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RESEARCH ARTICLE

Relationships among *Crataegus* accessions sampled from Hatay, Turkey, as assessed by fruit characteristics and RAPD

S. Serçe · Ö. Şimşek · C. Toplu · Ö. Kamiloğlu · O. Çalışkan · K. Gündüz · M. Özgen · Y. A. Kaçar

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Abstract The genus *Crataegus* known as hawthorns, is the largest genus among the *Maloideae*, which comprises 265 species. Turkey is one of the genetic centers of *Crataegus* and there are more than 20 species found in Turkey. The fruits of *Crataegus* are used as food and have high flavonoid, vitamin C, glycoside, anthocyanidin, saponin, tannin, and antioxidant levels. In this study, we attempted to characterize 15 *Crataegus* accessions sampled from Hatay, located in Eastern Mediterranean region of Turkey. The accessions belonged to several species; *C. aronia* (L.) DC. var. *aronia*, *C. aronia* var. *dentata* Browicz, *C. aronia* var. *minuta* Browicz, *C. monogyna* Jacq. subsp. *azarella* (Griseb.) Franco, and *C. orientalis* Pall. ex M. Bieb. var. *orientalis*. Fruit characteristics of the accessions exhibited considerable variation. The multivariate, principle component and cluster analyses indicated that the accessions belonged to three groups: (1) *C. aronia* var. *arona* accessions; (2) *C. aronia* var. *dentata* accessions; and, (3) *C. monogyna* subsp. *azarella* and *C. orientalis* var. *orientalis* accessions. The principle component analysis results also revealed that the first three components explained 46, 21, and 14% of the variation, comprising a total of 81%. The fruit length and width, leaf area, and soluble solids contents were highly correlated characteristics for the first three components. The 19 RAPD primers generated a total of 107 bands, where 76 of these were polymorphic. The molecular data analyses by principle coordinate and clustering showed similar results to those of pomological characteristics. There were three groups, (1) *C. aronia* var. *arona* accessions; (2) *C. aronia* var. *dentata* accession; and, (3) *C. monogyna* subsp. *azarella*. *C. orientalis* var. *orientalis* accession grouped with *C. aronia* var. *arona* accessions. Therefore, it can be concluded that, overall, the diversity patterns of pomological and molecular data, generated by RAPD, for *Crataegus* are in good agreement and the accessions of *C. aronia* var. *aronia*, *C. aronia* var. *minuta*, *C. monogyna* subsp. *azarella* and *C. orientalis* var. *orientalis* accessions.

S. Serçe (✉) · C. Toplu · Ö. Kamiloğlu · O. Çalışkan · K. Gündüz
Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University, 31034 Antakya, Hatay, Turkey
e-mail: sedatserce@gmail.com

Ö. Şimşek · Y. A. Kaçar
Biotechnology Department, Institute of Basic and Applied Science, Çukurova University, 01010 Adana, Turkey

M. Özgen
Department of Horticulture, Faculty of Agriculture, Gaziosmanpaşa University, 60240 Taşlıçiftlik, Tokat, Turkey

Y. A. Kaçar
Department of Horticulture, Faculty of Agriculture, Çukurova University, 01010 Adana, Turkey

Keywords *Crataegus aronia* · *C. monogyna* · *C. orientalis* · Genetic resources · Germplasm · Hawthorn

Introduction

Crataegus species are known as hawthorns and are a well-defined genus, traditionally defined as belonging to the tribe *Crataegeae*, subfamily *Maloideae* of the *Rosaceae* (Tutin et al. 1990; Phipps et al. 1991; Lippert 1995). The subfamily *Maloideae* comprises about 28 genera and 940 species of ecologically and economically important trees and shrubs. According to Judd et al. (1999), the genus *Crataegus* is the largest among the *Maloideae* and comprises 265 species, while Christensen (1992) estimated the number of hawthorn species was between 150 to 1,200, with 50 to 100 occurring in Eurasia. The large numbers of species that have been described have made *Crataegus* taxonomy controversial (Evans and Campbell 2002).

