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Analysis of morphological and pomological features of apricot in the Nakhchivan Autonomous Republic of Azerbaijan

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Abstract: Apricot (*Prunus armeniaca* L.) is grown across a wide geographical area and has been cultivated in Azerbaijan for more than three thousand years. The purpose of the study was to characterize the apricot varieties and forms collected from the Nakhchivan Autonomous Republic of Azerbaijan. Fourty-four apricot varieties and forms were studied according to 10 (phenological, pomological, morphological) parameters. A wide variation was found between yield, total soluble solids and fruit weight among varieties and forms. Fruits of the most of apricot varieties and forms were small, only two of them—Hampa and Limon Erik 2—had a fruit weight more than 50 g. In general, the fruits had yellow skin and flesh with high total soluble solids (TSS). Five varieties are characterized by orange, two by white, and three by yellowish-green skin ground color (SGC). A high correlation was found between several morphological and pomological features. Maximum Pearson correlation indices were found between bud break season and blossom season, fruit weight and fruit length, blossom season and harvest season. Fruits that were longer and wider had high fruit weight. The results of the PC (principal component) analysis revealed the first four components (PC1 - PC4) explained by 87.49% of the variance observed between varieties and forms. The presented study shows that the more attractive and yellow-skinned Azerbaijani apricot varieties and forms are suitable to produce dried apricots. Data from statistical analysis can be used to select different varieties and forms for apricot breeding programs. The research will provide a solid basis for the effective management and sustainable use of apricot germplasms for future breeding programs in the region.

Key words: Apricot, Phenology, Pomology, *Prunus armeniaca* L.

1. Introduction

Apricot, *Prunus armeniaca* L. (Rosaceae, subfamily Prunoidae) is one of the third most important stone fruit with a very small genome (2n = 16), grown in temperate climates, mainly in the Mediterranean countries, Russia, United States and Pakistan (Ercisli, 2009; Martinez-Mora et al., 2009; Gecer et al., 2020; Rampáčková et al., 2021; 2022).

Apricot is among the preffered fruits in human health and nutrition thanks to its biochemical compounds and rich nutritionl contents (Yaman and Uzun; 2020). World annual apricot production was about 4 million tons in 2020 and Turkey has an annual production of around 850,000 tons with the leading apricot (*Prunus armeniaca* L.) producer of the world (FAO 2021). Apricot production in the world is increasing steadily year by year and such increase is closely related to breeding activities carried out in different apricot producing countries (Pinar et al., 2017; Cavusoglu et al., 2021). The genus *Prunus* combines 8 species, mainly distributed in East, Central, Middle and Minor Asia, as well as in the Caucasus. Only one of these species, *Prunus armeniaca*, the common apricot, is cultivated.

Despite its global distribution, mainly commercial production is concentrated in the Mediterranean, which accounts for 55% of world production (Martínez-Mora et al., 2009; Milosevic et al., 2021; Karatas et al., 2022). There are more than 2000 apricot varieties grown worldwide. Economically important varieties grown in some leading apricot producing countries are: European group - Giant, Dagen, Violet, Verte, Karagoynuk, Stanley, President, Sugar, Firenze - 90 and Japanese group - Santa Rosa, Laroda, Formosa, Red Hart, Klimax, Angelona and Friar. The varieties Shalakh, Badam Erik, Gyrmyzyyanag, Abu Talibi, Ag Teberze, Hagverdi, etc., are mainly grown in Azerbaijan. In the Azerbaijani language, "apricot" is a slightly different repetition of the "uryug" word of the Turkish origin peoples of Central Asia. Among the economic regions of Azerbaijan, Nakhchivan constitutes 30% of total production of apricot[1].

