How to cite: Yılmaz, N., M. Şeker, E. Gür, M. A. Gündoğdu, S. Palatoz & N. Ekinci, 2021. Effects of different trunk girdlings on fruit yield and pomological characteristics of persimmon (*Diospyros kaki* L. cv. Hachiya). Ege Univ. Ziraat Fak. Derg., 58 (4): 481-488, https://doi.org/10.20289/zfdergi.842801

Research Article
(Araştırma Makalesi)

Ege Üniv. Ziraat Fak. Derg., 2021, 58 (4):481-488
https://doi.org/10.20289/zfdergi.842801

Effects of different trunk girdlings on fruit yield and pomological characteristics of persimmon (*Diospyros kaki* L. cv. Hachiya)

Hachiya Trabzon hurması (*Diospyros kaki* L. cv. Hachiya) çeşidinde değişik bilezik alma uygulamalarının meyve verimi ve pomolojik özellikler üzerine etkileri

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Received (Alınış): **19.12.2020** **Accepted** (Kabul Tarihi): **09.05.2021**

ABSTRACT

Objective: This study was performed to determine the effects of two girdling practices on yield and some pomological properties of persimmon trees in 2019.

Material and Methods: The gridling practices were applied to Hachia variety, common in Çanakkale, as single girdling, double girdling and control. Girdling treatments were performed after full blossom in full yield trees. Fruit yield and some pomological properties of the variety were determined. Fruit weight, fruit width, fruit size, fruit skin colour (L, a, b), pH, titratable acidity (TA) (%), fruit flesh firmness (kg / cm^2) and total soluble solid content (TSS) were determined.

Results: The highest yield per tree was obtained from the control (120.74 kg tree-1) treatment. The largest fruits with a value of 383.23 g were obtained from double girdling treatment. The double girdling application provided the highest values in terms of fruit length and fruit width (79.22 mm, 94.71 mm, respectively). There was a significant difference ($p<0.05$) between applications in terms of total soluble solid content.

Conclusion: The girdling treatments significantly increased fruit weight, fruit size and total soluble solid amount in “Hachiya” variety.

Keywords: carbohydrate metabolism, *Diospyros kaki* L., girdling, quality,

ÖZ

Amaç: Bu çalışma, Trabzon hurması ağaçlarında bilezik alma uygulamalarının verim ve bazı pomolojik özelliklerine etkilerini belirlemek amacı ile 2019 yılında yürütülmüştür.

Materyal ve Yöntem: Çanakkale ilinde yetiştiriciliği yaygın olarak yapılan ‘Hachiya’ çeşidine ait ağaçlarda bilezik alma; kontrol, tek ve çift bilezik alma şeklinde uygulanmıştır. Tam verim çağındaki ağaçlarda bilezik alma uygulamaları tam çiçeklenme sonrası yapılmıştır. Çeşidin meyve verim ve bazı pomolojik özellikleri belirlenmiştir. Meyve ağırlığı, meyve çapı, meyve yüksekliği, meyve kabuk rengi (L, a, b), pH, titre edilebilir asitlik (TA) (%), meyve eti sertliği (kg / cm^2) ve suda çözünebilir toplam kuru madde içeriği (TSS) belirlenmiştir.

Araştırma Bulguları: En yüksek ağaç başına verim Kontrol (120.74 kg ağaç$^{-1}$) uygulamasından elde edilmiştir. En iri meyveler 383.23 g değeri ile çift bilezik alma uygulamasından elde edilmiştir. Çift bilezik alma uygulaması meyve boyu ve meyve eni değerleri bakımından en yüksek değerleri oluşturmuştur (sırasıyla 79.22 mm, 94.71 mm). Suda çözünebilir toplam kuru madde içeriği bakımından uygulamalar arasında farklılık olduğu ($p<0.05$) belirlenmiştir.

Sonuç: Bilezik alma uygulamaları “Hachiya” çeşidinde meyve ağırlığını, meyve büyüklüğünü ve toplam kuru madde miktarını önemli ölçüde artırmıştır.

