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The Effect of Collection Time and Plant Growth Regulators on Rooting Ability of Tombul Hazelnut Cultivar

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Keywords

Corylus avellana, Cutting, rooting, Callusing, IBA, Putrescine

Abstract

The study was carried out to determine the effect of cutting time, IBA and putrescine treatments on the rooting of the cuttings of Tombul hazelnut cultivar. The plant material of study consisted of cuttings prepared from one-year-old root sucker of Tombul hazelnut cultivar. The cuttings collected on three different dates (June 15, July 10 and August 4) were performed three treatments (control, 2000 ppm IBA and 2000 ppm IBA+1600 ppm putrescine). Depending on the interaction of cutting time and treatment, the highest rooting was determined in the cuttings treated IBA collected in June (16.7%), while the lowest in the control cuttings (0%) in all periods. Except for the cuttings treated IBA+putrescine collected in August, callus did not occur in other treatments. The number of roots per cutting was determined between 0.0 (control in all treatments) and 15.5 (taken in July and treated with IBA). Root length was measured from 0.0 cm (control in all treatments) to 8.0 cm (received in June and treated with IBA). The best results in rooting level were recorded in cuttings treated IBA collected in July (4.0). The best results in terms of rooting and root properties of cuttings of Tombul hazelnut cultivar were generally determined in cuttings treated IBA collected in June.

Özet

Tombul Fındık Çeşidinin Köklenme Kabiliyeti Üzerine Çelik Alma Zamanı ve Bitki Büyüme Düzenleyicilerinin Etkisi

Çalışma, Tombul fındık çeşidinin çeliklerinin köklenmesi üzerine çelik alma zamanı, IBA ve putresin uygulamalarının etkisini belirlemek amacıyla yürütülmüştür. Çalışmanın bitkisel materyalini Tombul fındık çeşidine ait bir yaşlı kök sürgünlerinden hazırlanan çelikler oluşturmuştur. Çelikler, 3 farklı tarihte (15 Haziran, 10 Temmuz ve 4 Ağustos) alınmış ve hazırlanan çeliklere 3 farklı uygulama (kontrol, 2000 ppm IBA ve 2000 ppm IBA+1600 ppm putresin) yapılmıştır. Çelik alma zamanı ve uygulama interaksiyonuna bağlı olarak, en yüksek köklenme oranı Haziran'da alınan ve IBA uygulanan çeliklerde (%16.7), en düşük ise tüm dönemlerde kontrol çeliklerinde (%0) belirlenmiştir. Ağustos'da alınan ve IBA+putresin uygulanan çelikler hariç, diğer uygulamalarda kalluslenme meydana gelmemiştir. Çelik başına kök sayısı 0.0 (tüm uygulamalarda kontrolde)-15.5 (Temmuz'da alınan ve IBA uygulanan) arasında belirlenmiştir. Kök uzunluğu ise 0.0 cm (tüm uygulamalarda kontrolde)-8.0 cm (Haziran'da alınan ve IBA uygulanan) arasında ölçülmüştür. Köklenme düzeyi bakımından en iyi sonuçlar Temmuz'da alınan ve IBA uygulanan çeliklerde (4.0) kaydedilmiştir. Genel olarak, Tombul fındık çeşidinde ait çeliklerde köklenme ve köklenme özellikleri bakımından en iyi sonuçlar Haziran'da alınan ve IBA uygulanan çeliklerde belirlenmiştir.

Anahtar Kelimeler

Corylus avellana, Çelik, köklenme, Kalluslenme, IBA, Putresin

1. INTRODUCTION

Hazelnut is an important specie of nut. It is widely grown in Türkiye, Caucasus, Asia, Europe, Iran, and North America in the northern hemisphere of the world. In recent years, new hazelnut orchards have been established in Chile, Australia, and South Africa in the southern hemisphere and the production quantity is increasing every year (Silvestri et al., 2021). According to 2023 FAO data, hazelnut production areas have increased by 66% and production quantity has increased by 45% in the last ten years. Considering the demand for hazelnut production, efficient propagation techniques that can provide good quality sapling material at a low cost are required for the establishment of new orchards and, in particular, the renewal of old orchards in Türkiye.