Crataegus fruit generally persists on the shrubs throughout winter and represents an important source of food for many birds and small mammals (Courtney and Manzur 1985; Dickinson and Campbell 1991; Guitia'n 1998). In some parts of the world, including Turkey, the hawthorns fruits are also used as food and it is reported that they have high flavonoid, vitamin C, glycoside, anthocynaidin, saponin, tannin, and antioxidant levels (Ljubuncic et al. 2005) as well as phenolics (Schussler and Hölzl 1995; Chang and Zuo 2002).

Turkey is one of the genetic centers for *Crataegus* (Ercsili 2004), but there are few studies that have attempted to describe the *Crataegus* genus of Turkey. Browicz (1972) described some of the *Crataegus* species from Turkey in Flora of Turkey, and Christensen (1992) made many additions to this list. From the studies of Dönmez, new species and information are being added on the *Crataegus* species (Dönmez 2004, 2005, 2007). Currently, there are more than 20 species of *Crataegus* species in Turkey, including *C. monogyna* Jacq., *C. pentagyna* Willd., *C. azarolus* L., *C. orientalis* M. Bieb., *C. rhipidophylla* Gaud. and *C. laevigata* (Poir) DC. There have been few reports describing characteristics of some *Crataegus* species accessions. For example, Demiray (1986) reported the anatomical and morphological characteristics of *C. monogyna* Jacq. subsp. *monogyna* and *C. pentagyna* W. et K. Some physical and chemical properties of *Crataegus* sampled from Konya, Turkey were reported by Özcan et al. (2005).

As fruit characteristics are important discriminative variables to distinguish *Crataegus* species, the objective of this study was to determine the relationships among *Crataegus* species grown in Hatay, Turkey by using the pomological fruit characteristics and molecular markers.

Materials and methods

Materials

Wild growing *Crataegus* populations were surveyed during the growing season of 2007. Individual trees were selected from some populations based on several distinct characteristics. Sampling locations of the accessions studied are presented in Table 1. The accessions were coded based on the sampling district. Thus, A, B, and Y represented Antınözü, Belen, and Yayladağı, respectively. Based on tree, leaf, flower, and fruit characteristics and previously published information (Browicz 1972; Christensen 1992; Büttner 2001; Dönmez 2004, 2005, 2007), the accessions were assigned to the respective species. For the leaf sizes measurements, 30 leaves randomly picked from each accession.

Pomological characteristics

Approximately 2 kg of randomly sampled fully mature fruits were harvested from each accession. The fruits were judged to have reached the full maturation stage based on their size, firmness, and external and internal fruit color. The fruits were carried to the laboratory within 6 h and the pomological analyses were completed within 24 h. Fruit and seed weights were determined using a scale, sensitive to 0.01 g. Fruit width and length were measured using digital calipers. The fruit shapes were determined considering the fruit index determined by fruit width/fruit length. The fruit shape was regarded as 'oblate' for the indexes above 1.1 and 'globose' for the indexes between 0.9 and 1.1. Total soluble solids content (TSS) was determined with a refractometer (Atago, Model ATC-1E) and titratable acidity (TA)

Table 1 *Crataegus* accessions, their species, fruit color, and sampling locations evaluated in this study

Accession	Species	Fruit shape	Fruit color	Sampling		
				Longitude	Latitude	Altitude (m)
A-1	*Crataegus aronia* var. *aronia*	Oblate	Yellow-orange	35° 59′ 02 N	36° 13′ 12 E	642
A-2	*Crataegus aronia* var. *aronia*	Oblate	Yellow-green	35° 59′ 26 N	36° 14′ 09 E	699
A-3	*Crataegus monogyna* subsp. *azarella*	Globose	Red	36° 02′ 33 N	36° 15′ 41 E	579
B-2	*Crataegus aronia* var. *minuta*	Globose	Yellow	36° 26′ 17 N	36° 07′ 24 E	1,013
B-3	*Crataegus aronia* var. *dentata*	Globose	Yellow	36° 24′ 29 N	36° 08′ 30 E	862
B-5	*Crataegus aronia* var. *dentata*	Globose	Yellow-green	36° 26′ 04 N	36° 09′ 22 E	875
B-6	*Crataegus aronia* var. *dentata*	Globose	Yellow-green	36° 26′ 17 N	36° 09′ 58 E	795
B-7	*Crataegus aronia* var. *dentata*	Oblate	Light yellow	36° 26′ 18 N	36° 09′ 58 E	796
B-9	*Crataegus aronia* var. *dentata*	Oblate	Yellow	36° 25′ 31 N	36° 08′ 22 E	792
B-10	*Crataegus aronia* var. *dentata*	Oblate	Yellow	36° 26′ 08 N	36° 09′ 28 E	899
Y-1	*Crataegus aronia* var. *aronia*	Globose	Yellow-green	36° 02′ 25 N	36° 07′ 37 E	857
Y-2	*Crataegus aronia* var. *aronia*	Globose	Yellow-green	35° 58′ 14 N	36° 09′ 20 E	640
Y-3	*Crataegus orientalis* var. *orientalis*	Globose	Red	35° 58′ 32 N	36° 09′ 50 E	540
Y-4	*Crataegus aronia* var. *aronia*	Globose	Yellow-green	35° 57′ 38 N	36° 09′ 23 E	622
Y-5	*Crataegus aronia* var. *dentata*	Oblate	Yellow	35° 56′ 45 N	36° 09′ 41 E	619

