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Evaluation of 'Yomra' Hazelnut (*Corylus avellana* L.) Clones

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Abstract: This research was carried out in order to select superior clones with breeding aims in terms of late leafing, nut quality and yield in the Yomra hazelnut population of Düzce province and Akçakoca districts in 2020-2021. In the study, 98 Yomra hazelnut clones were examined and 20 clones were selected. Average yield per trunk cross-sectional area of selected clones changed from 83.25 to 32.43 g/cm^2, kernel ratio varied between 48.89 and 55.90%. It was determined that the nut weight, nut size and nut shape index, shell thickness, kernel weight , kernel size, and good kernel ratio of selected clones were respectively: 1.82 g to 3.90 g , 16.45 to 20.06 mm, 0.96 to 1.06, 0.87 mm to1.25 mm; 0.97 g to 1.91 g, 12.52 mm–14.88 mm, and 91.38% - 99.14%. It was determined that 5 clones (MZ 06, MZ 24, MZ 30, MZ 42 and 35 MZ 47) were superior to other clones. As a results, a significant genetic difference was observed in the Yomra hazelnut population.

Keywords: Clonal Selection, *Corylus avellana* L., Late leafing, Nut quality, Yield

Yomra Fındık Klonlarının (*Corylus avellana* L.) Değerlendirilmesi

Öz: Bu araştırma, 2020-2021 yıllarında Düzce ili ve Akçakoca ilçesi Yomra fındık popülasyonunda geç yapraklanma, meyve kalitesi ve verim ıslah amaçları yönünden üstün özellikli klonların seçilmesi amacıyla yürütülmüştür. Çalışmada 98 adet Yomra klonu incelenmiş ve 20 adet klon seçilmiştir. Seçilen klonların birim gövde kesit alanına düşen ortalama verimi 83.25 g/cm^2 ile 32.43 g/cm^2 arasında iç randımanı ise % 48.89 ile % 55.90 arasında değişmiştir. Seçilen klonların meyve ağırlığı, meyve iriliği, meyve şekil indeksi, kabuk kalınlığı, iç ağırlığı, iç iriliği ve sağlam iç oranı değerleri sırasıyla 1.82-3.90 g; 16.45-20.06 mm; 0.96-1.06; 0.87-1.25 mm; 0.97-1.91 g, 12.52-14.88 mm ve % 91.38-99.14 arasında bulunmuştur. Çalışmada; 5 klonun (MZ 06, MZ 24, MZ 30, MZ 42 ve 35 MZ 47) diğer klonlara göre daha üstün nitelikte olduğu tespit edilmiştir.

Anahtar Kelimeler: *Corylus avellana* L., Geç Yapraklanma, Meyve Kalitesi, Klonal Seleksiyon, Verim.

1. Introduction

Hazelnut production in the world is 1220427 tons. Türkiye ranks first in world hazelnut production with 765000 tons. Italy ranks 2nd with 98670 tons, Azerbaijan ranks 3rd with 72104 tons, and the USA ranks 4th with 70 310 tons. Although Türkiye ranks first in the world in hazelnut production, its yield is low. The average yield is 255.50 kg/da in the USA, 116.87 kg/da in Italy, 140.18 kg/da in Azerbaijan, and the average yield in Türkiye is 102.82 kg/da (Anonymous, 2024a). The amount of hazelnut production in Düzce province is 83052 tons in an area of 63 454 hectares. 16661 tons of hazelnuts were produced in an area of 12999 hectares in the central district and 29207 tons of hazelnuts were produced in an area of 21887 hectares in Akçakoca district (Anonymous, 2024b).

The most important hazelnut cultivars used in hazelnut cultivation in Türkiye are Cavcava, Çakıldak, Foşa, İncekara, Kalınkara, Kan, Kara, Kargalak, , Mincane, Palaz, Sivri, Tombul, Uzunmusa, Yassı Badem, Yuvarlak Badem, Okay 28, Giresun Melezi, Allahverdi, Çetiner and Yomrali.

Turkish and European hazelnut cultivars were independently selected from local types grown over centuries (Thompson et al., 1977). Commercial hazelnut nurseries do not exist in Türkiye. The plants of selected genotypes ("grower selections") have been used for a long time for establishing new orchards since the plants are readily propagated clonally with rooted suckers from neighboring orchards in Türkiye. Thus, plantations in the region are composed of mixtures of clones, which provide an opportunity to select the superior genotypes in terms of yield and nut quality. Among the existing hazelnut cultivars, it is important to select clones that are productive, resistant to diseases and pests, and have little or no alternance.

On the other hand, there are many studies in Türkiye aiming to develop new cultivars using different breeding methods. Selection breeding studies initiated in the 1970s continue (Balık et al., 2018; Bilgen et al., 2018; Çetiner, 1976; İslam, 2003; İslam & Çayan, 2019; Kan, 2019; Karakaya, 2021; Şahin, 2019). From these studies, many clones with superior yield and nut quality have been identified. Some of these clones have been registered as new cultivars. ‘Okay 28’ and ‘Giresun Melezi’ varieties were developed in the hybridization breeding program that started in 1980 (Balık, 2018; Okay, 1999). Türkiye's special hazelnut variety breeding studies continue. New cultivars with high yield are needed to increase the comparative competitive conditions of hazelnut cultivation in Türkiye. In this context, it is important to find clone candidates with high yield values through clonal selection within the cultivars.