Anahtar sözcükler: karbonhidrat metabolizması, *Diospyros kaki* L., bilezik alma, kalite,

INTRODUCTION

Persimmon (*Diospyros kaki* L.) is a species in the Ebenaceae family originating in East Asia, which is also called Japanese persimmon, eastern persimmon, Chinese persimmon, Sharon fruit, kaki or simply persimmon. Many varieties were developed in Japan, Korea and China (Yamada et al., 2012; Uçar Özkan et al., 2013).

Persimmons have proved to be extremely adaptable to extensive ranges of climatic conditions. Persimmon is one of the species that can be cultivated in temperate and subtropical climate zones and has becoming increasingly important in fruit growing regions in Turkey. In recent years, the numbers of intensive persimmon orchards in Turkey, particularly in the Mediterranean region, have been rising gradually each year. It is popular among growers and consumers (Şeker et al., 2018).

The world's total persimmon production was 4,711,458 tons in 2018. China was the highest producer of about 3,168,751 tonnes. About 90% of the production of persimmon was produced in China, Spain (492,320 tons) and Korea (346,679 tons) (FAO, 2020).

According to the Turkish Statistical Institute, Turkey produced 51,317 tons of persimmon in 2019. While Adana (10,422 tonnes) was first place for production of persimmon, Çanakkale (1,814 tonnes) was in ninth position. In addition, Çanakkale is one of the most important provinces for fruit growing in Turkey due to favourable ecological conditions (TUIK, 2020). In the district, many fruit species, including temperate and subtropical fruits, are produced with the highest quality characteristics. Persimmon plantations have increased owing to the enormous interest of local growers (Şeker et al., 2004).

Carbon and nitrogen are two chemical elements in organic matter, and carbon-nitrogen ratio (C:N) is extremely significant. The productivity and growth of a plant are considerably influenced by the relative proportions of carbohydrates and nitrogen. The C:N ratio of fruit trees can be changed through simple horticultural practices like girdling (Gawankar et al., 2019). In many studies, girdling treatments were used to increase fruit quality and yield (Arakawa et al., 1997; Goren et al., 2004). The treatment of girdling of the trunk is done to control excessive shoot growth and to promote early fruiting, especially in young trees (Cutting and Lyne, 1992; Fumuro, 1997). Girdling of the stem temporarily directs photosynthesis products to the above-ground parts of the tree, causing a decrease in root growth. Therefore, growth regulators, such as cytokines, are reduced in the root system (Miller et al., 1994).

Consequently, fruit development accelerates while the vegetative growth of the tree decreases due to girdling effects. In order words, girdling prevents the transport of nutrients from the leaves to the roots by phloem. Girdling applications can increase the photosynthetic assimilation products in the canopy. As a result, fruit set, fruit yield and quality characteristics including size, soluble solid content etc. are increased (Choi et al., 2010). There are numerous studies in which girdling was applied to the trunks or large branches of various fruit species. According to the results of previous studies, when girdling is applied at specific growth stages to several fruit crops, it increased fruit set and fruit quality characteristics. For instance, branch girdling treatment of "Hass" avocado (*Persea americana*) increased the fruit weight by 35% at the stage of rapid fruit growth (Fallahi et. al., 2018). In a study carried out with kiwi fruits, Assar et al. (2009) observed that pruning and girdling in early summer provided light canopies and optimum light formation to improve fruit quality. Also in the same research, girdling performance combined with 3:1 and 4:1 leaves to fruit ratios provided higher total soluble solids contents and ascorbic acid in 'Hayward' kiwi fruit. The skin colour of stone fruits (*Prunus spp.*) was developed after trunk girdling treatment at the pit-hardening stage (Choi et al., 2010). In a comprehensive study of girdling treatment in pear (*Pyrus communis*), trees had increased yield compared with non-girdling trees in two seasons (Raffo et al., 2011). Vine girdling treatment of table grapes (*Vitis vinifera*) increased cluster and berry diameters but decreased soluble solid contents and total acidity (Fallahi et al., 2018). Girdling treatments of round seedless grapes increased cluster length, cluster weight and number of berries per cluster (Çoban, 2001). Girdling and scoring applications were equally effective in increasing fruit size of nectarine and peach