by titration of 5 ml of fruit juice with 0.1 N NaOH to pH 8.1, expressed as g malic acid per 100 ml juice. Juice pH was measured using a pH meter (InoLab, Model WTW). Leaf area was determined by a portable photosynthesis analyzer (Model LCA-4, ADC Bioscientific Ltd., Hoddesdon, UK). Fruit external color was measured with a Minolta CR-300. For all pomological measurements, three sub-samples of 10 fruits were used.

Molecular analysis

Young leaves were collected from each accession, frozen in liquid nitrogen and stored at −80°C. High molecular weight genomic DNA was extracted from the leaf samples following the miniprep protocol using CTAB (Dellaporta et al. 1983). DNA concentration was measured using a NanoDrop, ND 100 spectrophotometer (NanoDrop Technologies, Inc.) and gel electrophoresis. DNA was diluted in water to a final concentration of 50 ng/μl and stored at −20°C.

100 RAPD primers from Operon Technologies (Alameda, CA, USA) were screened initially on a sample of the accessions. Primers that produced reproducible, polymorphic bands were used to amplify the rest of the accessions. 1,910-mer primers, which were found to be polymorphic, were used to generate the RAPD markers. Amplification reactions were done in 10 μl volumes containing 2× PCR Master mix (Fermantas, K0171), 1 unit of Taq DNA polymerase (Fermentas, EP0402), $MgCl_2$, 30 ng of the primer, and 20 ng of DNA. The mixtures were assembled at 0°C and then transferred into a thermal cycler, which was cooled to 4°C. The amplification was carried out in a thermal cycler (Eppendorf, Master Gradient) using a program consisting of an initial denaturation step of 2 min at 94°C, and then 55 cycles of 2 min at 94°C, 1 min at 37°C, 2 min 72°C, followed by a 10 min elongation step at 72°C. PCR products were stored at 4°C before analysis.

The amplification products were separated by electrophoresis on 2% agarose gels with 0.5 μg/ml ethidium bromide in 1× TAE buffer (40 mM Tris–Acetate, 1 mM EDTA, pH 8.0) for 3 h at 70 V. The fragment patterns were photographed under UV light for further analysis. A 1 kb DNA ladder was used as the molecular standard in order to confirm the appropriate RAPD markers.

Statistical analyses

Data from fruit characteristics were analyzed using SAS procedures (SAS Inst. 2005). The means and

standard errors were calculated using TABULATE. CLUSTER was used, with the AVERAGE method, to generate a dendrogram of 15 accessions based on pomological characteristics. Principle Coordinate Analysis (PCA) was carried out using the PRINCOMP procedure and the accessions were plotted on the first two PCs.

RAPD data were recorded to generate a binary matrix as either (1) for the presence of a band and (0) for its absence. Only reproducible bands were scored for all accessions tested. Sets 1 and 2 were analyzed separately by Principle Coordinate Analysis (PCoA) and Cluster analyses using NTSYS program (Rohlf 1998). First, a similarity matrix was generated using Jaccard coefficients. This matrix was then used for PCoA. For cluster analyses, the UPGMA (Unweighted Pair Group Method using Arithmetic Average) method was used to construct a dendrogram. The bootstrap values for the clusters were calculated using the PAUP program with 100 replicate (Swofford 1998). The representativeness of the generated dendrogram was evaluated by estimating the cophenetic correlation for the dendrogram and comparing it with the similarity matrix, using Mantel's matrix correspondence test (Mantel 1967).