1 Azərbaycan Respublikasının Kənd Təsərrüfatı Nazirliyi (2019). Çoxillik əkmələr [online]. Website http://www.agro.gov.az/

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Genetic variability is an important condition for a plant breeding program (Bozhuyuk et al., 2021). The development of new varieties of fruits is usually based on genetic resources (Kumar et al., 2015; Hasanbegovic et al., 2021; Milosevic et al., 2021; Bozhuyuk, 2022). Creation and characterization of the germplasm collection are important stages of breeding programs (Yilmaz and Gurcan, 2012; Dogan et al., 2014; Bolaric et al., 2021; Grygorieva et al., 2021). The collection and characterization of the main germplasm is carried out by describing phenological, pomological and morphological features such as tree vigor and growth habit, fruit quality features, leaf, stone, flower, pollen, stigma and stylus, blooming and harvest time (Kumar et al, 2015).

The discovery and use of different apricot genotypes allow to determine the desired fruit and product characteristics and their use in breeding (Kumar et al., 2015). In apricot breeding programs, special attention pays focusing on high-quality fruits, resistant to winter cold and late spring frosts, late flowering and long ripening periods, as well as resistance to different abiotic and biotic conditions in different countries (Milošević et al., 2010).

Azerbaijan is rich in different varieties of fruits and apricot has a special place among them. The homeland of the most of these fruit varieties (Alcha-Erik, Ag Novrasta, Qirmizi Novrasta, Hagverdi Eriyi, Agjanabat, Ag Tabarza or Balyarim, Tokhum Shemsi, Qara and Sari Teberze, Abutalibi, Khosrov Shahi) is Nakhchivan. For thousands of years, apricot growing has an exceptional place in the livelihood of the people of Nakhchivan. Fresh, dried and stone extracted apricots were used both in the supply of fruit to the family and in the production of marketable products (Novruzov, 2018).

Historical sources contain information about the cultivation of apricots in Nakhchivan three thousand years ago. Traditional apricot varieties of this region have historically been exported to neighboring countries. Local population from ancient times strictly followed to select appropriate varieties and number of trees to the climatic conditions of the land, while planting apricot orchards and most importantly, the organization of the sale of this fruit (Novruzov, 2018). Total production of fresh apricots in 2020 was 28,977 tons in Azerbaijan. Nakhchivan region is the most important apricot production center of the country. In 2020, the total fresh apricot production of Nakhchivan was 9093 tons.

In Azerbaijan, apricot varieties are cultivated in Nakhchivan, Agdash, Terter, Goranboy and in the other regions. Harvest season lasts from mid-June to early July in these regions. Environmental factors contribute to the high quality of fruit in these regions.

Germplasm collection and characterization are key stages in breeding programs (Kumar et al., 2015). Assessment of the pomological, morphological characteristics and fruit quality of the apricot germplasm of Azerbaijani apricots is important for future apricot breeding activities. In this study, the morphological, pomological and phenological characteristics of 44 apricot cultivars and forms which are grown in the Nakhchivan Autonomous Republic were assessed.

2. Materials and methods

Fruit samples for study were sampled from 44 apricot varieties and forms grown in Babek, Sherur and Ordubad districts of the Nakhchivan Autonomous Republic. All trees were the same age (except Maychicheyi and Limon Erik 2) and grown under the same conditions. Maychicheyi and Limon Erik 2 apricot varieties ripen earlier than other varieties and forms. The studied parameters for apricot germplasma are given in Table 1.

In the collection, the principal component analysis method was used to determine the correlation between the traits and to establish the relationships between the samples. These methods are widely used in the characterization of apricot genetic resources (Asma and Ozturk, 2005). SPSS and XLSTAT statistical programs were used for correlation and principal component analysis.

Studied parameters:

1. Bud break season (BBS): 1 (late February), 2 (early March) and 3 (mid-March).
2. Blossom season (BS): 1 (early March), 2 (mid-March), 3 (late March) and 4 (early April).
3. Harvest season (HS): 1 (mid-June), 2 (late June), 3 (early July), 4 (mid-July), 5 (late July), 6 (early August) and 7 (mid-September).
4. Leaf fall season (LFS): 1 (mid-October), 2 (late October) and 3 (early November).
5. Fruit weight (FW): mean weight of 50 fruits in grams.
6. Fruit length (mm).
7. Fruit width (mm).
8. Skin ground color (SGC): 1 (yellow), 2 (orange), 3 (white) and 4 (yellowish green).
9. Flesh color (FC): 1 (yellow), 2 (orange), 3 (white), and 4 (cream).
10. Total soluble solids (TSS) (°BRIX): TSS was measured by Fuji handheld brix refractometer.