In previous hazelnut breeding studies, genetic diversity was not investigated in the Yomra hazelnut population of Düzce province and Akçakoca district. The aim of this research is to identify promising clone candidates within the Yomra hazelnut populations. In our research, clone candidates were selected based on leafing time, yield and nut quality parameters.

2. Material and Method

2.1. Material

This research was conducted in Düzce Central District and Akçakoca District between 2020 and 2021 (Figure 1). A total of 98 Yomra hazelnut clone candidates were examined and 52 clone candidates were identified.

2.1.1. Some characteristics of Yomra hazelnut cultivar

Yomra is widely found in the hazelnut orchards of Trabzon and Düzce provinces. The average nut weight of the variety is 2.06 g, the kernel weight is 1.28 g, and the kernel ratio is 57.6% (Köksal, 2018). The time of beginning of leaf budburst of the Yomra cultivar is later than Tombul, Mincane and any other Turkish cultivars. Yomra variety leaves 3-5 days earlier than Çakıldak variety. Yield characteristics are similar to other varieties (Balık et al., 2016).

2.1.2. Climate characteristics of the research area

It was reported that the annual average temperature, the annual average rainfall, the relative humidity and the daily average temperature were respectively: 13.7^{o}C, 829.90 mm, 75.28%, and 14.2 °C (Anonymous, 2024c).

2.2. Method

2.2.1. Determination of time of beginning of leaf budburst

Time of beginning of leaf budburst was determined according to Descriptors for Hazelnut (*Corylus avellana* L.) criteria (Köksal and Güneş, 2008).

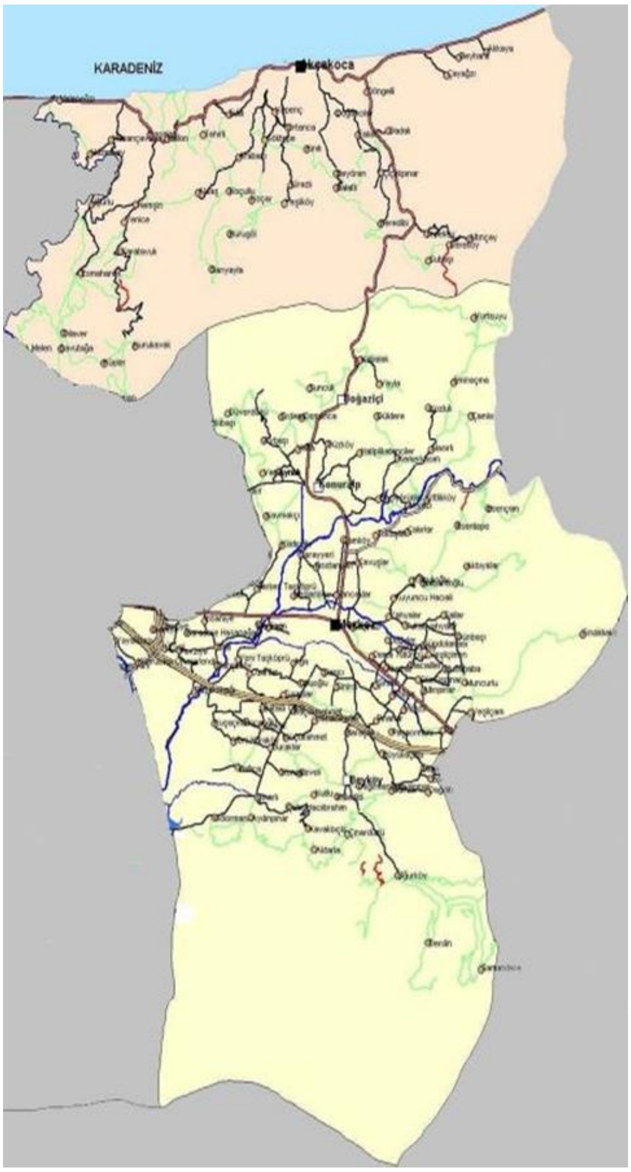

Figure 1. Map of the region where the research was conducted.
Şekil 1. *Araştırmanın yapıldığı alanın haritası*

2.2.2. Preselection of clones

Orchards were selected based on, yield, disease and pest observations (*Xanthomonas coryline, Phyllactinia guttata, Alaninus nucum L., Xyleborus dispar, Palemona prasine).* In the orchards where the research was conducted, care was taken to have 5-6 plants in the ‘Ocak’. Late leafing plants were marked and selected in these orchards.

2.2.3. Yield (g/cm^2 and g/plant)

It was determined by weighing all nuts harvested from a plant (one branch). The yield per unit trunk cross-sectional area and the yield per branch of genotypes with late leafing time were determined. The yield was calculated based on formula (F_1) (Köksal & Güneş, 2008).

