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Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey

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Abstract

The purpose of this study was to characterize the Irano-Caucasian apricot germplasm that was collected in Anatolia, Turkey. Fifteen (pomological, phenological, and yield) parameters were studied in this germplasm, consisting of 128 apricot cultivars and types. A wide variation was found in harvest season, fruit yield, total solids soluble (TSS), total acidity, fruit, pit, and kernel mass. Most of the cultivars and types had a relatively small fruit size; only seven had a fruit mass $\geq$50 g. In general, fruits had yellow skin ground color and flesh color as well as mostly sweet kernels and high TSS. While there was a high correlation between fruit, pit and kernel mass and also between TSS and total acidity, a low or no significant correlation was determined between other pomological or phenological characteristics. The Levent apricot type possessed a substantially late ripening with a total period of 190–200 days for fruit development, a characteristic that makes this apricot type highly suitable for breeding studies.

Introduction

Apricot is mostly grown in Mediterranean countries, Russia, USA, Iran and Pakistan. Total world production of fresh apricot is between 2.2 and 2.7 million tons/year. Turkey is the leading producing country both for fresh and dried apricot. Total fresh and dried apricot production of Turkey in 2001 was 500 and 120 thousand metric tons, respectively, composing a 15–20% fresh and 65–80% dried apricot production of the world (Camlıbel 1996; Anonymous 2002; FAO 2002).

Apricots are grown throughout Turkey, except in the very humid region around the Black Sea and cold mountain area of Anatolia. The most important apricot growing region is Eastern Anatolia. Malatya, a location in this Anatolian region, is the most important apricot production center of the country. This region produces 50% fresh and 90% dried apricot of the whole country (DIE 1998). The most important apricot cultivars in the Malatya region are Hacihaliloglu, Kabaası, Hasanbey, Soganci, and Cataloglu. The harvest season of apricot fruit in this region starts at early June until late July. The most common post-harvest processing of apricot fruit in this region is carried out in a sequence of sulfur-drying (sulfurization), sun-drying and pit removal. The ecological factors contribute to world famous high quality fruit from this region. Furthermore, Malatya is known as the biggest dried apricot export center as 80–85% of world apricot export originates from this region (Asma 2000; FAO 2002).

Anatolia is known for its favorable ecological potential for growing apricot and also some other horticultural crops (Ulkumen 1973). The cultivation of apricot in Anatolia dates back to years 300s BC and the most common type of cultivation being

through seed propagation, both contributing to evolution of various types of wild apricot. When these wild-type apricots are compared with other wild apricot germplasms from other regions of the world, they can be classified as *Prunus armeniaca Anatolica* (Ozbek 1978). However, most of these apricot germplasms were replaced by new apricot cultivars after 1970s, when apricot growers realized the high quality and higher commercial value of cultivated varieties. A State Apricot Germplasm Preservation Project was launched in 1978 in order preserve a collection of 225 apricot germplasms belonging to Irano-Caucasian ecogeographical group. Some pomological characteristics of 42 germplasms from this group has been published in The European Apricot Catalogue (Nikalasson and Bjarnason 1989).

While there have been many studies concerning the relatively small germplasm resources of European ecogeographical group (Paunovic 1988; Audergon et al. 1991; Guerriero et al. 1995; Badenes et al. 1998), the number of reports on Irano-Caucasian ecogeographical group, which shows a wide variation, are limited (Dokuzoguz 1966; Gulcan 1988). The determination of phenological, pomological characteristics and fruit quality of Irano-Caucasian ecogeographical group germplasms is important for future apricot breeding.

In this study, the morphological and pomological characteristics of 128 germplasms of apricot from Irano-Caucasian ecogeographical group were evaluated.

Material and methods

This study was carried out on 128 apricot cultivars and types in Malatya Fruit Research Institute (MFRI), Turkey. These germplasms, propagated through budding, were originally collected from different cultivation sites in Anatolia. All trees were at the same age (except Levent apricot type) and received the same standard cultural practices. The Levent type was brought into the field in a latter time and it possessed an extremely late ripening.

MFRI is located at 38° 21′ N latitude, and 38° 18′ E longitude. It has 12.6 °C annual average temperature, and 495 mm annual precipitation. The average temperature and monthly precipitation in April–October are 19.9 °C and 26 mm, respectively. The soil type at MFRI is alluvial with a pH 7.90.

As a tool for germplasm description, we have used principal component analysis to study correlations among variables and establish relationship among cultivars. This method is commonly applied for characterization of genetic resources in such studies (Hilling and Iezzoni 1988; Perez-Gonzales 1992; Perez-Gonzales et al. 1993; Badenes et al. 1998).