3. Results and discussion

3.1. Characterization of samples

Bud break season of the apricot germplasm is mainly prolonged from late February to mid-March, the blossom season between March and early April, and the leaf fall season from mid-October to early November in this region. During the 6 years of the study, variation was observed for 15–20 days in the phenological stages. The germplasm Genotype 3 and Genotype 2 were determined to late blossom compared with others (Table 1). Late blossoming is an important factor to protect any damage

Table 1. Description of apricot varieties and forms.

Varieties	BBS	BS	HS	LFS	FW	FL	FWi	TSS	FC	SGC
Yeni Forma 1	2	3	2	2	12.3	25	22	11	2	2
Jir Zeferani	2	3	2	2	21.0	30	26	14	1	1
Jir Erik	2	3	2	2	14.0	25	24	13	2	2
Gaysi	2	3	2	2	19.3	31	27	13	1	1
Maychicheyi	1	2	1	1	35.6	38	35	18	1	4
Balyarim	1	2	1	2	31.8	35	37	15	1	1
Hampa	1	2	1	2	50.6	40	43	17	1	1
Yeni Forma 2	1	2	1	2	41.0	40	34	17	1	1
Jir Nakhchivan	1	2	1	2	15.3	27	27	21	1	1
Yay Sherefi	1	2	1	2	28.1	37	31	14	1	1
Shalakh 1	1	2	1	2	49.9	44	38	17	1	1
Teberze 1	1	2	1	2	29.2	37	33	24	1	1
Tokhum Shemsi	1	2	1	2	16.5	27	27	16	2	2
Gejyetishen	1	2	1	2	31.7	40	34	18	1	1
Badami	1	2	1	2	37.9	43	35	18	1	1
Helena	1	2	1	2	33.2	40	35	17	1	1
Mehmani	2	3	2	2	43.6	41	37	18	1	1
Hagverdi 1	2	3	2	2	39.2	39	35	19	1	1
Ag Nabati	2	3	2	2	33.7	41	34	14	1	1
Kurdeshi	2	3	2	2	29.3	39	31	12	4	3
Talibi	2	3	2	2	39.1	36	33	17	1	1
Genotype 1	2	3	2	2	44.5	43	38	16	1	1
Ag Badami	2	3	2	2	25.2	40	39	13	1	1
Agjanabad 1	2	3	2	2	37.8	41	35	16	1	1
Limon Erik 1	2	3	2	2	34.8	38	34	18	1	1
Forma 1	2	3	2	2	31.3	35	32	14	1	1
Shemsi	1	2	2	2	31.1	38	33	18	1	1
Agja Nabad 2	1	2	2	2	39.7	42	38	21	1	1
Goyje Nabad	1	2	2	2	39.6	42	38	21	1	1
Hagverdi 2	1	2	2	2	32.4	37	36	15	1	1
Genotype 3	2	4	3	3	32.2	40	37	24	1	4
Ordubad Sherefi	1	2	1	2	27.8	36	34	24	1	1
Heydari	1	2	1	2	40.5	41	37	13	1	1
Ordubad Jiri	1	2	1	2	20.5	31	28	16	2	2
Forma 2	1	2	1	2	40.0	40	36	18	1	4
Genotype 2	2	4	3	3	29.2	37	33	24	1	1
Ordubad Nabati	1	2	1	2	35.6	41	35	23	1	1
Yeni Forma 3	1	2	1	2	23.0	32	32	22	1	1
Shalakh 2	2	3	2	2	45.1	46	38	12	1	1
Alcha Erik	2	3	2	2	23.0	32	30	11	4	3
Abu Talibi	2	3	2	2	34.2	41	35	21	2	2
Teberze 2	2	3	2	2	26.3	30	28	20	1	1
Limon Erik 2	1	2	1	1	53.1	50	39	15	1	1
Esgerabat	2	3	2	2	45.0	41	37	20	1	1

caused by spring frosts in continental climates (Guleryuz, 1988; Unal et al., 1999).

