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Exploring of Walnut Genetic Resources in Kazakhstan and Evaluation of Promising Selections

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Abstract
Kazakhstan has very rich walnut genetic resources; however there is no ongoing walnut breeding program. Kazakhstan government has several projects in cooperation with Russia, USA, Bulgaria, Czech Republic and Poland for plant breeding purposes. In the present research walnut genetic resources originated from Jabağıl, Tulkıbas, Sayram, Lenger, and Botanical Garden of International Hodja Ahmet Yesevi Turkish-Kazakh University of Kazakhstan were evaluated during 2015-2018. In the pre-selection stage, 47 genotypes were selected according to their lateral bearing, disease and pest tolerance. In the next step, 10 genotypes with high nut quality and high yield were selected. These genotypes were grafted onto seedling walnut rootstocks in Turkey. All of the grafted genotypes had fruit at the first year. Among 47 genotypes, we recorded nut weight between 6.21-15.18 g, kernel weight 2.36-6.64 g, kernel percentage 33.55-70.96% and average nut length 2.61-4.19 cm and nut diameter between 2.65 to 3.39 cm. The selected genotypes have been found to have very low fruit quality compared to commercial walnut varieties in the world. However, these genotypes have been evaluated as a good genetic resource for lateral bearing which can be used in breeding programs.

Keywors: Selection, Evaluation, *Juglans*, Nut, Population.

Introduction

Persian walnut (*Juglans regia* L.) is native to ancient Persia platuea which include several countries of Middle East and Central Asia (Hassankhah et *al*., 2014). Identification and evaluation of walnut germplasm of Central Asia is important for ongoing walnut breeding programs in the world particularly in the countries which has similar climates and elevations such as Turkey and Iran. In the previous studies, Californian researchers collected walnut genetic resources from China, Afghanistan, Kazakhstan, Turkmenistan and Kyrgyzstan since 1970's and genetic resources collected from the Central Asian region have been widely used in the California walnut breeding program. The same did Germain (1997), which had examined the characteristics of 873 walnut genotypes originating from Central Asia and Ukraine used in France walnut breeding

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program. In Kazakhstan, where the continental climate prevails, there are rich walnut genetic resources that are tolerant to very low temperatures and some of them have good fruit quality. These genetic resources are very important for special fruit breeding programs in Kazakhstan to make introgression resistance to winter frost, late flowering, adaptation to different ecological conditions, tolerance to pests and diseases, early harvest date, high yield and fruit quality genetic characters.

In this study, considerable number of walnut promising genotypes of Kazakhstan was identified; some were examined, and here described.

Material and Methods

Plant Materials

The seedling of Persian walnut (*Juglans regia* L.) trees were identified and evaluated at Jabağıl, Tulkıbas, Sayram and Lenger regions of Kazakhstan and also at Botanical Garden of International Hodja Ahmet Yesevi Turkish-Kazakh University of Kazakhstan (Fig 1). In the year 2015-2016 an exploring expedition was conducted by an international team of Turkish and Kazaki researchers, during vegetative season in the above mentioned regions to explore, identify and collect walnut genetic materials. The climate data of each region are reported in Table 1.

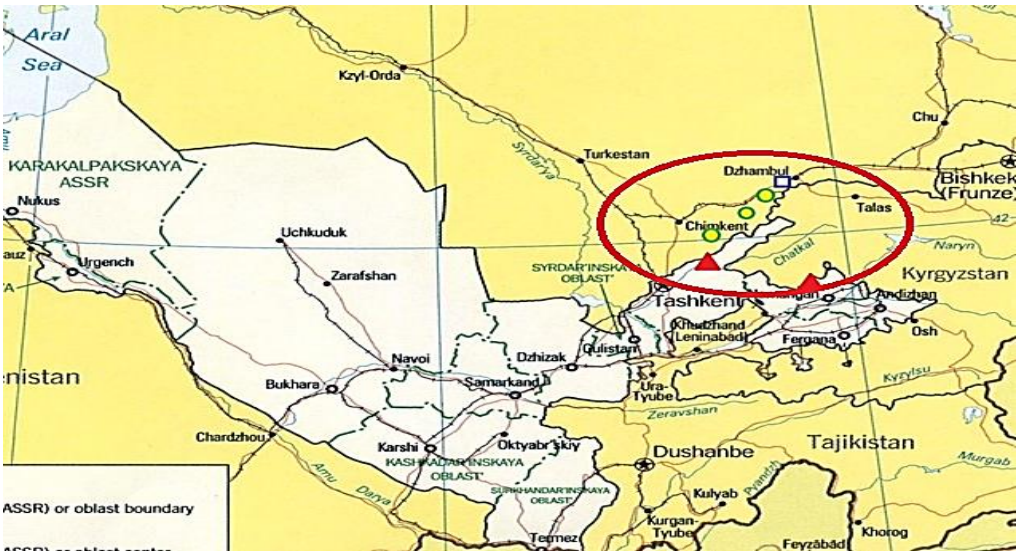

Fig. 1. Geographical area in which walnut genetic resources were examined within the borders of Kazakhstan