(*Prunus persica*) and loquat (*Eriobotrya japonica*). Also, bark girdling treatments may impair trees and vine health if callusing is slow or inadequate (Fernandez-Escobar et al., 1987; Agusti et al., 1998; Agusti et al., 2005; Fallahi et al., 2017). According to Furr et al. (1945), vascular connectivity was re-established much faster after scoring than after girdling in orange (*Citrus sinensis*) trees. Steyn et al. (2008) stated that scoring and girdling treatments of 'Triumph' persimmon caused improved fruit quality and increased yield without decreasing bloom. The increase in fruit properties caused by girdling treatments also reduces shoot growth, but few studies are available about persimmon (Hasegawa and Sobajima 1992; El-Shaikh et al., 1999; Choi et al., 2010). It was concluded that frequency of girdling and scoring treatments might have major long-term effects on apple tree performance (Fallahi et al., 2018).

The aim of this study was to evaluate the effects of different girdling treatments for Hachiya persimmon trees on fruit yield and some pomological characteristics in ecological conditions in Çanakkale. In this article, first year findings are presented.

MATERIAL and METHODS

Materials

The study was carried out in the commercial orchard of a producer in Umurbey in Lapseki District of Çanakkale Province. The persimmon plot in the orchard was established in 2012 by planting grafted seedlings on Caucasian persimmon (*D. lotus* L.) rootstock at 4.5 x 4 planting density and pruned according to the modified leader training system. Persimmon cv. Hachiya cultivar is in the pollination constant astringent (PCA) group. Hachiya fruits have clear orange flesh and remain astringent at the harvesting stage (Yesiloglu et al., 2018)**.** The cultivar is the main persimmon cultivar in commercial orchards in Turkey. The fruits of 'Hachiya' are seedless or have few seeds. Hachiya fruits ripen from the beginning of October to mid-November in ecological conditions in Çanakkale. The fruits of 'Hachiya' are generally used for drying rather than fresh fruit consumption (Çelik and Ercişli, 2010).

Methods

In this research, each tree was accepted as one replicant and three replicants were used for each treatment. Girdling treatments were applied in the orchard on May 10, 2019 at the end of full blossom. Girdling was applied as single girdling (SG), double girdling (DG) and untreated trees were used as control. Tree trunks were girdled by removing a ring of bark 1 cm wide, 20 cm above the graft-union (Figure 1a). In DG treatment, there was 10 cm between the girdling treatments (Figure 1b).

The experiment plot was fertilized by N, P, K and other nutrients during the vegetation period according to Kitagawa and Glucina (1984). The experimental trees were drip irrigated during June – October s by using four sprinklers for each tree. The only insecticide was applied against the Mediterranean fruit fly (*Ceratitis capitata*) for fruit protection as per instructions by Çanakkale Directorate of Provincial Agriculture and Forestry. The fruits were harvested on November 2, 2019 when the fruit skin turned light green colour to yellow, then their yield and pomological characteristics were compared.

Yield Characteristics

Fruit yield: Fruit yield per tree (kg) and yield per unit section of the trunk section (kg/ cm^2).

Pomological Characteristics

After harvesting, the fruits in the experiment were directly analysed at the Post-Harvest Physiology Laboratory of Çanakkale Onsekiz Mart University Faculty of Agriculture, Department of Horticulture. Pomological characteristics were determined by measuring fruit weight, fruit width, fruit length, fruit skin colour (L, a, b), pH, titratable acidity (TA) (%), firmness (kg/ cm^2) and total soluble solid content (TSS) (%). In the study, each tree was accepted as one replicant and there were three replicants for each treatment.

Figure 1. a) Single girdling practice; **b)** Double girdling practice.

Şekil 1. a) *Tek bilezik alma uygulaması;* ***b.*** *Çift bilezik alma uygulaması***.**

Statistical Analysis

The study was set up with three replicants in random blocks according to the trial pattern, and one tree was included in each repetition. The data obtained as a result of the experiment were evaluated using JMP 7.0 statistics program. Significant differences in treatments were compared using LSD test at alpha= 0.05 (SAS, 2019).