Parameters studied

The fifteen variables that we either measured or classified in this study were:

1. Tree size (TS), determined as crown size: Crown size $\geq$75 m^3, 1 (large); 75–50 m^3, 2 (medium); and $\leq$50 m^3, 3 (small).
2. Bud break season (BBS): 1 (late February), 2 (early March) and 3 (mid-March).
3. Blossom season (BS): 1 (early march), 2 (mid-March), 3 (late March), and 4 (early April).
4. 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).
5. Leaf fall season (LFS): 1 (mid-October), 2 (late October) and 3 (early November).
6. Fruit weight (FW): mean weight of 50 fruits in grams.
7. Pit weight (PW): mean weight of 50 pits in grams.
8. Kernel weight (KW) mean weight of 50 kernels in grams.
9. Skin ground color (SGC): 1 (yellow), 2 (orange), 3 (white), and 4 (green-yellowish).
10. Flesh color (FC): 1 (yellow), 2 (orange), 3 (white), and 4 (cream).
11. Kernel taste (KT): 1 (sweet), and 2 (bitter).
12. Flesh/pit ratio (FPR): (mean fruit weight – mean pit weight)/(mean pit weight).
13. Total solids soluble (TSS) (BRIX): TSS was measured by Fuji hand held brix refractometer.
14. Yield (Y): mean fruit yield per apricot tree (kg/tree).
15. Total acidity (TA): Total acidity was measured by neutralization of fruit juice to pH 7.0 with 0.1 N NaOH and total acidity given as gram malic acid + citric acid/100 ml fruit juice (Cemeroglu 1992).

Results and discussion

Characteristics of cultivars

Data in Table 1 represent 15 variables for apricot germplasms studied. While Dortyol 1, Dortyol 2, Dortyol 4, Ordubat, 4203, and 5103 had a small tree size ($\leq$50 m^3), the rest were between medium and large size. The tree size and vegetative growth are affected by genetic and ecological factors. Although, they are not the main adaptation indicators, strong vegetative growth and large tree size are desired characteristics by an apricot grower.

Bud break season for these germplasms in this region is generally from late February to mid-March, the full blossom being observed between early March and early April. A 15–20 day variation in phenological phases was observed during the 9 years of study course. The germplasms K 0620, K 4205, Kayseri P.A., Sakıt 2, Sakıt 7, 693 K, 5103, and 14 Hacıhaliloglu were determined to late blossom compared with others. The difference in blossoming periods of germplasms under same geographical conditions might be a result of the total exposure temperature required. Late blossoming is an important factor to protect any damage caused by spring frosts in continental climates (Guleryuz 1988; Unal et al. 1999). In this region, late spring frosts end around mid-April and since all the cultivars and types in germplasm blossomed before early April, they were all under the risk of spring frost damage. In deed, the loss in fruit yields caused by frost damage is well known in this region (Kadıoglu 1977; Asma et al. 1994).

There are large variations in harvest season between apricot cultivars and types. The most cultivars and types were harvested at late June and early July. The earliest harvest was made for Turfanda and Turfanda-E.M. on mid-June. The fruits K 5001, 1343, 1345, 1860, 30 Hacıhaliloglu, and 34 Hacıhaliloglu were harvested on mid-July, and Gec Aprikoz and Ordubat were harvested in late July. Guz Aprikozu was harvested early August. The latest harvest was for Levent apricot type in mid-September, a period that is 50–55 days later compared to other apricot cultivars and types. A two-month later harvesting season for this type is an important element and make this type a promising one for future apricot breeding.

An important feature of Ordubat apricot cultivar is that its on-branch dried fruits do not drop, but, still stays strongly connected and making its fruit to be directly harvested from trees. Also, in general, there were large variations between fruit weight and pit weight in all germplasms studied. The largest fruits (>50 g) were determined to belong to Agcenebat, Aprikoz, Guz Aprikozu, Gec Aprikoz, Hasanbey, K 3816, Ziraat Okulu. The fruit weights from 49 cultivars and types were determined below $\leq$30 g. This shows that Irano-Caucasian ecogeographical group apricots are mainly composed of low fruit weight varieties. The pit weight of these apricots was changed between 3.6 g (Ziraat Okulu) and 1.4 g (Kayseri P.A.). The largest kernel weight (0.9 g) was determined for Ziraat Okulu and the lowest (0.3 g) being for Akçadag Gunay, Dortyol 2, K 0616, Kayseri P.A., Ordubat, Sebbiyiki, 31 K 03, 31 K 04 and 31 K 05. Parallel to its economical value, the interest in apricot kernel has increased in recent years. While the large and sweet kernels are being used for direct consumption, the bitter ones find application in pharmaceutical and cosmetic industry (Arı 1999).

