TÜBİTAK

Research Article

Turk J Agric For
36 (2012) 688-694
© TÜBİTAK
doi:10.3906/tar-1111-14

Morphological diversity of the Turkish apricot (*Prunus armeniaca* L.) germplasm in the Irano-Caucasian ecogeographical group

Kadir Uğurtan YILMAZ[1,*], Sevgi PAYDAŞ KARGI[2], Salih KAFKAS[2]

[1]Department of Horticulture, Faculty of Agriculture, Erciyes University, 38039 Melikgazi, Kayseri – TURKEY

[2]Department of Horticulture, Faculty of Agriculture, Çukurova University, 01330 Balcalı, Adana – TURKEY

Received: 14.11.2011 ● Accepted: 26.04.2012

Abstract: Apricot germplasm collection and characterization are the essential stages of breeding programs for diversity. Traditionally, germplasm collection and characterization are performed by describing phenological, pomological, and morphological characteristics of the germplasm. In this study, 93 apricot accessions and 1 apricot × plum hybrid (Kayısı Eriği) were collected from different regions of Turkey and were evaluated for 57 morphological UPOV (International Union for the Protection of New Varieties of Plants) characteristics, along with 13 pomological traits. Turkish apricot trees were generally found to be either strong (29.8%) or very strong (54.3%). Only 12 accessions (GÜ-52, Çanakkale, Çekirge-52, Karacabey, Geç Aprikoz, Güz Aprikozu, Alyanak, Hasanbey, Alkaya, Paşa Mişmişi, Ağerik, and Ziraat Okulu) had large fruits. Of the total 93 specimens, 67 accessions did not exhibit kernel bitterness. Important dried cultivars of Turkey contain more than 25% total soluble solids (TSS). The harvest period of the majority (84 accessions) started at the end of June and lasted until mid-July. Principle coordinate analysis (PCoA) and principle component analysis (PCA) revealed that eigenvalues of the first 3 components were able to represent 32.67% of total variance in PCoA and 23.63% of total variance in PCA. The eigenvalue of pomological PCA analysis was able to represent 73% of total variance. Significant negative correlations were determined among fruit juice acidity, TSS, and pH. The morphological distance index between Turkish apricots varied from 0.21 to 0.79. Information revealed in this study may be useful for both breeders and apricot breeding programs.

Key words: Genetic resource, collection, UPOV, apricot breeding, PCA, PCoA

Introduction

The apricot is one of the most cultivated stone fruits in the world (Hurtado et al. 2002; Vilanova et al. 2003; Ercisli 2009). It belongs to the family Rosaceae, the genus *Prunus* L., the subgenus *Prunophora* Focke, and the section *Armeniaca* (Lam.) Koch (Rehder 1967). There are 4 different species and 1 naturally occurring interspecific hybrid under the generic term of apricot. These are: *P. armeniaca* L., the cultivated apricot; *P. sibirica* L., the Siberian apricot; *P. mandshurica* (Maxim.) Koehne, the Manchurian apricot; *P. mume* (Siebold) Siebold & Zucc., the Japanese apricot; and *Prunus* × *dasycarpa* Ehrh., the black or purple apricot. Among them, *P. armeniaca* is the most widely cultivated (Mehlenbacher et al. 1990; Hormaza 2002; Ercisli 2004; Altındağ et al. 2006; Uzun et al. 2007; Yılmaz et al. 2009; Uzun et al. 2010).

Turkey is one of the major apricot producing countries in the world, although it is not the genetic origin of the apricot. Apricots are widely grown all

* E-mail: ugurtanyilmaz@yahoo.com

around Anatolia, except for the extremely rainy Eastern Black Sea Region and the very high and cold areas of the East Anatolia Region. Because of the presence of different apricot cultivars and types that are adaptable to different ecological conditions, apricot production is possible in many areas, from the coast to inland regions. Generally, the table apricot varieties are grown in southern and western regions (Mediterranean, Aegean, and Marmara regions) of Anatolia, while the dried varieties are predominantly grown in the inner regions (Ercisli 2009). Apricot is a good source of revenue for the producer, has been cultivated for many years, and has created highly variable genetic resources in Anatolia (Yılmaz 2008).