F_1 (g/cm^2) = Total yield per branches (g) / $\pi.r^2$ (1)

2.2.4. Pomological characteristics

All nuts were collected from one branch selected from the southern side of the plants. These nuts were counted. The nuts used in pomological characteristics were dried until the kernel nut moisture content was reduced to 6%. Nuts samples were placed in 1 kg paper bags and stored in the refrigerator at ~4°C. Pomological characteristics were examined in 30 nuts randomly taken from selected branch according to Descriptors for Hazelnut (*Corylus avellana* L.) criteria In the measurements, a digital caliper sensitive to 0.01 mm and an electronic scale sensitive to 0.01 g were used. The nut size (F_2), kernel size (F_3), good kernel (F_4) and kernel percentage (F_5) were calculated based on formulas respectively (Köksal & Güneş, 2008).

$F_2 = \sqrt[3]{a.b.c}$ (2)

(a:Nut length; b:Nut width, c:Nut thickness)

$F_3 = \sqrt[3]{a.b.c}$ (3)

(a:Kernel length; b:Kernel width, c:Kernel thickness)

F_4= (%): ([Number of good kernels/Total number of kernels]) x100 (4)

F_5= ([Kernel weight/Nut weight]x100) (5)

2.2.5. Harvest time

The nuts were harvested when the moisture value dropped below 30%, and when 3/4 of the husks turn red or brown.

2.2.6. Selection of superior clones

The "Modified Weighted Rating Method" was used for the selection of clones. The importance levels and class ranges of the characters used in the weighted rating method are presented in Table 1.

Table 1. Treatments, importance levels, class intervals and score table of the modified weighted grading method
Çizelge 1. *Değiştirilmiş tartılı derecelendirme yönteminde kullanılana özellikler, önem düzeyleri, sınıf aralıkları ve puanları*

Characters	Importance level (%)	Class	Class intervals			Score
			2020	2021	Means	
Yield (g/cm²)	30	High	48.78–70.27	68.69–97.18	58.33–83.25	5
		Medium	27.28–48.77	40.20–68.68	34.41–58.32	3
		Low	5.79–27.27	11.71–40.19	9.99–34.40	1
Kernel ratio (%)	15	High	47.45–54.66	51.49–54.30	49.85–54.17	5
		Medium	40.23–47.44	48.67–51.48	45.53–49.84	3
		Low	33.02–40.22	45.86–48.66	41.21–45.52	1
Nut weight (g)	15	High	3.18–3.88	3.20–3.92	3.19–3.90	5
		Medium	2.48–3.17	2.48–3.19	2.48–3.18	3
		Low	1.78–2.47	1.76–2.47	1.77–2.47	1
Shell thickness (mm)	10	High	1.11–1.26	1.47–1.79	1.22–1.41	1
		Medium	0.97–1.10	1.14–1.46	1.02–1.21	3
		Low	0.83–0,96	0.82–1.13	0,83–1.01	5
Good kernel ratio (%)	10	High	88.89–100	94.64–100	92.41–99.14	5
		Medium	77.78–88.88	90.24–94.63	85.69–92.40	3
		Low	66.67–77.77	85.85–90.23	78.96–85.68	1
Kernel cavity (mm)	15	High	3.73–4.87	3.76–4.91	3.75–4.89	1
		Medium	2.60–3.72	2.60–3.75	2.60–3.74	3
		Low	1.46–2.59	1.45–2.59	1.45–2.59	5
Blanching (%)	5	High	80.33–100	80.33–100	80.33–100	5
		Medium	60.67–80.32	60.67–80.32	60.67–80.32	3
		Low	41.00–60.66	41.00–60.66	41.00–60.66	1

Based on the 2020 and 2021 modified weighted rating total scores, clones with scores higher than 350 were selected as promising clones. Others were eliminated. In addition, all clones with fluctuations in their weighted rating scores in 2020 and 2021 have been eliminated. Again, clones that showed fluctuations in yield values over the years despite having high weighted rating scores were also eliminated.

It was determined that the Yomra hazelnut population examined in our research had negative characteristics in terms of yield, kernel percentage, nut weight, shell thickness, good kernel cavity and blanching. These characters were given priority in the pre-selection of clones. Thus, clones with superior characteristics in terms of these characters were selected from the population with disadvantageous characters.

2.2.7. Cluster analyses

The yield (g/cm²), nut weight, nut size, nut shape, shell thickness, kernel weight, kernel size, kernel shape, kernel cavity, good kernel and blanching characteristics of 98 clones were used in the cluster analysis. NTSYSpc21 statistical program was used in cluster analyses.