As given also in Table 1, the skin ground color of 47 apricot cultivars and types were orange, and the 79 were yellow. The skin and flesh color of Agerik apricot type were white. Also differently from the rest, skin ground color of Hacikiz apricot was yellowish-green and its flesh was cream color. In this study, the kernel taste of 86 cultivars and types was sweet and that of the remaining was bitter. There was large variation both in flesh/pit ratio and TSS. The highest flesh/pit ratio was determined for Aprikoz (Salak), Geç Aprikoz, Guz Aprikozu, and Hasanbey, and the smallest flesh/pit ratio was for Canakkale, Dortyol 1, K3814, Kayseri P.A., Levent and Yerli Izmir. High flesh/pit ratio is a generally desired trait in table-consumed apricots. According to the evaluated chemical characteristics, the total acidity was determined from 1.55% (1295 apricot type) to 0.20% (Hasanbey). The total soluble solids of cultivars and types studied here, ranged from 27.0 (clon 30 of Hacıhaliloglu) to 11.0 (1295 apricot type). The highest yield ($\geq$100 kg/tree) was found for Aprikoz (Salak), Turfanda-E.M. and Tokaloglu-Yalova, and the lowest yield ($\leq$20 kg/tree) was determined for K 3816, Kayısı Erigi, and Zerdali 2.

Table 1. Description of apricot cultivars.