Results

Pomological characteristics

The *Crataegus* accessions were discovered to belong to several species. A-1, A-2, Y-1, Y-2 and Y-4 were *C. aronia* var. *aronia;* A-3 was *C. monogyna* subsp. *azarella*; B-2 was *C. aronia* var. *minuta*; B-3, B-5, B-6, B-7, B-9, B-10, and Y-5 were *C. aronia* var. *dentata*; and B-2 was *C. orientalis* var. *orientalis.* The subjective evaluations of external fruit color are presented in Table 1. The fruit color varied from light yellow to red. Indeed, all *Crataegus* accessions exhibited considerable variation (Table 2). The largest fruits were from B-3 and B-7 (14.9 and 14.3 g), while the smallest were from A-3 and Y-4 (1.4 and 1.6 g). B-3 and B-7 had the greatest fruit length and width (30.8 and 27.0 mm; 31.1 and 26.3 mm, respectively). The lowest averages for these traits

Table 2 Means and mean separations (by LSD at 5%) of several fruit characteristics for *Crataegus* accessions sampled from Hatay, Turkey

Accession	Fruit weight (g)	Fruit width (mm)	Fruit length (g)	Seed number (seed/fruit)	Seed weight (g)	Flesh/ seed ratio	Soluble solids (%)	pH	Acidity (%)	Leaf area (cm^2)	L*	a*	b*	*C**	*h°*
A-1	3.5	18.4	15.1	2.33	0.65	4.40	14.6	3.08	1.19	5.7	71.6	9.5	56.5	57.8	80.3
A-2	5.6	20.8	17.8	3.13	1.06	4.34	19.1	3.04	1.57	3.6	74.7	−4.2	53.2	53.6	94.7
A-3	1.4	9.3	9.6	1.00	0.14	8.60	6.1	3.99	0.98	5.5	35.9	29.2	30.1	42.1	46.3
B-2	2.7	17.1	15.0	1.50	0.43	6.16	12.3	3.16	1.67	3.0	76.4	−3.8	52.9	53.2	94.3
B-3	14.9	30.8	27.0	2.27	1.50	8.99	17.9	3.08	1.39	13.6	76.6	−1.7	52.2	52.3	92.0
B-5	6.9	23.0	22.0	2.47	1.41	4.22	14.4	3.16	1.38	12.3	76.9	−7.4	51.1	51.8	98.5
B-6	4.7	20.2	19.8	2.63	1.32	2.56	8.1	3.68	0.53	14.3	79.6	−9.1	36.7	38.0	104.0
B-7	14.3	31.1	26.3	2.43	1.44	9.23	14.3	3.03	1.52	17.1	79.0	−5.1	50.8	51.2	96.0
B-9	6.9	24.1	20.2	2.43	1.49	3.67	21.5	3.22	1.98	11.0	73.0	1.7	51.5	51.9	86.6
B-10	9.2	24.6	20.6	2.67	1.85	3.99	22.5	3.47	1.49	11.9	73.0	−1.5	55.9	56.2	91.6
Y-1	3.1	17.7	16.0	2.07	0.68	4.37	15.3	3.05	1.79	2.6	73.4	−1.3	44.7	45.3	92.1
Y-2	3.4	17.8	17.8	2.57	0.49	6.11	14.1	3.08	1.78	2.3	76.1	−4.0	53.8	54.1	94.5
Y-3	4.1	18.7	18.8	2.53	0.87	3.70	22.5	3.26	1.46	4.5	54.3	30.0	36.8	47.9	51.1
Y-4	1.6	14.3	12.5	2.63	0.38	3.24	11.1	3.11	1.73	3.3	73.3	−6.1	53.6	54.2	96.7
Y-5	9.0	26.5	21.4	2.67	1.31	5.94	23.5	3.21	1.41	9.4	76.2	1.5	61.2	61.3	88.7
Mean	6.1	21.0	18.7	2.36	1.00	5.30	16.5	3.19	1.49	8.0	71.3	1.8	49.4	51.4	87.2
SE	0.62	0.85	0.69	0.09	0.35	0.77	0.04	0.05	0.73	0.73	1.67	1.78	1.26	0.89	2.42

