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Clonal selection in Mincane hazelnut (Coryllus avellana L.) cultivar in Akçakoca district of Düzce Province

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Abstract: Türkiye has dominated world hazelnut production for a long time and one of the most important hazelnut growing areas in the Black Sea region is Düzce province. Agriculture plays an important role in Düzce economy and hazelnut orchards occupy 45% of total agricultural areas. Mincane hazelnut cultivar widely grown in Akçakoca and shows variability particularly for nut characteristics. Thus, this study was aimed to select promising clones with superior features from the population of the Mincane hazelnut cultivar. In the selection study, some important nut characteristics were examined. According to a modified weighted ranking method results, 7 Mincane hazelnut clones were selected as promising. In the selected clones, nut weights varied between 1.85 g (81AKC21)–2.12 g (81AKC11), kernel weight 0.90 g (81AKC15)–1.08 g (81AKC05), kernel ratio 46.66% (81AKC11) –56.09% (81AKC21), shell thickness 1.10 mm (81AKC05)–1.17 mm (81AKC17 and 81AKC15), nut size 15.72 mm (81AKC15)–17.21 mm (81AKC10), kernel size 11.23 mm (81AKC15)–12.43 mm (81AKC10) and kernel shape index 1.08 (81AKC19)–1.22 (81AKC21), respectively. In the selected clones, the number of fruits per cluster was found to be between 1.85 (81AKC21)–4.85 (81AKC17) and clones 81AKC11 and 81AKC15 gave 100% intact kernel.

Key words: Hazelnut, Mincane cultivar, variability, clonal selection

1. Introduction

Hazelnut is an important food item in terms of nutrition with the fat, protein, vitamins and minerals it contains. The edible inner part of hazelnuts (kernel) constitutes approximately 50% of the nut. The average chemical composition of hazelnut kernels is 2.0%–6.5% moisture, 10%–24% protein, 50%-–73% oil, 10%–22% carbohydrate, 1%–3% cellulose, 1%–3.4% ash. The protein content of hazelnut kernels varies between 10%–24%, and its digestibility varies between 73%–83%, depending on the variety, cultural treatments and ecological factors. The amount of protein in hazelnuts is higher than eggs and grains, and almost equal to the amount contained in meat and legumes. Protein quality is lower than eggs and meat products (Ozdemir and Akinci, 2004; Matthäus and Ozcan, 2012; Rezaei et al., 2014; Klockmann et al., 2016; Król and Gantner, 2020; Muller et al., 2020; Gulsoy et al., 2023).

The total amount of sugar in dry matter is between 2.8%–7.9%. For individual sugars a total of 90% is sucrose, 6% is stachyose, 3% is raffinose, and 1% is glucose, fructose and myoinositol (Bignami et al., 2005; Hosseinpour et al., 2013; Ghisoni et al., 2020; Król et al., 2019; Król and Gantner, 2020). Sucrose provides flavor to hazelnut kernels, and in some varieties, it is present in high enough amounts to be felt by tasting. Since stachyose and raffinose have very little sweetness, they have no effect on the taste of hazelnuts (Bignami et al., 2005). In addition, starch is found in the dry matter at a rate of 1%–3.6%. Dietary fiber (pulp) and pectins are found in hazelnuts at a rate of 1%–3%. These compounds prevent the toxic effects of chemical compounds in the intestine, colon diseases, constipation and heart diseases, and reduce serum lipid levels and blood sugar (Perna et al., 2016; Rondanelli et al., 2023).

Türkiye is the leading country in world hazelnut production and hazelnuts grow in the country between 40°–41° latitude and 37°–42° longitude. Hazelnut is one of the most important agricultural products of Türkiye, where a total of 4 million people directly or indirectly provide their livelihood. An average of 650–700 thousand tons of shelled hazelnuts are produced [1]annually in a total area of

[1]Food and Agriculture Organization of the United Nations (2021). FAOSTAT [online]. Website https://www.fao.org/statistics/en/ [accessed on 18 November 2023]
[2]Turkish Statistical Institute (2022). TUIK. [online]. Website https://www.tuik.gov.tr/ [accessed on 18 November 2023]

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740 thousand ha and 85% of the hazelnuts produced are exported (Ercisli et al., 2011; Gurcan et al., 2018; Omur, 2023).

World total hazelnut production is 1,077,117 t. Türkiye, the world's most important hazelnut producing country, accounts for 63.5% of the production with 684,000 t. Italy (84,670 t), USA (70,310 t), Azerbaijan (67,630 t), and Georgia (46,000 t) are the other important hazelnut producing countries (FAOSTAT, 2021). Düzce province ranks 5th in hazelnut production in Türkiye with 83,052 t on an area of 63.454 ha. In Düzce province, the highest hazelnut production obtained from Akçakoca district with 29,207 t in an area of 21,857 ha (TUİK, 2022).

World production is based on fewer than 20 ancient *C. avellana* cultivars that originated with the selection and clonal propagation of superior plants primarily in the Mediterranean Basin and along the Black Sea coast. Large nuts are sold in-shell, while the majority of the world's hazelnuts are sold as kernels for use by the confectionary industry (Mehlenbacher and Molnar, 2021).

Since Türkiye is the homeland of hazelnuts and its cultivation dates back to ancient times, it has many varieties that emerged as a result of natural hybridization (Çalışkan, 1995; Gurcan et al., 2018). In general hazelnut producers establish orchards with plant obtained from suckers from their own orchard material or neighboring orchards. If these suckers belong to a branch coming from seeds, it causes the existence of different clones within the varieties in the orchards (Ercisli, 2004; Gulsoy et al., 2023). In addition, long growing period also may have encouraged mutation and finally variability and thus the main hazelnut varieties grown in Türkiye such as Tombul, Foşa, Çakıldak, Palaz, and Mincane shows morphological differences within varieties (Ercisli et al., 2011). This diversity between and within fruit species, varieties, genotypes, accessions constitute an important resource for breeders in particular for selection studies (Celik et al., 2007; Ozrenk et al., 2020; Dawadi et al., 2022; Delialioglu et al., 2022; Korkmaz et al., 2022; Ozer and Makineci, 2022). In this regard, many selection studies have been carried out on hazelnut varieties grown in Türkiye (Demir and Beyhan, 2000; Islam, 2000; Balik and Beyhan, 2014; Gogus, 2015; Turan, 2022).

The aim of this study was to examine the fruit characteristics of the selected clones of the Mincane hazelnut variety, which is widely grown in the Akçakoca district of Düzce province, and to determine the superior clones according to the "A modified Weighted Ranking" method.

2. Material and method

2.1. Material

This study was carried out between 2020–2021 in the villages of Akçakoca district, which has an important place in hazelnut production of Düzce province (Figure 1).

The material of the study consists of clones of the Mincane hazelnut variety. In the first year of the study, villages in Akçakoca district were visited, 23 clones were marked in line in terms of high yield and better nut characteristics, and all nuts of the branch were harvested. In the second year, in addition to the 23 clones examined in the first year, another clone, which was stated to be very productive and bear nut every year, was added and nuts were taken from 24 clones. Type numbers were given to the branches from which nut samples were taken, starting from 81AKC01, according to the order of sampling.