Table 1. The climate data of research area (Turkestan /Kazakhstan) (Anonymous, 2020)

		January	February	March	April	May	June	July	August	September	October	November	December
Turkestan	Average temperature (^{0}C)	-7,0	-3,0	12	17	22	28	34	26	19	16	8	4
	Minimum temperature (^{0}C)	-14.0	-8.0	-2,0	3.0	12	18	21	19	15,0	11	-2	-8
	Maximum temperature (^{0}C)	4	3.1	24	30	34	42	48	44	32	28	18	10
	Rainfall (mm)	21	24	0	31	23	3	0	0	12	13	22	30
Shymkent	Average temperature (^{0}C)	-6,0	-2,0	14	18	20	26	32	25	19	14	9	-2
	Minimum temperature (^{0}C)	-15.0	-9.0	-2,0	4.0	14	19	22	18	14,0	11	-2	-7
	Maximum temperature (^{0}C)	6	4.0	22	28	34	42	45	42	32	26	18	8
	Rainfall (mm)	59	59	75	70	47	13	7	2	8	40	59	63
Kentau	Average temperature (^{0}C)	-8,0	-5,0	9	16	19	24	31	22	13	12	6	2
	Minimum temperature (^{0}C)	-17.0	-10.0	-5,0	1.0	9	16	19	16	13,0	7	-5	-10
	Maximum temperature (^{0}C)	3	2.5	20	26	31	39	45	40	30	22	15	7
	Rainfall (mm)	28	32	22	25	28	17	0	0	22	16	24	32

Methods

Phenological and pomological traits of the selected walnut genotypes including: percentage of lateral bearing, tolerance to anthracnose and bacterial blight diseases, fruit size and tree age were evaluated using descriptors of UPOV (UPOV, 1999). About 2500 wild walnut trees were investigated primarily based on visual observations. The winter frost damage on trees was examined using visual observations. Trees damaged by winter frost were eliminated in our research. Among the studied trees, 47 of them with a high rate of lateral bearing, no signs of disease and large fruits were marked.

Determination of lateral bearing

The percentage of lateral bearing was quantified by number of shoot on twenty branches. Fruit set habit of the genotypes within the populations where classified into three groups: Fruit set at the tip of one-year-old shoots (I. Terminal bearing), fruit set mainly on the top of long shoots bound on branches of two years or older (II. Fruiting in clusters), fruit set all along the one-year-old shoots (III. Fruiting on lateral branches) according to UPOV criterions (UPOV, 1999).

Evaluation of tolerance to anthracnose and bacterial blight (Xaj) diseases

The susceptibility of genotypes to anthracnose (Anonymous, 1996) and *Xaj* diseases (Ozaktan et al., 2011) were determined based on observations at their location. The evaluations were made on the fifty leaves before harvesting time. The scales presented in Table 2 and Table 3 were used for scoring.

Exam of nut characteristics

Fifty fruits samples were randomly collected from the marked trees at harvest time. The fruit characteristics were examined in the pomology laboratory of Gaziosmanpaşa University. The fruits collected from selected genotypes were dried and the humidity was reduced to 8%. Nut width (E) (mm), nut length (L) (mm) and shell thickness (T) (mm) were measured with a 0.01 mm sensitive caliper. The fruit shape index was calculated using the formula R = (E + L) / 2T. Kernel weight (KW) and nut weight (NW) of the genotypes were weighed with a 0.01 g sensitive electronic scale. The kernel ratio was calculated using the formula KR= (KW/NW)×100. Walnut color was classified as extra light, light, light amber and amber according to California walnut color chart. The empty kernel rate and kernel shrivel rate in walnuts were also calculated.