Varieties	TS	BBS	BS	HS	LFS	FW	PW	KW	SGC	FC	KT	FPR	BRİX	TA	Y
Ablugoz-Izmir	1	2	3	3	3	41.7	2.9	0.6	1	1	1	13.4	20.5	0.97	50.5
Abuzer Gulen	1	2	3	3	2	24.5	1.7	0.4	1	1	1	13.4	15.0	1.05	28.9
Adilcevaz 1	1	1	2	2	2	33.7	2.3	0.5	1	1	2	13.7	21.9	0.75	88.3
Adilcevaz 2	1	1	2	2	2	30.4	1.9	0.4	1	1	2	15.0	14.0	1.15	67.8
Adilcevaz 3	1	1	2	2	3	29.5	2.0	0.4	1	1	2	13.8	18.2	0.80	69.9
Adilcevaz 4	1	1	2	3	3	35.8	2.1	0.4	1	1	2	16.1	21.5	0.60	61.7
Adilcevaz 5	1	1	2	3	2	38.7	2.4	0.5	1	1	1	15.1	26.0	0.57	62.1
Agcenebat	1	2	2	3	3	52.2	3.0	0.7	1	1	2	16.4	17.0	1.15	46.6
Agerik	1	2	2	2	2	43.0	2.5	0.6	3	3	1	16.2	16.6	1.20	71.4
Akçadag Gunay	1	1	3	3	2	26.3	1.9	0.3	1	1	1	12.8	18.0	0.73	52.9
Alioglu	2	2	2	3	2	24.8	1.8	0.4	1	1	2	12.8	17.0	0.88	54.0
Alyanak	2	2	2	2	2	45.5	2.7	0.6	2	2	2	15.9	14.0	1.05	62.5
Amasya-Izmir	2	1	3	2	2	45.7	2.4	0.5	1	1	1	18.0	19.0	0.80	43.0
Aprikoz (Salak)	1	2	2	2	2	62.6	2.6	0.6	1	1	1	23.1	18.6	0.45	102.0
Armeniaca 11	2	1	1	2	3	33.3	2.4	0.5	1	1	1	12.9	18.0	0.71	27.0
Artvin P.A	2	2	3	3	3	31.4	2.3	0.6	1	1	1	12.7	15.0	1.20	68.0
Beyaz Meyveli	1	2	3	2	2	29.3	2.2	0.5	1	1	1	12.3	18.9	0.93	43.0
Canakkale	2	2	2	3	2	27.3	2.3	0.5	2	2	1	10.9	17.0	1.25	35.5
Cataloğlu	1	2	2	3	3	29.5	1.8	0.4	1	1	1	15.4	25.9	0.28	69.6
Cekirge 52	1	2	2	2	2	44.0	2.7	0.6	2	2	2	15.3	16.0	1.10	85.9
Cigli	2	1	3	2	2	28.9	1.7	0.4	2	1	1	16.0	15.3	1.35	64.3
Cologlu	2	2	2	3	3	35.1	2.2	0.5	1	1	1	15.0	22.2	0.36	57.3
Dortyol 1	3	2	2	3	2	20.4	1.6	0.3	1	1	2	11.8	19.0	0.63	21.6
Dortyol 2	3	1	1	2	2	19.5	1.4	0.3	1	1	2	12.9	17.9	0.75	25.5
Dortyol 4	3	1	2	2	2	22.8	1.5	0.3	1	1	1	14.2	14.0	1.05	36.0
Ethembey	2	2	2	2	2	36.4	2.1	0.5	2	2	2	16.3	14.2	1.10	77.4
Guz Aprikozu	1	2	2	6	3	57.2	2.7	0.6	1	1	1	20.2	19.0	0.40	74.6
Gec Aprikoz	1	2	3	5	3	67.6	3.1	0.7	1	1	1	20.8	23.0	0.53	67.4
Hacıhaliloglu	1	2	2	3	3	32.2	2.0	0.4	1	1	1	15.1	26.5	0.35	73.5
Hacıkız	2	2	2	3	3	33.5	2.2	0.5	4	4	1	14.2	21.5	0.45	77.5
Hasanbey	1	2	2	2	2	53.2	2.3	0.8	1	1	1	22.1	20.8	0.20	70.5
Imrahor	2	2	3	2	2	35.6	2.4	0.5	2	1	2	13.8	16.0	1.05	90.8
Iri Bitirgen	1	1	2	2	3	39.2	2.3	0.5	1	1	1	16.0	21.0	0.71	73.6
Ismailaga	1	2	2	3	3	45.2	2.4	0.5	1	1	1	17.8	23.2	0.60	52.0
K 0616	1	1	3	3	3	29.8	1.8	0.3	2	2	2	15.6	16.7	1.15	45.0
K 0618	1	1	3	2	3	34.4	2.2	0.5	1	1	1	14.6	15.3	1.22	20.0
K 0619	1	2	3	3	2	33.8	2.1	0.4	2	1	1	15.1	19.0	1.05	40.0
K 0620	1	3	4	3	3	25.0	2.0	0.4	1	1	2	11.5	13.6	1.30	22.0
K 0621	1	2	3	3	3	39.2	2.4	0.6	2	1	2	15.3	13.3	1.28	25.0
K 3809	1	2	3	3	3	24.5	2.0	0.4	2	2	2	11.3	14.2	1.20	20.0
K 3810	2	1	3	3	2	28.8	1.9	0.4	2	2	2	14.2	19.2	1.08	20.8
K 3811	1	1	2	3	3	45.0	2.9	0.7	2	1	1	14.5	16.4	1.13	15.0
K 3812	1	1	3	3	3	30.4	2.2	0.5	1	1	2	12.8	19.0	0.75	25.6
K 3814	2	1	3	3	3	27.0	2.4	0.6	2	1	2	10.3	16.3	0.80	21.0
K 3816	1	2	3	3	3	50.5	2.9	0.7	1	1	2	16.4	19.0	0.80	18.0
K 4205	2	3	4	3	2	36.8	2.3	0.5	1	1	1	15.0	13.1	1.33	28.0
K 4206	1	1	3	3	2	25.0	1.9	0.4	1	1	1	12.2	20.0	0.68	33.2
K 5001	1	1	3	4	3	32.5	2.0	0.5	1	1	2	15.3	17.9	0.75	21.4
K 5104	2	1	3	3	3	26.9	1.8	0.4	2	2	2	13.9	16.7	0.95	25.0
Kabaası	2	2	3	3	3	35.8	2.2	0.5	1	1	1	15.3	26.2	0.40	62.9
Kamelya-Izmir	1	1	3	3	2	37.7	2.6	0.6	1	1	1	13.5	14.0	1.20	45.0
Kadıoglu	1	2	2	3	3	36.7	2.3	0.4	1	1	1	15.0	25.2	0.38	56.9
Karacabey	1	2	2	3	2	47.8	2.9	0.6	2	2	2	15.5	14.5	1.25	66.4
Kayısı Erigi	2	1	1	3	2	30.1	2.2	0.5	1	1	2	17.3	12.7	1.45	9.5

Continued on next page

Table 1. Continued.