2.2. Method

The number of clusters and the number of nuts in the clusters were determined in the nuts harvested from the marked branches during the 2020 and 2021 harvest periods. The sorted nuts were dried at room temperature, and then their nut characteristics were examined. The evaluation of the examined clones was made according to the "A modified Weighted Ranking" method (Turan, 2007; Balik and Beyhan, 2014; Gogus, 2015). In the method, yield, kernel ratio, nut weight, kernel weight, number of nuts in the cluster, nut size, kernel size, shell thickness and kernel shape index criteria were taken into account. In addition, nut characteristics such as the number of nuts in the cluster, the number of clusters, the ratio of cracked-skinned nuts, nut dimensions, nut shape index, nut size, kernel dimensions, intact kernel ratio, empty kernel ratio, double kernel ratio and wrinkled kernel ratio were examined in all clones. Evaluations were made on 30 randomly selected nuts from each clone. At the end of study 7 clones were selected according to 'A Modified Weighted Ranking Method' (Figure 2).

Data analysis

The principal component analysis (PCA) and heatmap with dendrograms analysis has been performed using OriginLab software (10.1, OriginLab, Northampton, MA, USA). For heatmap analysis, data on the traits investigated in nut clones were standardized by z-score normalization method.

3. Results and discussion

As indicated in Table 1, there were a wide variability among clones in terms of most of the parameters searched. In the Mincane clones examined in 2020, branch yield varied from 297.64 g (81AKC20) to 1871.27 g (81AKC15), nut weight was between 1.36 g (81AKC13)–2.28 g (81AKC07), kernel weight was 0.65 g (81AKC13)–1.06 g (81AKC05 and 81AKC21), kernel ratio 38.64% (81AKC02)–56.38% (81AKC21), shell thickness 0.91 mm (81AKC13)–1.26 mm (81AKC02, 81AKC03 and 81AKC08), nut size 14.89 mm (81AKC09)–17.06 mm (81AKC10), kernel size 10.16 mm (81AKC08)–12.40 mm (81AKC05), kernel shape index 1.04 (81AKC19)–1.48 (81AKC13) and the number of nuts in cluster varied between 1.73 (81AKC21)–5.55 (81AKC23), respectively (Table 1).

In the clones sampled in 2021, branch yield was 163.04 g (81AKC09)–2763.37 g (81AKC24), nut weight was 1.57 g (81AKC16)–2.22 g (81AKC01), kernel weight was 0.81 g (81AKC24)–1.15 g (81AKC01), kernel ratio 45.45% (81AKC08)–57.57% (81AKC05), shell thickness 1.00 mm (81AKC05)–1.49 mm (81AKC04), nut size 14.83 mm (81AKC22)–17.00 mm (81AKC21), kernel size 11.19 mm (81AKC22)–12.83 mm (81AKC10), kernel shape index 1.04 (81AKC01)–1.28 (81AKC12) and number of nuts in the cluster varied from 1.96 (81AKC21)–4.78 (81AKC14) (Table 2).

The evaluation was made according to the "A modified Weighted Ranking" method by taking the average of the values of the nut characteristics determined in 2020 and 2021 in the examined Mincane hazelnut clones (Table 3). In Table 4, the criteria taken as basis in the "A modified Weighted Ranking" method, the classes formed by the clones and the scores of the classes, and the relative scores determined according to these criteria are given.

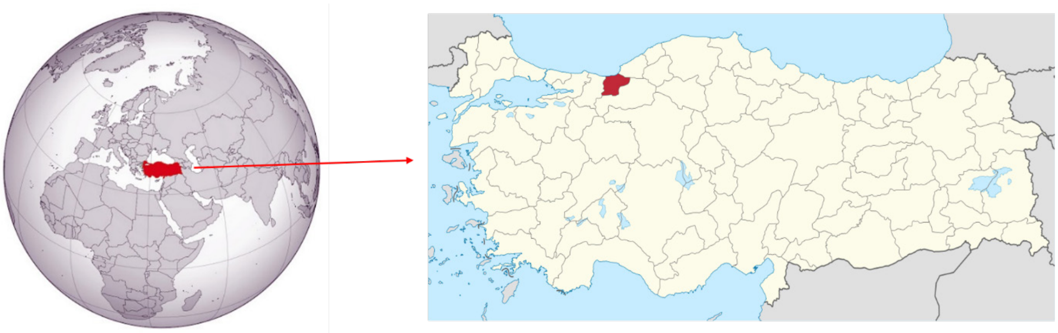

Figure 1. The geographical location of Düzce province.

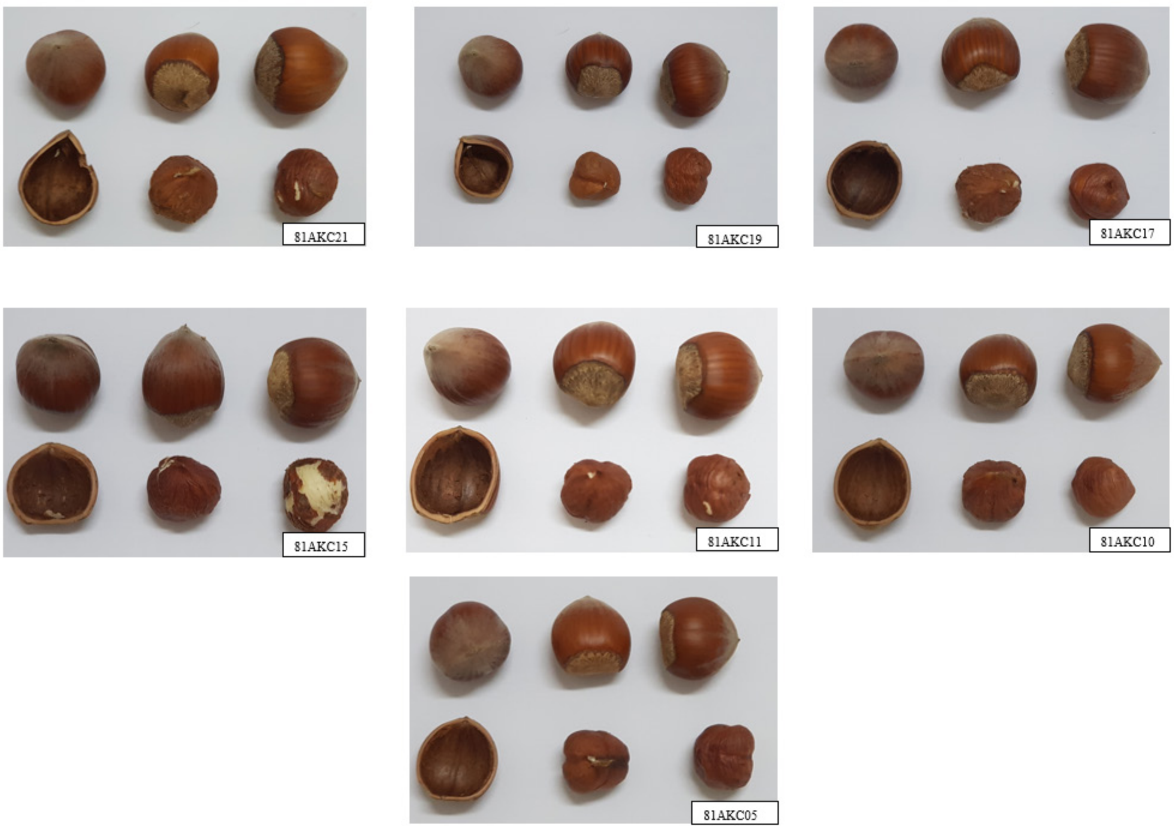

Figure 2. Nut and kernel view of selected promising clones of Mincane hazelnut variety.