Table 2. Identification of anthracnose susceptibility of selected genotypes in their origins (Anonymus, 1996)

Scale values of susceptibility	Symptoms on leaves
0	No spots, healthy
1	The twenty scattered 0.1 or 0.5 cm wide spots or merged spots covered 1/4 of the leaflet
2	More than twenty scattered spots larger than 0.5cm wide or combined spots covering ½ of leaf
3	Too many spots of various widths, or combined spots take up more than ½ of the leaflet

Table 3. Identification of *Xaj* susceptibility of the selected genotypes in their origins (Özaktan et al., 2011)

Scale values of susceptibility	Symptoms on leaves
0	No spots, healthy
0-1	Yellowish halos, no necrosis
1-2	1-3 necrotic spots or blight
2-3	4-10 necrotic spots or blight
3-4	Wide necrosis and blight on 1/2 of the leaf

Propagation of promising genotypes with grafting and comparison with 'Chandler'

Among the 47 genotypes that were determined as promising in the field conditions, 10 genotypes were re-selected according to nut characteristics and lateral bearing rate. The ten selected genotypes were grafted onto *Juglans regia* L. seedling rootstocks. Leafing date and fruit characteristics of the grafted genotypes in the same ecological conditions were compared with 'Chandler' variety in Turkey.

Results

This research was carried out to determine genetic variability and to select promising genotypes within the Kazakhstan walnut populations. The average nut length (cm) of five different populations was between 2.61±0.20 (for Tulkıbas 1) to 4.19±1.26 (Jabağıl 9), nut width (cm) ranged from 2.65±0.07 cm (Botanical 1) to 3.39±0.14 cm (Tulkıbas 3); nut thickness (mm) was between 2.38±0.12 (Botanical 1) to 3.29±0.19 (Tulkıbas 3); nut weight was between 6.21±0.75 g (Tulkıbas 7) to 15.18±1.09 g (Jabağıl 9); kernel weight was between 2.36±0.12 g (Sayram 1) to 6.64±0.65 g (Tulkıbas 7), kernel ratio was between 33.55±3.76% (Sayram 4) and 71.01±5.67% (Botanical 7), and the fruit shape index value was between 0.91 (Tulkıbas 3) and 1.37 (Jabağıl 9) (Table 4).

Tulkıbas genotypes were found to be more promising than the other four different populations in terms of fruit nut characteristics (Table 3). The traits of Kazakhstan walnut genotypes presented in the Table 3 were not similar to those of Turkish and Iranian varieties.

The average nut length (cm) among the selected genotypes in the Tulkıbas population was between 3.04±0.19 (Tulkıbas 3-4) and 3.74±0.35 (Tulkıbas 5), nut width (cm) ranged from 2.75±0.12 (Tulkıbas 8) to 3.29±0.13 (Tulkıbas 3), nut weight (g) between 08.56±0.58 (Tulkıbas 8) and 14.27±1.09 (Tulkıbas 3), and kernel ratio (%) changed from 36.72±8.07 (Tulkıbas 3) to 61.71±14.07 (Tulkıbas 7) (Table 4).

Among promising genotypes in the Jabağıl population, the average nut length (cm) ranged between 3.11 ± 0.15 (Jabağılı 8) and 4.19±1.26 (Jabağıl 9); nut width (cm) ranged from 2.87 ± 0.08 (Jabağıl 2) to 3.17±0.11 (Jabağıl 6); nut weight (g) varied from 08.69±2.12 (Jabağıl 4) to 14.14±0.75 (Jabağıl 6) and kernel ratio (%) was determined between 38.14±4.56 (Jabağıl 9) and 49.59±15.10 (Jabağıl 4) (Table 4).

In Sayram population, the average nut length (cm) ranged between 2.61±0.20 (Sayram 2) and 3.22±0.25 (Sayram 6); nut width (cm) ranged from 2.58±0.12 (Sayram 1) to 3.06±0.07 (Sayram 3); nut weight (g) was between 6.48±1.05 (Sayram 1) to 10.31±1.11 (Sayram 4) and kernel percentage (%) was determined between 33.55±3.76 (Sayram 4) and 70.96± 0.54 (Sayram 5) (Table 4).

In Lenger population, average nut weight (cm) was between 2.71±0.15 (Lenger 4) and 3.13±0.08 (Lenger7), nut width (cm) was between 2.67±0.12 (%) (Lenger 1) and 3.13±0.08 (Lenger 7), nut weight (g) ranged from 08.05±1.65 (Lenger 1) to 10.51±1.19 (Lenger 4) and kernel ratio varied between 41.37±5.40 (Lenger 5) to 54.86±4.20 (Lenger 2) (Table 3).

In Botanical Garden population, average nut length (cm) was between 2.65±0.11 (Botanical 3) and 3.70±0.25 (Botanical 8); nut width (cm) ranged from 2.54±0.10 (Botanical 1) to 3.11±0.08 (Botanical 10); nut weight (g) varied between 06.21±1.75 (Botanical 7) and 11.70±1.03 (Botanical 10), and kernel percentage (%) was determined between 34.18±4.52 (Botanical 10) to 71.01±5.67 (Botanical 7) (Table 4).