Table 3 First three principle component (PC) scores of the variables used to evaluate *Crataegus* accessions sampled from Hatay, Turkey

Character	PC1	PC2	PC3
Fruit weight	0.29	0.31	0.18
Fruit width	0.34	0.22	0.12
Fruit length	0.32	0.27	0.07
Seed number	0.26	−0.12	−0.10
Seed weight	0.30	0.27	0.01
Flesh/seed ratio	0.00	0.25	0.29
Soluble solids	0.22	−0.07	0.42
pH	−0.25	0.31	−0.11
Acidity	0.12	−0.36	0.29
Leaf area	0.21	0.44	−0.10
L	0.32	−0.14	−0.30
a	−0.26	0.13	0.43
b	0.28	−0.28	0.11
C	0.21	−0.28	0.33
H	0.27	−0.13	−0.43
Eigen value	6.88	3.11	2.07
Proportion	0.46	0.21	0.14

were measured in A-3 (9.3 and 9.6 mm). The greatest number of seeds was recovered from A-2 (3.13 seeds/fruit). Y-5 was the accession with the greatest soluble solid content (23.5%), followed by B-10 and Y-3 (22.5%). Like most other traits, A-3 had the lowest SS content. Conversely, pH was highest in A-3 followed by B-6 (3.68). TA was greatest in B-9 (1.98%) and lowest in B-6 (0.53%) (Table 2).

Leaf area means ranged from 2.3 cm^2 (Y-2) to 17.1 cm^2 (B-7). Fruit external color measurements were highly variable. L* ranged from 35.9 (A-3) to 79.6 (B-6) while a* and b* values ranged from −9.1 (B-6) and 30.1 (A-3); 30.0 (Y-3) and 61.2 (Y-5).

The results of the PCA for 15 pomological characteristics are presented in Table 3. The first three PC explained the 46, 21, and 14% of variation, comprising a total of 81%. The fruit length and width were the most important traits, forming PC1, while leaf area and soluble solids were highly correlated by PC2 and PC3, respectively. When all the results were considered, the discriminating fruit characteristics were as follows: fruit width and length, seed number,

Table 4 Arbitrary oligonucleotide primers, numbers of total and polymorphic bands, and polymorphisms studied to reveled molecular relationship among *Crataegus* accessions sampled from Hatay, Turkey

Primer code	Size (bp) (Min.–Max.)	Total band number	Polymorphic band number	Polymorphism (%)
OPAF-1	350–750	5	3	60
OPAF-11	350–1,600	7	4	57
OPAF-12	300–1,600	6	4	67
OPAF-13	500–1,600	5	4	80
OPAF-3	350–750	3	1	33
OPAI-11	950–1,600	5	3	60
OPAI-12	600–1,400	4	3	75
OPAI-14	400–800	4	4	100
OPAI-18	700–1,300	4	3	75
OPAI-19	250–950	4	4	100
OPAI-4	350–1,800	4	4	100
OPAI-5	650–1,500	7	6	86
OPAI-8	350–2,000	6	4	67
OPAJ-1	400–1,400	8	6	75
OPAJ-10	500–200	5	4	80
OPAJ-3	350–1,400	8	7	88
OPAJ-4	650–1,300	4	3	75
OPAJ-7	550–2,000	11	2	18
OPAJ-8	300–1,600	7	7	100
Total/mean		107	76	73

seed weight, L* of external fruit color, leaf area, acidity, PH, fruit weight, and soluble solids.

The two-dimensional presentation of the accession tested is presented in Fig. 1. As shown, the accessions can be divided into three main groups. The first group is presented by A-3, an accession of *C. monogyna* subsp. *azarella*. The second group is compromised of *C. aronia* var. *dentata* accessions. All other accessions from several species were grouped together for the third group.