There were wide variations between apricot samples for the harvest season. Harvest season in many varieties and forms were obtained in mid-June. Maychicheyi, Balyarim, Hampa, Yeni Forma 2, Jir Nakhchivan, Yay Sherefi, Shalakh 1, Teberze 2, Tokhum Shemsi, Gecyetishen, Badami, Ordubad Sherefi, Heydari, Ordubad Jiri, Forma 2, Ordubad Nabati, Yeni Forma 3 and Limon Erik 2 apricot varieties and forms were harvested in mid-June. Yeni Forma 1, Jir Zeferani, Jir Erik, Gaysi, Mehmani, Hagverdi 1, Ag Nabati, Kurdeshi, Talibi, Genotype 1, Ag badami, Agjanabad, Limon Erik 1, Forma 1, Shemsi, Agja Nabad, Goyje Nabad, Hagverdi 2, Shalakh 2, Alcha Erik, Abu Talibi, Teberze 2 and Esgerabat varieties and forms were harvested in late June and Genotype 3 and Genotype 2 were harvested in early July.

Significant differences were observed between samples related to fruit attributes. The average fruit weight and size are given in Table 1. Fruit length and width ranged from 25 mm to 50 mm and 22 to 43 mm, respectively. The maximum value for FL was observed in Limon Erik 2 (50 mm), and Shalakh 2 (46 mm), and the minimum values were obtained from Yeni Forma 1 (25 mm), Jir Erik (25 mm). The highest FWi was obtained in Hampa (43 mm), Ag Badami (39 mm) and Limon Erik 2 (39 mm). As in the previous parameter, the lowest fruit width was recorded in Yeni Forma 1 (22 mm).

FW is a key quantitative indicator that affects fruit quality and is a key feature that consumers focus on (Dirlewanger et al., 1999). In our study, fruit weight was changed in the range of 12.3–53.1 g. Such high variability for FW has been reported earlier (Badenes et al., 1998; Ruiz and Egea, 2008b; Hernandez et al., 2010; Milošević et al., 2010). From the studied 44 samples, the highest fruit weights were recorded for Limon Erik 2 (53.1 g) and Hampa (50.6 g). The FW of these varieties was classified as medium to large according to the Apricot Descriptor (IPGRI and CEC, 1984). Fruit weight of Forma 2, Heydari, Shalakh 1, Genotype 1, Mehmani and Shalakh 2 was changed in the range of 40–49.9 g. These varieties are considered as medium weighted. The lowest values for FW were observed in Jir Erik (14 g) and Yeni Forma 1 (12.3 g), which can be classified as very small. Medium-sized fruits with attractive appearance are desirable in apricot breeding (Mratinić et al., 2011). These results are consistent with the results of Yaman and Pinar (2021), Yaman and Turan (2021) and Asma and Ozturk (2005). Thus, half of the varieties included in the current study had the desired fruit weight, consistent for consumer's demand.

TSS, which affects fruit taste, was very high in collection samples and ranged from 11 to 24 °Brix. High values for TSS were recorded in the genotypes Teberze 1 (24 °Brix), Genotype 3 (24 °Brix), Ordubad Sherefi (24 °Brix) and Genotype 2 (24 °Brix). Yeni Forma 1 and Alcha Erik had the least total soluble solids. As noted by Ayanoglu et al. (1995), apricot genotypes with TSS > 20 °Brix had excellent taste and quality. As shown in Table 1, most of the studied apricot varieties and forms were characterized by yellow skin ground color and flesh color. SGC for 5 cultivars —Yeni Forma 1, Jir Erik, Tokhum Shemsi, Ordubad Jiri and Abu Talibi— was orange. In Kurdeshi and Alcha Erik varieties, the skin ground color was white and flesh color was creamy. Finally, Maychicheyi, Genotype 3 and Forma 2 varieties had a yellowish-green skin ground color.