The average nut weights of Kazakhstan walnut population were in the middle group according to UPOV walnut descriptors. The kernel percentage of the walnut trees in Tulkıbas population was high and in the other populations was medium, according to UPOV (Anonymous, 1999). In all walnut genotypes of five

Table 4. Main nut characteristics, disease susceptibility and leafing date of the studied Kazakhstan Persian walnut populations

Genotypes	Nut length (cm)	Nut width (cm)	Nut thickness (cm)	Nut weight (gr)	Kernel weight (g)	Kernel ratio (%)	Nut shape index	Ease of kernel removal	Kernel color	Light coloured (%)	Shell roughness	Empty Kernel (%)	Shrunken kernel (%)	Lateral bud fruitfulness (%)	Anthracnose susceptibility	Xaj susceptibility
Tulkıbas 1	3.38±0.11	3.25±0.92	3.07±0.08	11.57±0.71	6.38±0.90	55.14±10.40	1.07	Very easy	Extra Light	90	Soft	0	2	90	2	0
Tulkıbas 2	3.51±0.16	3.10±0.19	3.00±0.11	11.84±1.42	5.74±0.50	48.47±14.13	1.15	Very easy	Extra Light	100	Soft	0	0	90	1	0
Tulkıbas 3	3.04±0.19	3.39±0.14	3.29±0.15	14.27±1.09	5.24±0.91	36.72±8.07	0.91	Easy	Extra Light	80	Soft	4	4	90	1	1
Tulkıbas 4	3.04±0.12	3.02±0.15	2.94±0.18	09.34±2.45	5.07±0.09	54.28±6.11	1.02	Easy	Extra Light	90	Soft	2	2	90	1	0
Tulkıbas 5	3.74±0.35	3.29±0.14	3.14±0.20	12.62±1.20	6.38±0.06	50.55±3.72	1.16	Easy	Extra Light	100	Soft	0	0	100	1	0
Tulkıbas 6	3.56±0.20	3.31±0.28	3.15±0.30	13.38±2.23	6.55±0.03	48.95±9.90	1.10	Easy	Extra Light	100	Soft	0	0	90	2	0
Tulkıbas 7	3.62±0.09	3.14±0.10	2.90±0.09	10.76±2.89	6.64±0.65	61.71±14.07	1.20	Very easy	Extra Light	100	Soft	0	0	80	1	0
Tulkıbas 8	3.07±0.12	2.73±0.10	2.75±0.12	08.56±0.58	4.48±0.09	52.33±4.83	1.12	Very easy	Light	100	Medium	0	0	90	1	0
Jabağıl 1	3.78±0.10	2.95±0.08	2.93±0.08	11.23±0.82	5.53±0.65	49.24±8.27	1.29	Easy	Light	80	Soft	2	2	80	1	1
Jabağıl 2	3.26±0.10	2.87±0.08	2.83±0.15	09.77±1.50	4.24±0.15	49.24±4.09	1.35	Easy	Light	80	Soft	2	4	100	1	0
Jabağıl 3	3.18±0.16	3.03±0.12	2.81±0.09	10.34±1.09	4.51±0.07	43.61±6.50	1.14	Easy	Light	80	Soft	2	2	70	1	0
Jabağıl 4	3.47±0.13	3.01±0.12	2.87±0.12	08.69±2.12	4.31±0.35	49.59±15.1	1.09	Easy	Light	70	Medium	2	4	90	1	0
Jabağıl 5	3.14±0.06	3.16±0.10	2.82±0.08	11.12±0.80	4.26±0.05	38.30±2.25	1.18	Easy	Light	80	Soft	2	2	80	1	0
Jabağıl 6	3.75±0.18	3.17±0.11	3.26±0.10	14.14±0.75	6.16±0.82	43.56±3.77	1.05	Easy	Light	70	Soft	0	4	70	2	0
Jabağıl 7	3.18±0.08	3.12±0.07	2.93±0.08	11.86±0.45	4.76±0.93	40.13±7.30	1.17	Easy	Light	90	Soft	0	2	90	2	0
Jabağıl 8	3.11±0.15	3.01±0.04	3.02±0.06	09.65±2.72	4.60±0.06	47.66±1.50	1.05	Easy	Light	100	Soft	0	0	100	1	0
Jabağıl 9	4.19±1.26	3.02±0.11	3.08±0.09	15.18±1.09	5.79±0.06	38.14±4.56	1.03	Easy	Light	80	Soft	4	4	90	1	0
Jabağıl 10	3.86±1.56	2.92±3.3	2.70±1.43	09.57±0.92	5.85±0.45	61.12±2.15	1.37	Easy	Light	100	Soft	0	0	80	1	0
Sayram 1	2.85±0.25	2.58±0.12	2.47±0.15	06.48±1.05	2.36±0.12	36.41±1.12	1.13	Medium	Light amber	70	Rough	4	6	80	1	0
Sayram 2	2.615±0.2	2.65±0.12	2.55±0.12	06.72±1.03	2.63±0.95	39.13±6.43	1.01	Easy	Light amber	70	Rough	4	4	80	1	0
Sayram 3	2.94±0.07	3.06±0.07	2.91±0.08	08.78±1.31	4.23±1.23	48.17±1.90	0.98	Easy	Light	80	Rough	2	2	70	1	0