Table 1. Fruit properties of Mincane clones (2020 year).

Clones	BY	CN	NPC	CSN	NL	NW	NT	NW1	ST	NSI	NS	KW1	KL	KW	KT	KS	KSI	KR	IKR	EKR	DKR	WKR
81AKC01	1434.79	323	3.29	0	15.79	17.64	14.76	1.77	1.13	0.97	16.06	0.74	12.41	10.83	9.69	10.98	1.21	41.81	100	0	0	0
81AKC02	470.91	117	3.04	0	15.96	17.09	14.46	1.76	1.26	1.01	15.84	0.68	12.10	10.61	9.03	10.58	1.23	38.64	96.7	0	0	3.33
81AKC03	905.05	193	3.34	0	16.43	17.08	14.93	1.91	1.26	1.03	16.14	0.83	12.18	11.83	9.98	11.33	1.12	43.46	96.7	0	0	3.33
81AKC04	322.23	78	3.24	0	16.31	17.54	14.61	1.96	1.13	1.01	16.16	0.94	13.14	11.49	10.26	11.63	1.21	47.96	96.7	0	0	3.33
81AKC05	980.56	230	2.79	0	17.08	17.45	15.41	2.05	1.19	1.04	16.65	1.06	13.52	12.39	11.30	12.40	1.14	51.71	100	0	0	0
81AKC06	681.46	174	2.94	0	16.63	17.50	15.74	1.73	1.09	1.00	16.62	0.76	12.18	11.53	10.75	11.49	1.09	43.93	96.7	3.33	0	0
81AKC07	952.48	181	3.23	0	15.90	17.48	14.04	2.28	1.20	1.01	15.81	0.92	13.20	11.59	9.86	11.55	1.23	40.35	100	0	0	0
81AKC08	1543.20	368	4.18	0	15.55	17.25	13.54	1.50	1.26	1.01	15.45	0.62	11.93	10.26	8.29	10.16	1.29	41.33	93.3	6.67	0	3.33
81AKC09	584.42	129	3.67	0	15.03	16.63	13.02	1.61	1.12	1.01	14.89	0.73	12.38	10.64	8.81	10.61	1.27	45.34	100	0	0	0
81AKC10	435.32	99	3.12	0	16.70	18.69	15.80	1.90	1.14	0.97	17.06	0.92	13.89	11.47	10.71	12.02	1.25	48.42	96.7	0	0	3.33
81AKC11	1685.94	232	4.09	0	16.98	18.34	15.34	2.06	1.18	1.01	16.89	0.93	13.24	12.00	10.77	12.00	1.16	45.15	100	0	0	0
81AKC12	601.02	101	5.21	0	15.89	17.90	13.98	1.56	1.07	1.00	15.92	0.79	13.89	10.77	9.14	11.26	1.40	50.64	93.3	6.67	0	6.67
81AKC13	1009.47	265	5.00	0	15.93	17.50	13.87	1.36	0.91	1.02	15.77	0.65	13.61	9.72	8.65	10.66	1.48	47.79	96.7	3.33	13.33	3.33
81AKC14	1567.78	310	4.31	0	16.07	17.13	14.64	1.84	1.21	1.01	15.94	0.82	12.63	11.54	9.69	11.29	1.19	44.57	100	0	0	0
81AKC15	1871.27	410	3.62	0	16.25	16.39	14.15	1.77	1.14	1.06	15.60	0.81	12.09	11.38	9.48	10.98	1.16	45.76	100	0	0	0
81AKC16	855.93	161	4.04	0	15.79	17.87	14.20	1.86	1.14	0.98	15.95	0.89	13.41	11.52	9.91	11.61	1.25	47.85	100	0	0	0
81AKC17	1124.44	153	4.69	0	15.95	18.14	14.13	2.03	1.17	0.99	16.07	0.99	13.75	12.23	10.72	12.23	1.20	48.77	96.7	3.33	0	3.33
81AKC18	307.85	69	2.96	0	16.34	17.68	14.23	1.97	1.19	1.02	16.08	0.97	13.41	11.71	9.90	11.67	1.24	49.24	96.7	3.33	0	0
81AKC19	600.93	136	2.72	0	17.30	16.92	14.98	1.98	1.25	1.08	16.40	0.98	12.16	12.93	10.34	11.81	1.04	49.49	93.3	6.67	0	0
81AKC20	297.64	68	3.12	0	16.59	17.48	14.80	2.08	1.22	1.03	16.29	0.97	12.92	12.09	10.24	11.75	1.16	46.63	100	0	0	0
81AKC21	768.45	277	1.73	0	16.68	18.52	15.76	1.88	0.97	0.97	16.99	1.06	14.61	11.83	10.67	12.37	1.30	56.38	96.7	3.33	0	3.33
81AKC22	328.12	58	3.45	0	15.75	17.03	13.81	1.88	1.22	1.02	15.53	0.99	13.52	12.09	10.53	12.05	1.20	52.66	96.7	3.33	0	3.33
81AKC23	1241.64	200	5.55	0	14.99	17.83	13.19	1.53	0.97	0.97	15.34	0.82	14.45	10.57	9.15	11.39	1.46	53.59	100	0	0	0
81AKC24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Branch yield (BY); Nut number per cluster (NPC); Cluster number (CN); Cracked-skinned nuts (CSN); Nut weight (NW1); Nut length (NL); Nut width (NW); Nut thickness (NT); Shell thickness (ST); Nut shape index (NSI); Nut size (NS); Kernel weight (KW1); Kernel length (KL); Kernel width (KW); Kernel thickness (KT); Kernel size (KS); Kernel shape index (KSI); Kernel ratio (KR); Intact kernel ratio (IKR); Empty kernel ratio (EKR); Double kernel ratio (DKR); Wrinkled kernel ratio (WKR)

Table 2. Fruit properties of Mincane clones (2021 year).