3.2. Correlation between variables

A high correlation was established between several phenological and pomological features (Table 2). As

Table 2. Correlation between the studied parameters.

	BBS	BS	HS	LFS	FW	FL	FWi	TSS	FC
BS	0.938**								
HS	0.804**	0.877**							
LFS	0.302*	0.517**	0.526**						
FW	–0.136	–0.133	–0.089	–0.210					
FL	–0.133	–0.100	–0.035	–0.152	0.894**				
FWi	–0.223	–0.166	–0.074	–0.069	0.868**	0.876**			
TSS	–0.272	–0.088	–0.023	0.310*	0.137	0.146	0.239		
FC	0.252	0.187	0.132	0.000	–0.365*	–0.308*	–0.391**	–0.399**	
SGC	0.074	0.162	0.090	0.000	–0.176	–0.143	–0.142	–0.051	0.486**

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level. Abbreviations: BBS: bud break season; BS: blossom season; HS: harvest season; LFS: leaf fall season; FW: fruit weight; FL: fruit length; FWi: fruit width; TSS: total solids soluble; FC: flesh color; SGC: skin ground color.

expected, the highest rates were recorded between bud break season and blossom season, fruit weight and fruit length, blossom season and harvest season, fruit length and fruit width. Thus, larger fruits (FL and FWi) had a higher weight. The Pearson correlation indices with fruit length and width on fruit weight were determined as r = 0.894 and r = 0.868, respectively.

These results agreed with those of Badenes et al. (1998) who reported a high correlation (r = 0.87) between bud break season and blossom season and also a correlation (to a lesser extent) between bud break season and harvest season (r = 0.79).

Considering comparison previous studies, for example Salari et al. (2020) studied on 19 morphological, pomological, and fruit quality characteristics of Afghan apricot samples and found a high positive correlation between leaf blade length and leaf blade width and negative correlation between leaf blade width and leaf blade length/leaf blade width. Corrado et al. (2021) studied on 12 morphological features of Italy apricot samples and found positive correlations between fruit width, length, and volume. Yilmaz et al. (2012) determined positive correlations between fruit height, fruit width, fruit weight, L color value, stone weight, and flesh to stone ratio. Negative significant correlations were also observed among acidity, TSS, and pH.

3.3. Principal component analysis (PCA)

Principal component analysis is used to find relationships between data, their similarities and differences (Mattos et al., 2010; Milosevic and Milosevic, 2010). This analysis was used by several authors to identify genetic relationships between genotypes and to study the correlation between fruit traits, tree and phenological characteristics in apricot collections (Badenes et al., 1998; Gurrieri et al., 2001; Azodanlou et al., 2003).

Table 3. Principal component analysis between apricot genotypes.

PC	Eigen value	Variation, %	Sum of variations, %
1.	3.63	36.34	36.34
2.	2.55	25.53	61.87
3.	1.48	14.82	76.69
4.	1.08	10.80	87.49
5.	0.51	5.10	92.59
6.	0.35	3.46	96.06
7.	0.17	1.70	97.76
8.	0.11	1.09	98.84
9.	0.10	0.97	99.81
10.	0.02	0.19	100.00

We also have used this in our study. The results of the PCA analysis revealed that 87.49% of the observed variability was explained by the first four components (PC1-PC4) (Table 3). The first component analysis (PC1) consisted 36.34% of the total variation. PC1 is mainly represented by bud break season, blossom season, and harvest season features (Table 4). The second component (PC2) consisted 25.53% of the total variation and the main characteristics in PC2 were fruit weight, fruit length, and fruit width. Symptoms included in the third main component are leaf fall season (0.541) and TSS (0.692). As observed in PCA, the first three components represented 76.69% of the total variance. This value is much lower than those of reported by Reza et al. (2014), Asma and Ozturk (2005), and Yilmaz et al. (2012) (54%, 70%, and 73%, respectively).

