayısı özellikleri incelenmiştir.

Araştırma Bulguları: Foşa fındık çeliklerinin köklenme kabiliyeti üzerine çelik alma zamanı ve uygulamalarının önemli bir etkisi olmuştur. Çelik alma zamanı ve uygulama interaksiyonuna bağlı olarak, kallüslenme oranı %1.7 (15 Haziran'da IBA+putresin uygulamasında)-96.7 (10 Temmuz'da IBA uygulamasında) arasında belirlenmiştir. Köklenme oranı %0 (3 Ağustos'ta kontrol uygulamasında ve 28 Ağustos'ta kontrol ve IBA+putresin uygulamasında)-26.7 (10 Temmuz'da IBA uygulamasında) arasında değişmiştir. Çelik başına kök sayısı 0 (3 Ağustos'ta kontrol uygulamasında ve 28 Ağustos'ta kontrol ve IBA+putresin uygulamasında)-13.1 (10 Temmuz'da IBA uygulamasında) arasında tespit edilmiştir. Kök uzunluğu 0 (3 Ağustos'ta kontrol uygulamasında ve 28 Ağustos'ta kontrol ve IBA+putresin uygulamasında)-7.4 cm (10 Temmuz'da IBA uygulamasında) arasında ölçülmüştür. En iyi köklenme skalası 10 Temmuz'da alınan ve IBA uygulanan (2.5) çeliklerde belirlenmiştir. Bunu 15 Haziran'da alınan ve IBA uygulanan (2.3) çelikler takip etmiştir.

Sonuç: Foşa fındık çeşidinden erken dönemde alınan IBA uygulanmış yarı odun çeliklerinin köklenme kabiliyetinin daha yüksek olduğu belirlenmiştir.

Anahtar Kelimeler: Çelik, köklenme, kalluslenme, yaşayan çelik, kök sayısı

Introduction

Root suckers are widely used in the establishment of hazelnut orchards in Türkiye (Acı and Beyhan, 2018). The saplings produced by this method are weak rooted, and the mother plant's roots are also damaged during sucker removal (Kopuzoğlu and Şen, 1991). This situation has a negative impact on plant growth. Furthermore, some suckers used in orchard establishment can be random seedlings developed from seed (Acı and Beyhan, 2018; İslam, 2018). Standard production cannot be achieved in orchards established with these saplings, and yield and quality decrease as a result (Balta, 1989; Kantarcı and Ayfer, 1989). In recent years, Çakıldak and Foşa cultivars, which the late leafing and low yield fluctuation, have been widely used in the establishment of new hazelnut orchards in Türkiye (Beyhan et al., 2007; Beyhan, 2015). As stated above, the negative aspects of sapling production with root suckers require the development of propagation techniques for high-quality, low-cost sapling production in these cultivars, which are commonly used in the establishment of new orchards.

Hazelnut is typically propagated by vegetative methods such as rooted suckers, grafting, cutting, and layering (Balta, 1993; Acı and Beyhan, 2018; İslam et al., 2020; Ates Demirel, 2023; Balta, 2023). Grafting and layering propagation methods require large areas and produce a small number of plants. The tissue culture method is limited due to its high cost, poor adaptation of explants to in vitro conditions, and contamination during culture (Savangikar, 2004; Bacchatte et al., 2008; George and Manuel, 2013). Cutting propagation is a simple, inexpensive, and easy method when compared to other methods (Cristofori et al., 2010). Many factors such as cultivar, genotype, cutting time, cutting type, cutting age, temperature, humidity, light, rooting media, hormone and application dose are effective on propagation by cutting in hazelnut (Balta, 1989; Cristofori et al., 2010; İslam et al., 2019). Some plant species begin root formation without any application, whereas others require the application of plant growth regulators, usually auxins (Syros et al., 2004). Cutting propagation in the hazelnut is difficult and necessitates the use of auxin (Cristofori et al., 2010). Many researchers have reported that IBA increase the rooting of hazelnut cuttings (Balta, 1989; Contessa et al., 2011a; İslam et al., 2019). Polyamines (putrescine, spermidine, and spermine) have been used to increase rooting in cuttings in recent years, in addition to IBA. Polyamines, particularly putrescine, promote root formation in hazelnut cuttings. Polyamines can supply and store nitrogen for rooting and promote the formation of primary, lateral, and adventitious roots (Cristofori et al., 2010; Contessa et al., 2011a). They are also involved in cell division, protein synthesis, and DNA replication, as well as tissue and organ differentiation (Bais and Ravishankar, 2002). There has been little research on the propagation by cuttings of Turkish hazelnut cultivars. These studies focused on the hazelnut cultivars Tombul, Palaz, and Sivri (Kantarcı and Ayfer, 1994; Balta, 1989; Özdemir and Dumanoğlu, 2018). The purpose of this study was to determine the effect of collection time, IBA, and putrescine treatments on propagation by cuttings of Foşa cultivar, one of our important hazelnut cultivars.