Sayram 4	3.10±0.17	2.96±0.10	2.81±0.11	10.31±1.11	3.46±0.19	33.55±3.76	1.07	Very easy	Extra light	70	Medium	4	6	70	1	0
Sayram 5	2.84±0.15	2.80±0.16	2.51±0.16	06.82±1.27	4.84±0.31	70.96±1.54	1.07	Easy	Light	100	Medium	0	0	90	1	0
Sayram 6	3.22±0.25	2.97±0.09	2.83±0.10	09.73±0.64	4.41±0.09	45.32±1.85	1.11	Easy	Light amber	80	Medium	2	2	70	1	0
Sayram 7	3.11±0.18	2.74±0.15	2.63±0.15	08.61±1.21	4.55±0.29	52.84±7.40	1.16	Easy	Light amber	90	Medium	0	2	80	1	0
Sayram 8	3.022±0.10	2.65±0.07	2.57±0.06	07.14±0.54	3.71±0.13	51.96±4.49	1.16	Easy	Light amber	100	Soft	0	0	90	1	0
Sayram 9	3.00±0.11	2.97±0.13	2.80±0.05	08.16±0.72	3.75±0.43	45.96±3.75	1.04	Easy	Light	80	Soft	0	2	100	1	0
Sayram 10	3.21±0.3	2.82±0.18	2.74±0.15	08.96±1.10	4.60±0.22	51.33±3.21	1.15	Easy	Light	100	Soft	0	0	90	1	0
Lenger 1	3.12±0.23	2.672±0.12	2.61±0.10	08.05±1.65	3.69±0.34	45.83±3.01	1.18	Medium	Light amber	70	Medium	4	2	70	2	1
Lenger 2	2.89±0.11	2.98±0.2	2.93±0.24	08.73±1.88	4.79±0.18	54.86±4.20	0.98	Medium	Light amber	100	Soft	0	0	70	1	0
Lenger 3	3.55±0.23	2.96±0.15	2.94±0.17	09.92±1.35	4.40±0.96	44.35±8.98	1.20	Easy	Light amber	70	Soft	2	4	90	1	0
Lenger 4	2.71±0.15	3.11±0.14	2.66±0.26	10.51±1.19	5.33±0.74	50.71±9.50	0.94	Easy	Light amber	80	Soft	2	2	90	2	1
Lenger 5	3.34±0.16	2.88±0.11	2.75±0.09	08.87±1.09	3.67±0.06	41.37±5.40	1.19	Medium	Light amber	70	Rough	4	4	80	2	1
Lenger 6	3.14±0.18	2.98±0.09	2.81±0.08	09.15±0.78	4.08±0.35	44.59±6.24	1.08	Medium	Light amber	70	Rough	2	4	100	1	0
Lenger 7	3.14±0.09	3.13±0.08	2.87±0.09	08.44±0.5	4.56±0.18	53.96±1.38	1.05	Very easy	Light	80	Soft	0	2	90	0	1
Lenger 8	2.95±0.12	2.90±0.10	2.74±0.22	08.44±1.28	4.02±0.22	47.63±0.98	1.05	Easy	Light	80	Soft	2	2	70	1	1
Botanical 1	3.08±0.11	2.54±0.10	2.38±0.12	06.30±0.8	3.10±0.06	49.20±8.11	1.25	Medium easy	Light amber	70	Medium	2	2	80	2	1
Botanical 2	2.80±0.08	2.68±0.14	2.58±0.13	06.71±0.75	3.62±0.22	53.94±9.81	1.11	Medium Easy	Light	80	Medium	2	2	90	2	1
Botanical 3	2.65±0.11	2.84±0.14	2.71±0.12	06.71±0.90	3.48±0.04	51.86±1.85	1.06	Medium easy	Light amber	70	Rough	4	2	80	2	1
Botanical 4	3.01±0.13	2.922±0.11	2.83±0.10	08.99±0.10	4.50±0.06	50.05±5.03	1.06	Medium Easy	Light amber	80	Rough	2	2	70	2	1
Botanical 5	2.74±0.22	2.71±0.14	2.57±0.11	07.18±0.76	4.08±0.18	56.82±2.73	0.95	Medium Easy	Light amber	90	Medium	0	0	100	2	1
Botanical 6	3.09±0.10	2.79±0.10	2.69±0.06	10.13±1.24	4.10±0.07	40.47±7.79	1.05	Medium	Extra light	70	Medium	4	6	80	2	1
Botanical 7	2.66±0.22	2.76±0.09	2.76±0.11	06.21±0.75	4.41±0.05	71.01±5.67	1.04	Medium Easy	Light	90	Rough	0	0	60	2	1
Botanical 8	3.70±0.25	3.10±0.35	3.12±0.30	11.12±1.53	4.04±1.75	36.33±8.63	1.13	Medium Easy	Light	70	Medium	4	4	80	1	1
Botanical 9	2.89±0.21	3.05±0.09	2.76±0.13	08.34±2.17	4.43±0.05	52.75±12.9	0.96	Medium Easy	Light	80	Medium	2	0	70	2	0
Botanical 10	3.213±0.15	3.11±0.08	2.78±0.12	11.70±1.03	4.00±0.03	34.18±4.52	1.19	Medium	Light	70	Medium	4	4	70	2	1
Botanical 11	3.20±0.18	3.08±0.22	2.94±0.21	10.71±1.81	5.30±0.25	49.48±6.39	0.99	Easy	Extra light	90	Medium	2	2	60	2	1