Table 4. Correlation between samples and first 5 PC.

Variables/parameters	PC_1	PC_2	PC_3	PC_4	PC_5
BBS	0.731	0.544	–0.203	–0.238	–0.161
BS	0.736	0.642	–0.046	–0.038	–0.119
HS	0.650	0.679	0.018	–0.025	–0.051
LFS	0.439	0.429	0.541	0.265	0.456
FW	–0.708	0.580	–0.301	0.015	0.004
FL (mm)	–0.674	0.609	–0.308	0.077	0.081
FWi (mm)	–0.718	0.587	–0.174	0.148	0.111
TSS (°Brix)	–0.281	0.220	0.692	0.486	–0.211
FC	0.539	–0.282	–0.536	0.303	0.364
SGC	0.316	–0.138	–0.405	0.772	–0.253

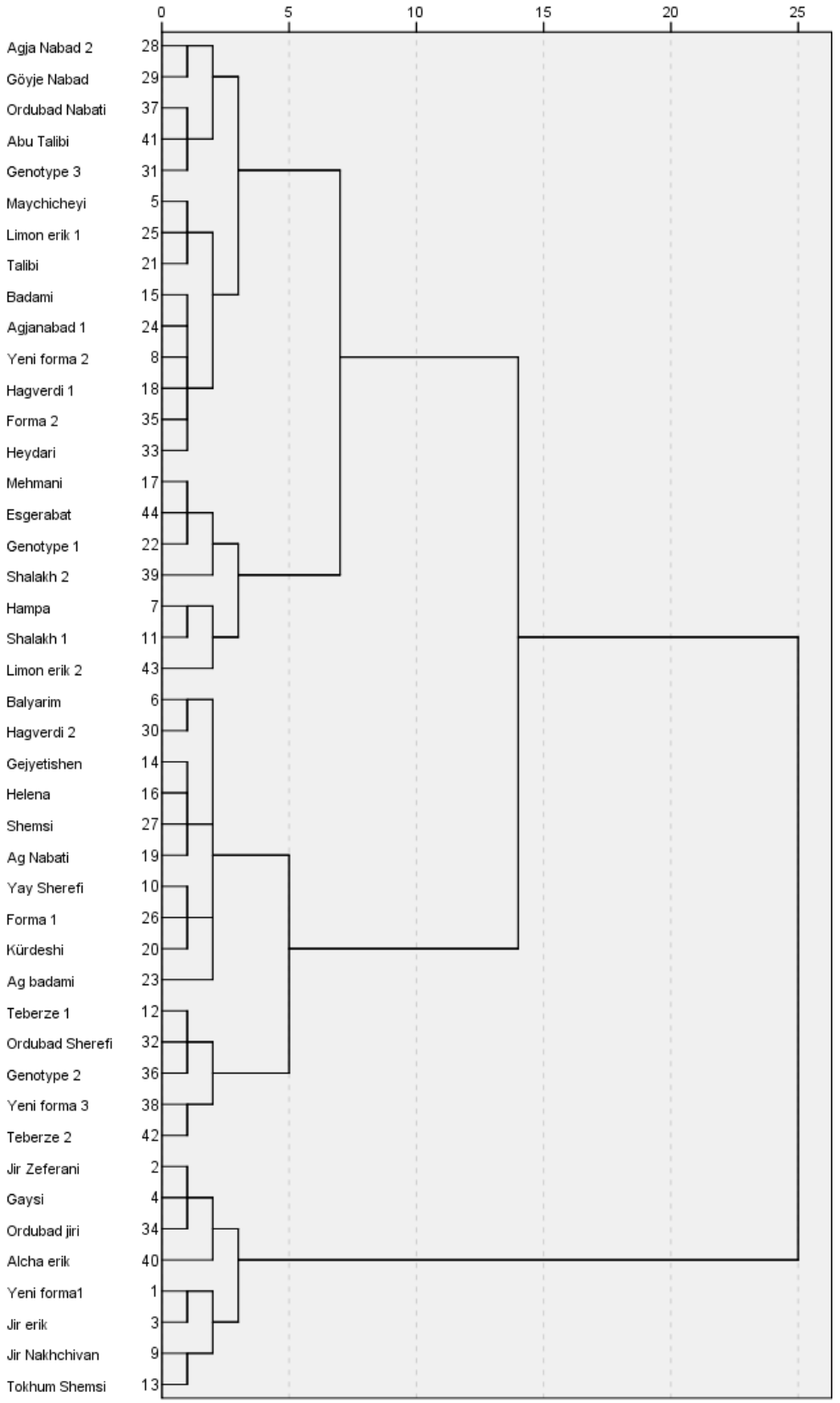

Figure. Grouping of apricot genotypes in spreading in Nakhchivan according to morphological and pomological quantitative indicators.

3.4. Cluster analysis

As a result of cluster analysis, apricot cultivars and forms at Euclidean distance were grouped into 2 main groups based on 10 parameters using the Ward method. The dendrogram showing the results from the cluster analysis is shown in Figure Located in the first group 21 samples (Agja Nabad 2, Goyje Nabad, Ordubad Nabati, Abu Talibi, Genotype 3, Maychicheyi, Limon Erik 1, Talibi, Badami, Agjanabad 1, Yeni Forma 2, Hagverdi 1, Forma 2, Heydari, Mehmani, Esgerabat, Genotype 1, Shalakh 2, Hampa, Shalakh 1, Limon Erik 2) consisted 47.73% of all genotypes.

This group is divided into 2 main clusters. This cluster includes fourteen samples, which consisted 31.82% of all samples. This cluster is divided into 2 subclusters. The first sub cluster includes five samples, which are apricot varieties with high fruit length, fruit width and high TSS. The second subcluster includes nine samples (Maychicheyi, Limon Erik 1, Talibi, Badami, Agjanabad 1, Yeni Forma 2, Hagverdi 1, Forma 2, Heydari). The second cluster includes 7 samples (Mehmani, Esgerabat, Genotype 1, Shalakh 2, Hampa, Shalakh 1, Limon Erik 2), which are apricot varieties with higher fruit weight, fruit length and fruit width compared to other clusters.