The development of new fruit cultivars generally has been based on genetic resources. Germplasm collection and characterization are essential stages of breeding programs. Main germplasm collection and characterization are performed by describing phenological, pomological, and morphological characteristics such as tree vigor and growth habit, fruit quality features, leaf, stone, flower, stigma and stylus, pollen, blooming, and harvest time.

Comparing and combining the results of characterization research published by different groups is a difficult task, since separate morphological, phenological, and pomological characteristics have been assessed by those research groups. These difficulties often limit the use of reported data from these authors. The international criteria of the International Union for the Protection of New Varieties of Plants (UPOV) and the International Plant Genetic Resources Institute (IPGRI) were created in order to remove this unclear situation and to enable researchers to use common descriptive characteristics. Therefore, a wide range of morphological criteria included in the international UPOV apricot guidelines (TG/70/4, 06.04.2005) were taken into consideration in the present study. Additionally, 13 common pomological characteristics were used to describe Turkish apricot accessions. The data from morphological and pomological traits were evaluated statistically by using principle component analysis (PCA), principle coordinate analysis (PCoA), standard deviation, correlation, and morphological distance index.

Materials and methods

Plant materials and experimental design

A total of 93 apricot accessions and 1 apricot × plum accession, collected from different regions of Turkey and preserved at the Apricot Research Station in Malatya, were used (Figure) as the plant material of this study. Pomological analysis and morphological characterization of the accessions were carried out for 3 years, in 2004, 2005, and 2006. A total of 30 fruits (10 fruits from each tree) were examined for the assessment of fruit quality criteria.

Assessment of pomological and morphological characteristics

The UPOV descriptor list (UPOV Apricot Guideline TG/70/4 – 06.04.2005) was used for morphological characterization. A total of 70 criteria in the UPOV apricot descriptor were assessed for the 94 accessions, including 13 common pomological features {fruit size [fruit thickness (FT), fruit height (FH), fruit width (FWD)]; fruit weight (FW) and stone weight (SW); flesh firmness (FF); total soluble solids (TSS); L, a, and b color values; acidity (AC); and flesh-to-stone ratio (FSR)} and 57 morphological features (7 related to tree, 16 to leaf, 4 to flower, 25 to fruit, 3 to stone, and 2 to phenology). Pomological and morphological data were not provided here due to the abundance of data.

Statistical analysis

PCoA and PCA were performed over the data obtained from the assessment of morphological and pomological characteristics. The SAS software package (SAS version 8.02, SAS Institute, Cary, NC, USA) was used to evaluate the correlations between pomological characteristics. Morphological distance indexes were calculated by using NTSYSpc 2.11V (Rohlf 2004) and a dendrogram was obtained by using UPGMA (unweighted pair group method with arithmetic mean) cluster analysis method.

Results

Morphological and pomological characteristics of Turkish apricot accessions

According to the morphological characteristics (UPOV), Turkish apricot trees were generally found to be "strong" (29.8%) or "very strong" (54.3%).

Fourteen accessions showed "medium vigor", while only Ordubat trees had "weak vigor" among all genotypes. The Ordubat apricot cultivar, which is not suitable for fresh consumption, has cracks in its fruit and is dryable on the tree (Yılmaz 2008). Ordubat may serve as an available cultivar for dwarf apricot orchards as a seedling rootstock due to its poor habitus.

Tree habitus of apricots in general has been clustered under the UPOV classes of "upright to spreading" (25.5%), "spreading" (41.5%), and "drooping" (13.8%). Among the studied apricots, only Kayısı Eriği showed the "fastigiate" canopy feature. The Kayısı Eriği tree looks like other plum trees, and it is almost impossible to distinguish without the fruits on it. Kayısı Eriği is a hybrid plant and can only be identified by observing the fruit's morphological characteristics. Since it is an apricot × plum hybrid, it can be said that the fastigiate characteristic of Kayısı Eriği comes completely from the plum. Unlike Kayısı Eriği, apricot tree growth habits are very different from each other. Dörtyol-1, Sakıt-1, Sakıt - 2, Adilcevaz-2, Şekerpare Iğdır, and Ordubat were determined to have a "weeping" habitus.