Hazelnut is a species with a high tendency to suckering, and these are commonly used for propagation. It is also propagated by grafting, cutting (Balta, 1993; Şenyurt, 2017; Ates Demirel, 2023; Balta, 2023), layering (Acı and Beyhan, 2018), and in recent year by tissue culture (Kaplan et al., 2020; İslam and Ekbiç, 2020). The layering method is expensive and requires large areas in the field, and the number of plants obtained in the grafting method is low (Ercisli and Read, 2001). There is a problem in the propagation of hazelnut by tissue culture due to the limited suitability of explants to in vitro conditions and limited adaptation in the formation of sterilized explants (Bacchetta et al., 2008). Cutting propagation is an alternative and valid method due to its low cost, easy, and obtains a large number of plants (Gerçekçioğlu et al., 2009).

When propagating cuttings, it's important to promote the formation of roots. Many internal (genetic structure, water and nutrient content of the mother plant and the cutting, hormones, etc.) and external factors (temperature, humidity, light, collection time, etc.) affect the rooting of cuttings (Gerçekçioğlu et al., 2009). Plant growth regulators are important for increasing uniform rooting with the number and quality of roots per cutting, and especially accelerating root formation in cuttings of hard-to-root species (Ercişli and Read, 2001; Çelik et al., 2015; Algül et al., 2016; Balta et al., 2019).

When the cuttings propagation studies in hazelnut are examined, IBA is widely used as a plant growth regulator for rooting (Balta, 1989; Ercişli and Read, 2001; Cristofori et al., 2010; Özdemir and Dumanoğlu, 2018). It has been reported that IBA synthesizes the special proteins required for root formation and promotes rooting because it is slowly degraded by enzyme systems that degrade auxin and have a continuous effect (Zenginbal et al., 2006). In addition, polyamines (putrescine, spermidine, spermine) and ethylene-blocking compounds (silver nitrate and 1-MCP (1-methylcyclopropane) are other plant growth regulators used in the propagation of hazelnut cuttings in recent years (Cristofori et al., 2010; Contessa et al., 2011a, b). Among these, putrescine, a polyamine, has been reported to improve rooting and root quality in some hazelnut cultivars when combined with IBA (Cristofori et al., 2010; Contessa et al., 2011a). Polyamines play an important role in physiological processes such as embryogenesis, cell division, and root formation (Liu et al., 2006). They can supply and store nitrogen for rooting as well as promote the formation of primary, lateral, and adventitious roots (Cristofori et al., 2010).

The purpose of this study was to examine the effect of collection time, IBA, and putrescine treatments on propagation with the cutting of the Tombul cultivar, which is the world's best-quality hazelnut cultivar. The effect of putrescine on rooting in this cultivar was determined for the first time in this study, and it contributed to the limited cuttings propagation studies in this cultivar.

2. MATERIAL AND METHODS

2.1. Material

The study was carried out in the propagation unit inside the high plastic tunnel in the Application and Research Area of the Agriculture Faculty of Ordu University in 2021. The material of the study consisted of cuttings belonging to the Tombul hazelnut cultivar. The cuttings were taken from a producer's orchard in the Yaglidere district of Giresun province, where cultural and technical treatments were made completely (excluding irrigation). In order to promote rooting in cuttings, IBA (Indole-3-butyric acid) and putrescine (1, 4-diaminobutane) were used as plant growth regulators and agricultural perlite (3-7 mm) were used as rooting medium.

2.2. Methods

At three different periods (June 15, July 10, and August 4), cuttings were taken from 1-year-old suckers in the 'ocaks' of the Tombul hazelnut cultivar. The cuttings were wrapped in a damp cloth to minimize moisture loss and transported to the high plastic tunnel environment where planting would be made quickly. The cuttings were formed from the basal (lower) part of the shoots formed that year, with one leaf on it, and were 13-15 cm in long. Then, the cuttings were disinfected with a fungicide solution (0.2%) against fungal diseases.

At each collection time, the cuttings were divided into three groups, each with three replications and twenty cuttings. There was no treatment to the first group cuttings (control). Second group cuttings were treated with 2000 ppm IBA for 5 seconds, third group cuttings were treated with 1600 ppm putrescine for 20 minutes and then 2000 ppm IBA for 5 seconds. The cutting propagation studies performed in the hazelnut were taken into account in the selection of treatment doses (Ercisli and Read, 2001; Cristofori et al., 2010). The IBA-treated cuttings were kept in a shady condition for 10 minutes before planting in the rooting media to allow the alcohol to evaporate.