The second main cluster includes 15 samples (Balyarim, Hagverdi 2, Gecyetishen, Helena, Shemsi, Ag Nabati, Yay Sherefi, Forma 1, Kurdeshi, Ag Badami, Teberze 1, Ordubad Sherefi, Genotype 2, Yeni Forma 3, Teberze 2). The samples included in this cluster consisted 34.09% of all samples. This cluster is divided into two subclusters. The first sub cluster includes ten samples (Balyarim, Hagverdi 2, Gecyetishen, Helena, Shemsi, Ag Nabati, Yay Sherefi, Forma 1, Kurdeshi, Ag Badami). The samples included in this cluster have a high fruit length. The second subcluster includes five samples (Teberze 1, Ordubad Sherefi, Genotype 2, Yeni Forma 3, Teberze 2). Genotypes grouped in this subcluster have high TSS. In the second group Jir Zeferani, Gaysi, Ordubad jiri, Alcha Erik, Yeni Forma 1, Jir Erik, Jir Nakhchivan, Tokhum Shemsi genotypes are concentrated.

4. Conclusion

Presented study is the first on analyze the genetic diversity of apricot varieties/forms in the region. The results of this study will provide the basis for effective management and sustainable use of apricot germplasm in future breeding programs in the region. The information provided may be useful for both fruit growers and apricot breeding programs. The results could be used as an important reference to compare genetic resources, characterize apricot genotypes, and select the best parents for apricot breeding activities.

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