Table 2. Distribution of genotypes examined within the Yomra hazelnut population according to their characters.
***Çizelge 2**. Yomra fındık populasyonunda incelenen genotiplerin karakterlerine göre dağılımı.*

Characters	Class	Values	The Number of Clones	Rate (%)
Yield (g/cm²)	High	58.33–83.25	**5**	**5,10**
	Medium	34.41–58.32	32	32,65
	Low	9.99–34.40	61	62,24
Kernel percentage (%)	High	49.85–54.17	**68**	**69,39**
	Medium	45.53–49.84	28	28,57
	Low	41.21–45.52	2	2,04
Nut weight (g)	High	3.19–3.90	**1**	**1,02**
	Medium	2.48–3.18	12	12,24
	Low	1.77–2.47	85	86,73
Shell thickness (mm)	High	1.22–1.41	7	7,14
	Medium	1.02–1.21	45	45,92
	Low	0,83–1.01	**46**	**46,94**
Good kernel ratio (%)	High	92.41–99.14	**71**	**72,45**
	Medium	85.69–92.40	23	23,47
	Low	78.96–85.68	4	4,08
Kernel cavity (mm)	High	3.75–4.89	14	14,29
	Medium	2.60–3.74	38	38,78
	Low	1.45–2.59	**46**	**46,94**
Blanching (%)	High	80.33–100	**57**	**58,16**
	Medium	60.67–80.32	30	30,61
	Low	41.00–60.66	11	11,22

3. Results and Discussion

3.1. First Year Results

A total of 98 clones candidates were selected in 2020. Time of beginning of leaf budburst of the selected clones were observed between 19 March and 9 April. We recorded the yield (g/cm^2) between 5.79 and 70.27; kernel ratio between 54.66 and 33.02%; nut weight 1.78±0.27 g–3.88±0.30 g. Average shell thickness is between 0.83±0.10 mm and 1.26±0.16 mm; rate of good kernel observed between 100% and 41.00% and kernel cavity was determined to between 1.46±0.68 mm and 4.87±1.18 mm (Table 1).

3.2. Second Year Results

According to 2021 data, time of beginning of leaf budburst was determined between 21 March and 7 April (Table 2). We observed the yield (g/cm^2) 11.71 and 97.18; kernel ratio was determined between 45.86 and 54.30%; nut weight varied between 1.76±0.27 g and 3.92±0.31 g. We recorded the good kernel between 85.85 and – 100.00% and the blanching was determined between 41.00 and 100.00% (Table 1).

The proportion of clones with high yield and high nut weight is low in the Yomra hazelnut population examined in our research (Table 2). It is important to select clones that are productive and have nut weight from the Yomra hazelnut population, which has a later leafing time than other Turkish hazelnut cultivars.

Table 3. Weighted rating scores of superior clones
Çizelge 3. *Üstün klonların tartılı derecelendirme puanları*

Clones	2020	2021	Mean	Altitude	Leafing date (2020-2021)
MZ06	420	420	420	210	March 22-23
MZ24	420	410	415	364	March 25-25
MZ47	390	390	390	515	March 25-28
AA02	390	380	385	25	March 23-29
MZ42	370	390	380	503	March 22-26
AA05	380	380	380	52	March 25-22
AA08	380	380	380	75	March 27 -28
AA10	380	380	380	85	March 29-2 April
AA13	380	380	380	93	March Mart
AA15	380	380	380	95	March Mart
AA24	380	380	380	162	April 1-5
AA17	360	380	370	100	April 1-4
MZ30	370	360	365	410	April 1-9
MZ01	360	360	360	169	April 1-2
MZ34	350	370	360	433	April 1-5
MZ50	360	350	355	530	March 29
AA23	360	350	355	155	March 29-30
AA25	360	350	355	165	March 29-30
MZ09	360	340	350	220	March 26-28
MZ21	350	350	350	315	March 23-3 April

3.3. Superior Clones

In our research, superior clones were selected from the Yomra hazelnut population in terms of yield, kernel ratio, nut weight, shell thickness, good kernel, kernel cavity and blanching. It is observed that the 20 clones candidates selected from the 98 clones that were pre-selected from the populations (Table 3). The weighted rating scores of superior clones ranged between 350-420. The altitudes of the selected clones were determined between 25 and 530 m above sea level. The bud burst time of the superior clones selected according to years were observed between 22 March and 1 April (Table 3.)

The superior clones of are described in Table 4. Yield is an important breeding aim. After high-yield genotypes are selected, the nut quality criteria of these genotypes are evaluated. There is a negative correlation between high yield and nut size. If genetic diversity is high in the population, the probability of selecting promising genotypes increases. In this research, genetic diversity was found quite high in the Yomra hazelnut population where our research was conducted. MZ 06, MZ 24, MZ 30, MZ 42 and MZ 47 clones were found to be more valuable than other clone candidates in terms of yield, nut weight and kernel percentage.

Most of the hazelnut orchards in Türkiye were established according to the 'ocak system'. In other countries, the single stem planting system with grafting is common. In Türkiye, the yield of hazelnut varieties is determined on one branch selected from one ‘Ocak’. Differences in training systems make it difficult to compare the yield of cultivars between countries.

