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ORIGINAL ARTICLE

Pomological and Phenological Description of the New 'Bahri Koz' Cultivar of Walnut (*Juglans regia* L.) and Its Nutritional Value

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ABSTRACT

'Bahri Koz' is a walnut cultivar that reaches a mid-early harvest maturity and has some superior fruit traits. In 2019, the cultivar was registered and patented by the Variety Registration and Seed Certification Center of the Republic of Türkiye Ministry of Agriculture and Forestry. To determine the pomological and phenological traits of the 'Bahri Koz', 27 different traits were examined. The pomological analysis determined that the in-shell nut weight of 'Bahri Koz' was 12-14g, the kernel weight was 6.5-7.0g, and the kernel ratio was 51-54%. The shell and kernel of the cultivar were determined to be light in color and the surface of the shell to have a smooth structure. 'Bahri Koz' had superior traits compared to the 'Chandler' cultivar in terms of some of the pomological parameters such as in-shell nut weight, kernel weight, and kernel percentage. The new cultivar was seen to reach leafing, harvest maturity, and defoliation at an earlier date than 'Chandler'. The dichogamy status of the cultivar was determined to be protandrous and in this respect, a pollinator cultivar was recommended for the establishment of orchards with 'Bahri Koz'. This cultivar was also shown to be rich in lipid and unsaturated fatty acid content.

Introduction

Walnut (*Juglans regia* L.) is an important fruit species of the genus *Juglans* that has been consumed by humanity since ancient times. Some of the characteristics of walnut include being long-lived, deciduous, monoecious, open-pollinated, and generally dichogamous. It is widely cultivated in temperate regions such as Asia, Europe, North and South America, South Africa, Australia, and New Zealand (McGranahan and Leslie, 2012). Walnut trees are commonly found in almost every corner of Anatolia as one of its regions of origin and among Turkish people there is a great traditional interest in walnut trees and their cultivation. This situation is very significant as it provides a wide variety for walnut breeders.

Walnut is an important delicious and high-energy food rich in healthy fatty acids, vitamins, and minerals. Walnut kernels have a high-fat content consisting mainly of unsaturated fatty acids (Chatrabnous *et al.*, 2018). Linoleic acid is the major

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fatty acid type, followed by oleic acid and linolenic acid. Walnuts are also rich in vitamins A and E (Kafkas *et al*., 2017; Özcan and Sutyemez, 2019). Because of this healthy nutrient content, the consumption of walnuts is steadily increasing, as well as the scientific studies carried out on them. Some studies conducted in recent years have revealed that the consumption of walnuts reduces the risk of cardiovascular disease by increasing high-density lipoprotein (HDL) cholesterol and lowering low-density lipoprotein (LDL) cholesterol. Moreover, their consumption has also been found to reduce the risk of Alzheimer's disease. The positive effects of walnuts on human health are attributed to the high rate of unsaturated fatty acids (Spaccarotella *et al*., 2008; Orhan *et al*., 2011; Jahanbani *et al.*, 2016; Sánchez-González *et al*., 2017).

Initially, walnut-breeding studies began in the form of a method based on the selective breeding of walnut genotypes having superior traits grown from one open-pollinated seedling population (Sarikhani *et al.*, 2021). In subsequent years, cross-breeding studies began to be carried out in various countries such as the USA, France, China, and Türkiye. However, selection, which is a part of all breeding studies, is still used to choose and preserve naturally existing genotypes that have superior traits. These studies constitute an important genetic resource in terms of conserving genetic diversity and providing an infrastructure for transferring some important traits to future breeding studies.

Important considerations in walnut breeding programs include improvement of lateral bud flowering, nut quality, late leafing, early defoliation, and resistance to certain diseases and pests. Since the walnut is especially susceptible to damage by late spring frosts, late leafing has been the cornerstone of many breeding studies. In this respect, some important walnut cultivars such as 'Payne' and 'Franquette', which were identified as late-leafed in the 1800s, were selected. In the following years, both high lateral flowering and late leafing cultivars such as 'Chandler' and 'Howard' were developed in the USA, whereas France developed important cultivars such as 'Fernor' and 'Fernette', which also exhibited late leafing (Bernard *et al*., 2018). Türkiye's first walnut cultivars were registered in 1990 (Anonymous, 2021), followed by the development of the first cross-bred walnut cultivar named 'Diriliş' in 2016 (Sütyemez *et al*., 2018).