RESULTS and DISCUSSION

The yield per tree and tree trunk cross-section for the treatments are presented in Table 1. According to the obtained results, fruit yield per tree was significantly different among the trees. The highest yield per tree was obtained from controls (120.74 kg tree^{-1}), and the lowest yield was obtained from SG treatment (51.65 kg tree^{-1}) and DG treatment (57.35 kg tree^{-1}). Yesiloglu et al. (2004) stated that the yield per tree varied among persimmon varieties due to genotypic differences. According to their findings, the lowest yield was obtained from 'Hachiya' cultivar. Fajt and Komel (2004) compared nine persimmon varieties in Slovenia. 'Fuji', 'Kaki Tipo' and 'Hachiya' varieties had the highest, whereas 'O'Gosho' and 'Hanna Fuyu' had the lowest yield. As the previous research findings stated that fruit yield varied among different persimmon varieties, fruit yield and quality parameters should be improved by different applications including girdling. Yesiloglu et al. (2009) applied DG treatment on 9-year-old 'Interdonato', 'Kıbrıs', and 'Molla Mehmet' lemon trees. They determined that DG resulted in the highest yield per tree (166.64 kg tree^{-1}) for the 'Kıbrıs' variety in the first year, contrarily they obtained the lowest yield for control trees in the 'Interdonato' variety (19.40 kg tree^{-1}) in the second year. Yildiz (2011) determined the yield per tree for two years was 22.35 kg tree^{-1}, and the yield per unit area of the trunk section was 0.20 kg cm^{-2} for 'Hachiya' variety.

Some of the fruit characteristics (fruit weight, fruit length, fruit width and fruit skin colour) were measured in the post-harvest study. A statistical difference was found in terms of fruit weight, fruit size, fruit width and fruit skin colour (L *, b *, a *) in the examined treatments (Table 2).

Table 1. Effects of girdling treatments on fruit yield

Çizelge 1. *Bilezik alma uygulamalarının meyve verimine etkileri*

Treatments	Yield per tree (kg tree^{-1})	Yield to tree trunk cross-section (kg cm^{-2})
Control	120.74 a[1]	1.12 a[1]
Single Girdling	51.65 b	0.49 b
Double Girdling	57.35 b	0.58 ab

[1] The differences between the means are shown by separate letters. (P≤0.05).

Table 2. Measurement results for fruit weight, fruit length, fruit width, fruit skin colour (L*, a *, b *) parameters after treatments

Çizelge 2. *Uygulamalardan sonra meyve ağırlığı, meyve boyu, meyve eni, meyve kabuk rengi (L*, a *, b *) parametrelerinin ölçüm sonuçları*

Treatments	Fruit weight(g)	Fruit length (mm)	Fruit width (mm)	Fruit skin colour		
				L*	a*	b*
Control	264.21 c	71.96 c	81.86 c	68.42 a	6.07 b	73.25 b
Single Girdling	299.20 b	76.07 b	85.31 b	68.45 a[1]	9.53 a[1]	76.12 a[1]
Double Girdling	383.23 a[1]	79.22 a[1]	94.71 a[1]	65.35 b	8.14 ab	71.71 b

[1] The differences between the means are shown by separate letters. (P≤0.05).

Fruit weight were different among the treatments. While the largest fruits were obtained from the DG treatments at 383.23 g, the lowest fruit weight was determined in the control treatments (264.21 g). There was 45.05% difference between DG and control fruits. So, DG application resulted in larger fruits. This could be particularly important for markets demanding large fruit.

'Hachiya' fruit weight from the trees without girdling treatments were reported in previous studies. The fruit weight was 215 g in Antalya (Onur, 1995); 152 g in Adana (Yeşiloğlu et al. 2004); and 203.94 g in Dörtyol (Yildiz, 2011). Contrarily, Choi et al. (2010), reported that girdling had no statistically significant effect on the fruit weight of 'Fuyu' persimmon cultivar. This difference could be due to cultivar characteristics and ecological conditions.