Table 5. Main nut characteristics, disease susceptibilities and leafing date of the selected walnut genotypes of Kazakhstan

Genotypes	Nut length (cm)	Nut width (cm)	Nut thickness (cm)	Nut weight (g)	Kernel weight (g)	Kernel ratio (%)	Nut shape index	Ease of kernel removal	Kernel color	Light colored (%)	Shell roughness	Anthracnose susceptibility	*Xaj* susceptibility	Leafing date
Tulkıbas 1	4.47	4.25	4.04	13.25	7.22	54.48	1.07	Very easy	Light	70	Soft	2	2	12.04
Tulkıbas 2	4.21	3.35	3.29	12.98	6.20	47.76	1.15	Very easy	Light	80	Soft	1	2	12.04
Tulkıbas 4	3.96	3.56	2.94	11.57	6.01	51.98	1.02	Very easy	Light	70	Medium	1	2	12.04
Tulkıbas 5	4.13	3.69	3.14	13.01	6.35	48.78	1.16	Very easy	Light	90	Soft	1	1	13.04
Tulkıbas 6	4.17	3.97	3.15	14.66	7.00	47.76	1.10	Very easy	Light	90	Medium	2	2	13.04
Tulkıbas 7	4.80	3.85	2.90	13.73	8.21	59.78	1.20	Very easy	Light	90	Soft	1	1	12.04
Jabağılı 6	4.49	3.79	3.26	15.48	6.93	44.76	1.05	Very easy	Amber	40	Soft	2	2	15.04
Jabağılı 10	4.54	3.34	2.70	12.34	7.46	60.45	1.37	Very easy	Light	90	Soft	1	1	14.04
Sayram 5	3.56	3.38	2.51	9.13	6.36	69.65	1.07	Very easy	Light	100	Medium	1	2	13.04
Botanik 7	3.57	3.64	3.14	8.87	6.29	70.87	1.04	Very easy	Amber	70	Medium	2	2	12.04
Chandler	3.85	3.24	3.15	12.98	6.44	49.65	1.12	Very easy	Extra Light	90	Soft	1	1	26.04

populations, the nut shape index value ranged between 1.00 and 1.25. All of the genotypes were in the round group.

Fruits were observed in the first year in all the grafted genotypes. Nut characteristics and leafing date of the grafted genotypes in the 3rd year's old plants are presented in Table 5. The average nut weight of the grafted genotypes varied from 8.87 g (Botanical 7) to 15.48 g (Jabağıl 6). Kernel weight varied from 6.01 g (Tulkıbas 4) to 7.00 g (Tulkıbas 7). Kernel percentages ranged from 47.76% (Tulkıbas 4) to 70.87 % (Botanical 7) and were higher than 50% in 6 out of 10 grafted genotypes (Table 4). The kernel color of ten selected genotypes was generally observed as light. The leafing time of the ten selected types was found earlier than Chandler cultivar (Table 5).

We found a significant correlation among pomological nut traits. A positive correlation was found between nut length, nut width, nut thickness, nut weight and kernel weight. The highest correlation coefficient was calculated between nut width and nut thickness (0.857). An insignificant negative correlation was determined between nut characteristics and *Xaj* and anthracnose. A positive significant correlation (0.446) was found between *Xaj* and anthracnose (Table 6).