Varieties	TS	BBS	BS	HS	LFS	FW	PW	KW	SGC	FC	KT	FPR	BRİX	TA	Y
Kayseri P.A	1	3	4	3	2	17.0	1.4	0.3	2	2	2	10.3	15.4	1.35	46.6
Kurukabuk	1	2	2	2	3	38.5	2.5	0.5	1	1	1	14.4	15.4	1.40	92.6
Levent	2	2	2	7	3	23.2	2.1	0.5	1	1	1	10.1	16.0	0.85	48.0
Mahmudun Erigi	1	1	2	3	3	41.0	2.5	0.7	1	1	1	15.4	25.7	0.50	65.5
Mektep	2	1	2	3	3	31.0	2.1	0.5	1	1	2	13.8	14.4	0.88	43.2
Mektep-Izmir	2	2	2	3	3	39.7	2.3	0.5	2	2	2	16.3	17.4	0.75	34.0
Ordubat	3	1	2	5	2	26.5	1.5	0.3	1	1	1	16.7	20.6	0.50	25.4
Pasa Mismisi	1	3	2	2	3	41.2	2.4	0.6	1	1	1	16.2	20.7	0.65	51.1
Proyma	2	1	2	2	3	23.6	1.5	0.4	1	1	1	14.7	15.0	1.05	45.7
Proyma-Izmir	2	2	2	2	3	30.5	2.3	0.5	1	1	1	12.3	15.1	1.20	34.0
Sakıt 1	2	1	3	3	2	32.0	1.8	0.4	1	1	1	16.8	19.8	0.75	39.2
Sakıt 2	2	3	4	3	2	25.4	1.8	0.4	1	1	1	13.1	20.5	0.65	33.3
Sakıt 3	2	1	3	2	2	28.3	1.9	0.4	2	2	1	13.9	17.5	0.73	30.0
Sakıt 4	2	1	3	3	2	32.4	2.1	0.5	1	1	1	14.4	22.8	0.55	24.5
Sakıt 7	2	3	4	3	3	33.1	2.0	0.4	1	1	1	15.6	16.0	1.25	36.8
Sam	2	2	2	2	2	33.0	2.0	0.4	2	2	2	15.5	14.1	1.38	60.5
Seftalioğlu	1	2	2	3	3	32.6	1.9	0.4	1	1	1	16.2	18.0	0.85	65.0
Sebbiyki	1	1	1	3	2	26.3	1.9	0.3	2	1	1	12.8	16.0	1.10	52.9
Sekerpare	1	2	3	3	3	25.5	1.8	0.4	1	1	1	13.2	23.9	0.22	92.4
Sogancı	1	2	2	3	3	34.4	1.9	0.4	1	1	1	17.1	25.8	0.33	74.2
Turfanda	1	2	3	1	2	36.6	2.2	0.4	1	1	2	15.6	15.7	1.40	80.0
Turfanda-E.M	1	2	3	1	3	37.9	2.7	0.6	1	1	2	13.0	15.1	1.35	109.0
Tokaloglu-Eregli	1	2	2	3	3	37.0	2.5	0.5	2	1	1	13.8	18.2	1.10	70.5
Tokaloglu-Erz.	1	2	2	3	3	41.8	2.2	0.5	1	1	1	18.0	17.5	1.18	70.1
Tokaloglu-Izmir	1	1	3	2	3	38.7	2.8	0.6	2	2	1	12.8	15.9	1.25	37.5
Tokaloglu-Yalova	1	2	2	2	3	38.2	2.4	0.5	2	2	2	14.9	16.0	1.25	104.3
Yeğen-E.M.	1	2	2	3	3	29.7	2.2	0.4	1	1	1	12.5	22.9	0.40	54.7
Yerli Izmir	1	1	1	2	2	28.1	2.4	0.6	2	1	1	10.7	18.5	0.65	39.0
Zerdali 1	1	2	2	3	3	24.1	2.0	0.4	2	2	1	11.1	20.0	0.55	75.2
Zerdali 2	1	2	3	3	3	33.2	2.1	0.4	1	1	2	14.8	21.0	0.65	19.7
Zerdali 3	1	2	2	3	2	37.9	2.6	0.5	2	1	2	13.6	17.0	0.80	29.0
Zerdali 6	1	2	3	3	3	27.2	2.1	0.4	1	1	2	12.0	16.9	0.80	21.5
Zerdali 8	1	2	2	3	3	29.2	1.9	0.4	1	1	1	14.4	21.0	0.45	25.0
Ziraat Okulu	2	2	2	2	2	68.0	3.6	0.9	2	1	2	17.9	15.5	0.95	68.4
62 K	1	1	1	3	3	32.0	2.4	0.5	1	1	2	12.3	15.5	1.10	25.9
63 K	1	2	3	3	2	48.9	2.9	0.6	2	2	2	15.9	12.0	1.45	48.9
64 K	1	3	3	3	3	26.3	1.9	0.4	2	2	1	12.8	22.6	0.45	30.2
65 K	1	2	3	3	2	21.8	1.6	0.4	2	1	2	12.6	18.8	0.70	25.3
67 K	1	3	3	3	2	27.3	2.0	0.5	2	2	1	12.7	17.1	0.73	48.0
68 K	1	2	3	3	3	30.3	2.3	0.5	2	1	1	12.2	16.1	1.20	20.8
69 K	2	1	3	3	2	33.9	2.1	0.5	2	1	1	15.1	21.4	0.40	39.7
693 K	1	3	4	3	2	39.8	3.0	0.7	1	1	2	12.3	14.0	1.15	74.8
691	1	1	3	3	3	30.1	1.8	0.4	2	2	1	15.7	16.0	1.22	35.0
692	2	1	3	3	3	29.9	1.8	0.4	1	1	1	15.6	20.0	0.75	34.0
1295	2	1	3	3	3	33.8	2.5	0.6	2	2	1	12.5	11.0	1.55	32.7
1297	2	1	2	3	3	41.9	2.7	0.6	2	2	1	14.5	13.9	1.35	35.0
1298	1	2	3	3	3	34.4	1.9	0.4	2	2	1	17.1	13.0	1.30	22.0
1342	1	1	1	2	2	34.8	2.0	0.4	1	1	1	16.4	14.4	1.30	33.0
1343	1	1	2	4	3	41.8	2.6	0.6	2	2	1	15.1	18.0	0.97	30.7
1345	2	1	2	4	3	32.2	2.1	0.4	2	2	1	14.3	17.5	0.70	45.9
1346	2	1	2	3	3	34.5	2.2	0.5	2	2	1	14.7	20.0	0.80	28.0
1364	1	2	3	3	3	27.6	2.2	0.5	1	1	1	11.5	19.0	1.05	23.5
1860	1	1	3	4	2	35.4	2.4	0.5	2	2	1	13.8	19.0	1.20	38.0
3803	1	2	2	2	3	35.2	2.4	0.6	1	1	1	13.7	14.5	1.25	40.5
3808	1	1	1	3	3	38.2	2.3	0.5	2	2	1	15.6	20.6	0.70	30.7