Material and Methods

Material

The research was carried out in the high plastic tunnel located in the Application and Research Area of Agriculture Faculty of Ordu University. The material of the study consisted of softwood and semi-hardwood cuttings prepared from 1-year-old root suckers of Foşa hazelnut cultivar grown in a producer's orchard in Yomra (Trabzon) region. The orchard where the cuttings were taken is 45-50 years old. In the orchard, cultural and technical applications (except for irrigation) were made on regularly. Perlite (3-7 mm) was used as rooting medium. IBA (Indole-3 butyric acid, $C_{12}H_{13}NO_2$) and putrescine (1, 4-diaminobutane) were used to promote rooting in the cuttings.

Methods

Cuttings of the Foşa hazelnut cultivar were collected from the plants' 1-year-old root suckers on June 15, July 10, August 4 and August 28 of 2021 year for the study. The root suckers were carefully checked to ensure that they were free of diseases and pests. The cuttings were wrapped in a damp cloth to reduce moisture loss and quickly transported to the high plastic tunnel located in the Application and Research area of Ordu University, where the study was conducted. The cuttings were prepared from the basal part of the shoots formed that year, with 1 leaf on it, and were 13-15 cm in length. While preparing the cuttings, the base part was cut straight under the bud and the upper part was angled cut above the bud. To prevent fungal infections, the prepared cuttings were disinfected with a 0.2% fungicide solution (Captan, %50 WP). Prepared cuttings were subjected to control, 2000 ppm IBA and 2000 ppm IBA+1600 ppm putrescine. Studies on hazelnut propagation by cuttings were used as a reference in the selection of IBA and putrescine doses (Ercişli and Read, 2001; Cristofori et al., 2010). Each period's cuttings were divided into three different groups. The first group of cuttings had no treatment (control), the second group was treated 2000 ppm IBA (with rapid dipping method for 5 seconds), and the third group was treated 2000 ppm IBA with 1600 ppm putrescine (the cuttings were first applied to putrescine for 20 minutes, then was immersed in IBA solution for 5 seconds). Before IBA-treated cuttings were planted in rooting medium, they were kept shaded for 15 minutes to the alcohol to evaporate. The treated cuttings were planted in the rooting medium at 10 × 5 cm row spacing rows and above, with two-thirds of the cuttings remaining in perlite, with three replications for each treatment and 20 cuttings per replication. A misting system was used to keep the at 85-90% humidity of rooting media. After 60 days, the cuttings planted in the rooting medium on June 15 and July 10 were removed. After 75 days, the cuttings planted on August 4 and August 28 were removed. Rooting, callusing, survived cuttings, dead cuttings, number of roots per cutting, root length, rooting level, number of cuttings with buds, number of cuttings with shoots, and number of cuttings with leaves were investigated in the removed cuttings. The investigated properties were determined using the methods described by Balta (1989) and Özdemir and Dumanoğlu (2018).

Callusing (%): It was assessed by observing in cuttings formed callus and expressed as a percentage.