When the fruit length and diameter of the treatments are considered, they had similarities to fruit weight. The highest values were obtained with the fruit length 79.22 mm and fruit width 94.71 mm in the DG treatment. Onur (1995) reported that fruit width was 74.00 mm and fruit length was 64.07 mm for the 'Hachiya' variety in Antalya, while Yildiz (2011) calculated that the fruit width was 67.72 mm and the fruit length was 69.06 mm in Dörtyol. Şeker et al. (2004) detected that fruit width varied between 32.87-77.58 mm and fruit length between 32.40-74.81 mm in Çanakkale.

The fruit length and width are generally parallel to the fruit weight and these parameters vary depending on the age and yield characteristics as well as variety, ecological conditions and cultural management (irrigation, fertilization, pruning etc.) (Ağaoğlu et al., 2001).

Fruit skin colour changed among the treatments and the findings are presented in Table 2. L* value indicates the changes in the brightness of the colour and reaches maximum value as the L * value approaches 100. The L * value for the fruit skin colour was highest from control (68.42) and SG treatments (68.45). The lowest L * value was obtained from DG treatment (65.35). The a * values, with positive value symbolizing red colour and the negative values symbolizing green colour, were highest for the (9.53) DG treatment and lowest at 6.07 for the controls. The b* positive values represent yellow and negative values represent blue. The highest value was obtained from the SG treatment (76.12). The lowest values were obtained from the DG treatment (71.71) and control (73.25). Çelik et al. (2008) reported that L* value was 63.39, a* value was 32.29 and b* value was 62.04 for the external appearance

of 'Hachiya' in Artvin. Choi et al. (2010) found different skin colour values with different girdling treatments. These differences occurring in the colouring of the fruits can vary depending on the ecological conditions (light, temperature difference between day and night etc.) and cultural management techniques (pruning, irrigation, fertilization etc.) (Mowat (2003a; 2003b)).

There were no statistically significant differences in terms of pH, TA (%) and fruit firmness (kg/ cm^2) in the fruits from treated and untreated trees. However, TSS (%) values varied among the treatments (Table 3). The highest TSS (%) value was obtained from the DG (17.13) treatment. Choi et al. (2010) stated that girdling treatments on 'Fuyu' trees had no statistically significant effect on TSS content. The soluble solid content of the fruit could be affected by genotype, environmental and seasonal conditions, total yield, lighting position of tree and maturity of the fruit (Bassi et al., 2016).

Table 3. Measurement results for pH, TSS (%), TA (%), and firmness (kg/cm^2) parameters after treatments

Çizelge 3. *Uygulamalardan pH, Suda çözünebilir toplam kuru madde içeriği (TSS), Titre edilebilir asitlik (TA) (%), Meyve eti sertliği (kg / cm2) parametrelerinin ölçüm sonuçları*

Treatments	pH	TSS (%)	TA (%)	Firmness (kg/cm2)
Control	5.32 a	15.50 b	3.30 a	13.26 a
Single Girdling	5.27 a	16.17 ab	3.03 a	16.75 a
Double Girdling	5.32 a	17,13 a1	3.23 a	13.95 a

[1] The differences between the means are shown by separate letters. (P≤0.05).

CONCLUSION

Preliminary results from the study showed that girdling treatments may be helpful for quality improvement of "Hachiya" persimmon fruits. In conclusion, girdling treatments significantly increased fruit weight, fruit size and TSS (%) in 'Hachiya' cultivar. On the other hand, the effects of girdling treatments on yield should be surveyed in long-term studies because the yield is affected by many effects such as biotic (disease and pests) and abiotic factors (fertilization, watering, pruning and other cultural processes) in persimmon orchards. The girdling treatment of persimmon trees may have potential similar to vineyards and some temperate fruit crops such as pome and stone fruits; however, there are limited studies about persimmon fruit trees. Undoubtedly, girdling treatments have strong effects on carbohydrate metabolism, accumulation of assimilates, amount of carbohydrates, uptake of nutrients and key activities of many enzymes in the trees. The data on this research was obtained from one year evaluation; however, the study should be repeated and enlarged by determining the cumulative yield effects and pomological characteristics in the following years.

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