Continued on next page

Table 1. Continued.

Varieties	TS	BBS	BS	HS	LFS	FW	PW	KW	SGC	FC	KT	FPR	BRİX	TA	Y
4201	1	2	3	3	3	33.0	2.1	0.5	1	1	2	14.7	19.0	0.55	20.0
4202	1	2	3	3	3	37.8	2.4	0.6	2	2	1	14.8	21.1	0.50	31.0
4203	3	1	1	3	2	22.1	1.6	0.4	2	2	2	12.8	16.3	1.20	27.0
5103	3	3	4	2	3	26.0	1.8	0.5	2	2	1	13.4	14.0	1.30	55.2
07 K 09	2	1	2	3	2	27.3	2.1	0.5	1	1	1	12.0	18.0	0.95	26.4
07 K 11	2	1	1	3	2	23.3	1.7	0.4	2	2	1	12.7	18.0	1.05	39.3
07 K 14	2	1	2	3	2	27.9	2.0	0.5	1	1	1	13.0	15.4	1.20	23.7
07 K 15	2	1	2	3	2	23.0	1.9	0.4	1	1	1	11.1	18.0	1.10	25.5
31 K 03	2	1	3	3	2	23.6	1.5	0.3	1	1	1	14.7	19.5	0.90	48.5
31 K 04	2	1	3	2	2	27.2	1.6	0.3	1	1	1	16.0	15.0	1.05	23.0
31 K 05	2	1	2	3	2	22.9	1.5	0.3	1	1	1	14.3	18.8	0.75	24.0
01 K 12	2	1	3	3	3	22.8	1.6	0.4	2	2	2	13.3	17.3	0.80	28.0
01 K 13	2	1	3	2	2	32.5	2.5	0.6	1	1	1	12.0	16.0	1.14	23.0
14 Hacıhaliloglu	1	3	4	3	3	26.5	2.0	0.4	1	1	1	12.3	25.9	0.35	43.0
28 Hacıhaliloglu	1	2	2	3	3	25.0	1.7	0.4	1	1	1	13.7	24.0	0.30	60.5
25 Hacıhaliloglu	1	2	2	3	3	22.5	1.5	0.4	1	1	1	14.0	25.9	0.35	53.0
30 Hacıhaliloglu	1	1	1	4	3	35.3	2.4	0.6	1	1	1	13.7	27.0	0.30	69.3
31 Hacıhaliloglu	1	2	2	3	2	26.9	2.0	0.5	1	1	1	12.5	25.0	0.42	79.5
34 Hacıhaliloglu	1	2	2	4	3	26.0	1.7	0.4	1	1	1	14.3	25.5	0.40	95.3