'Bahri Koz' is a new walnut cultivar from the Kahramanmaraş Sütçü İmam University walnut-breeding program in Türkiye. This cultivar was selected from seedling populations of Kahramanmaraş Province (Türkiye) and registered in the Turkish list of fruit varieties in 2019. In this study, carried out between 2019 and 2020, a number of phenological and pomological traits of the 'Bahri Koz' walnut cultivar were determined and compared with those of the 'Chandler' walnut cultivar.

Material and Methods

The 'Bahri Koz' walnut cultivar was selected from Kahramanmaraş Province in 1994 (Sütyemez, 1998) and subsequently registered and patented by the Republic of Türkiye as the 'Bahri Koz' cultivar in 2019 (Anonymous, 2021). To determine the performances of the 'Bahri Koz' and 'Chandler' cultivars, ten replicates were grafted over *Juglans regia*, cv. Maraş 18 rootstocks during the 2002 vegetation period. These walnut cultivars were planted in the same year at the Kahramanmaraş Sütçü İmam University Faculty of Agriculture Nut Application and Research Center (SEKAMER), located at 37° 35' 27" N latitude, 37° 03' 28" E longitude, and 930 m above sea level. As an average between Mediterranean and Continental climates, the climate of the region is mild, with annual precipitation of 727 mm and an average annual temperature of 16.9°C. The soil structure in general is suitable for walnut cultivation. In this study, we examined data for the years 2019 and 2020 and compared them with the data we obtained for the 'Chandler'. Some significant pomological and phenological traits were evaluated according to the Walnut Descriptor (IPGRI, 1994). These parameters

are presented in Tables 1 and 2. In this study, a fatty acid analysis was also conducted to determine the nutritional content of the 'Bahri Koz'. Oil extraction and fatty acid analysis of the nuts were carried out according to the methods of Bligh and Dyer (1959) and Kafkas *et al*. (2017) using gas chromatography.

Table 1. Descriptors of the phenological traits.

Traits	Description
Leafing date	Date when 50% of terminal buds have enlarged and the bud scales have split exposing the green leaves
First male bloom date	When first pollen shedding occurs
Last male bloom date	When last pollen shedding occurs
First female bloom date	Date of initial pistillate flower receptivity
Last female bloom date	Date of last pistillate flower receptivity
Male flowering period	Catkin receptive duration
Female flowering period	Female flower receptive duration
Female abundance	Female flower abundance: 3 (Light); 5 (Intermediate); 7 (High)
Catkin abundance	Male flower abundance: 3 (Light); 5 (Intermediate); 7 (High)
Lateral bud flowering	Percent of lateral buds with female flowers
Dichogamy	Female flowers and catkins receptive duration overlap status: 1 (Protandrous); 2 (Protogynous); 3 (Unknown)
Estimated yield	Rate in relation to age and volume of tree: 3 (Low); 5 (Intermediate); 7 (High)
Harvest date	Date when nuts are harvestable
Defoliation date	Date of defoliation

Table 2. Descriptors of the pomological traits.

Traits	Description
Nut shape	1: Round; 2: Triangular; 3: Broad ovate; 4; Ovate; 5: Short trapezoid; 6: Long trapezoid; 7: Broad eliptic; 8: Eliptic; 9: Cordate
Shell texture	1: Very smooth; 3: Smooth; 5: Medium; 7: Rough; 9: Very rough
Shell color	1: Very light; 3: Light; 5: Medium; 7: Dark; 9: Very dark
Shell strength	1: Paper; 3: Weak; 5: Intermediate; 7: Strong
Shell thickness (mm)	Measured with a digital caliper near center of half-shell
In-shell weight (g)	Average of total 50 nuts
Kernel weight (g)	Average of total 50 nuts
Kernel veins (%)	Percent of kernels with conspicuous veins
Kernel percentage (%)	Kernel weight/nut weight × 100
Kernel color	1: Extra light; 2: Light; 3: Light amber; 4: Amber
Kernel fill	3: Poor; 5: Moderate; 7: Well
Kernel flavor	1: Satisfactory; 2: Unsatisfactory
Ease of removal of kernel halves	1: Very easy; 3: Easy; 5: Moderate; 7: Difficult; 9: Very difficult