Rooting (%): It was calculated as a percentage by dividing the number of rooted cuttings by the total number of cuttings.

Survived cuttings (%): It was calculated as a percentage by dividing the number of survived cuttings by the total number of cuttings.

Dead cuttings (%): It was calculated as a percentage by dividing the number of dead cuttings by the total number of cuttings.

Number of roots per cutting (number): In each treatment, the number of roots formed in the basal section of the rooted cuttings was counted.

Root length (cm): The length of the roots formed in the cuttings was measured with a digital caliper (Mitutoyo, Japan) sensitive to 0.01 mm.

Rooting level: In the rooted cuttings were determined according to 1-4 (1-very weak, 2-poor, 3-moderate, 4-good) scale.

Number of cutting with buds (number): It was calculated by counting the number of bud-forming cuttings.

Number of cutting with leaves (number): It was determined by counting the number of cuttings that formed leaf.

Number of cutting with shoot (number): It was calculated by counting the number of shoot-forming cuttings

Statistical analysis

The study planned a randomized plot design with three replications. The obtained data were evaluated using the statistical package program JMP 14.0 (trial). The LSD multiple comparison method was used to determine the differences in collection time, treatments, and interactions at the 5% significant level.

Results and Discussion

The effect of collection time, treatments, and collection time×treatment on callus formation was significant ($p<0.05$). Depending on the collection time, the highest callus formation was detected on July 10 (57.2%) and the lowest on August 28 (10.0%). In terms of applications, control had the highest callus formation (39.6%), while IBA+putrescine had the lowest (9.6%). Depending on the collection time×treatment interaction, callusing was ranged from 3.3 (in IBA+putrescine in the August 28) to 96.7% (in IBA in the July 10) (Table 1). No research has been found in the literature on the propagation by cuttings of Foşa hazelnut cultivar. It was reported that collection time and IBA treatment had a significant effect on callusing in the hazelnut cultivars Tombul, Palaz, and Sivri. Depending on the collection time, the highest callusing was determined in November (62.3%). In terms of treatments, 2000 ppm IBA (44.2%) was determined (Balta, 1989). In 3 different Italian hazelnut cultivars treated with IBA and putrescine, the highest callusing was reported in June (25.2%) and the lowest in September (9.8%), depending on the collection time. In terms of treatments, the 2000 ppm IBA had the highest callusing (25.6%), and control had the lowest (10.9%) (Cristofori et al., 2010). In contrast, in semi-hardwood cuttings of four different Italian hazelnut cultivars treated with IBA and putrescine, control had the highest callusing (39.5%), IBA+putrescine combination had the lowest (6.0%) (Contessa et al., 2011a). Furthermore, the cuttings collected at different times from foreign hazelnut genotypes, the best callusing was observed in cuttings collected in the mid-July and IBA treated (Ercisli and Read, 2001). Similarly, in the present study, the highest callusing was found in semi-hardwood cuttings collected early period (July 10). The obtained results in treatments were consistent with the findings reported by Contessa et al. (2011a).

