Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 29 (3), 622-628
Mustafa Kemal University Journal of Agricultural Sciences, 29 (3), 622-628
https://dergipark.org.tr/tr/pub/mkutbd
e-ISSN: 2667-7733

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Relationships between the number of nuts per cluster and fruit characteristics in the Foşa hazelnut cultivar

Foşa fındık çeşidinde çotanaktaki meyve sayısı ile meyve özellikleri arasındaki ilişkiler

Tuba BAK[1], Emrah GÜLER[2], Turan KARADENİZ[1]

[1]*Pamukkale University, Faculty of Agriculture, Department of Horticulture, Çivril, Denizli, Türkiye.*
[2]*Bolu Abant İzzet Baysal University, Faculty of Agriculture, Department of Horticulture, Bolu, Türkiye.*

ARTICLE INFO

Article history:
Recieved / Geliş: 13.05.2024
Accepted / Kabul: 14.06.2024

Keywords:
Foşa hazelnut cultivar
Number of nuts per cluster
Nut characteristics
PCA

Anahtar Kelimeler:
Foşa fındık çeşidi
Salkımdaki meyve sayısı
Meyve özellikleri
PCA

Corresponding author/Sorumlu yazar:
Tuba BAK
tubabak81@gmail.com

ABSTRACT

This research aimed to determine the effect of the number of nuts per cluster on the fruit characteristics of the Foşa hazelnut cultivar grown in the Arsin district of Trabzon province, Türkiye. Hazelnuts are divided into groups of 1 to 7 according to the number of nuts in cluster. Nut weight, nut length, nut width, nut depth, kernel weight, kernel length, kernel width, kernel depth, shell thickness, kernel ratio, husk length, husk width, and husk opening of the hazelnuts in each group were examined. Principal component analyses (PCA) was used to determine the relationship between the number of nuts in cluster and fruit characteristics. Nut weight, shell thickness, husk length, and husk width values were the highest values in single nut clusters. If the number of nuts in the cluster exceeds four, nut and kernel weights decrease. There was a negative relationship between the nut weight and nut length when the number of nuts in the cluster was above four. A strong relationship were observed in clusters 1, 2, 3, and 4, but a weaker relationship, was seen especially in clusters 5 and 7. A negative relationship was determined between the nut weight and nut length. This study clarified that increasing nut numbers shifts quality characteristics, particularly in a negative trend.

ÖZET

Bu araştırmada, Trabzon ili Arsin ilçesinde yetiştirilen Foşa fındık çeşidinde çotanak başına fındık sayısının meyve özelliklerine etkisinin belirlenmesi amaçlanmıştır. Fındıklar çotanaktaki fındık sayısına göre 1 ile 7 arası gruplara ayrılmıştır. Her gruptaki kabuklu fındık ağırlığı, kabuklu fındık uzunluğu, kabuklu fındık genişliği, kabuklu fındık kalınlığı, iç ağırlığı, iç uzunluğu, iç genişliği, iç kalınlığı, kabuk kalınlığı, iç oranı, zuruf uzunluğu, zuruf genişliği ve zuruf açıklığı incelenmiştir. Çotanaktaki fındık sayısı ile meyve özellikleri arasındaki ilişkiyi belirlemek için Temel bileşen analizi (PCA) kullanılmıştır. Fındık ağırlığı, kabuk kalınlığı, zuruf uzunluğu ve zuruf genişliği değerleri tekli fındık kümelerinde en yüksek değerleri göstermiştir. Çotanaktaki fındık sayısı 4'ü geçtiğinde fındık ve iç ağırlıkları azalmıştır. Çotanaktaki fındık sayısı 4'ün üzerinde olduğunda ise fındık ağırlığı ile uzunluğu arasında negatif bir ilişki tespit edilmiştir. 1, 2, 3 ve 4'lü çotanaklarda güçlü bir ilişki, ancak özellikle 5'li ve 7'li çotanaklarda daha zayıf bir ilişki belirlenmiştir. Fındık ağırlığı ile uzunluğu arasında negatif ilişki tespit edilmiştir. Bu çalışma, artan çotanak başına fındık sayısının kalite özelliklerini özellikle olumsuz bir eğilimle değiştirdiğini ortaya koymuştur.