Clones	BY	CN	NPC	CSN	NL	NW	NT	NW1	ST	NSI	NS	KW1	KL	KW	KT	KS	KSI	KR	IKR	EKR	DKR	WKR
81AKC01	467.01	87	2.85	10.00	16.81	17.64	15.74	2.22	1.24	1.01	16.73	1.15	13.00	13.16	11.83	12.66	1.04	51.80	96.07	3.33	0	3.33
81AKC02	997.78	166	3.44	3.33	16.63	17.37	15.05	2.20	1.24	1.03	16.35	1.09	12.98	12.00	10.96	11.98	1.13	49.55	96.07	3.33	0	0
81AKC03	1666.66	304	3.85	0.00	16.28	17.17	14.90	2.00	1.18	1.02	16.11	0.97	12.39	12.32	11.33	12.02	1.05	48.50	100.00	0	0	0
81AKC04	793.32	178	3.09	0	15.77	17.36	14.20	1.93	1.49	1.00	15.78	0.91	12.89	11.62	10.32	11.61	1.18	47.15	96.70	3.33	0	0
81AKC05	1354.19	359	2.56	10.00	16.95	16.83	15.14	1.91	1.00	1.06	16.31	1.09	13.14	12.35	11.58	12.36	1.10	57.07	90.00	10.00	0	0
81AKC06	949.99	222	3.05	0	16.50	17.81	16.14	1.97	1.39	0.97	16.82	1.04	12.95	12.52	11.99	12.49	1.06	52.79	100.00	0	0	0
81AKC07	1709.33	290	3.75	0	15.79	16.88	14.37	1.98	1.18	1.01	15.68	0.95	12.80	11.70	10.52	11.67	1.15	47.98	100.00	0	0	0
81AKC08	1164.69	158	4.45	0	16.62	17.60	15.17	2.09	1.22	1.01	16.46	0.95	12.83	12.07	11.05	11.98	1.11	45.45	96.70	3.33	6.66	0
81AKC09	163.04	32	3.06	0	15.75	17.59	13.98	1.93	1.12	1.00	15.77	0.95	13.19	11.59	9.92	11.56	1.23	49.22	96.70	3.33	0	0
81AKC10	1061.48	199	3.27	0	17.32	18.65	16.09	2.12	1.08	1.00	17.35	1.08	14.23	12.37	11.90	12.83	1.17	50.94	100.00	0	0	0
81AKC11	1607.84	220	4.10	3.33	16.82	18.06	15.31	2.18	1.13	1.01	16.73	1.05	13.57	12.40	11.10	12.36	1.15	48.17	100.00	0	3.33	0
81AKC12	671.12	114	4.53	0	17.05	18.67	15.08	2.13	1.18	1.01	16.93	1.09	14.74	12.22	10.83	12.60	1.28	51.17	100.00	0	10.00	3.33
81AKC13	206.93	38	3.87	0	17.04	18.45	14.85	1.91	1.08	1.02	16.78	1.01	14.39	12.18	10.56	12.37	1.27	52.88	86.67	13.33	0	0
81AKC14	1147.06	164	4.78	0	15.63	17.30	14.76	1.81	1.13	0.98	15.89	0.93	12.45	11.74	10.47	11.55	1.12	51.38	93.30	6.67	0	0
81AKC15	1793.32	288	3.76	0	16.31	16.35	14.87	2.02	1.19	1.04	15.84	0.98	11.97	11.74	10.72	11.47	1.07	48.51	100.00	0	0	0
81AKC16	525.71	101	4.20	3.33	14.72	17.32	13.67	1.57	1.02	0.95	15.24	0.83	12.84	11.09	9.86	11.26	1.23	52.87	100.00	0	0	0
81AKC17	869.99	105	5.00	3.33	16.38	17.70	14.47	2.07	1.17	1.02	16.19	0.98	13.14	12.38	10.68	12.07	1.14	47.34	90.00	10.00	0	0
81AKC18	1091.83	231	3.11	0	16.50	17.46	14.27	2.05	1.21	1.04	16.08	0.95	12.96	11.94	10.17	11.69	1.17	46.34	100.00	0	0	0
81AKC19	2135.03	462	3.49	0	17.13	17.55	15.04	1.89	1.05	1.05	16.57	0.92	12.58	12.02	10.44	11.68	1.12	48.68	96.70	3.33	0	0
81AKC20	1593.42	341	3.72	0	16.36	17.12	14.99	1.81	1.26	1.02	16.16	0.91	13.59	13.04	11.55	12.73	1.11	50.28	100.00	0	0	0
81AKC21	483.77	160	1.96	0	16.97	18.15	15.89	1.81	1.35	1.00	17.00	1.01	13.29	12.54	10.84	12.22	1.14	55.80	93.30	6.67	0	0
81AKC22	488.23	118	3.08	0	14.86	16.15	13.48	1.71	1.07	1.00	14.83	0.85	12.23	11.42	9.91	11.19	1.15	49.71	100.00	0	3.33	0
81AKC23	848.30	121	3.88	0	16.61	17.83	14.89	2.19	1.23	1.02	16.44	1.03	13.19	11.67	10.64	11.83	1.18	47.03	100.00	0	0	0
81AKC24	2763.37	562	4.21	0	17.90	16.34	14.48	1.69	1.27	1.16	16.24	0.81	13.65	12.30	11.01	12.32	1.17	47.93	100.00	0	0	0

Branch yield (BY); Nut number per cluster (NPC); Cluster number (CN); Cracked-skinned nuts (CSN); Nut weight (NW1); Nut length (NL); Nut width (NW); Nut thickness (NT); Shell thickness (ST); Nut shape index (NSI); Nut size (NS); Kernel weight (KW1); Kernel length (KL); Kernel width (KW); Kernel thickness (KT); Kernel size (KS); Kernel shape index (KSI); Kernel ratio (KR); Intact kernel ratio (IKR); Empty kernel ratio (EKR); Double kernel ratio (DKR); Wrinkled kernel ratio (WKR)

Table 3. Average nut properties of clones (average of 2020 and 2021).