Turkish apricot trees mostly have a "strong" branching degree (89.4%). Only Ordubat and Sakıt - 1 showed weaker growth with less branching than the others. All accessions showed an equal "distribution of flower buds". This was mostly due to the maturity (approximately 40 years old) stages of the trees. Investigation of younger trees will probably provide much more accurate results.

Apricot "flower diameters" varied equally from medium (47.9%) to large (47.9%). Only 4 accessions (Ablugoz, Tevfik Yıldırım, Levent, Kayısı Eriği) have small flowers.

With regard to "fruit size", 4 accessions (92-23-02, Kayseri (PA), Hırmanlı, Tekeler) had very small, 14 accessions (01-K-12, 31-K-03, 31-K-04, Sakıt-2, Sakıt-4, Dörtyol-1, Dörtyol-4, 92-58-03, Kadıoğlu-12, Tevfik Yıldırım, Akçadağ Günay, Sivas (PA), Kurukabuk, Proyma) had small, 12 accessions (GÜ-52, Çanakkale, Çekirge-52, Karacabey, Geç Aprikoz, Güz Aprikozu, Alyanak, Hasanbey, Alkaya, Paşa Mişmişi, Ağerik, Ziraat Okulu) had large, and the remaining 64 accessions had medium-sized fruits. Ağerik did not show "fruit pubescence", but it showed medium "fruit glossiness". However, pubescence and fruit glossiness were quite evident for Alkaya and Soğancı.

Karacabey, Sivas (PA), Kadıoğlu-12, and Abuzer Gülen had a medium orange ground color. While Hatay's apricots such as Dörtyol-1, Dörtyol-4, Sakıt-1, Sakıt-2, Sakıt-3, İri Bitirgen, Kamelya, GÜ-8, Zerdali No. 1, Mahmudun Eriği, and Kayısı Eriği gave quite good results for "relative area of over color" of fruits, these accessions were grouped in the UPOV group of "dark intensity of over color" except for Dörtyol-1. Fruits showed a generally solid flush over color pattern (92.5%). There were no accessions with whitish green flesh color. Only 3 apricots (07-K-15, GÜ-52, Çekirge-52) had dark orange "fruit flesh color".

"Adherence of seeds to flesh" of fruits was not observed, and the kernels of 67 apricots were not bitter. Recently, sweet kernels have been used for direct consumption as a snack food like almond; similarly, the bitter kernels are used in the pharmaceutical and cosmetics industries (Arı 1999).

Other results showed that Ordubat had low flesh firmness. The taste of Kayısı Eriği was like a plum. Important dried cultivars of Malatya had more than 25% TSS. In contrast, some apricots like Ziraat Okulu, Hırmanlı, and Karacabey had low TSS values.

During the 3-year experiment, the same apricots had the highest and the lowest acidity values. While Hacıkız had the lowest titratable AC, Abuzer Gülen had the highest AC value.

In addition, Adilcevaz-2, Mehmet Yüksel 1860, GÜ-2, and Tokaloğlu Erzincan showed absolute periodicity.

Statistical analysis

PCoA and PCA analysis

SAS software was used to evaluate UPOV morphological descriptor data. Both PCoA and PCA were performed due to the categorical nature of the data. For both analyses, eigenvalues for the first 3 components of the 57 criteria and their cumulative variations (%) were calculated. Eigenvalues and cumulative variations calculated in PCoA and PCA are not presented here as tables due to the huge size of the tables.

Results revealed that eigenvalues of the first 3 components were able to represent 32.67% of the total variability in PCoA and 23.63% of the total variability in PCA. Fruit size (0.297) was found to be the most significant characteristic for principle component 1 (PC1), depth of fruit suture (0.331) for principle component 2 (PC2), and leaf blade length (0.301) for principle component 3 (PC3).

PCA results indicated that the eigenvalue was able to represent 73% of the total variability (Table). Fruit thickness (0.397), fruit weight (0.391), fruit height (0.382), fruit width (0.380), and flesh-to-stone ratio (0.361) were found to be significant variables of PC1. The pH (–0.454) and acidity (0.440) were highly correlating variables with PC2. The b color value (0.724) and L color value (0.611) were found to be significant traits for PC3.