The effect of collection time, treatments, and collection time×treatment on rooting was significant ($p<0.05$). While July 10 (14.4%) was determined as the best collection time, rooting decreased as the collection time progressed. In terms of applications, the highest rooting was determined in IBA (11.7%), the lowest in control (0.8%). Rooting ranged from 0.0 (in control in the August 3; in control and IBA+putrescine in the August 28) to 26.7% (in IBA in July 10) depending on the time×treatment interaction (Table 1). It was determined that cutting time and IBA application had an important impact on the rooting of hardwood cuttings of Turkish hazelnut cultivars (Tombul, Palaz, and Sivri). Rooting varied from 0 (November and December) to 1.7% (October) based on collection time, and from 0 (control) to 4.2% (6000 ppm IBA) depending on treatment (Balta, 1989). Several studies have reported that IBA promotes the rooting of hazelnut cuttings (Ercisli and Read, 2001; Contessa et al., 2011b). It was reported that collection time, IBA, and putrescine treatments all had an important impact on rooting in three different Italian hazelnut cultivars. The maximum rooting was detected in June and August (13.6% and 15.9%, respectively), while the lowest was recorded in July (5.4%). In terms of treatments, the highest rooting was reported in the IBA+putrescine combination (31.9%), and the lowest in the control (0.7%) (Cristofori et al., 2010). Similarly, in semi-hardwood cuttings of four different Italian hazelnut cultivars, the highest rooting was determined in the IBA+putrescine combination (47.0%), and the lowest in the control (12.2%) (Contessa et al., 2011a). When the researchers' findings are evaluated, it is clear that softwood and semi-hardwood cuttings have the best rooting, and IBA and putrescine treatments increase rooting. The cuttings collected in July and treated with IBA had the highest rooting in the current study, followed by the cuttings (semi-hardwood) collected in the same period and treated with IBA+putrescine. The rooting values obtained were generally lower than the findings of some researchers. The observed differences are thought to be due to genetic structure, cutting age, hormone dose, nutritional status, and also the age of the plants from which the cuttings were taken.

The effect of collection time, treatments, and collection time×treatment on survived and dead cuttings was significant ($p<0.05$). The best results in terms of survived and dead cuttings were determined on July 10 based on the collection time. In terms of treatments, both were found in the control. The survived cutting rate was ranged from 1.7 (in IBA+putrescine on June 15) to 56.7% (in control on August 28) depending on the collection time×treatment interaction. Dead cuttings rate determined between 43.3 (in control in the August 28) and 98.3% (in IBA+putrescine in the June 15) (Table 1). Depending on the collection time, the highest survived rate in hardwood cuttings of Tombul, Palaz, and Sivri hazelnut cultivars was reported in October (24.9%), and the lowest in

December (3.9%). In terms of applications, 2000 ppm IBA had the highest value (28.9%), while 4000 ppm IBA had the lowest (25.4%) (Balta, 1989). In semi-hardwood cuttings of four different Italian hazelnut cultivars, the highest survival rate was found in control (71.3% and 80.8%) in most cultivars. In the other, both IBA (82.9%) and IBA+putrescine (66.3%) treatments have been effective (Contessa et al., 2011a). Similarly, many researchers found that control treatment had a higher survival rate than IBA-treated cuttings (Santelices and Palfner, 2010; Contessa et al., 2011b). In the current study, the highest survived cuttings ratio was similarly determined in the control depending on the treatments. The values obtained in the survived cuttings rate were lower than the findings of many other researchers. According to different researchers, media humidity, natural auxin content in cuttings, and callus formation all have a significant effect on the survived cuttings rate (Kamaluddin and Ali, 1996; Kalyoncu, 1996; Baul et al., 2010).

Çizelge 1. Table 1. Callusing, rooting, survived cuttings, and dead cuttings rates in IBA and putrescine treated cuttings collected at four different times from the Foşa hazelnut cultivar

Mean value	**Callusing (%)**	**Rooting (%)**	**Survived cuttings (%)**	**Dead cuttings (%)**
Collection time				
June 15	16.7 b[z]	4.4 b	12.2 b	87.8 a
July 10	57.2 a	14.4 a	35.6 a	64.4 b
August 3	25.0 b	5.0 b	23.8 ab	76.1 ab
August 28	10.0 b	0.6 b	26.1 ab	73.9 ab
Significance	***	***	*	*
LSD (0.05)	21.61	6.28	17.30	17.36
Treatments				
Control	39.6 a	0.8 b	40.4 a	59.6 b
IBA	32.5 a	11.7 a	22.5 b	77.5 a
IBA+putrescine	9.6 b	5.8 b	10.4 b	89.6 a
Significance	*	*	***	***
LSD (0.05)	21.53	5.79	12.47	12.51
June 15				
Control	31.7 d	1.7 d	18.3 d	81.7 d
IBA	16.7 e	10.0 c	16.7 de	83.3 cd
IBA+putrescine	1.7 g	1.7 d	1.7 g	98.3 a
July 10				
Control	48.3 c	1.7 d	31.7 c	68.3 e
IBA	96.7 a	26.7 a	48.3 b	51.7 f
IBA+putrescine	26.7 d	15.0 b	26.7 c	73.3 e
August 3				
Control	63.3 b	0.0 d	54.7 ab	45.0 fg
IBA	5.0 g	8.3 c	10.0 ef	90.0 bc
IBA+putrescine	6.7 fg	6.7 c	6.7 fg	93.3 ab
August 28				
Control	15.0 e	0.0 d	56.7 a	43.3 g
IBA	11.7 ef	1.7 d	15.0 de	85.0 cd
IBA+putrescine	3.3 g	0.0 d	6.7 fg	93.3 ab
Significance (interaction)	***	***	***	***
LSD (0.05)	6.12	4.44	7.51	7.69