The yield value (g/cm²) of the superior clones ranged 58.33 to 83.25, and average yield was calculated as 47.82 g/cm^2 (Table 4). Superior clones MZ06 and MZ24 have the highest yield value. The yield value of Palaz clones was between 8.2 (P-50) and 363.4 g/cm^2 (P-27) and the average yield value was 83.77 g/cm^2. In the Çakıldak population, yield values varied between 24.5 (Ç-80) and 323.5 g/cm^2 (Ç-11). The average yield value is given as 67.2 g/cm^2 (Karakaya, 2021). The yield values of selected clones was found lower than other Turkish hazelnut clone candidates. Low yield may be caused by insufficient rainfall. As a matter of fact, the total rainfall in Ordu (1045 mm) and Giresun (1290 mm) is higher than Düzce province (829 mm).

Across the clones studied here, nut weight ranged from 1.82 to 3.90 g, while kernel weight ranged from 0.97 to 1.91 g with clones MZ42 and MZ47 showed highest kernel and nut weight (Table 5). For nut weight a heritability estimate of 0.63 was determined by Yao and Mehlenbacher (2000). Islam, (2003) determined nut weights between 1.69 and 2.28 g for ‘Tombul’, between 2.05 and 2.71 g for ‘Palaz’, and between 1.56 and 2.34 for ‘Uzunmusa’. In the high range of reported values for several cultivars: 3.89 g ‘Gunslebert’ and 3.82 g Grada de Viseu (Ferrão et al., 2021), 2.9 g ‘Willamette’(Mehlenbacher et al., 1991); 2.10-2.60 g ‘Tonda Gentile Romana clones (Monastra et al., 1997), 1.98–2.25g ‘Gironell Clones, 1.40-2.01 g, 1.40-2.01 g ‘Negret’ (Rovira et al., 1997), 2.9 g ‘Lewis’ (Mehlenbacher et al., 2000), 2.50 g ‘Clark’ (Mehlenbacher et al., 2001), 2.29-2.50 g ‘Palaz clones’, 1.88-2.01 g ‘Çakıldak clones’ (İslam & Özgüven, 2001), 3.70g ‘Jefferson’ (Mehlenbacher et al., 2011), 2.75-2.88g ‘Pollyo’ (Mehlenbacher et al., 2019), 2.08 g ‘Somerset’ (Molnar et al., 2020); 2.06 g ‘Yomra’(Köksal, 2018), 2.13-2.27 g ‘the clones candidate of Palaz’ (Balık&Beyhan 2014), 3.90 g ‘Barcelona’ and 3.40 g ‘Dorris’ (Mehlenbacher et al., 2013). MZ47 has a much higher nut weight than other hazelnut cultivars.

Table 4. Yield and nut characteristics of selected clones

Çizelge 4. *Seçilen klonların verim ve kabuklu meyve özellikleri*

Clones	Yield (g/plant)	Yield (g/cm²)	Kernel percentage (%)	Nut weight (g)	Nut size (mm)	Nut length (mm)	Nut width (mm)	Nut height (mm)	Nut Shape index	Bleaching (%)	Fibrousness
AA02	375.10	66.84	53.67bcde*	2.21±0.24fgh	18.11	17.75±0.77efg	19.26±0.79cd	17.37±0.59efg	0.97	86	Low fibrous
AA05	483.30	42.20	54.22abcde	1.99±0.26jk	17.40	16.94±1.30hı	18.52±0.86efg	16.80±0.81hıj	0.96	91	Low fibrous
AA08	336.09	42.26	55.90a	2.20±0.20fgh	17.98	17.54±0.68fgh	19.05±0.83cde	17.40±0.50defg	0.96	91	Low fibrous
AA10	539.26	46.31	54.96abc	2.16±0.25ghıj	17.95	17.56±0.75fgh	19.13±0.87cde	17.21±0.94fgh	0.97	100	Low fibrous
AA13	531.35	46.01	52.34e	2.36±0.28def	18.76	18.23±2.16de	20.12±2.03ab	18.01±2.03bc	0.96	95	Low fibrous
AA15	425.85	39.79	55.39ab	2.14±0.16hıj	17.44	17.03±0.76hı	18.27±0.58fgh	17.04±0.58fghı	0.96	94	Low fibrous
AA17	314.70	42.06	54.35abcde	2.18±0.25gh	17.74	17.74±0.86efg	18.82±0.75def	16.74±0.76hıj	1.00	89	Fibrous
AA23	450.26	42.81	52.69de	2.56±0.23d	19.10	18.93±0.76bc	20.03±0.73ab	18.37±0.59b	0.99	82	Unfibrous
AA24	497.61	42.04	54.94abc	2.11±0.21ıj	17.34	17.79±0.72efg	17.74±0.65hı	16.52±0.65ıj	1.04	99	Unfibrous
AA25	415.97	32.43	52.34e	2.40±0.14cde	17.59	17.29±0.60ghı	18.64±0.60defg	16.90±0.63ghıj	0.97	91	Low fibrous
MZ01	445.67	35.86	54.16abcde	2.31±0.27efg	16.90	17.49±0.86fgh	16.91±0.70j	16.36±0.60j	1.06	92	Low fibrous
MZ06	478.28	63.91	53.87abcde	2.30±0.28efgh	17.77	18.31±0.75cde	18.12±0.81gh	16.93±0.72ghı	1.05	81	Unfibrous
MZ09	182.35	34.10	52.45e	2.24±0.27efgh	17.40	18.03±0.80def	17.34±0.80ıj	16.87±0.77ghıj	1.06	54	Unfibrous
MZ21	335.20	47.70	54.56abcd	2.39±0.32de	18.23	18.59±1.44bcd	18.53±1.21efg	17.59±1.14cdef	1.03	81	Unfibrous
MZ24	467.21	83.25	54.58abcd	2.26±0.28efgh	17.81	18.27±0.86de	18.07±0.87gh	17.12±0.62fgh	1.04	93	Low fibrous
MZ30	360.32	62.70	53.90abcde	2.16±0.29ghıj	17.50	17.72±0.85efg	17.77±0.95hı	17.03±0.69fghı	1.02	85	Unfibrous
MZ34	369.11	44.09	54,81abc	2.51±0.31cd	18.42	18.32±0.70cde	19.10±1.02cde	17.85±0.74bcde	0.99	73	Unfibrous
MZ42	334.54	67.40	49.33f	2.86±0.32b	18.90	19.20±1.00b	19.61±0.94bc	17.94±0.72bcd	1.02	88	Fibrous
MZ47	803.96	39.00	48.89f	3.90±0.31a	20.06	20.43±0.89a	20.61±1.29a	19.18±0.98a	1.03	92	Fibrous
MZ50	318.60	35.65	53.02cde	1.82±0.24k	16.45	16.75±0.88ı	16.89±0.89j	15.75±0.79k	1.03	95	Fibrous
Range	182.35: 803.96	32.43: 83.25	48.89: 55.90	1.82: 3.90	16.45: 20.06	16.75: 20.43	16.89: 20.61	15.75: 19.18	0.96: 1.06	54.00: 100.00	-
Mean	423.24	47.82	53,52	2.35	17.94	18	18.63	17.25	1.01	86	-