Table. The principle components (PCs) for the Turkish apricots accessions analyzed for 13 pomological traits in Malatya.

Traits	PC1	PC2	PC3
Fruit thickness	0.397	0.146	–0.032
Fruit height	0.382	0.179	–0.038
Fruit width	0.380	0.216	0.013
Fruit weight	0.391	0.205	–0.158
Fruit firmness	0.114	–0.055	0.106
Total soluble solids	0.130	–0.376	0.023
pH	0.225	–0.454	0.049
Acidity	–0.196	0.440	0.179
L	0.217	–0.138	0.611
A	–0.211	0.279	–0.114
B	–0.015	0.190	0.724
Kernel weight	0.241	0.402	–0.087
Flesh-to-stone ratio	0.361	–0.140	–0.089
Eigenvalue	5.23	2.92	1.52
Proportion (%)	40.00	22.00	11.00

Correlation among pomological traits

Correlations between pomological traits were observed, but these data are not given in tables in this article. Correlations between fruit weight and fruit size and between fruit weight and flesh-to-stone ratio were found to be significant. While correlations between fruit firmness and fruit height were found to be significant, correlations between fruit firmness and the others features were not significant. In this study, although significant negative correlations were observed among fruit thickness, acidity, and color value, there were significant positive correlations among 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. There were correlations between the L and the a and b color values, but there was no correlation between the a and b values themselves.

Morphological distance between Turkish apricots

Unweighted pair group method with arithmetic mean (UPGMA) cluster analysis revealed distance indexes between 0.21 and 0.79. A total of 93 apricot genotypes and 1 plumcot genotype were examined for morphological distance. The closest apricots were Şekerpare and Şekerpare Benzeri (0.21); 07-K-09 and 07-K-14 (0.21); Sakıt-2 and Dörtyol-1 (0.23); 92-58-01 and Adilcevaz-4 (0.23); Kabaaşı and Çataloğlu (0.23); Mahmudun Eriği and Adilcevaz-5 (0.23); Proyma and Akçadağ Günay (0.23); Tekeler and Hırmanlı (0.23); Hacıhaliloğlu and Şeftalioğlu (0.25); Hacıhaliloğlu and Zerdali No. 1 (0.25); Hacıhaliloğlu and Mahmudun Eriği (0.25); Dörtyol-1 and 31-K-03 (0.25); Şam and Tokaloğlu Yalova (0.25); 92-58-01 and 92-58-03 (0.25); Hacıhaliloğlu and Çataloğlu (0.26); Zerdali X1 and Akçadağ Günay (0.26); 92-58-02 and Adilcevaz-4 (0.26); Sakıt-2 and Sakıt-4 (0.26); Hacıhaliloğlu and Kabaaşı (0.28); and Hacıhaliloğlu and Kurukabuk (0.28). The furthest ones were Ağerik and Turfanda Eski Malatya (0.74); Ağerik and Kadıoğlu-12 (0.77); Tekeler and Ağerik (0.77); and Karacabey and Ağerik (0.79).

According to the analysis of the morphological index, all of the apricots were distinguishable from one another. The dendrogram had 2 main groups. The first group had several subgroups. The second group consisted of GÜ-52, Güz Aprikozu, Geç

Aprikoz, Ordubat, and Ağerik. Kayısı Eriği was an out-grouper in the first group (Figure). Although the apricots showed heterogeneous distribution for origin in the first subgroup, Şekerpare Iğdır, Şekerpare Benzeri, Şekerpare, Sakıt-1, Sakıt-2, Sakıt-4, the 92-58 group, and the Adilcevaz group were gathered in the first sub-subgroup of the second subgroup. Adilcevaz-4 and apricots of the 92-58 group were in same subgroup. It is obvious that apricots of the 07-K group are gathered in the second sub-subgroup of the second subgroup as a different group. Well-known apricots of Malatya such as Hacıhaliloğlu, Çataloğlu, Kabaaşı, Soğancı, Hasanbey, and Alkaya were gathered in same subgroup, as well. Mahmudun Eriği and Adilcevaz-5 found a place in this group. Apricots with very small fruits like Kayseri (PA), Tekeler, Hırmanlı, and 92 - 23 - 02 were also gathered in the same group (Figure).