[z] The differences in between same letters in the same row is statistically insignificant ($p<0.05$).
* significant at $p<0.05$ and *** significant at $p<0.001$

The number of roots per cutting and root length were significantly affected by collection time, treatments, and collection time×treatment ($p<0.05$). The highest number of roots per cutting (6.3) and root length (4.3 cm) were recorded on July 10, while the lowest were found on August 28 (0.1 and 0.1 cm, respectively). In terms of treatments, IBA had the highest number of roots per cutting (6.2) and root length (4.7 cm), while control had the lowest (0.6 and 0.3 cm, respectively). The root number varied between 0.3 (in the IBA on August 28) and 13.1 (in the IBA on July 10), depending on the collection time×treatment interaction (Table 2). In the cuttings of foreign hazelnut genotypes, the highest roots number (6.8) was determined the cuttings collected in June and treated with 1500 ppm IBA, while the lowest in control application (0.0) at all collection times (Ercisli and Read, 2001). In 3 Italian hazelnut cultivars collected cutting at different times and treated with IBA and putrescine, the highest root number was determined in September (3.0) and the lowest in June (1.4). In terms of treatments, the highest was detected in 2000 ppm IBA (4.5), the lowest in 1000 ppm IBA (0.4). In combinations of IBA+putrescine, it was found to be between 3.0 (1000 ppm IBA+1600 ppm putrescine) and 3.9 (1000 ppm IBA+1600 ppm putrescine) (Cristofori et al., 2010). Except for Tonda di Giffoni, in the semi-hardwood cuttings of four different Italian hazelnut cultivars (Tonda di Giffoni, Tonda Gentile delle Langhe, Daria, and Tonda Gentile Romana) treated to IBA and putrescine, the highest root number was determined in the 1000 ppm IBA treatment (15.8, 14.4, and 11.5, respectively), and the lowest in the control (5.3, 1.5, and 1.0, respectively). The highest root length was measured in the 1000 ppm IBA treatment (6.7 cm, 5.6 cm, and 8.5 cm, respectively), while the lowest was measured in the control (4.3, 3.9, and 1.0 cm, respectively). Also, putrescine treatment had no effect on root length, according to Contessa et al. (2011a).

When the findings of the researchers were evaluated, cuttings treated with IBA had the most root number and length when compared to putrescine and control treatments. The current study found similar results. Furthermore, although the according to researchers differ, the best results in terms of collection time were reported in June (Ercisli and Read, 2001), July, and August (Cristofori et al., 2010). In the current study, the best results in terms of collection time were determined in in July. This result was consistent with the findings of Cristofori et al. (2010). The results obtained in terms of root number per cutting and root length are generally consistent with the researchers' findings.