Results

Phenological traits

Traits such as leafing, flowering habits, harvest times, and defoliation date are used as the selection criteria in walnut-breeding programs. Leafing and defoliation dates in particular are among the main objectives of many walnut-breeding studies (Solar *et al*., 2014; Ebrahimi *et al*., 2015; Khadivi *et al*., 2019; Vahdati *et al.*, 2019; Bükücü *et al*., 2020; Hassani *et al.*, 2020; Kouhi *et al.*, 2020; Fallah *et al.*, 2022). Because the walnut is sensitive to spring and autumn frosts, significant economic losses occur when walnuts

are damaged by these two negative ecological conditions. The average leafing date of 'Bahri Koz' was observed as 28 March. In terms of this trait, it was emerging from dormancy 22 days earlier than 'Chandler'. The average defoliation date of 'Bahri Koz' was determined as October 27, about nine days earlier than the 'Chandler'. The calculations performed using these two phenological traits revealed that the average vegetation periods of the 'Bahri Koz' and 'Chandler' cultivars were 213 and 200 days, respectively.

Determining the blooming dates of the male and female flowers is very important in fruit species having a dichogamy tendency such as walnut. In this study, the first and last male bloom dates of 'Bahri Koz' were determined as 29 March and 5 April, respectively. Moreover, the female flower bloom date occurred between 7 April and 14 April. In light of these data, it was determined that the 'Bahri Koz' had a protandrous flowering trait that was similar to that of 'Chandler'. Potential pollinizers of 'Bahri Koz' include 'Sütyemez 1' and 'Howard'. Data for the 'Chandler' cultivar are presented in Table 3.

Although the catkin abundance was determined as high in 'Chandler', it was observed as intermediate in 'Bahri Koz'. Lateral bud flowering is an important parameter that indicates the productivity of walnuts and it is among the goals of many walnut-breeding programs (Sütyemez *et al*., 2018; Khadivi *et al*., 2019). In this study, we examined this trait separately for the 'Bahri Koz' and 'Chandler' cultivars and found that the values were 70% and 91%, respectively. It was determined that 'Bahri Koz' had an intermediate estimated yield (Table 3).

Table 3. Phenological traits of 'Bahri Koz' and 'Chandler' walnut cultivars.

Phenological Traits	Cultivars	
	Bahri Koz	**Chandler**
Leafing date	28 March	19 April
First male bloom date	29 March	20 April
Last male bloom date	5 April	30 April
First female bloom date	7 April	28 April
Last female bloom date	14 April	5 May
Male flowering period	7 days	10 days
Female flowering period	7 days	7 days
Female abundance	Light (3)	High (7)
Catkin abundance	Intermediate (5)	High (7)
Lateral bud flowering	70%	91%
Dichogamy	Protandrous	Protandrous
Estimated yield	Intermediate (5)	High (7)
Harvest date	11 September	6 October
Defoliation date	27 October	5 December

Pomological traits

The study examined 13 different parameters to determine the pomological traits, presented as the average values between 2019 and 2020. The 'Bahri Koz' shell surface structure was determined as smooth and that of the 'Chandler' shell as medium. In addition, the in-shell nuts of 'Bahri Koz' were light-colored, large, and round. The shell thickness of the cultivar was 1.41 mm and its shell strength was intermediate. The average 'Bahri Koz' in-shell nut weight varied between 12 and 14 g, whereas the average kernel weight of the cultivar was 6.5-7.0 g and the kernel percentage was around 51-54%. The in-shell nut weight of 'Chandler' varied between 11 and 13 g, and its kernel weight between 5 and 6 g with 45-49% kernel percentage. 'Bahri Koz' yielded a superior performance compared to 'Chandler' in terms of in-

shell nut weight, kernel weight, and kernel percentage traits (Table 4). Some important pomological trait results of the 'Bahri Koz' are presented in Fig. 1.