*Each data value is represented as means ± standard deviation. Means within columns followed by different letters differ significantly (p≤0.05)

Yao and Mehlenbacher, (2000), reported that the heritability of kernel weight in hazelnuts, was 0.67. Average kernel weight in selected clone candidates was 0.97 g (MZ50)–1.91 g (MZ47). Values reported as kernel weight for some hazelnut varieties: 1.45 g ‘Willamette’ (Mehlenbacher et al., 1991), 1.01–1.11 g, Tonda Gentile Romana’ (Monastra et al., 1997), 0.82–0.94 g, ‘Negret’, (Rovira et al., 1997), 0.99–1.43 g Palaz superior clones (Bostan & İslam 1999), 1.23–1.44 1.01–1.09 g Çakıldak clones (İslam & Özgüven, 2001). The kernel weight of MZ47 clone was found higher than ‘Barcelona’, ‘Clark’, ‘Dorris’, ‘Lewis’ and ‘York’ (Mehlenbacher et al., 2013). Also, MZ47 clone has higher kernel weight than other Turkish hazelnut cultivars. Although the nut weight of the MZ47 clone is similar to the Barcelona variety, its kernel weight higher than ‘Barcelona’ (Mehlenbacher et al., 2013).

Shell thickness ranged from 0.87 mm to 1.25 mm across our clones. It was seen that the another studies determined that it varied between the given values; Kan and İslam (2023) 0.89-1.34 mm, İslam & Çayan (2019), 0.60-1.24 mm, Uzun (2021) 0.71-1.42 mm, Petriccione et. all, (2010),1.0 and 1.8, İslam (2003) 0.75–0.93 mm. These values indicate that the selected clones have a shell thickness comparable to other cultivars described in the literature. Kernel percentage is one of the most important nut trait (Table 5).

Heritability estimates of 0.92 (Thompson, 1977) and 0.87 (Yao and Mehlenbacher, 2000) have been reported for this trait. In our research, the kernel percentage of clones varied between 48.89% (MZ47) and 55.90% (AA08) and was above the average of several hazelnut cultivars. The kernel percentage value was found to be lower than 50% in only two clones. The kernel percentage was determined as 51.59–57.31% (P-60) in Palaz clones and 49.62–58.84% in Çakıldak clones (Karakaya, 2021). In our research, the kernel percentage values of the selected clones were observed similar to the Palaz and Çakıldak populations. In our research, the kernel percentage of the selected clones were found to be similar to the Willamette', Tonda Gentile Romana', 'Gironell' clones, Palaz, 'Lewis' and Clark (Mehlenbacher et al., 1991; Monastra et al., 1997; Rovira et al., 1997; Bostan & İslam 1999; Mehlenbacher et al., 2000; Mehlenbacher et al., 2001; Mehlenbacher et al., 2011). We recorded the blanching (%) between 54.00 -100.00% (Table 4).It was determined that the good kernel (%) ranged between 91.38 and 99.14 ((Table 4). Good kernel (%) values given by some researchers: İslam, (2003) 69.90-92.15, Turan &Beyhan, (2009) 32.00-98.00, Pekdemir, (2019) 57.00-59.00, Karakaya, (2021) 73.70-90.70, Aydemir et al., (2023) 53.00-95.00. As a matter of fact, the good kernel ratio (%) values of our clones are higher than Willamette, 'Negret', 'Lewis', 'Clark', 'Jefferson', Okay 28' varieties. It is especially important that our MZ47 clone has a high value. The kernel nuts of the 7 clones selected as promising are unfibrous (Table 4).