Cite/Atıf Bak, T., Güler, E., & Karadeniz, T. (2024). Relationships between the number of nuts per cluster and fruit characteristics in the Foşa hazelnut cultivar. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 29* (3), 622-628. https://doi.org/10.37908/mkutbd.1482947

INTRODUCTION

Hazelnuts are grown on 1 million and 61 thousand hectares of land worldwide, of which Türkiye holds 744 thousand hectares. Türkiye accounts 765 thousand tons of the 1 million 195 thousand tons of hazelnuts produced in the world, being the leading country with 63.98% of the world's production. According to the Food and Agriculture Organization of the United Nations (FAO), hazelnuts are produced in 39 countries in the world and Italy (98 670 tons), Azerbaijan (72 104.6 tons), USA (70 310 tons), Chile (62 557.07 tons), and Georgia (33 400 tons) are important hazelnut producing countries (FAO, 2024a). Although Türkiye is the leading country in hazelnut exports, it is far behind other hazelnut-producing countries in terms of hazelnut yield. Türkiye ranks 18th with a yield of 102.8 kg da^{-1}. The highest yield per decare in the world is in Greece (256.9 kg da^{-1}), the USA (255.5 kg da^{-1}), and China (205.6 kg da^{-1}) (FAO, 2024a). In Türkiye, we fall behind other countries in terms of yield due to production with old branches, the completion of the economic life of orchards, and the inadequacy of technical practices.

In Türkiye, hazelnuts have adapted to the climate characteristics of the Black Sea Region (Balta et al., 2018) and are a traditional product of the region (Karadeniz, 2021a). Hazelnuts are grown in 39 provinces in Türkiye, especially in Ordu (198 841 tons), Samsun (112 536 tons), Sakarya (82 581 tons), Giresun (72 060 tons), and Düzce (66 647 tons) (TUİK, 2024b).

Anatolia is known for growing the highest-quality hazelnut cultivars and wild species worldwide (Karadeniz, 2018) and being home to unique genetic resources (Balta & Karadeniz, 1997). Twenty standard hazelnut cultivars are grown in Türkiye, including Tombul, Palaz, Çakıldak, and Foşa cultivars (Hazelnut Research Institute, 2024c).

In Türkiye, the 'ocak' system is used for hazelnut cultivation (Bak & Karadeniz, 2021). Hazelnuts have a husk that surrounds the fruit. Fruits bear in the husk and shape the clusters with different numbers of fruits depending on the cultivar, which refers to the number of nuts in the cluster. The number of nuts in a cluster is a cultivar characteristic of hazelnuts. Although many factors such as pruning, fertilization, irrigation, planting, and training systems affect yield and quality in hazelnut cultivation, the genetic structure of the varieties is the most important factor.

The heritability of the number of nuts in cluster, accepted as a cultivar trait, is high (Yao & Mehlenbacher, 2000). It is known that the number of nuts in the cluster is important for yield (Güler & Balta, 2020) and quality (Thompson et al., 1996), and as the number of nuts in cluster increases, the nuts become smaller (Bak & Karadeniz, 2021).

This research was carried out to determine the relationships between the number of nuts in the cluster and the fruit characteristics of the Foşa hazelnut cultivar.

MATERIALS and METHODS

Material

The Foşa hazelnut which is a cultivar that is generally grown in Trabzon and its surroundings were used in this study. This cultivar is intended for the domestic market thanks to its good taste, round shape, kernel ratio of 50%, and membrane removal capacity of 85% (Botta et al., 2019). Its shell is reddish-brown. It usually forms two nuts in a cluster, and 275-363 shelled fruits weigh about 1 kg (Karadeniz, 2021b). The study material was obtained from the Arsin district of Trabzon province, Türkiye.

Methods

Characteristics of nut and husk

The research selected 3 "Ocak" to represent the Foşa hazelnut cultivar. 40 clusters were randomly selected from each. 40 clusters were randomly selected from each "Ocak".The samples taken were divided into 1, 2, 3, 4, 5, 6, and 7 groups according to the number of nuts in the cluster. In each group, the number of nuts in the cluster, nut weight, nut length, nut width, nut depth, kernel weight, , kernel length, kernel width, kernel depth, shell thickness, kernel ratio, husk length, husk opening, and husk width were determined.

The nut and kernels, separated according to the number of nuts in the cluster, were weighed one by one with a scale sensitive to 0.01 g. The length, width, depth, and thickness of the nuts and kernels were measured with the help of a digital caliper sensitive to 0.01 mm. Shell thickness was measured using a caliper sensitive to 0.01 mm from the middle or near-middle part of the fruit base upwards to the thickest part of the bulging part. Kernel ratio was determined by dividing the weight of nuts by the weight of kernels using the following formula (Bak, 2010; Güler & Balta, 2020).