The cluster resulting from the analysis of 15 pomological traits by AVERAGE method of SAS'S CLUSTER procedure is presented in Fig. 2. Overall, this dendrogram was similar to that of PCA. For example, there were three groups on the dendrogram. The groups were formed by the same accessions with

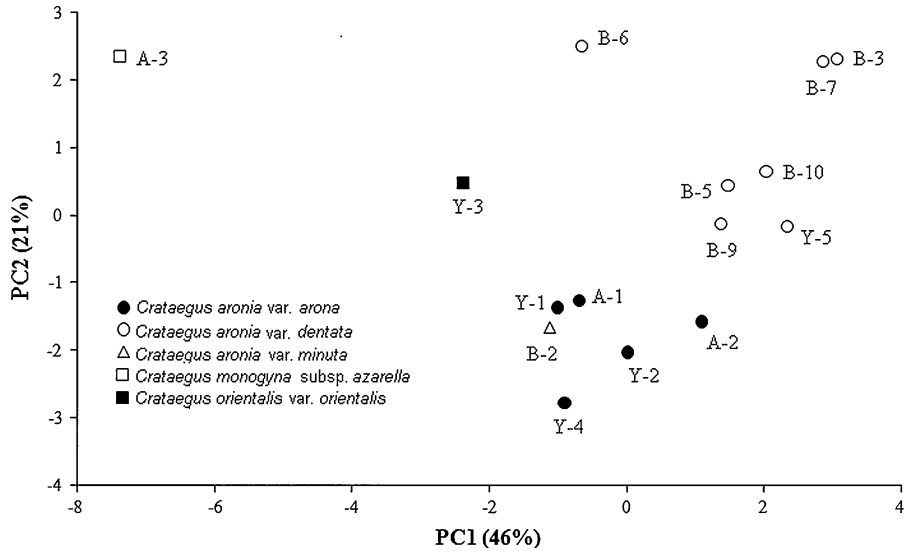


Fig. 1 Plot of *Crataegus* accessions sampled from Hatay, Turkey on the first two principle components (PC)

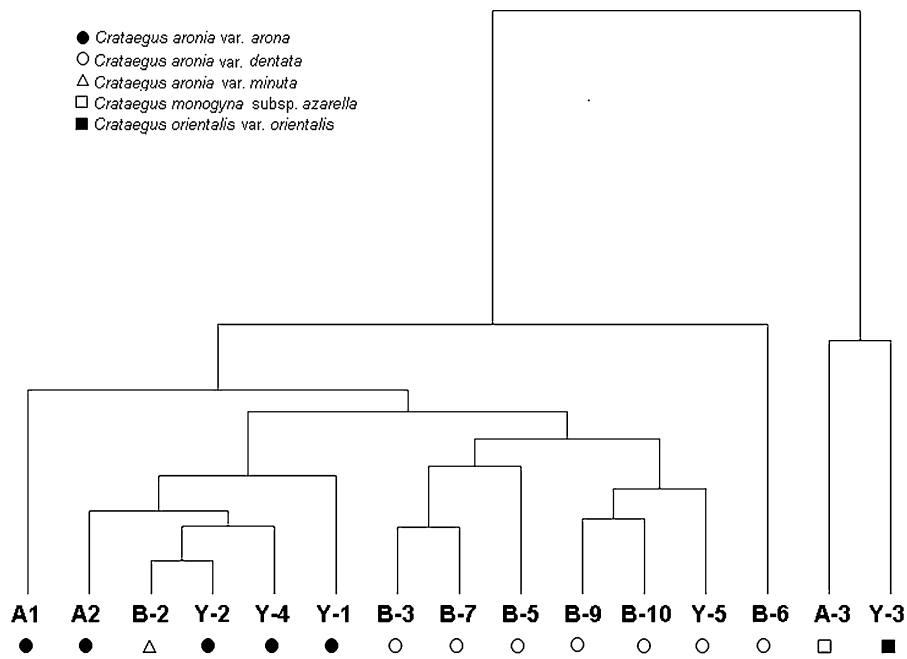


Fig. 2 Dendrogram of 15 pomological characteristics for *Crataegus* accessions sampled from Hatay, Turkey

few exceptions. The accession Y-3 (*C. orientalis* var. *orientalis*) was clustered by A-3 (*C. monogyna* subsp. *azarella)*. B-6 from *C. monogyna* subsp. *azarella* was separated from other accessions from the same species.