Table 5. Kernel characteristics of selected clones
Çizelge 5. *Seçilen klonların iç meyve özellikleri*

Clones	Kernel weight (g)	Kernel size (mm)	Kernel Length (mm	Kernel width (mm)	Kernel height (mm)	Kernel Shape Index	Shell thickness (mm)	Kernel cavity (mm)	Good Kernel (%)
AA02	1.19±0.15fgh*	14.13	13.24±0.76defg	14.96±1.40bcd	14.25±0.82bcd	0.98	0.98±0.07hı	2.62±0.96cd	95.60
AA05	1.08±0.15ı	13.56	12.73±0.76g	14.40±1.15defg	13.61±0.73efgh	0.90	0.90±0.06k	1.61±0.78e	97.79
AA08	1.23±0.10efgh	14.21	13.29±0.69cdef	14.96±0.76bcd	14.44±0.39abc	0.90	0.87±0.07k	2.17±0.81cde	97.38
AA10	1.19±0.15fgh	13.98	13.29±0.73cdef	14.82±0.93cde	13.87±0.98defg	0.89	0.89±0.08k	2.33±0.82cd	97.24
AA13	1.23±0.11efgh	14.20	13.18±0.73efg	15.50±0.86ab	14.02±0.85cde	0.89	0.97±0.06ıj	2.35±0.83cd	98.64
AA15	1.18±0.08fgh	13.66	13.10±0.65efg	14.18±0.57fg	13.72±0.50defgh	0.91	0.91±0.06	2.37±1.05cd	95.04
AA17	1.18±0.13fgh	14.07	13.30±0.91cdef	15.27±0.85abc	13.71±0.91defgh	0.97	0.97±0.06ıj	2.53±0.82cd	96.93
AA23	1.35±0.12bcd	14.88	14.12±0.68b	15.61±0.91a	14.93±0.67a	0.93	1.03±0.06fgh	3.65±1.10a	95.86
AA24	1.16±0.11hı	13.66	13.74±0.61bcd	14.06±0.75fgh	13.21±0.81hı	1.01	0.91±0.06jk	2.57±0.74cd	97.96
AA25	1.26±0.10def	13.81	13.39±0.50cdef	14.44±0.79def	13.61±0.82efgh	0.96	0.96±0.05ıj	2.31±1.02cd	93.52
MZ01	1.25±0.17efg	12.86	13.18±1.16efg	12.57±0.85k	12.88±0.81ıj	1.04	1.19±0.11bc	2.18±0.77cde	99.14
MZ06	1.24±0.17efgh	13.55	13.63±0.82bcde	13.37±0.80ıj	13.67±0.87efgh	1.01	1.13±0.07cd	2.58±1.20cd	95.16
MZ09	1.17±0.16fghı	13.21	13.04±0.85fg	13.26±1.11ıj	13.34±1.09ghı	0.98	1.07±0.13ef	2.06±0.88de	94.11
MZ21	1.30±0.16cde	13.93	13.78±1.08bc	13.79±0.89ghı	14.25±0.86bcd	0.98	1.06±0.08ef	3.74±1.24a	97.15
MZ24	1.23±0.15hı	13.56	13.75±0.80bcd	13.47±1.18hıj	13.45±0.90fgh	1.02	1.05±0.07ef	2.42±0.90cd	96.93
MZ30	1.16±0.16hgı	13.29	13.39±0.62cdef	12.89±1.05jk	13.61±0.74efgh	1.01	1.07±0.13	2.75±1.07bc	90.69
MZ34	1.37±0.17bc	14.47	14.07±0.87b	14.63±1.09cdef	14.73±0.58ab	0.96	0.99±0.09ghı	3.33±1.02ab	98.14
MZ42	1.41±0.15b	14.37	14.97±0.87a	14.27±0.92efg	13.90±0.81cdef	1.06	1.25±0.16a	3.70±1.19a	96.25
MZ47	1.91±0.15a	13.42	14.78±1.23a	13.19±1.44ıjk	12.39±1.46j	1.16	1.23±0.11ab	1.99±0.98de	98.05
MZ50	0.97±0.16	12.52	12.14±0.67h	12.99±0.69jk	12.46±0.83j	0.96	1.05±0.07efg	2.05±0.97de	96.47
Range	0.97: 1.91	12.52: 14.88	12.14: 14.97	12.57: 15.61	12.39: 14.93	0.89: 1.16	0.87: 1.25	1.61: 3.74	91.38: 99.14
Mean	1.25	13.77	13.51	14.13	13.7	0.97	1.03	2.57	96.44

*Each data value is represented as means ± standard deviation. Means within columns followed by different letters differ significantly ($p \leq 0.05$)

3.4. Cluster Analysis

The population dendrogram is divided into 2 main groups and 2 subgroups in each group. In the analyses, the matrix correlation coefficient was found to be 0.74 at the 1% significance level. In the analyses, the matrix correlation coefficient was calculated as 0.76 at the 1% significance level. According to the dendrogram, clone 18 (81AA23) formed a different subgroup, and clones 13 (81AA08) and 14 (81AA10) were found to be identical between them (Figure 1).