The nuts were harvested under Kahramanmaraş ecological conditions around the second week of September, which was about three weeks earlier than the 'Chandler' harvest. Determining the harvest time of the walnut is very important for its subsequent storage, marketable life, and quality.

The kernel of 'Bahri Koz' was easily removed from the shell as a whole or as two halves, resulting in a very high ratio of intact kernels, which is an important quality trait for walnuts. The kernel color was light with vein values of 28%. The walnut kernel is edible even before full maturation, which some consumers prefer, and in this case, it is classified as fresh walnut. According to consumer opinions, 'Bahri Koz' had a more pleasant aroma and taste compared to 'Chandler'. 'Bahri Koz' nuts and kernels are illustrated in Fig. 2.

Table 4. Pomological traits of 'Bahri Koz' and 'Chandler' walnut cultivars.

Pomological Traits	Cultivars	
	Bahri Koz	**Chandler**
Nut shape	Round (1)	Ovate (5)
Shell texture	Smooth (2)	Medium (5)
Shell color	Light (3)	Light (3)
Shell strength	Intermediate (5)	Weak (3)
Shell thickness	1.41 mm	1.22 mm
In-shell weight	12-14 g	11-13 g
Kernel weight	6.5-7.0 g	5.0-6.0 g
Kernel veins	28%	17%
Kernel percentage	51-54%	45-49%
Kernel color	Light (2)	Light (2)
Kernel fill	Well (7)	Well (7)
Ease of removal of kernel halves	Moderate (5)	Very easy (1)
Kernel flavor	Satisfactory (1)	Satisfactory (1)

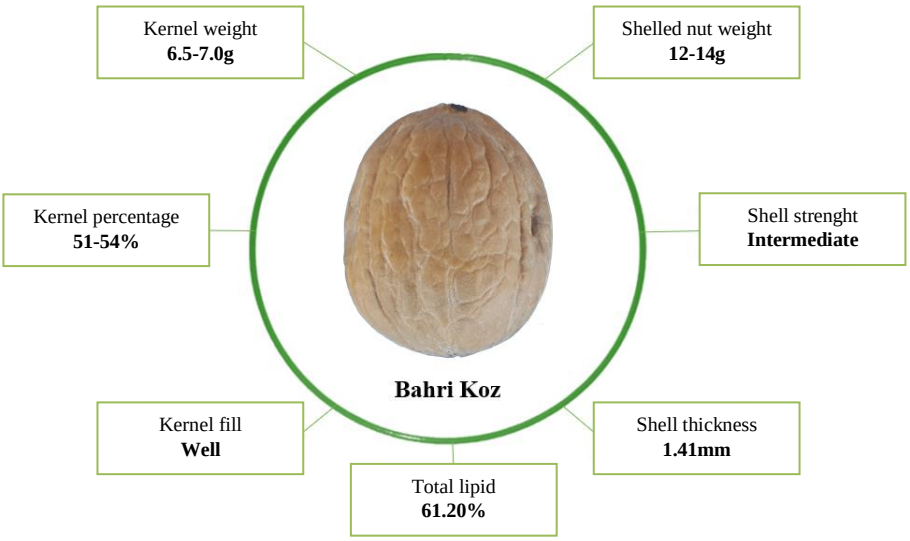

Fig. 1. Some significant trait values of 'Bahri Koz'.

Fig. 2. Fruits of 'Bahri Koz' walnut cultivar.

Fatty acid content

The most important reason for the recent increase in the consumption of walnuts is that they are rich in unsaturated fatty acids, which are especially beneficial for human health. Many studies have reported that walnut consumption partially reduces the risk of cardiovascular problems and Alzheimer's disease (Lavedrine *et al*., 1999; Orhan *et al*., 2011; Sánchez-González *et al*., 2017). In this study, we evaluated the total lipids, saturated fatty acids (SFAs), and unsaturated fatty acids including monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). These values in the cultivars are presented in Table 5. The total lipid content of 'Bahri Koz' was found to be 61.20%, which was lower than that of 'Chandler' (63.14%). The highest fatty acid value was 57.56% in linoleic acid, which is a significant unsaturated fatty acid. The total SFA value of the cultivar was determined as 7.59%, whereas the total MUFA value was found as 69.08% (Bayındır, 2021).