Molecular analysis

RAPD analysis was successful to generate polymorphic band patterns for *Crataegus* accessions. Out of 100 primers tested, 19 yielded clear and reproducible bands. The results for these bands were presented in Table 4. The band size ranged from 250 base pair (bp) (OPAI-19)—2,000 bp (OPAI-8 and OPAJ-7). The total bands generated were between 3 (OPAF-3) and 11 (OPAJ-7) while the polymorphic bands were between 1 (OPAF-3) to 7 (OPAJ-3 and OPAJ-8). Thus, percentage polymorphism ranged from 33 to 100%.

The two-dimensional presentation of the PCoA results generated by the 107 bands yielded from 19 RAPD primers is presented in Fig. 3. As shown, there were three apparent groups. The first group is the accession A-3 itself. The second group is formed by *C. aronia* var. *dentata*. The last group is composed from the rest of the accessions of other species.

The RAPD data was also used to generate an UPGMA dendrogram (Fig. 4). The result of the Mantel test, $r = 0.99$, indicated that the resulting dendrogram and the similarity matrix generated by the binary data set had a very good fit. There were three apparent groups in also this dendrogram. Again, A-3 (*C. monogyna* subsp. *azarella*) formed a group by itself. The second group included the accessions of B-2, B-3, B-5, B-6, B-7, B-9, B-10, and Y-5. These accessions belonged to the *C. aronia* var. *dentata*, except B-2 *C. aronia* var. *minuta*. The bootstrap values indicated that this group can be divided into several subgroups. For example, B-3 and B-5 accessions grouped together and B-9 and B-10 were separated from other accessions. The node separating Y-5, B-6, and B-7 was also statistically supported. The last group included the accessions of A-1, A-2, Y-1, Y-2, Y-4 (*C. aronia* var. *arona*), and Y-3 (*C. orientalis* var. *orientalis*).

Discussion

We attempted to characterize *Crataegus* accessions sampled from Hatay, Turkey using both fruits characteristics and molecular data. Both data sets

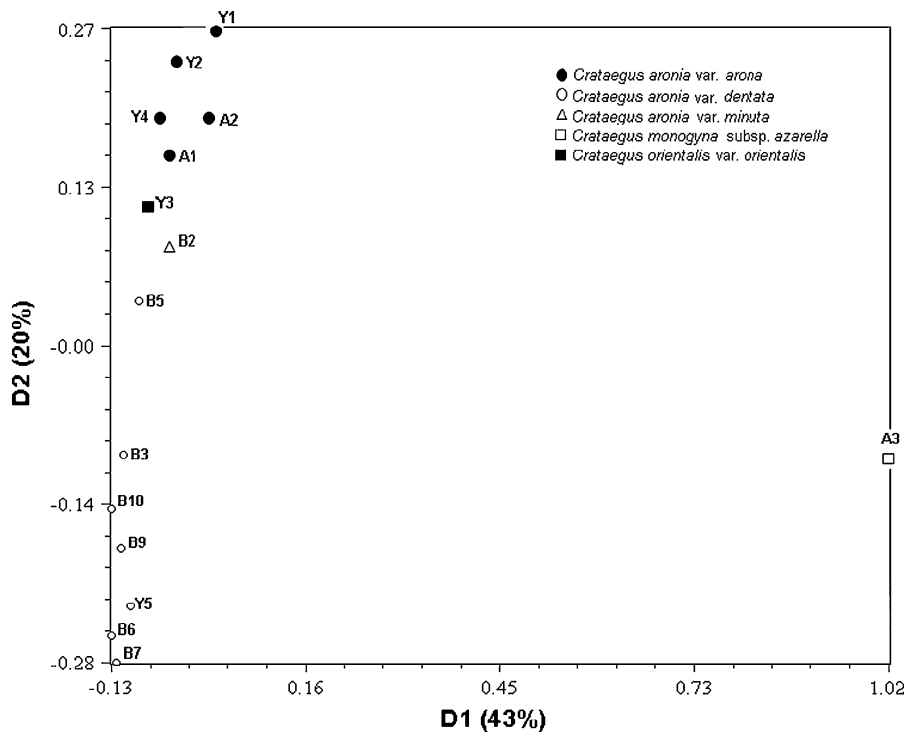


Fig. 3 Principle coordinate analysis of RAPD bands, generated by 19 primers, for *Crataegus* accessions sampled from Hatay, Turkey