Clones	BY	CN	NPC	CSN	NW1	NW	NT	NL	ST	NSI	NS	KW1	KL	KW	KT	KS	KSI	KR	IKR	EKR	DKR	WKR
81AKC01	950.90	205	3.07	5	2.00	16.30	17.64	15.25	1.18	0.99	16.73	0.95	12.70	11.99	10.76	11.82	1.13	46.80	98.04	1.67	0	1.67
81AKC02	734.35	142	3.24	2	1.98	16.29	17.23	14.76	1.25	1.02	16.09	0.89	12.54	11.31	9.99	11.28	1.18	44.09	96.39	1.67	0	1.67
81AKC03	1285.86	249	3.60	0	1.96	16.35	17.12	14.91	1.22	1.02	16.13	0.90	12.29	12.07	10.66	11.67	1.08	45.98	98.35	0	0	1.67
81AKC04	557.78	128	3.17	0	1.95	16.04	17.45	14.41	1.31	1.01	15.97	0.93	13.01	11.56	10.29	11.62	1.19	47.55	96.70	1.67	0	1.67
81AKC05	1167.38	295	2.68	5	1.98	17.01	17.14	15.28	1.10	1.05	16.48	1.08	13.33	12.37	11.44	12.38	1.12	54.39	95.00	5.00	0	0
81AKC06	815.73	198	3.00	0	1.85	16.57	17.65	15.94	1.24	0.99	16.72	0.90	12.57	12.02	11.37	11.99	1.07	48.36	98.35	1.67	0	0
81AKC07	1330.91	236	3.49	0	2.13	15.84	17.18	14.21	1.19	1.01	15.74	0.94	13.00	11.64	10.19	11.61	1.19	44.17	100	0	0	0
81AKC08	1353.95	263	4.32	0	1.80	16.08	17.43	14.35	1.24	1.01	15.96	0.79	12.38	11.16	9.67	11.07	1.20	43.39	95.00	5.00	3.33	1.67
81AKC09	373.73	81	3.37	0	1.77	15.39	17.11	13.50	1.12	1.01	15.33	0.84	12.78	11.12	9.36	11.09	1.25	47.28	98.35	1.67	0	0
81AKC10	748.40	149	3.20	0	2.01	17.01	18.67	15.94	1.11	0.98	17.21	1.00	14.06	11.92	11.30	12.43	1.21	49.68	98.35	0	0	1.67
81AKC11	1646.89	226	4.10	2	2.12	16.90	18.20	15.33	1.15	1.01	16.81	0.99	13.40	12.20	10.94	12.18	1.16	46.66	100	0	1.67	0
81AKC12	636.07	108	4.87	0	1.85	16.47	18.28	14.53	1.13	1.00	16.43	0.94	14.31	11.49	9.98	11.93	1.34	50.91	96.65	3.34	5.00	5.00
81AKC13	608.20	152	4.44	0	1.64	16.48	17.98	14.36	1.00	1.02	16.27	0.83	14.00	10.95	10.45	11.74	1.37	50.34	91.69	8.33	6.67	1.67
81AKC14	1357.42	237	4.55	0	1.83	15.85	17.21	14.70	1.17	0.99	15.92	0.88	12.54	11.64	10.08	11.42	1.16	47.97	96.65	3.34	0	0
81AKC15	1832.30	349	3.69	0	1.90	16.28	16.37	14.51	1.17	1.05	15.72	0.90	12.03	11.56	10.10	11.23	1.11	47.14	100	0	0	0
81AKC16	690.82	131	4.12	2	1.72	15.26	17.59	13.93	1.08	0.97	15.59	0.86	13.13	11.30	10.38	11.44	1.24	50.36	100	0	0	0
81AKC17	997.22	129	4.85	2	2.05	16.17	17.92	14.30	1.17	1.00	16.18	0.99	13.45	12.31	10.70	12.15	1.17	48.06	93.35	6.67	0	1.67
81AKC18	699.84	150	3.04	0	2.01	16.42	17.57	14.25	1.20	1.03	16.08	0.96	13.19	11.82	10.03	11.68	1.21	47.79	98.35	1.67	0	0
81AKC19	1367.98	299	3.11	0	1.94	17.21	17.23	15.01	1.15	1.07	16.49	0.92	12.37	12.47	10.39	11.74	1.08	49.09	95.00	5.00	0	0
81AKC20	945.53	205	3.42	0	1.95	16.48	17.30	14.89	1.24	1.02	16.22	0.94	13.25	12.56	10.89	12.24	1.13	48.46	100	0	0	0
81AKC21	626.11	219	1.85	0	1.85	16.83	18.34	15.82	1.16	0.99	17.00	1.04	13.95	12.19	10.75	12.30	1.22	56.09	95.00	5.00	0	1.67
81AKC22	408.18	88	3.27	0	1.80	15.30	16.59	13.64	1.14	1.01	15.18	0.92	12.87	11.76	10.22	11.62	1.17	51.18	98.35	1.67	1.67	1.67
81AKC23	1044.97	161	4.72	0	1.86	15.80	17.83	14.04	1.10	0.99	15.89	0.93	13.82	11.12	9.89	11.61	1.32	50.31	100	0	0	0
81AKC24	2763.37	562	4.21	0	1.69	17.90	16.34	14.48	1.27	1.16	16.24	0.81	13.65	12.30	11.01	12.32	1.17	47.93	100	0	0	0

Branch yield (BY); Nut number per cluster (NPC); Cluster number (CN); Cracked-skinned nuts (CSN); Nut weight (NW1); Nut length (NL); Nut width (NW); Nut thickness (NT); Shell thickness (ST); Nut shape index (NSI); Nut size (NS); Kernel weight (KW1); Kernel length (KL); Kernel width (KW); Kernel thickness (KT); Kernel size (KS); Kernel shape index (KSI); Kernel ratio (KR); Intact kernel ratio (IKR); Empty kernel ratio (EKR); Double kernel ratio (DKR); Wrinkled kernel ratio (WKR)

Table 4. Fruit properties used in a modified weighted ranking method. classes. coefficients. class intervals and relative scores.

Properties	Coefficients	Classes	Class intervals	Score
Branch yield (g)	20	Very high High Medium Low Very low	2763.37–2285.44 2285.43–1807.50 1807.49–1329.56 1329.55–851.62 851.61–373.68	9 7 5 3 1
Nut weight (g)	20	Very high High Medium Low Very low	2.13–2.03 2.02–1.92 1.91–1.81 1.80–1.70 1.69–1.59	9 7 5 3 1
Kernel weight (g)	20	Very high High Medium Low Very low	1.08–1.02 1.01–0.95 0.94–0.88 0.87–0.81 0.80–0.74	9 7 5 3 1
Kernel ratio (%)	15	Very high High Medium Low Very low	56.09–53.55 53.54–51.00 50.99-48.45 48.44–45.90 45.89–43.35	9 7 5 3 1
Shell thickness	5	Very high High Medium Low Very low	1.03–0.97 1.10–1.04 1.17–1.11 1.24–1.18 1.31–1.25	9 7 5 3 1
Nut size	5	Very high High Medium Low Very low	17.21–16.81 16.80–16.40 16.39–15.99 15.98–15.58 15.57–15.17	9 7 5 3 1
Kernel size	5	Very high High Medium Low Very low	12.43–12.16 12.15–11.88 11.87–11.60 11.59–11.32 11.31–11.04	9 7 5 3 1
Kernel shape index	5	Very high High Medium Low Very low	1.12–1.06 1.19–1.13 1.26–1.20 1.30–1.27 1.37–1.07	9 7 5 3 1
The number of nuts per cluster	5	Very high High Medium Low Very low	4.87–4.27 4.26–3.66 3.65–3.05 3.04–2.44 2.43–1.83	9 7 5 3 1

As a result of the "A modified Weighted Ranking" method, score of the clones sampled in 2020–2021 was found to be between 280 and 670 (Table 5), and 7 clones with scores of 500 and above were considered promising. The nut characteristics of 7 clones considered promising are given in Table 6 and Figure 3 as the average of two years.

Yield in hazelnut varies according to years, cultivation and climatic conditions. Branch yield in the clones selected in the study varied between 748.40 (81AKC10)–1832.30 (81AKC15) g (Figure 3). In a similar study, Turan (2022) reported the branch yield of Mincane hazelnut variety as 304.45–519.56 g.