The effect of collection time, treatments, and collection time×treatment on rooting level was significant ($p<0.05$). The best results in terms of rooting level were obtained with cuttings collected on July 10 and treated with IBA (2.5). It was followed by the IBA+putrescine treatment, which was collected on June 15 (2.3). The rooting level was not determined depending on no rooting in some treatments (in control on August 3, in control on August 28, and in IBA+putrescine on August 28) (Table 2). It was reported that IBA application increased rooting level in softwood cuttings of Tonda di Giffoni cultivar (Tombesi et al., 2018). Similar results were obtained in softwood cuttings of the Tombul hazelnut cultivar, with rooting levels ranging from 0 (control) to 2.8 (2000 ppm IBA) (Özdemir and Dumanoğlu, 2018). However, it was found that the rooting level of hardwood cuttings of various hazelnut genotypes was lower in cuttings treated with IBA (Braun and Wyse, 2019c). Except for Braun and Wyse (2019c), the results obtained in terms of rooting level were similar to those of other researchers. Some observed differences may be due to variety and collection time.

The number of cuttings with buds was significantly affected by collection time, treatments, and collection time×treatment ($p<0.05$). The best results in terms of number of cuttings with buds were determined in cuttings collected on August 28 (4.1) and in the control treatment (4.3), respectively, depending on the collection time and treatments. In terms of collection time×treatment, the highest number of cutting with buds was determined as 8.7 (in the control in August 28). It was followed by a control treatment collected on August 3 (5.3). No bud formation was observed in some collection time×treatment interactions (Table 2). The number of cuttings with buds in Ennis and Casina hazelnut cultivars was reported to be between 0.0-10.3% and 0.0-70%. The highest number of cutting with buds was determined in July for both cultivars, depending on the collection time (Bassil et al., 1991). In semi-hardwood cuttings of four different Italian hazelnut cultivars treated with IBA and putrescine, the control had the maximum number of buds (18.1%). The lowest were obtained at 2000 ppm IBA (2.5%) and 1000 ppm IBA+putrescine (8.4%). It was also noted that when the IBA dose increased the rate of budding cuttings decreased (Contessa et al., 2011b). When compared to the researchers' findings, the results obtained in terms of the number of budding cuttings differed in terms of collection time, but were similar in terms of treatments. The observed differences may be related to the genetic structure, nutritional situation, and age of the plants from which the cuttings were collected. The effect of collection time, treatments, and collection time×treatment on the number of cuttings with shoot was significant ($p<0.05$). In terms of collection time, shoots occurred in cuttings collected in June and July (0.8 and 0.9, respectively), but not in cuttings collected in August. Shoots occurred only in control cuttings (1.3) in terms of treatments. Shoot formation was solely determined in the control group depending on the collection time×treatment (Table 2). Consistent with the current study's findings, shoots formed in cuttings collected in June (0.11) and July (0.11) from the Tombul hazelnut cultivar, but no shoots formed in cuttings collected in August. In terms of applications, it was noted that shoots formed in the cuttings treated with IBA and IBA+putrescine, but no shoots formed in the control cuttings (Avcı, 2023).

Table 2. Number of roots per cutting, root length, rooting level, number of cutting with buds, number of cutting with shoot, and number of cutting with leaves in IBA and putrescine treated cuttings collected at four different times from the Foşa hazelnut cultivar