The treated cuttings were planted in a perlite-containing rooting unit with 8×5 cm spacing between rows, with 2/3 of the cuttings remaining in the rooting medium. The humidity of the rooting media was kept at 85-90% using a misting unit. After 60 days, the cuttings planted on June 15 and July 10 were removed from the rooting media, and the cuttings planted on August 4 were removed after 75 days. The following properties were investigated in the removed cuttings, and evaluated using the methods described by Balta (1989), Contessa et al. (2011a), and Ozdemir and Dumanoğlu (2018).

2.2.1. Callusing (%)

The presence of callus on the cuttings was determined by observation. Callusing was determined by the ratio of callused cuttings to the total number of cuttings and expressed as %.

2.2.2. Rooting (%)

It was determined by the ratio of rooted cuttings to the total number of cuttings and expressed as %.

2.2.3. Survived Cuttings (%)

It was detected by counting the survived cuttings and dividing them by the total number of cuttings and results expressed as %.

2.2.4. Dead Cuttings (%)

It was determined by the ratio of dead cuttings to the total number of cuttings and expressed as %.

2.2.5. Number of Cutting with Shoot and Leaves

It was detected by counting the cuttings with shoots and leaves.

2.2.6. Number of Roots per Cutting

The roots emerging from the basal part of the rooted cuttings were counted and determined by dividing by the number of rooted cuttings.

2.2.7. Root Length (cm)

In the rooted cuttings were measured using a digital caliper with a sensitivity of 0.01 mm (Mitutoyo, Japan).

2.2.8. Rooting Level

It was determined by observation on a scale of 1-4 (1-very poor, 2-poor, 3-moderate, 4-good).

2.3. Statistical Analysis

Data were evaluated using the JMP 14.0 (trial) statistical package program. The differences between the collection time, treatments, and their interactions were determined at the 5% significance level according to the Tukey multiple comparison method.

3. RESULTS AND DISCUSSION

While the effect of collection time and treatments on callusing was insignificant, the effect of collection time×treatments interaction was significant ($p<0.05$). Depending on the interaction of collection time×treatments, the highest callusing was detected in the cuttings treated with IBA+putrescine and collected in August (1.67%). In other treatments, callus did not occur (Table 1). Depending on the collection time and treatments, the callusing was reported 0% (collected in December and treated 4000 and 6000 ppm IBA)-77.5% (collected in November and treated 4000 ppm IBA) in hardwood cuttings of Tombul hazelnut cultivar (Balta, 1989), and 0-100% (collected in July and treated control) in hybrid hazelnut genotypes (Ercisli and Read, 2001). Effects of collection time, IBA and putrescine treatments on callusing of cuttings of Nocchione, Tonda di Giffoni, and Tonda Gentile Romana cultivars were insignificant. Depending on collection time, IBA, and putrescine treatments, callusing was determined as 9.8% (collected in August)-25.2% (collected in June), 10.9 (control)-24.7% (2000 ppm IBA), and 23.9% (1000 ppm IBA+putrescine), respectively, and putrescine treatment has been reported to increase callusing (Cristofori et al., 2010). Callusing in semi-hardwood cuttings of Tonda di Giffoni, Tonda Gentile delle Langhe, Daria, and Tonda Gentile Romana cultivars was determined between 6.0% (1000 ppm IBA+1600 ppm putrescine)-39.5% (control) (Contessa et al., 2011a). When the researchers' results are evaluated, it is understood that the higher callusing is softwood and semi-hardwood cuttings collected in the early period, and in low dose IBA+putrescine treatment. Similar to the findings of Cristofori et al. (2010), callusing was not significantly affected by collection time or treatments in the current study. The highest callusing was observed in the IBA+putrescine treatments. In other treatments, callusing did not occur. The observed differences may be related to the genetic structure, cutting age, the plant's age and nutritional status.