Kernel Ratio (%) = [Kernel weight/Nut weight] x 100

Husk length was determined by measuring the distance between the bottom and top parts (İşbakan & Bostan, 2020). The husk width was determined by measuring the part of the husk surrounding the nut. The husk opening was measured at the tip surrounding the nut.

Statistical analysis

The data were subjected to Tukey's HSD test with an α of 0.05 to compare the means. Principal component analysis (PCA) was performed to determine the relationships of the features and nuts per cluster utilizing the 'ggplot2' (Wickham, 2016) package of R studio software (Boston, USA) (RStudio Team, 2020).

RESULTS AND DISCUSSIONS

In the Foşa hazelnut cultivar, differences were observed between the number of nuts in the cluster and the nut characteristics examined (Table 1 and 2). Nut weight and shell thickness values are highest in single clusters. (3.00 g). There was a linear decrease in the nut weight when nuts per cluster increases from 1 to 7, which drops to 2.15 g in 7 nuts per clusters. Kernel weights had the same value for the single and triple nuts (1.45 g). The kernel ratio was highest in the six-nutted clusters (50.63%). However, the kernel ratio values were not found to be statistically significant. When there are more than 4 nuts in the cluster, there is a significant decrease in nut weight and kernel weight. Although it is not significant, the thickest kernels appear to be on single nuts. In studies conducted by different researchers on the Foşa hazelnut cultivar, nut weights were determined as 2.55-2.70 g by Balta et al. (2018), 1.85-2.24 g by Semiz (2016) , 1.96 g by Yıldız (2016), 2.22-2.66 g by Karadeniz (2001) and 1.79 g by Bostan (2001) . Kernel weights were reported as 1.24-1.37 g by Balta et al. (2018), 0.99-1.15 g by Semiz (2016), 1.10 g by Yıldız (2016), and 0.96 g by Bostan (2001). Balta et al. (2018) and Bak and Karadeniz (2021) reported that as the number of nuts in the cluster increases, the weight of nuts and their kernels decreases. Bostan (1997), in their study with different hazelnut cultivars, reported that as the number of nuts in the cluster increases, nut length and kernel length increase.The same researcher also reported that as the number of nuts in the cluster decreases, the weight, kernel width, and kernel weight of the nuts increase. Balta et al. (2018) reported that increasing numbers of nuts in the cluster decreases shell thickness. Turan (2021) stated that the ideal number of nuts in the cluster should be four, and as the number of nuts increases, the hazelnuts become smaller and put pressure on each other. Our research is partially similar to the findings of other researchers.

Table 1. Nut characteristics of the Foşa hazelnut cultivar according to nut numbers in the cluster
Çizelge 1. Foşa fındık çeşidinin çotanaktaki meyve sayılarına göre fındık özellikleri

NPC	NWT (g)	NL (mm)	NW (mm)	ND (mm)	ST (mm)
1	3.00 ± 0.25 a	19.72 ± 0.81 a	19.64 ± 0.73 a	17.83 ± 0.43 a	1.25 ± 0.34 a
2	2.75 ± 0.31 a	20.14 ± 0.69 ab	19.81 ± 0.57 a	18.03 ± 0.73 a	1.10 ± 0.09 a
3	2.89 ± 0.24 ab	20.34 ± 0.76 b	20.00 ± 0.96 a	17.78 ± 0.47 a	1.11 ± 0.13 a
4	2.82 ± 0.34 abc	19.90 ± 0.60 b	19.57 ± 0.31 a	17.83 ± 1.14 a	1.22 ± 0.14 a
5	2.40 ± 0.19 bcd	19.86 ± 0.41 b	19.07 ± 0.86 ab	17.22 ± 1.04 ab	1.12 ± 0.13 a
6	2.47 ± 0.27 cd	21.21 ± 0.53 b	18.29 ± 0.98 bc	17.06 ± 0.94 ab	1.03 ± 0.13 a
7	2.15 ± 0.28 d	19.97 ± 1.11 b	18.02 ± 0.57 c	16.53 ± 0.67 b	1.10 ± 0.12 a

*Different letters in the same column indicate significant differences at $p \leq 0.05$.