Abbreviations: TS, tree size; BBS, bud break season; BS, blossom season; HS, harvest season; LFS, leaf fall season; FW, fruit weight; PW, pit weight; KW, kernel weight; SGC, skin ground color; FC, flesh color; KT, kernel taste; PFR, flesh/pit ratio; BRIX, total solids soluble; TA, total acidity; Y, yield.

Table 2. Correlation matrix among variables studied.

	TS	BBS	BS	HS	LFS	FW	PW	KW	SGC	FC	KT	FPR	BRIX	TA	Y
TS	1	−0.227	−0.095	−0.017	**−0.305***	−0.243	**−0.316***	**−0.296***	0.031	−0.057	0.051	−0.012	−0.031	0.130	**−0.354***
BBS	–	1	−0.138	−0.003	0.146	0.187	0.188	0.140	−0.037	−0.003	0.138	0.062	0.025	−0.037	−0.212
BS	–	–	1	−0.089	−0.044	−0.211	−0.115	−0.135	0.164	0.141	0.039	−0.234	−0.177	0.189	**−0.431***
HS	–	–	–	1	0.226	−0.135	−0.114	−0.103	0.013	0.043	−0.159	−0.085	**0.307***	**−0.335***	−0.228
LFS	–	–	–	–	1	0.065	0.119	0.110	−0.100	0.069	−0.095	−0.038	0.231	−0.197	0.020
FW	–	–	–	–	–	1	**0.823***	**0.705***	0.079	0.117	0.039	**0.674***	−0.070	0.040	**0.391***
PW	–	–	–	–	–	–	1	**0.855***	0.164	0.139	0.096	0.164	−0.180	0.198	0.200
KW	–	–	–	–	–	–	–	1	0.084	0.093	0.033	0.155	−0.121	0.120	0.159
SGC	–	–	–	–	–	–	–	–	1	**0.709***	0.150	−0.095	**−0.330***	**0.309***	−0.138
FC	–	–	–	–	–	–	–	–	–	1	0.085	0.003	−0.221	0.235	−0.077
KT	–	–	–	–	–	–	–	–	–	–	1	−0.048	**−0.347***	**0.263***	−0.020
FPR	–	–	–	–	–	–	–	–	–	–	–	1	0.072	−0.127	0.218
BRIX	–	–	–	–	–	–	–	–	–	–	–	–	1	**−0.870***	0.240
TA	–	–	–	–	–	–	–	–	–	–	–	–	–	1	−0.163
Y	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1

*Correlations significant ($p < 0.05$). Abbreviations: TS, tree size; BBS, bud break season; BS, blossom season; HS, harvest season; LFS, leaf fall season; FW, fruit weight; PW, pit weight; KW, kernel weight; SGC, skin ground color; FC, flesh color; KT, kernel taste; PFR, flesh/pit ratio; BRIX, total solids soluble; TA, total acidity; Y, yield.

Correlation among variables

No significant correlation was found considering phenologic variables such as bud break, blossom and harvest season (Table 2). Each variety was determined to be distinct with respect to the period from blossom to harvest season. These were contrary to the results of Badenes et al. (1998) who reported there was a high correlation ($r = 0.87$) between bud break and blossom season and also a correlation (to a lesser extent) between bud break and harvest season ($r = 0.79$). The apricot cultivars

used in their study were, however, from European ecogeographical group.

The correlation coefficients found for tree size, leaf fall season, pit weight, kernel weight, and yield were $r = -0.305$, -0.316, -0.296 and -0.354, respectively. The trees with smaller in size were also determined to have lower fruit yield, small pit and kernel. There was a negative correlation ($r = -0.431$) between blossom season and yield, indicating that trees with late blossoming had lower fruit yield.