The effect of collection time, treatments, and collection time×treatments interaction on rooting was significant ($p<0.05$). The best collection time was determined in June (10.0%). The best treatment was detected as IBA (9.44%), and it was determined that there would be no rooting in Tombul hazelnut cuttings without treatment. Depending on the interaction of collection time×treatments, the highest rooting was determined in the cuttings collected in June and treated IBA (16.7%), and the lowest in the control (0%) in all collection times (Table 1). Rooting in Tombul hazelnut cultivar was reported between 0-2.5% (collected in October and treated 2000 ppm IBA) (Balta, 1998) in the cuttings collected at different times and treated with IBA, and 0% (control)-43.3% (2000 ppm) in softwood cuttings (Özdemir and Dumanoğlu, 2018). In different Italian hazelnut cultivars, it was reported that the effects of collection time, IBA, and putrescine treatments on rooting were significant. Depending on the collection time, the highest rooting was recorded in the cuttings collected in August and June (15.9% and 13.6%, respectively), and in terms of treatments, the cuttings treated IBA+putrescine (31.9%) and IBA (21.6%) (Cristofori et al., 2010). Also, the rooting in the semi-hardwood cuttings of 4 different Italian hazelnut cultivars treated with IBA and putrescine was determined between 12.2% (control)-47.0% (1000 ppm IBA+1600 ppm putrescine) (Contessa et al., 2011a). When the results of the researchers are examined, it is understood that the promotes the rooting putrescine together with IBA in hazelnut cuttings, and the rooting ability of softwood and semi-hardwood cuttings is higher than hardwood cuttings. In the current study, the effect of putrescine on rooting was generally lower than IBA. However, putrescine positively affected on rooting in cuttings collected in July. Also, Cristofori et al. (2010) reported cuttings collected in June yielded the best results in terms of collection time, and this result overlaps with the findings of our study. Some differences in terms of rooting may be due to genetic structure, cutting age, hormone dose, mother-plant's age and nutritional status.

Table 1. Effect of collection time, IBA and putrescine treatments on callusing, rooting, survived cuttings, and dead cuttings in Tombul hazelnut cultivar

Mean value	Callusing (%)	Rooting (%)	Survived cuttings (%)	Dead cuttings (%)
Collection time				
June	0.0 a^{z}	10.0 a	10.6 a	89.4 b
July	0.0 a	2.8 b	3.9 b	96.1 a
August	0.6 a	3.9 b	7.2 ab	92.8 ab
Significance	ns	*	*	*
LSD (0.05)	0.94	5.94	5.31	5.31
Treatments				
Control	0.0 a	0.0 b	2.8 b	97.2 a
IBA	0.0 a	9.4 a	11.1 a	88.9 b
IBA+putrescine	0.6 a	7.2 a	7.8 a	92.2 b
Significance	ns	**	**	**
LSD (0.05)	0.94	5.36	4.86	4.86
June				
Control	0.0 b	0.0 d	0.0 f	100.0 a
IBA	0.0 b	16.7 a	18.3 a	81.7 f
IBA+putrescine	0.0 b	13.3 ab	13.3 b	86.7 e
July				
Control	0.0 b	0.0 d	1.7 ef	98.3 ab
IBA	0.0 b	3.3 cd	5.0 de	95.0 bc
IBA+putrescine	0.0 b	5.0 cd	5.0 de	95.0 bc
August				
Control	0.0 b	0.0 d	6.7 cd	93.3 cd
IBA	0.0 b	8.3 bc	10.0 bc	90.0 de
IBA+putrescine	1.7 a	3.3 cd	5.0 de	95.0 bc
Significance (interaction)	*	***	***	***
LSD (0.05)	1.65	6.80	4.36	4.36

z The differences between the same letters in the same row are statistically insignificant ($p<0.05$).
* significant at $p<0.05$, ** significant at $p<0.01$, *** significant at $p<0.001$, and ns: not significant

The effect of the interaction of collection time, treatments and collection time×treatments on survived and dead cuttings was significant ($p<0.05$). The best survived and dead cuttings rate was determined in June (10.6% and 89.4%, respectively) in terms of collection time and IBA (11.1% and 88.9%, respectively) with regards to treatments. Depending on collection time×treatments interaction, the best survived and dead cuttings rates were determined in cuttings treated IBA and collected in June (18.3% and 81.7%, respectively) (Table 1). Survived cuttings rate was reported from 2.5% (collected in October and treated

6000 ppm IBA) to 37.5% (collected in November and treated 2000 ppm IBA) depending on the collection time and IBA treatments in the hardwood cuttings of Tombul hazelnut cultivar (Balta, 1998). In semi-hardwood cuttings of 4 different Italian hazelnut cultivars, the highest survived cuttings rate was found in control (71.3% and 80.8%) in the many of cultivars. In some of the cultivars were determined in both IBA (82.9%) and IBA+putrescine (66.3%) treatment (Contessa et al., 2011a). In the current study, the best results in terms of survived and dead cuttings rate were detected in cuttings treated IBA and IBA+putrescine and collected in June. The values obtained in terms of these properties were lower than the findings of the researchers. This may be due to the absence of callus in the present cuttings. As a matter of fact, the rates of survived and dead cuttings are affected by ambient humidity, natural auxin content in cutting, and callus formation (Kamaluddin and Ali, 1996; Kalyoncu, 1996; Baul et al., 2010).