NPC: Number of nuts per cluster; NWT: Nut weight; NL: Nut length; NW: Nut width; ND: Nut depth; ST: Shell thickness

Table 2. Kernel characteristics of the Foşa hazelnut cultivar according to nut numbers in the cluster
Çizelge 2. Foşa fındık çeşidinin çotanaktaki meyve sayılarına göre iç özellikleri

NPC	KWT (g)	KL (mm)	KW (mm)	KD (mm)	KR (%)
1	1.45 ± 0.15 a	15.94 ± 0.75 a	14.44 ± 0.68 a	13.89 ± 1.32 a	48.83 ± 7.16 a
2	1.27 ± 0.21 a	15.90 ± 1.16 a	14.30 ± 1.22 a	12.61 ± 1.51 ab	45.97 ± 3.54 a
3	1.45 ± 0.14 a	16.19 ± 0.96 a	14.83 ± 1.28 a	14.10 ± 0.68 abc	49.97 ± 1.66 a
4	1.40 ± 0.20 ab	15.81 ± 0.73 a	14.43 ± 0.86 a	13.20 ± 1.46 abc	49.54 ± 2.39 a
5	1.15 ± 0.14 ab	15.54 ± 0.92 a	13.54 ± 0.75 ab	11.97 ± 1.23 abc	48.10 ± 2.96 a
6	1.25 ± 0.16 b	16.61 ± 1.24 a	13.79 ± 1.54 ab	13.26 ± 0.92 bc	50.63 ± 3.43 a
7	1.07 ± 0.20 b	15.27 ± 1.43 a	12.56 ± 0.76 b	12.19 ± 1.26 c	49.25 ± 4.84 a

*Different letters in the same column indicate significant differences at $p \leq 0.05$.

NPC: Number of nuts per cluster; KWT: Kernel weight; KL: Kernel length; KW: Kernel width; KD: Kernel depth; KR: Kernel ratio

The maximum husk length and husk widths of the Foşa hazelnut cultivar were in single cluster. Husk opening was not significantly different across different nut numbers in the cluster (Table 3). Kurt et al. (2022) reported that the husk length in the Foşa cultivar was 37.11 mm and the fruit was wrapped loosely. In their study with different hazelnut cultivars, İşbakan and Bostan (2020) reported that the husk length was 31.82-43.68 mm. Husk is an essential criterion in hazelnuts. Whether the husk is long or short is important in terms of its suitability for processing, depending on the openness of the husk and its wrapping around the nut. Yao and Mehlenbacher (2000) reported that there were positive relationships between husk length, nut weight, and kernel weight. İşbakan and Bostan (2020) reported a negative relationship between the husk length and the number of nuts in a cluster.

Table 3. Husk characteristics in terms of number of nuts per cluster
Çizelge 3. Çotanaktaki meyve sayısına göre zuruf özellikleri

NPC	HO (mm)	HL (mm)	HW (mm)
1	25.77 ± 10.36 a	38.34 ± 4.10 a	22.89 ± 2.10 a
2	27.17 ± 6.56 a	36.46 ± 2.71 ab	19.81 ± 0.93 ab
3	23.97 ± 3.59 a	36.58 ± 5.64 ab	21.00 ± 1.47 ab
4	29.68 ± 4.58 a	29.66 ± 3.59 abc	20.44 ± 0.84 b
5	27.25 ± 3.92 a	30.77 ± 2.66 bc	19.06 ± 1.94 b
6	26.66 ± 3.93 a	30.41 ± 3.76 bc	19.61 ± 1.19 b
7	24.15 ± 4.64 a	26.13 ± 3.82 c	18.52 ± 1.32 b

*Different letters in the same column indicate significant differences at $p \leq 0.05$.

NPC: Number of nuts per cluster;HO: Husk opening; HL: Husk length; HW: Husk width

The relationships between the number of nuts in cluster and fruit characteristics as in principal component analysis (PCA) biplot are shown in Figure 1. Principal component 1 (PC1) explained 55.9% of the variablity, while principal

component 2 (PC2) accounted for 21.6% of the variation. Single nuts stand out in terms of nut weight, nut depth, nut width, and husk length. It is seen that if there are 2 nuts in the cluster, the husk opening comes to the fore, if there are 4 nuts, the shell thickness comes to the fore, and if there are 3 nuts, the kernel depth comes to the fore. If there are 6 nuts in the cluster, it is observed that kernel ratio and nut length come to the fore. It is seen that there is a positive relationship between the nut weight, husk length, nut depth, nut width, shell thickness, and husk opening, and a negative relationship between the nut length and kernel ratio.