Discussion

The present study can be claimed as the most comprehensive morphological study on Turkish apricot genetic resources for breeding programs.

Asma and Ozturk (2005) reported that 128 Turkish apricots located in the Irano-Caucasian ecogeographical group generally had low fruit weight and exhibited high variations in harvest season, yield, TSS, total acidity, and fruit and kernel features. The authors reported that the fruit weight of only 7 apricots was over 50 g, and the others had lower fruit weights. According to the researchers, fruit ground color and flesh color of accessions were generally yellow and also had high TSS. Levent apricots needed 190–200 days for maturation. Therefore, it was the latest ripening apricot. Results of the current study are in good agreement with the findings of the aforementioned researchers.

Gülcan et al. (2006) reported that Ağerik had the highest fruit weight and Hacıkız had lowest; Abuzer Gülen had the highest acidity value; Ziraat Okulu had the lowest TSS; and Levent and Özal exhibited the latest ripening. These findings are also parallel to the results of current study.

Among all the components of the morphological data, 21 had a value of over 0.190 in the first 3 components in PCoA and PCA. Eigenvalues of these components represented 54.10% of total variability in PCoA and 48.25% of total variability in PCA. Harrison et al. (1997), Lavin (1997), Catling and Porebski (1998), and Hancock et al. (2004) used fewer morphological criteria to divide variation in strawberry accessions for morphological characterization. Keleş (2007) reported that 25 morphological characteristics included in PCA might be sufficient to characterize pepper genotypes instead of using 53 morphological traits. PCA results of the present study also revealed that 21 components might be sufficient for morphological characterization of apricots instead of using 57 features.

As observed in PCA for pomological characteristics, the eigenvalue represented 73% of total variability (Table). Asma and Ozturk (2005) found this value as 70% for 15 components (including phenological, pomological, and morphological features) in PCA. Using only 13 pomological traits resulted in a higher value in the present study.

The correlation between stone weight and flesh-to-stone ratio was determined to be low (10%) and not significant. This may be due more to smaller variations in stone weights of the apricot accessions than to variations in fruit weights. These results are parallel with the results of Asma and Ozturk (2005). Those researchers reported different results from those of Badanes et al. (1998), although they studied the same features. Asma and Ozturk (2005) explained this difference as being due to the ecogeographical group. They studied Turkish apricots in the Irano-Caucasian ecogeographical group, but Badanes et al. (1998) studied apricots in the European ecogeographical group.

Cultivated apricot varieties in the world emerged from chance seedlings or breeding programs. Characterization of these varieties is very important for breeders and also for countries generating revenue from apricot production. In addition, correct identification of these varieties is important for fruit culture. Using morphological, physiological,