The effect of collection time and treatments on number of cutting with shoot was insignificant, while the effect on the number of cutting with leaves was significant ($p<0.05$). According to collection time, the highest number of cutting with shoot was determined in June and July (0.1). It was detected (0.1) in IBA and IBA+putrescine depending on treatments. In terms of collection time×treatments, the highest number of cutting with shoot was determined in cuttings collected in June (0.3) and July (0.3), and treated with IBA+putrescine. No shoot formation was observed in other treatments (Table 2). Shoot formation in the cuttings treated IBA and putrescine collected at different times from Foşa hazelnut cultivar was reported only in the cuttings collected in June and July, and treated control (2.3 and 2.7, respectively). Similarly, it was noted that no shoot formation was observed in other treatments (Sayar, 2023).

According to the collection time, the highest number of cutting with leaves was determined in June and August (1.4). It was recorded in the IBA (2.0) depending on treatments. According to collection time×treatments, the highest number of cutting with leaves was detected (3.0) in cuttings collected in June, and treated IBA. The lowest was recorded in (0.0) cuttings collected in June, and control treatment (Table 2). On the contrary, the highest number of cutting with leaves in cuttings treated IBA and putrescine collected at different times from Foşa hazelnut cultivar was reported in cuttings treated control (1.3, 3.3, and 5.3, respectively) in all periods (June, July, and August) (Sayar, 2023). The observed differences may be related to genetic structure, mother-plant's age and nutritional status.

The effect of collection time on number of roots per cutting and root length was insignificant, while the effect of treatments and collection time×treatments interaction was significant ($p<0.05$). Depending on the collection time, the highest number of roots per cutting and root length was determined in July (10.2) and June (4.4 cm), while the lowest was determined in August (5.5 and 2.7 cm, respectively). In terms of treatments, the highest number of roots per cutting and root length was measured in the IBA treatment (10.1 and 6.0 cm, respectively). The lowest was determined in the control treatment (0.0 for both). Depending on collection time×treatments, the highest number of roots per cutting and root length was measured on cuttings collected in July and treated IBA (15.5), and cuttings collected in June and treated IBA (8.0 cm), respectively. It was followed by cuttings treated IBA+putrescine collected in July (15.2), and cuttings treated IBA collected in July (7.0 cm). The lowest was detected in the control treatment (0.0) in all periods (Table 2).

The highest number of roots per cutting and root length were reported in the IBA treatment (8.8 and 15.6 cm, respectively) and the lowest in the control (0.0 for both) in semi-hardwood cuttings of Tombul hazelnut cultivar (Özdemir and Dumanoğlu, 2018). In foreign hazelnut genotypes in which the effect of collection time and IBA treatment were examined, the highest number of roots per cutting was determined in the cuttings collected in June and treated with 1500 ppm IBA (6.8), while the lowest was recorded in the control treatment in the many of collection times (0.0) (Ercisli and Read, 2001). In the cuttings treated IBA and putrescine collected at different times from 3 different Italian hazelnut cultivars, the highest number of roots per cutting was determined in September in collection time. In terms of treatment, it was determined in 2000 ppm IBA (4.5) and 2000 ppm IBA+putrescine (3.9). The lowest was recorded in June in collection time and in 1000 ppm IBA (4.5) in treatments (Cristofori et al., 2010). In addition, in semi-hardwood cuttings of Tonda di Giffoni, Tonda Gentile delle Langhe, Daria, and Tonda Gentile Romana cultivars treated with IBA and putrescine, the highest number of roots per cutting and root length was found in 1000 ppm IBA treatment (15.8, 14.4 and 11.5; 6.7 cm, 5.6 cm and 8.5 cm, respectively), while the lowest was determined in the control treatment (5.3, 1.5 and 1.0; 4.3, 3.9 and 1.0 cm, respectively), except for Tonda di Giffoni cultivar. The effect of putrescine on root length was reported to be insignificant (Contessa et al., 2011a). Similarly, in the current study, the effect of putrescine on root length was insignificant, except for cuttings collected in August. When the findings of the researchers are generally evaluated, the best results in the number of roots per cutting and root length were reported in IBA in treatments, and June (Ercisli and Read, 2001), July and August (Cristofori et al., 2010) in collection time. Findings obtained in the number of roots per cutting and root length were consistent with the researchers' results.