Table 5. Average modified weighted ranking scores of clones (2020 and 2021) based on fruit properties.

Clones	Branch yield	Score	Nut weight	Score	Kernel weight	Score	Kernel ratio	Score	Shell thickness	Score	Nut weight	Score	Nut size	Score	Kernel shape index	Score	The number of nuts per cluster	Score	Total score
81AKC01	950.90	60	2.00	105	0.95	105	46.80	60	1.18	15	16.73	35	11.82	25	1.13	35	3.07	50	490
81AKC02	734.35	20	1.98	105	0.89	75	44.09	20	1.25	5	16.09	25	11.28	5	1.18	35	3.24	50	340
81AKC03	1285.86	60	1.96	105	0.90	75	45.98	60	1.22	15	16.13	25	11.67	25	1.08	45	3.60	50	460
81AKC04	557.78	20	1.95	105	0.93	75	47.55	60	1.31	5	15.97	15	11.62	25	1.19	35	3.17	50	390
81AKC05	**1167.38**	**60**	**1.98**	**105**	**1.08**	**135**	**54.39**	**180**	**1.10**	**35**	**16.48**	**35**	**12.38**	**45**	**1.12**	**45**	**2.68**	**30**	**670**
81AKC06	815.73	20	1.85	75	0.90	75	48.36	60	1.24	15	16.72	35	11.99	35	1.07	45	3.00	30	390
81AKC07	1330.91	100	2.13	135	0.94	75	44.17	20	1.19	15	15.74	15	11.61	25	1.19	35	3.49	50	470
81AKC08	1353.95	100	1.80	45	0.79	15	43.39	20	1.24	15	15.96	15	11.07	5	1.20	25	4.32	90	330
81AKC09	373.73	20	1.77	45	0.84	45	47.28	60	1.12	25	15.33	5	11.09	5	1.25	25	3.37	50	280
81AKC10	**748.40**	**20**	**2.01**	**105**	**1.00**	**105**	**49.68**	**100**	**1.11**	**25**	**17.21**	**45**	**12.43**	**45**	**1.21**	**25**	**3.20**	**50**	**520**
81AKC11	**1646.89**	**100**	**2.12**	**135**	**0.99**	**105**	**46.66**	**60**	**1.15**	**25**	**16.81**	**45**	**12.18**	**45**	**1.16**	**35**	**4.10**	**70**	**620**
81AKC12	636.07	20	1.85	75	0.94	75	50.91	100	1.13	25	16.43	35	11.93	35	1.34	5	4.87	90	460
81AKC13	608.20	20	1.64	15	0.83	45	50.34	100	1.00	45	16.27	25	11.74	25	1.37	5	4.44	90	370
81AKC14	1357.42	100	1.83	75	0.88	75	47.97	60	1.17	25	15.92	15	11.42	15	1.16	35	4.55	90	490
81AKC15	**1832.30**	**140**	**1.90**	**75**	**0.90**	**75**	**47.14**	**60**	**1.17**	**25**	**15.72**	**15**	**11.23**	**5**	**1.11**	**45**	**3.69**	**70**	**510**
81AKC16	690.82	20	1.72	45	0.86	45	50.36	100	1.08	35	15.59	15	11.44	15	1.24	25	4.12	70	370
81AKC17	**997.22**	**60**	**2.05**	**135**	**0.99**	**105**	**48.06**	**60**	**1.17**	**25**	**16.18**	**25**	**12.15**	**35**	**1.17**	**35**	**4.85**	**90**	**570**
81AKC18	699.84	20	2.01	105	0.96	105	47.79	60	1.20	15	16.08	25	11.68	25	1.21	25	3.04	30	410
81AKC19	**1367.98**	**100**	**1.94**	**105**	**0.92**	**75**	**49.09**	**100**	**1.15**	**25**	**16.49**	**35**	**11.74**	**25**	**1.08**	**45**	**3.11**	**50**	**560**
81AKC20	945.53	60	1.95	105	0.94	75	48.46	100	1.24	15	16.22	25	12.24	45	1.13	35	3.42	50	510
81AKC21	**626.11**	**20**	**1.85**	**75**	**1.04**	**135**	**56.09**	**180**	**1.16**	**25**	**17.00**	**45**	**12.30**	**45**	**1.22**	**25**	**1.85**	**10**	**560**
81AKC22	408.18	20	1.80	45	0.92	75	51.18	140	1.14	25	15.18	5	11.62	25	1.17	35	3.27	50	420
81AKC23	1044.97	60	1.86	75	0.93	75	50.31	100	1.10	35	15.89	15	11.61	25	1.32	5	4.72	90	480
81AKC24	2763.37	180	1.69	15	0.81	45	47.93	60	1.27	5	16.24	25	12.32	45	1.17	35	4.21	70	480

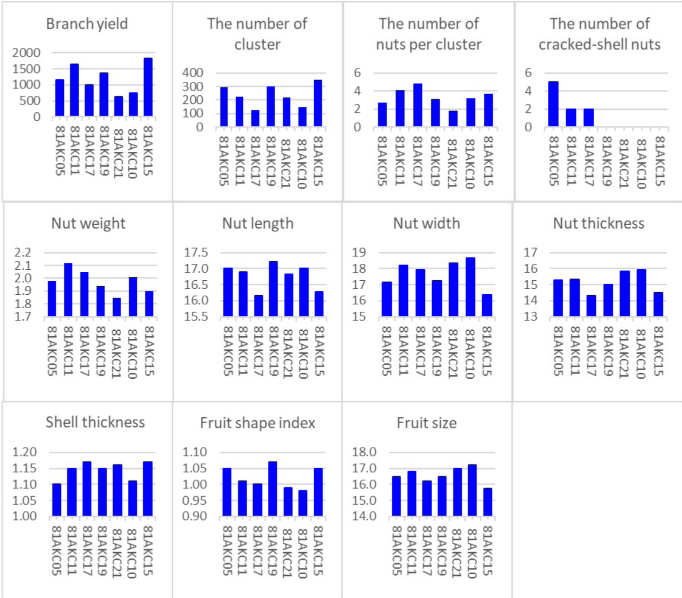

Figure 3. Some plant and nut characteristics of selected 7 clones.

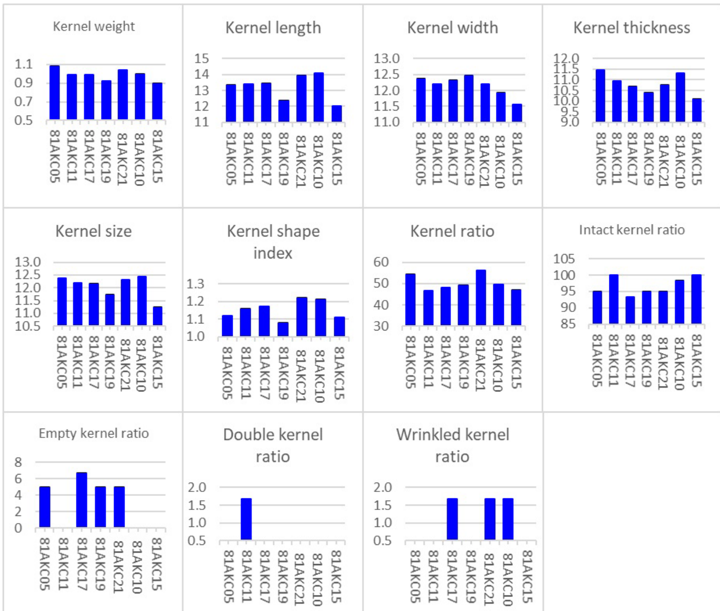

Figure 3 continue. Some plant and nut characteristics of selected 7 clone.