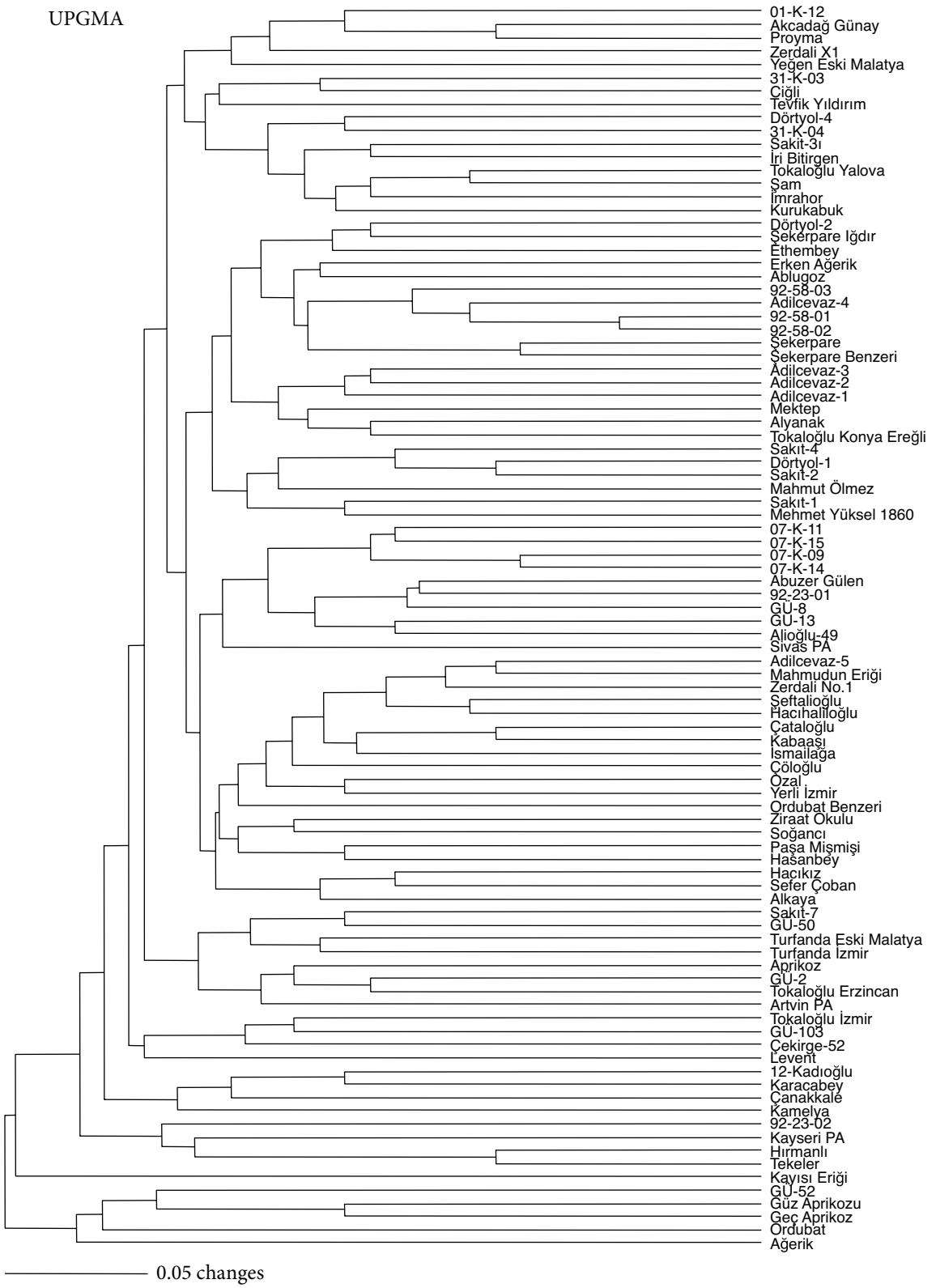

Figure. UPGMA cluster analysis for the Turkish apricots accessions analyzed for 13 pomological and 57 agronomical traits in Malatya.

and biochemical methods in genetic diversity studies requires intensive work. The present study is considered the most comprehensive morphological characterization study ever made for Turkish apricots in the Irano-Caucasian group. The results may serve as a significant reference for the comparison of genetic resources, the characterization of apricot genotypes, and for apricot breeding programs to select the best parents with the highest variation.

Acknowledgments

The authors are grateful to the Scientific and Technological Research Council of Turkey (Project No.: TÜBİTAK 104O1479) and the Çukurova University Academic Research Projects Unit (Project No: ZF2006D15) for financial support; to Dr Sedat Serçe for his help in statistical analysis; and to Dr Kahraman Gürcan for his help in the preparation of the manuscript. Thanks are also extended to Dr Zeki Gökalp for his kind help with the English in the manuscript.

References

Altındağ M, Şahin M, Eşitken A, Ercişli S, Güleryüz M (2006) Biological control of brown rot (*Moniliana laxa* Ehr.) on apricot (*Prunus armeniaca* L. cv. Hacihaliloglu) by *Bacillus*, *Burkholdria*, and *Pseudomonas* application under in vitro and in vivo conditions. Biol Contr 38: 369-372.

Arı N (1999) Kayısı Çekirdeği Yağının Efektif Bileşenleri ve Kullanımı. Yüksek Lisans Tezi. Ankara Üniversitesi, Sağlık Bilimleri Enstitüsü, p. 85.