4. Conclusions

A lot of clonal selection programs were performed in Türkiye and many cultivars were evaluated. 20 superior clones of 'Yomra' were identified in this study, although none of them were outstanding for all traits. Clones MZ06, MZ24, MZ30, MZ42 and MZ47 showed the best combination of percent pomological traits and yield. Studies are being carried out to preserve the promising clone candidates selected in our research and to use them as genetic resources in variety breeding.

Conflict of Interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

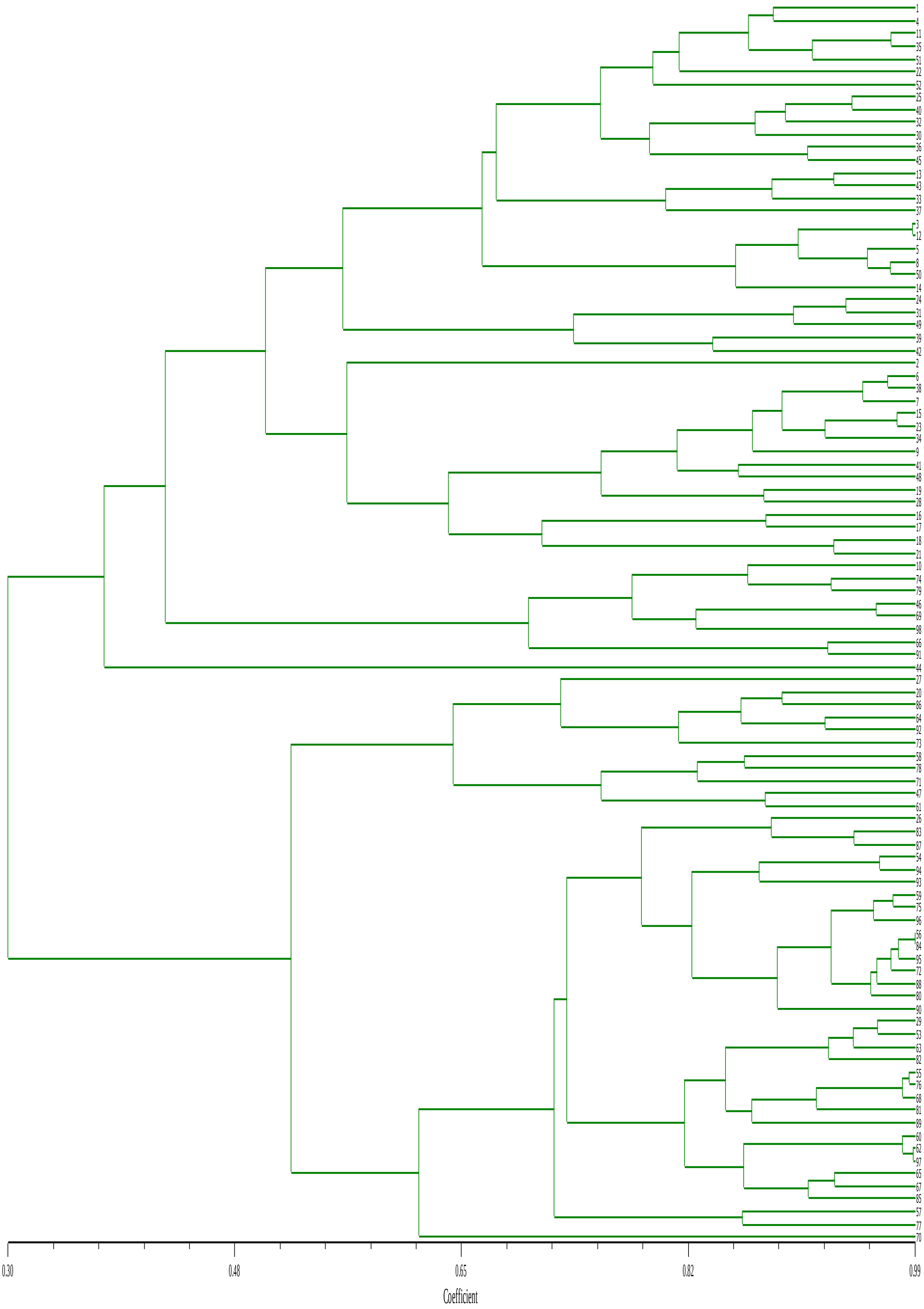

Figure 2. Dendrogram of Yomra clones according to the main nut characteristics
Şekil 2. *Yomra klonlarının başlıca meyve özelliklerine göre dendrogramı*

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