Mean value	**Number of roots per cutting**	**Root length (cm)**	**Rooting level (1-4)**	**Number of cutting with buds**	**Number of cutting with shoot**	**Number of cutting with leaves**
Collection time						
June 15	2.6 ab[z]	2.8 ab	1.0 ab	0.2 b	0.8 ab	0.4 a
July 10	6.3 a	4.3 a	1.7 a	1.6 b	0.9 a	1.9 a
August 3	2.7 ab	2.2 ab	1.2 a	1.8 b	0.0 b	2.0 a
August 28	0.1 b	0.1 b	0.1 b	4.1 a	0.0 b	1.4 a
Significance	*	*	*	*	*	ns
LSD (0.05)	4.17	2.74	0.90	2.25	0.87	1.67
Treatments						
Control	0.6 b	0.3 b	0.3 b	4.3 a	1.3 a	3.3 a
IBA	6.2 a	4.7 a	1.7 a	1.0 b	0.0 b	1.0 b
IBA+putrescine	2.0 b	2.1 b	1.1 a	0.5 b	0.0 b	0.1 b
Significance	**	***	**	***	***	***
LSD (0.05)	3.46	2.15	0.75	1.76	0.65	0.99
June 15						
Control	1.3 bc	0.3 d	0.3 b	0.0 f	2.3 a	1.3 cd
IBA	5.8 b	7.4 a	2.3 a	0.7 ef	0.0 b	0.0 d
IBA+putrescine	0.7 bc	0.8 cd	0.3 b	0.0 f	0.0 b	0.0 d
July 10						
Control	1.0 bc	0.7 cd	0.7 b	3.0 c	2.7 a	3.3 b
IBA	13.1 a	7.4 a	2.5 a	1.0 ef	0.0 b	2.0 bc
IBA+putrescine	4.7 bc	4.6 ab	1.9 a	0.7 ef	0.0 b	0.3 d
August 3						
Control	0.0 c	0.0 d	0.0 b	5.3 b	0.0 b	5.3 a
IBA	5.5 bc	3.5 bc	1.7 a	0.0 f	0.0 b	0.7 cd
IBA+putrescine	2.5 bc	2.9 bcd	2.0 a	0.0 f	0.0 b	0.0 d
August 28						
Control	0.0 c	0.0 d	0.0 b	8.7 a	0.0 b	3.0 b
IBA	0.3 bc	0.4 d	0.3 b	2.3 cd	0.0 b	1.3 cd
IBA+putrescine	0.0 c	0.0 d	0.0 b	1.3 de	0.0 b	0.0 d
Significance (interaction)	**	***	***	***	***	***
LSD (0.05)	5.75	3.0	0.98	1.29	0.40	1.38

[z] The differences in between same letters in the same row is statistically insignificant ($p<0.05$).

* significant at $p<0.05$, ** significant at $p<0.01$, *** significant at $p<0.001$, and ns: not significant

While treatment and collection time×treatment had a significant effect on the number of cuttings with leaves, collection time had no effect ($p<0.05$). The best results were determined on August 3 (2.0) and control (3.3), depending on the collection time and treatments, respectively. On 3 August (5.3), the control had the highest number of cutting with leaves in terms of time×treatment. It was followed by the July 10 control treatment (3.3). In several collection time×treatment interactions, no leaf development was observed (Table 2). The highest number of cuttings with leaves was recorded in Tombul hazelnut cuttings treated with IBA and IBA+putrescine in June (1.44) and August (1.44) depending on collection time. In terms of treatments, it was found in the IBA (2.0). The highest number of cuttings with leaves was reported in the cuttings collected in June and treated IBA (3.0), and the lowest in the control cuttings collected at the same time (Avcı, 2023). While the results in terms of collection time were similar to the researchers' findings, the results in terms of applications differed. The observed differences may be related to the genetic structure, nutritional situation, and age of the plants from which the cuttings were collected.

Conclusion

The collection time, IBA and putrescine treatments had a significant effect on the rooting ability of Foşa hazelnut cuttings. In terms of rooting rate, the cuttings collected in July and treated with IBA had the best results, while the control cuttings collected in August had the lowest. Other rooting properties (root length, root number, and rooting level) showed the best results on cuttings treated with IBA and collected on July 10th. When compared to IBA, putrescine treatment had a lower effect on rooting and root quality. As a result, the rooting ability of semi-hardwood cuttings treated with IBA and taken at an early stage from the Foşa cultivar was higher. It is suggested that different doses of IBA and putrescine be tested on the rooting of semi-hardwood cuttings collected early period from this cultivar.

Conflicts of interest

The authors declare no conflicts interest.

Authorship contribution statement

MFB: Contribution of the planning of the study, the methodology, the evaluated of data, the writing of the article, and the review & editing.

BS: Contribution of the establishment of the experiment, the conduct of study, and the writing of the article.

OK: Contribution of the methodology, the statistical analysis, and the writing of the article.

TK: Contribution of the evaluated of data, and the writing of the article.

HK: Contribution of the methodology, and the evaluated of data.

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