Asma BM, Ozturk K (2005) Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey. Genet Res Crop Evol 52: 305-313.

Badanes ML, Martinez-Calvo J, Llacer G (1998) Analysis of apricot germplasm from the European ecogeographical group. Euphytica 102: 93-99.

Catling PM, Porebski S (1998) A morphometric evaluation of the subspecies of *Fragaria chiloensis*. Can J Botany 76: 290-297.

Ercisli S (2004) A short review of the fruit germplasm resources of Turkey. Genet Res Crop Evol 51: 419-435.

Ercisli S (2009) Apricot culture in Turkey. Sci Res Essays 4: 715-719.

Gülcan R, Mısırlı A, Sağlam H, Yorgancıoğlu U, Erkan S, Gümüs M, Ölmez HA, Derin K, Paydaş S, Eti S, Demir T (2006) Properties of Turkish apricot land races. Acta Hort 701: 191-198.

Hancock JF, Serçe S, Portman CM, Callow PW, Luby JJ (2004) Taxonomic variation among North and South American subspecies of *Fragaria virginiana* Miller and *Fragaria chiloensis* (L.) Miller. Can J Botany 82: 1632-1644.

Harrison RE, Luby JJ, Furnier GR, Hancock JF (1997) Morphological and molecular variation among populations of octoploid *Fragaria virginiana* and *F. chiloensis* (Rosaceae) from North America. Amer J Bot 84: 612-620.

Hormaza JI (2002) Molecular characterization and similarity relationships among apricot (*Prunus armeniaca* L.) genotypes using simple sequence repeats. Theor Appl Genet 104: 321-328.

Hurtado MA, Romero C, Vilanova S, Abbott G, Llacer G, Badanes ML (2002) Genetic linkage maps of two apricot cultivars (*Prunus armeniaca* L.) and mapping of PPV (Sharka) resistance. Theor Appl Genet 105: 182-191.

Keleş D (2007) Characterization of Different Pepper Genotypes and Low Temperature Tolerance. PhD Thesis. Department of Horticulture, Institute of Basic and Applied Sciences, Çukurova University, p. 174.

Lavin A (1997) Caracterizacion botanica, fisiologica y agronomica de ecotipos Chilenos de *Fragaria chiloensis* (L.) Duch. Recolectados en las X y XI regiones de Chile. El Instituto de Investigaciones Agropecuarias, Santiago, Chile.

Mehlenbacher SA, Cociu V, Hough LF (1990) Apricots (*Prunus*). Acta Hort 290: 63-109.

Rehder A (1967) Manual of Cultivated Trees and Shrubs, 2nd ed. Macmillan, New York.

Rohlf JF (2004) NTSYS-pc: 2.11 Numerical Taxonomy and Multivariate Analysis System. Exeter Software, New York.

Uzun A, Gülşen O, Aka-Kaçar Y, Aras V, Demirel A, Bircan M, Paydaş S, Yıldız A (2007) Characterization of new apricot cultivars by RAPD markers. J Appl Hort 9: 132-135.

Uzun A, Gulsen O, Seday U, Bircan M, Yilmaz KU (2010) SRAP based genetic analysis of some apricot cultivars. Romanian Biotech Letters 15: 5396-5404.

Vilanova S, Romero C, Abbott AG, Llacer G, Badanes ML (2003) An apricot (*Prunus armeniaca* L.) F2 progeny linkage map based on SSR and AFLP markers, mapping Plum Pox Virus resistance and self-incompatibility traits. Theor Appl Genet 107: 239-247.

Yılmaz KU (2008) Phenological, Morphological and Pomological Characteristics of Some Local Apricot Genotypes and Determination of Their Genetic Relationships and Self-Incompatibility by Molecular Markers. PhD Thesis. Department of Horticulture, Institute of Basic and Applied Sciences, University of Çukurova, p. 342.

Yılmaz KU, Ercişli S, Asma BM, Doğan Y, Kafkas S (2009) Genetic relatedness in *Prunus* genus revealed by inter-simple sequence repeat markers. Hort Science 44: 293-297.