In nuts, in addition to the nut and kernel weight, the kernel ratio is also extremely important. In breeding studies, efforts are made to identify genotypes with high kernel ratios. Nut weight of the promising clones (2020–2021 average) selected under Akçakoca conditions is 1.85 g (81AKC21)–2.12 g (81AKC11), kernel weight is 0.90 g (81AKC15)–1.08 g (81AKC05) and kernel ratio is 46.66% (81AKC11)–56.09% (81AKC21). In studies conducted on Mincane clones in different regions, Turan (2022) reported nut weight as 1.69–1.90 g, kernel weight as 0.90–1.07 g and kernel ratio as 58.81%–48.08%; Karakaya (2023) stated that nut weight varies between 1.89–2.14 g, kernel weight between 0.96–1.06 g and kernel ratio between 50.0%–57.0% according to regions; Karaosmanoglu and Ustun (2017) stated that in Trabzon conditions, the average values are 1.69 g in nut weight, 0.88 g in kernel weight and 51.69% in kernel ratio on Mincane hazelnut.

Table 6. Characteristics of promising clones.

TRAITS	**CLONES**						
	81AKC05	81AKC11	81AKC17	81AKC19	81AKC21	81AKC10	81AKC15
Branch yield	1167	1647	997	1368	626	748	1832
The number of cluster	295	226	129	299	219	149	349
The number of nuts per cluster	2.68	4.10	4.85	3.11	1.85	3.20	3.69
The number of cracked-shell nuts	5	2	2	0	0	0	0
Nut weight	1.98	2.12	2.05	1.94	1.85	2.01	1.90
Nut length	17.01	16.90	16.17	17.21	16.83	17.01	16.28
Nut width	17.14	18.20	17.92	17.23	18.34	18.67	16.37
Nut thickness	15.28	15.33	14.30	15.01	15.82	15.94	14.51
Shell thickness	1.10	1.15	1.17	1.15	1.16	1.11	1.17
Fruit shape index	1.05	1.01	1.00	1.07	0.99	0.98	1.05
Fruit size	16.48	16.81	16.18	16.49	17.00	17.21	15.72
Kernel weight	1.08	0.99	0.99	0.92	1.04	1.00	0.90
Kernel length	13.33	13.40	13.45	12.37	13.95	14.06	12.03
Kernel width	12.37	12.20	12.31	12.47	12.19	11.92	11.56
Kernel thickness	11.44	10.94	10.70	10.39	10.75	11.30	10.10
Kernel size	12.38	12.18	12.15	11.74	12.30	12.43	11.23
Kernel shape index	1.12	1.16	1.17	1.08	1.22	1.21	1.11
Kernel ratio	54.39	46.66	48.06	49.09	56.09	49.68	47.14
Intact kernel ratio	95.00	100	93.35	95.00	95.00	98.35	100
Empty kernel ratio	5.00	0	6.67	5.00	5.00	0	0
Double kernel ratio	0	1.67	0	0	0	0	0
Wrinkled kernel ratio	0	0	1.67	0	1.67	1.67	0

Shell thickness is one of the most important features affecting nut quality and kernel ratio. It is known that shell thickness, which has a low heritability, increases in rainy years and in years when nitrogen fertilization is excessive (Balik and Beyhan, 2014). In promising genotypes, based on 2 years average, shell thickness was measured between 1.10 mm (81AKC05)–1.17 mm (81AKC17 and 81AKC15) (Figure 3). In previous studies, the shell thickness was determined as 0.97–1.25 mm (Turan, 2022), 1.07–1.23 mm (Karakaya, 2023), and 1.03 mm (Karaosmanoglu and Ustun, 2017) on Mincane clones.

In present study based on 2 years' average, the nut size of the promising genotypes was between 15.72 mm (81AKC15)–17.21 mm (81AKC10), the kernel size was 11.23 mm (81AKC15)–12.43 mm (81AKC10) and the kernel shape index was 1.08 (81AKC19)–1.22 (81AKC21). Karakaya (2023) determined the nut size as 16.15–16.68 mm and the kernel size as 12.57–13.05 mm, and Turan (2022) determined the kernel shape index as 1.09–1.26 in Mincane clones.

In hazelnuts, the number of nuts formed in the cluster is one of the criteria that determines the yield. Thompson et al. (1996) reported that this is a type of trait with high heritability. A low number of nuts in the cluster causes a decrease in productivity, and a large number causes the nut to become deformed and the fruit to remain small. Islam (2000) stated that increasing the number of nuts in cluster will lead to the formation of small nuts, but the skin will be thin and the yield will be high. In present study, the number of nuts per cluster in the selected genotypes varied between 1.85 (81AKC21) and 4.85 (81AKC17).

When the selected clones are evaluated according to their nut characteristics based on 2 years' average, the highest kernel weight is 1.08 g (81AKC05), the highest kernel ratio is 56.09% (81AKC21), the thinnest shell is 1.10 mm (81AKC05), the highest nut size is 17.21 mm (81AKC10), the highest kernel size is 12.43 mm (81AKC10), the highest nut weight is 2.13 g (81AKC07) and the highest branch yield is 1832.30 g (81AKC15). 81AKC11 and 81AKC15 clones gave 100% intact kernel.

In most of the vegetatively propagated fruit species, clones are used to produce new varieties. Clones are very useful tools to preserve the heterozygosity once obtained. In many crops the superior plants are maintained. The breeding method commonly used in the hazelnut crop is hybridization, with the purpose of obtaining segregating populations from which superior individuals combining traits of interest are selected. The main target traits in hazelnut tree breeding are fruit quality and resistance to major diseases (Mehlenbacher and Molnar, 2021).

In breeding of perennial plants, it is relevant to predict additive genetic values for selection of parents and the total genotypic values for selection of individuals aiming at vegetative propagation. If selection in clonal tests is based on an inadequate analytical procedure, it may be inefficient due to confusion among the genotypic and environmental effects.