Contrary to non-significant correlations found for phenological characteristics, the pomological characteristics of varieties studied here were highly correlated. This was $r = 0.823$ between fruit weight and pit weight. The same coefficient between fruit and kernel weight, and flesh/pit ratio was determined as $r = 0.705$ and 0.674, respectively. These could be justified as fruits with larger in size would also have larger pits, kernels and also higher flesh/pit ratio. The correlation between fruit weight and yield was determined to be $r = 0.391$. There was no direct correlation between fruit weight and TSS and also acidity levels. While, the correlation between skin ground color and flesh color was $r = 0.709$, the TSS and acidity were correlated negatively ($r = -0.870$), indicating a decrease in acidity parallel to increase in TSS. Byrne et al. (1991) found correlations between firmness, TSS, total acidity, and color attributes among peach cultivars. A study with apricots from European ecogeographical group, however, showed that these correlations were not found among the same fruit quality traits in apricot (Badenes et al. 1998). The differences between our results and that of Badenes et al. (1998) can be explained by different ecogeographical group apricots and the different size of the group of cultivar studied.

Table 3. Eigenvalues and proportion of total variability among apricot genotypes as explained by the first 10 principal components.

PC	Eigenvalue	Percent var.	Cumulative
1	7.393	49.283	49.283
2	1.836	12.241	61.525
3	1.227	8.178	69.703
4	0.995	6.662	76.335
5	0.778	5.187	81.522
6	0.688	4.585	86.107
7	0.591	3.941	90.048
8	0.516	3.437	93.486
9	0.284	1.893	95.379
10	0.185	1.586	96.964

Table 4. Correlation between original variables and the first eight PC.

Variable/factor	PC 1	PC2	PC3
Fruit weight (FW)	0.9650	−0.0001	0.0873
Pit weight (PW)	0.9530	−0.0885	0.1140
° Brix	0.9070	−0.1420	0.0224
Kernel taste (KT)	0.8920	0.2450	−0.0248
Leaf fall season (LFS)	0.8660	0.1990	−0.0102
Yield (Y)	0.8590	−0.0322	0.1270
Total acidity (TA)	0.7600	0.2550	−0.0347
Kernel weight (KW)	0.6412	0.1111	0.2152
Flesh/pit ratio (FPR)	0.2740	0.9230	−0.0267
Harvest season (HS)	−0.1472	0.0851	0.9750
Blossom season (BS)	0.1340	0.1420	0.0882
Flesh color (FC)	0.0705	0.0035	0.2141
Tree size (TS)	0.0897	0.0666	0.0365
Bud break season (BBS)	0.4379	0.1692	0.0238
Skin ground color (SGC)	−0.1230	−0.0257	0.0725

Principal component analysis

More than ninety per cent of the variability observed was explained by the first seven components (PC1–PC7) (Table 3). PC1 represents mainly fruit weight, pit weight, kernel weight, TSS, kernel taste, leaf fall season, yield, total acidity and account for 49.283% of the variance. Apricots with low fruit weight and total acidity and also high TSS were found in negative side of PC1. The apricots with high fruit weight and total acidity and low TSS were found to be condensed in positive PC1. PC2 represents flesh/pit ratio and account for 12.241% of the variance. Positive PC2 values indicate higher flesh/pit ratio apricots. PC3 represents harvest season and account for 8.178% of the variance. The late ripening apricots were determined in negative PC3 and early ripening apricots in positive PC3. Composing about 70% of total variance, these three components (PC1, PC2, and PC3) were further investigated. The rest of components (PC4–PC10) varied to a lesser extent (27.3% of total variance) and they were not further considered in this study. Table 4 shows the correlations between

the original variables and the first three principal components.

It is suggested that, although it will cause some missing in information, the use of first three principal components, which represent 70% of total variance, will save considerable time (since a few characteristics are studied) for identification of apricot germplasms.

Conclusion

This study was undertaken to determine some pomological and phenological characteristics of apricot germplasm belonging to Irano-Caucasian ecogeographical group from this region where 80% world dry apricot export originates. It has been determined that apricot germplasm from this group shows a wide variation in their harvest season, fruit yield, TSS, total acidity, fruit, pit, and kernel weight. One of the important findings of this study is that, among 128 cultivars and types studied only 7 were determined to have a fruit weight 50 g or above. This result shows that, most of the cultivars possessed a relatively small fruit weight and breeding studies to improve fruit size will be helpful in this respect. Also, this Irano-Caucasian group apricots were determined to have yellow skin ground color and flesh color with mostly sweet kernels and high TSS that naturally contributes to production of dry apricot processing.

The main factor determining the production of fresh fruit in these germplasm is late spring frosts and brown rot disease (*Monilia laxa*). A study involving the improvement of resistance of trees from this germplasm has been initiated in 1990 and continuing. Also, in this germplasm there are early and late ripening but low quality fruit variety and types. In this context, the use of Levent apricot type as a parental strain may find application for the extension of ripening period, and our hybridization studies are still underway.

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