Table 5. Total lipid, saturated fatty acid and unsaturated fatty acid values of 'Bahri Koz' and 'Chandler' cultivars.

Cultivars	Total lipid	Myristic acid	Palmitic acid	Arachidic acid	SFAs
Bahri Koz	61.20±6.87	0.16±0.21	6.93±0.04	0.55±0.64	7.64±0.90
Chandler	63.14±11.14	0.00±0.00	7.52±0.03	0.07±0.09	7.59±0.12
Cultivars	**Oleic acid**	**MUFAs**	**Linoleic acid**	**α-linolenic acid**	**PUFAs**
Bahri Koz	23.33±0.50	23.33±0.50	57.56±0.59	11.52±0.22	69.08±0.81
Chandler	16.39±0.12	16.39±0.12	62.27±0.32	13.70±1.05	75.97±1.37

Discussion

'Bahri Koz' is an important walnut cultivar selected in Kahramanmaraş, Turkey. In this study, 14 phenological, 13 pomological, and fatty acid contents of 'Bahri Koz' and 'Chandler' were revealed. 'Chandler' is widely cultivated in the world so we compared 'Bahri Koz' with 'Chandler'.

As a result of the phenological examinations, the leafing dates of 'Bahri Koz' and 'Chandler' were 28 March and 19 April, respectively. Some studies have reported 'Chandler' leafing date was in the first week of April under the ecological conditions in Iran. (Mahmoodi *et al*., 2016; Hassankhah *et al*., 2017). The difference could be due to the different ecologies in which the experiment was conducted. It was determined that Chandler's defoliation date was later than Bahri Koz's. In the studies conducted in Turkey, it was reported that the defoliation date of 'Chandler' usually occurred later than in the local genotypes (Akça *et al*., 2013; Sutyemez, 2016). It was determined that both walnut cultivars had the

protandrous flowering trait. This finding was consistent with those of other studies investigating the flowering traits of Chandler (Ertürk *et al*., 2013; Sutyemez, 2016). Lateral bud flowering is the most important trait which is a sign of a high yield for a walnut cultivar. We determined Chandler's lateral bud flowering as 91% and Bahri Koz's as 70%. Manthos and Rouskas (2021) reported that Chandler's lateral bud flowering was 90%, as similar as in our study.

'Bahri Koz' outperformed 'Chandler' for most of the pomological traits studied. While the in-shell nut weight of 'Bahri Koz' was determined as 12-14 g, this value was determined as 11-13 g for 'Chandler'. Kernel percentages were determined as 51-54% and 45-49% for 'Bahri Koz' and 'Chandler', respectively. McGranahan and Leslie (2015) reported that the in-shell nut weight of 'Chandler' was 13.4 g, its kernel weight 6.6 g, and kernel percentage 49.5%. The partial differences obtained within the scope of the study could be attributed to varying cultivation, ecological, and maintenance conditions. Mahmoodi *et al*. (2016) determined the shell thickness of 'Chandler' as 1.28 mm. In this study, the shell thickness of this cultivar was determined as 1.22 mm. Findings for other pomological traits, such as nut shape, nut color, kernel fill and kernel color, examined for 'Chandler' were similar to the study conducted by Manthos and Rouskas (2021).

The fatty acid contents of 'Bahri Koz' and 'Chandler' were also presented in the study. Kafkas *et al*. (2017) reported that in 'Chandler', the total lipid content was 62.30%, total saturated fatty acid 9.44%, and total unsaturated fatty acid 80.33%, which were consistent with the values we obtained in our study.

Conclusions

The 'Bahri Koz' walnut cultivar has been registered and preserved within the framework of walnut-breeding studies of the Kahramanmaras Sutcu Imam University (KSU). This cultivar possesses a number of important nut traits including intermediate yields, superior fruit quality, and earlier harvesting periods. Moreover, the cultivar has a high nutritional content in terms of beneficial fatty acids. 'Bahri Koz' is especially suitable for walnut growing areas where late frost events in spring are not likely.

Conflict of interests

The authors declare that they do not have any conflict of interest.

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