Differences between nut clones tested in this study were evaluated for twenty-two agronomic traits. The effectiveness of the examined traits in grouping the clones and the distribution of the clones were revealed by PCA analysis. PCA revealed that the first two principal components (PC1 and PC2) explained 60.82% of the total variance in the data set. The first principal component PC1 explained 42.28% of the data variation and the second principal component PC2 explained 18.54% (Figure 3). High positive correlation between nut length and kernel ratio was observed in the PCA plot. There were also high positive correlations between nut thickness and kernel size, intact kernel ratio and the number of nuts per cluster, wrinkled kernel ratio and nut width. On the other hand, principal component analysis categorized the examined nut clones into three different groups. The first group included clones 81AKC15 and 81AKC19, the second group included clones 81AKC05 and 81AKC21 and the third group included clones 81AKC17, 81AKC11, and 81AKC10 (Figure 4). In addition, a two-way hierarchical clustering heatmap was performed using normalized data (Figure 5). According to the analysis, the examined traits were clustered in two main groups. In general, kernel-related traits were grouped in the same cluster. However, dendogram heatmap analysis divided nut clones into two main clusters and three subclusters. Clones 81AKC15, 81AKC19, and 81AKC15 were grouped in the first subcluster, 81AKC17 in the second subcluster, 81AKC05, 81AKC21, and 81AKC10 in the third subcluster. In the dendogram, 81AKC05 and 81AKC15 clones were determined as the most distant nut clones from each other (Figure 4). These results were also found to be compatible with the PCA biplot graph.

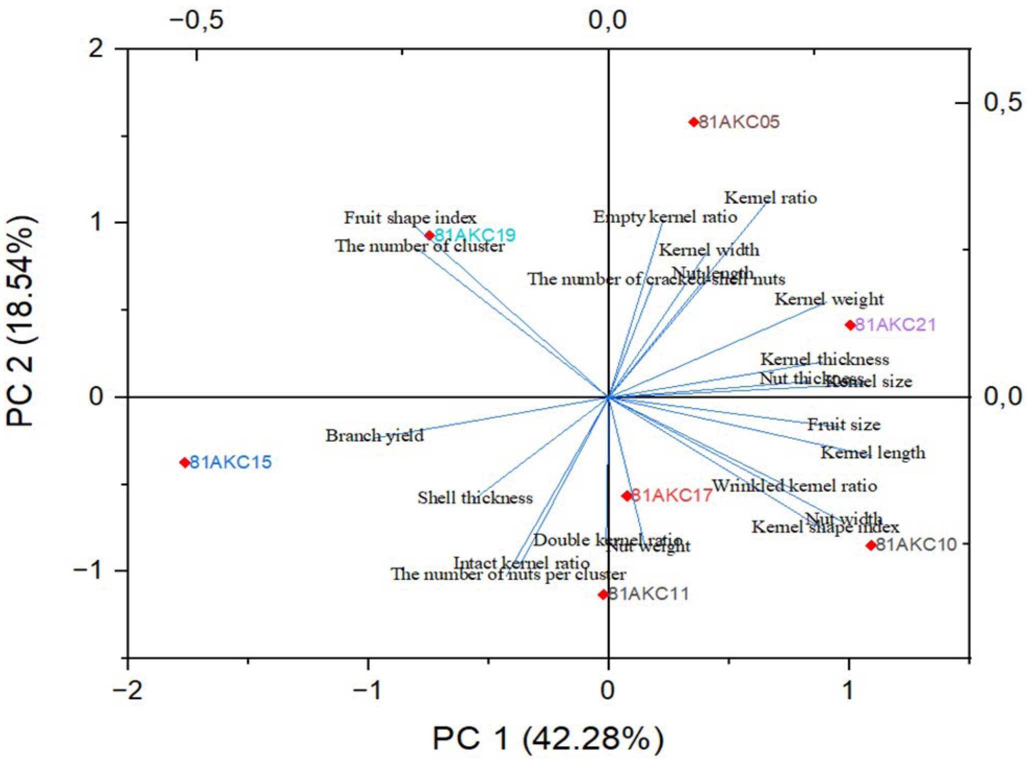

Figure 4. Principal Component Analysis (PCA) biplot showing the distribution of agronomic characteristics of nut clones in the first principal component and the second principal component.

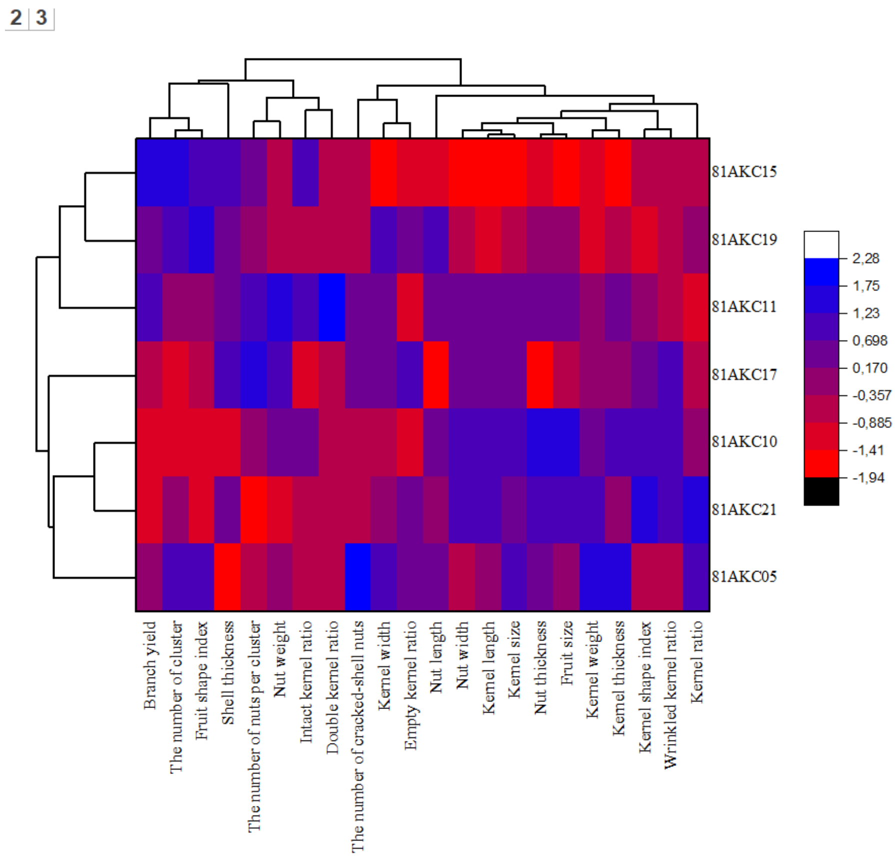

Figure 5. Hierarchical clustering heatmap of 22 traits measured in seven nut clones. In the map, each colored cell corresponds to the dataset for the nut clone in the rows and the trait under study in the columns.

4. Conclusions

As a result, it is seen that the clones examined in this study within Mincane variety grown in Akçakoca district of Düzce province have significant variability that indicate importance of clones for future breeding activities. 81AKC15 clone was the prominent clones in terms of branch yield and the number of cluster, 81AC11 for nut weight, 81AKC05 for kernel weight and 81AKC21 for kernel ratio. This could be genetic differences because all materials found similar conditions. For this reason, it is important to perform molecular studies to more objectively identified clones. In addition, these selection studies are of particular importance in terms of identifying and protecting hazelnut genetic resources.

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