Table 2. Effect of collection time, IBA and putrescine treatments on number of cutting with shoot, number of cutting with leaves, number of roots per cutting, root length, and rooting level in Tombul hazelnut cultivar

Mean value	Number of cutting with shoot	Number of cutting with leaves	Number of roots per cutting	Root length (cm)	Rooting level (1-4)
Collection time					
June	0.1 a	1.4 a	5.9 a^{z}	4.4 a	2.7 b
July	0.1 a	0.8 a	10.2 a	3.8 a	3.5 a
August	0.0 a	1.4 a	5.5 a	2.4 a	2.3 b
Significance	ns	ns	ns	ns	*
LSD (0.05)	0.26	0.89	6.17	3.07	0.63
Treatments					
Control	0.0 a	0.6 b	0.0 b	0.0 b	-
IBA	0.1 a	2.0 a	10.9 a	6.0 a	2.9
IBA+putrescine	0.1 a	1.1 b	10.7 a	4.6 a	2.7
Significance	ns	**	***	***	ns
LSD (0.05)	0.26	0.72	3.91	1.79	0.70
June					
Control	0.0 a	0.0 e	0.0 d	0.0 d	-
IBA	0.3 a	3.0 a	9.8 bc	8.0 a	2.6 bc
IBA+putrescine	0.0 a	1.3 bc	7.8 c	5.3 bc	2.8 bc
July					
Control	0.0 a	0.3 de	0.0 d	0.0 d	-
IBA	0.0 a	1.0 cd	15.5 a	7.0 ab	4.0 a
IBA+putrescine	0.3 a	1.0 cd	15.2 ab	4.5 c	3.0 b
August					
Control	0.0 a	1.3 bc	0.0 d	0.0 d	-
IBA	0.0 a	2.0 b	7.6 c	3.0 c	2.2 c
IBA+putrescine	0.0 a	1.0 cd	9.0 c	4.1 c	2.5 bc
Significance (interaction)	ns	***	***	***	*
LSD (0.05)	0.46	0.80	5.62	2.47	0.76

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

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

The effect of collection time and collection time×treatments interaction on the rooting level was significant, while the effect of treatments was insignificant ($p<0.05$). The best results in rooting level were recorded in cuttings treated IBA collected in July (4.0). It was followed by the cuttings treated with IBA+putrescine collected in the same period (3.0). In control treatment in all periods, the rooting level could not be determined because there was no rooting (Table 2). Similar to the results of the current study, it was reported that IBA treatment increased the rooting level in softwood cuttings of Tombul hazelnut cultivar, and the rooting level was between 0 (control)-2.8 (2000 ppm IBA) (Özdemir and Dumanoğlu, 2018). Similar results were noted for softwood cuttings of Tonda di Giffoni cultivar (Tombesi et al., 2018). On the contrary, it was reported that IBA negatively affected the rooting level of hardwood cuttings of different hazelnut genotypes (Braun and Wyse, 2019). The findings obtained in the rooting level were compatible with the many researchers' findings. Some observed differences may be due to the cultivar, hormone dose, mother-plant's age and nutritional status.

CONCLUSION

The effect of collection time and treatments on the rooting and rooting characteristics of Tombul hazelnut cuttings was significant. The best results on rooting, root number, and root length were determined in cuttings treated with IBA collected in June. The results obtained from the study showed that there would be no rooting in Tombul hazelnut cuttings without hormone treatment. The effect of putrescine on rooting and root quality of cuttings was lower than IBA treatment. However, compared to IBA, putrescine positively affected the rooting in cuttings collected in July, and root length in cuttings collected in August. Therefore, it is recommended to determine the effect of different doses of IBA and putrescine treatments in the cuttings propagation studies in both Tombul and other hazelnut cultivars in the future.

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