Cluster analysis of the 47 genotypes on the basis of six traits with high heritability coefficients was used to estimate the relationships between the selected genotypes in a dendrogram (Fig. 2). Based on this technique, genotypes were classified into three different cluster groups. Thirty two of the 47 genotypes were included in a single cluster group; whereas Tulkıbas 7, Jabağıl 10, Sayram 5 and Botanical 7 were located in a second group and Tulkıbas 3, Sayram 4, Botanic 8, Jabağıl 7, Lenger 5, Botanic 6, Sayram 1, Sayram 2 and Jabağıl 6 were located in the third cluster group.

Table 6. Correlations among nut characters and *Xaj* and Anthracnose susceptibility of 47 Persian walnut (*Juglans regia*) genotypes

	Nut widht	Nut thickness	Nut weight	Kernel weight	Kernel ratio	Fruit shape index	Lateral bud fruitfulness	Anthracnose susceptibility	*Xaj* susceptibility	Empty kernel	Shrunken kernel
Nut length	0.45**	0.589**	0.711**	0.619**	-0.181*	0.473**	0.310**	-0.104	0.244	0.079	-0.074
Nut width		0.857**	0.801**	0.706**	-0.175	-0.198	0.084	-0.087	-0.152	-0.244**	-0.041
Nut thickness			0.831**	0.680**	-0.223*	-0.166	0.088	-0.129	0.178	-0.195*	0.029
Nut weight				0.707**	-0.413**	-0.004	0.089	-0.016	-0.161	0.028	0.164
Kernel weight					0.321**	0.023	0.134	-0.002	-0.227	-0.502	-0.227*
Kernel ratio						0.003	0.058	0.037	-0.019	-0.661	-0.728**
Nut shape index							0.088	-0.133	-0.131	-0.075	-0.008
Lateral bud fruitfulness								-0.281	-0.273	-0.295	-0.106
Anthracnose susceptibility									0.446**	0.143*	-0.009
Xaj susceptibility										0.391**	0.145*
Empty kernel											0.754**

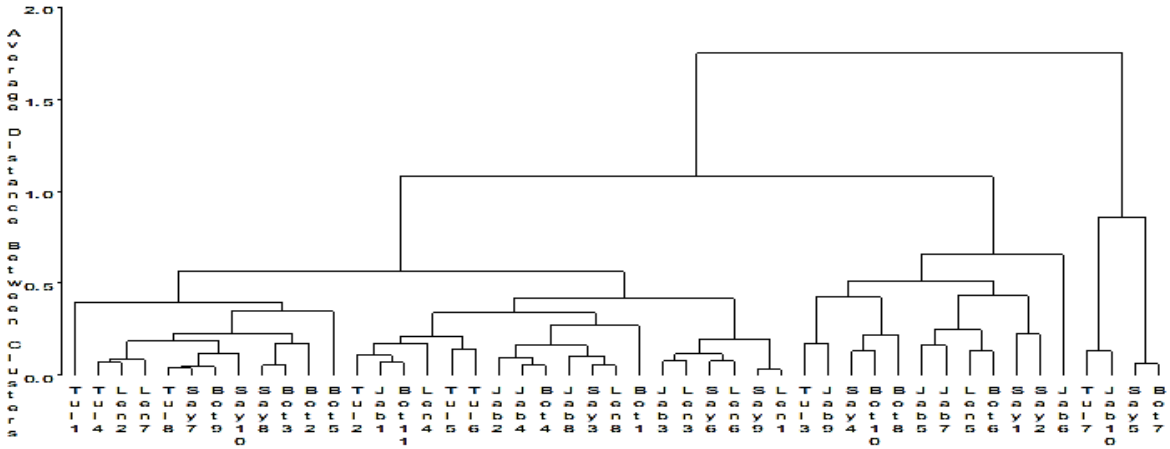

Fig. 2. Dendrogram of Kazakhstan genotypes according to the main nut characteristics

Discussion

In general, Turkish and Iranian walnut varieties have higher nut quality compared to Kazakhstan walnut selected genotypes (Akça and Şen 1994; Çelebioglu et al. 1988; Küden et al. 1997; Oğuz 1998; Ebrahimi et al., 2009; Mohammadi et al., 2015; Khorami et al., 2018).