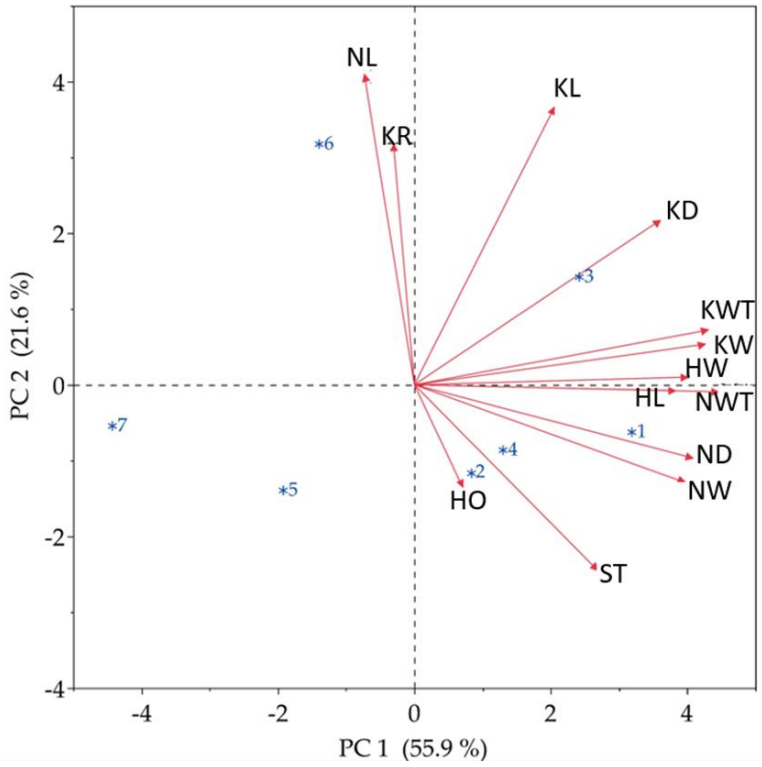

Figure 1. Distribution of the number of nuts per cluster and fruit characteristics in the PCA biplot

Şekil 1. PCA biplotta çotanaktaki fındık sayısı ve meyve özelliklerinin dağılımı.

NWT: Nut weight; NL: Nut length; NW: Nut width; ND: Nut depth; ST: Shell thickness; KWT: Kernel weight; KL: Kernel length; KW: Kernel width; KD: Kernel depth; KR: Kernel ratio; HO: Husk opening; HL: Husk length; HW: Husk width

In conclusion, although the number of nuts in a cluster is a variety characteristic of hazelnuts, different numbers of clusters can occur in hazelnut cultivars. This study demonstrates that the increment of nut numbers causes quality shifts, which are mostly negative. Moreover, increment of the number of nuts in the cluster increases the pressure on nuts that results shape differences, which is an undesired characteristic in the hazelnut processing industry. This study indicates that more than 4 nuts in the cluster causes undesired characteristics. Further studies should evaluate some cultivation practices in order to obtain relatively more uniform nut numbers in the clusters.

ACKNOWLEDGEMENTS

This research was presented as an oral presentation at the 6th International Agriculture Congress held in Prizren / Kosovo between 31 August - 4 September 2023.

STATEMENT OF CONFLICT OF INTEREST

The authors declare no conflict of interest for this research.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not required as there are no studies with human or animal subjects in this article.

REFERENCES

FAO. (2024a). *Food and Agriculture Organization of the United Nations (FAOSTAT).* https://www.fao.org/faostat/en/#data/QCL (Retrieved December: January, 2024).

TÜİK. (2024b). *Turkish Statistical Institute (TurkStat), Crop Production Statistics.* https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr (Retrieved December: January 2024).

Hazelnut Research Institute. (2024c). Republic of Türkiye Ministry of Agriculture and Forestry Hazelnut Research Institute. https://arastirma.tarimorman.gov.tr/findik/Menu/47/Findik-Cesitlerimiz (Retrieved December: February 2024).