A comparison nut data between Kazakh selections and varieties or selections from foreign countries was also carried out as explained below:

a) Californian varieties: the average nut weight (g) of UC Davis walnut varieties Sexton, Gillet, Forde, Ivanhoe and Solano were recorded as 16.70, 18.80, 17.70, 13.70 and 18.30, respectively. The average nut weight (g) of these varieties is 9.10, 9.60, 8.80, 7.70 and 10.30 g, and kernel ratio of them is 54.7, 51.10, 49.60, 56.30 and 56.20, respectively (Anonymous, 2016). The average nut weight of the new F_1 walnut genotypes introduced at UC Davis walnut breeding program in 2015 is between 12.0 g (03-001-665) and 24.5 g (06-013-20), their kernel weight is 6.6 g (09-005- 8) to 12.6 g (06-013-20) and their kernel percentage is between 65.4% (03-001-665) and 48.7% (05-001-412)

(Anonymous, 2016). Therefore, in term of nut quality, characteristics of selected walnut genotypes of Kazakhstan were lower than Californian walnut cultivars.

b) Turkish selected genotypes from North-eastern Anatolia region: The comparison showed that a ranges of the average fruit characteristics of the Kazakh selected genotypes were 9.07-16.01g for nut weight, 5.00-7.37g for kernel weight, 45.66-67.14% for kernel ratio and 0.58-1.53mm for shell thickness, which are lower than the Turkish selected varieties (Aslantaş, 2006).

c) Iranian walnut varieties: Iranian walnut genotypes selected from central part of Iran have nut weight between 6.0-15.2 g, kernel weight between 2.6-9.1 g, kernel ratio between 38.4-79.6%, and shell thickness between 0.4-1.4 mm (Arzani et al. 2008). Nut weight of another new candidate varieties were reported between 9-13 g (Eskandari et al., 2006). Average nut weight in Iranian commercial walnut varieties is between 7 and 9 g. It was determined that Kazakhstan walnut genotypes are lower than Iranian walnut genotypes in terms of fruit quality in general mean (Vahdati et al., 2019).

d) Ukraine selected varieties: Kazakhstan walnut genotypes are similar to those reported from Ukraine National Walnut Genetic Resources according with average nut weight of 10.8 g to 17.6 g and kernel ratio of 47.1% to 53.0% (Kondratenko et al 2006). In the walnut population grown from seed in Nohradhar region, average nut weight (g) varied between 4.85-16.59 g, kernel weight (g) changed from 1.02 to 6.91 and kernel ratio was observed between 16.68 and 51.66%. In Bharmaur population, nut weight was reported between 6.24 -23.61 g, kernel weight was between 2.61 and 8.02, and kernel ratio was between 20.74 - 53.51% (Sharma et al 2006). Kazakhstan and Nohradhar walnut genotypes were similar in terms of nut characteristics.

e) Kyrgyzstan selected genotypes: Nut characteristics of the Kazakh genotypes selected in our study were found similar to the genotypes selected from Jalalabad walnut population. Particularly low nut weight is a common treatment of both populations. In promising selected walnut genotypes of Kara-Alma walnut forests in Kyrgyzstan, mean nut weight varied between 7.82-11.31 g, kernel weight 3.83-5.40 g, kernel ratio (%) 39.47-54.98, shell thickness (mm) 1.08 to 1.85 and lateral bearing was determined between 0-60% among 19 walnut genotypes (Muratbek Kyzy, 2016). Therefore, it should be important to determine genetic similarity between Kazakhstan walnut genetic resources and Kyrgyzstan Jalalabad and Osh genetic resources and to define the variation within the populations.

f) Albania selected walnut varieties: Comparison between Kazahk selections and walnut populations from the region of Northern Albania showed high similarity in terms of pomological characteristics. The variation among seed grown for the nut weight (g) was between 3.8 and 21.1, the kernel weight (g) varied between1.85 and 9.8 and kernel percentage was between 32.6 and 63.8% (Zeneli et al., 2005).

The positive correlation between nut and kernel characteristics and the positive significant correlation between Xaj and anthracnose are similar with the results obtained by Amiri et al. (2010), Aslantaş (2006) and Khodadadi et al. (2016).

In conclusion, our results demonstrate that Tulkıbas population contains higher

nut quality than other populations. The selected genotypes have been found to have very low fruit quality compared to commercial walnut varieties in the world. However, these genotypes have been evaluated as a good genetic resource for lateral bearing which can be used in breeding programs. In addition, populations may contain important genes for winter cold tolerance. Low humidity in these areas reduced the spread of bacterial blight and anthracnose disease.

These data confirmed the high value of walnut genetic resources in Central Asia and recommend spreading the selected material identified between 1955 and 1968 in order to improve walnut growing in former URSS countries, more exactly 200 genotypes were selected which are preserving in a collection of the promising genotypes (Shevchenko, 1976).

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Conflict of interest

The authors declares no conflict of interest for this project.

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