Bak, T. (2010). Effects of different branch numbers on fruit quality criteria of hazelnut. (Publication no: 255949). [Master's Thesis, Ordu University]. (In Turkish with Abstract in English)

Bak, T., & Karadeniz T. (2021). Effects of branch number on quality traits and yield properties of european hazelnut (*Corylus avellana* L.). *Agriculture, 11* (5), 437. https://doi.org/10.3390/agriculture11050437

Balta, M.F., Balta, F., Yarılgaç, T., Karakaya, O., Uzun, S., & Kirkaya, H. (2018). Nut characteristics of 'Fosa' and 'Kargalak' hazelnuts related to number of nuts per cluster. In *IX International Congress on Hazelnut,* 1226 (pp. 167-170). https://doi.org/10.17660/ActaHortic.2018.1226.25

Balta, F., & Karadeniz, T. (1997). The evaluations on preselection of the hazelnut 'Tombul' and 'Palaz' cultivars grown in Carsamba and Terme (Samsun) districts. *Acta Horticulturae,* 445, 109-118 https://doi.org/10.17660/ActaHortic.1997.445.15

Bostan, S. (1997). Interrelationships among nuts per cluster and other some traits in hazelnut cultivars Tombul, Palaz and Sivri. *Yuzuncu Yıl University Journal of Agricultural Sciences,* 23-27. (In Turkish with Abstract in English)

Bostan, S.Z. (2001). The pomological characteristics of hazelnut cultivars in Zonguldak province. *Ondokuz Mayıs University Faculty of Agriculture Journal (Anatolian Journal of Agricultural Sciences), 16* (2), 34-42. (In Turkish with Abstract in English)

Botta, R., Molnar, T.J., Erdogan, V., Valentini, N., Torello Marinoni, D., & Mehlenbacher, S.A. (2019). Hazelnut (Corylus spp.) breeding. In: *Al-Khayri, J., Jain, S., Johnson, D. (eds) Advances in plant breeding strategies: Nut and beverage crops.* Springer, Cham. https://doi.org/10.1007/978-3-030-23112-

Güler, E., & Balta, F. (2020). Determination of yield and quality characteristics of hazelnut populations of Taskesti district (Mudurnu-Bolu). *International Journal of Agriculture and Wildlife Science, 6* (2), 115-128. https://doi.org/10.24180/ijaws.685813 (In Turkish with Abstract in English)

İşbakan, H., & Bostan, S.Z. (2020). Relationships between plant morphological traits, nut yield and quality traits in hazelnut. *Ordu University Journal of Science and Technology, 10* (1), 32-45. e-ISSN: 2146-6459. (In Turkish with Abstract in English)

Karadeniz, T. (2018). The world's best quality hazelnut, Tirebolu Karakaya Basin Tombul Hazelnut. Arı Sanat Publications. Publication No: 293, Istanbul. (In Turkish)

Karadeniz, T. (2021a). New techniques in hazelnut cultivation. Anatolian Agricultural Engineers Association Scientific Books. Publication No: 1, Bolu. ISBN:978-605-80128-4-4. (In Turkish)

Karadeniz, T. (2021b). Physical and chemical characteristics of Foşa hazelnut variety grown in Arsin district of Trabzon province, report. Trabzon/Arsin Municipality.

Kurt, H., Doğan, A., & Durmaz, O. (2022). Comparison of pomological characteristics of local hazelnut populations in Hizan (Bitlis) District with some of our standard varieties. Tarımsal Perspektif, Bölüm 15, 307-332. Editörler: (Prof. Dr. Ahmet Kazankaya, Dr. Öğr. Üyesi Adnan Doğan). Iksad Publications – 2022, ISBN: 978-625-8246-95-7.

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. http://www.rstudio.com/

Semiz, M. (2016). Some morphological and pomological characteristics of some hazelnut (*Corylus avellana* L.) genotypes in Çarsamba Plain (Samsun) and determination of their genetic relationships. (Publication no:455569) [Master's Thesis, Ordu University]. (In Turkish with Abstract in English)

Thompson, M.M., Lagerstedt, H.B., & Mehlenbacher, S.A. (1996). *Fruit breeding.* Volume III. Nuts. p:125-184.

Turan, A. (2021). Evaluation of traits of selection breeding studies conducted in hazelnut. II. *International Applied Statistics Conference (UYIK-2021),* Tokat / Turkey, 29 June - 2 July 2021. (In Turkish with Abstract in English)

Yao, Q., & Mehlenbacher, S.A. (2000). Heritability, variance components and correlation of morphological and phenological traits in hazelnut. *Plant Breeding, 119,* 369-381. https://doi.org/10.1046/j.1439-0523.2000.00524.x

Yıldız, T. (2016). The effects of nuts per cluster and the fruit stem lengths on fruit detachment force/husky fruit weight ratio at different maturity times of hazelnut (cv. Yomra). *Anadolu Journal of Agricultural Sciences, 31,* 393-398. https://doi.org/10.7161/omuanajas.269993

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.