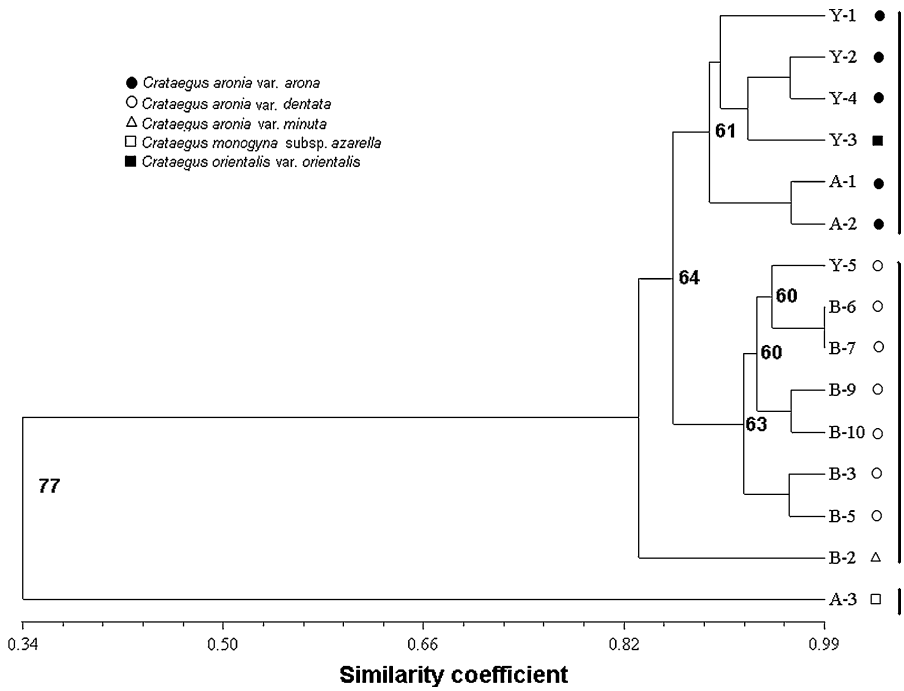


Fig. 4 UPGMA dendrogram of RAPD bands generated by 19 arbitrary oligonucleotide primers for *Crataegus* accessions sampled from Hatay, Turkey. Numbers in nodes represent bootstrap values in percentage and only higher than 50% are presented

were analyzed by two multivariate methods. PCO of pomological data and PCoA of molecular data resulted in similar grouping of the accessions. Both analyses had three groups. There was only one difference found from grouping of the accessions. The accession B-5, belonging to *C. aronia* var. *dentata*, was clustered among the other *C. aronia* var. *dentata* accessions by pomological data, while this accession was clustered among the accessions of group three when analyzed by molecular data. Therefore, it seems that the classification of B-5 at the species-level may be problematic.

The dendrograms of pomological and molecular data were also in overall agreement. For example, both analyses divided the accessions into three groups. When the accessions of the groups were considered, only one accession was grouped differently between the data sets. The accession Y-3, belonging to *C. orientalis* var. *orientalis*, was clustered by the accession A-3 when analyzed by pomological data although it was grouped with *C. aronia* var. *aronia* accessions when analyzed by RAPD data.

Our results indicate that RAPD can be successfully used to study the molecular relatedness of *Crataegus* accessions. There are many molecular markers available for horticultural researchers with different advantages and disadvantages (Staub et al. 1986; Hokanson 2001). RAPDs have been reported as problematic for reliability and reproducibility (Ellsworth et al. 1993; Williams and Clair 1993). However, there are also many current studies reporting successful applications of RAPD to characterize fruit accessions such as olive (Taamalli et al. 2006; Ganino et al. 2007), pomegranate (Zamani et al. 2007), and mulberry (Orhan et al. 2007). It should also be noted that the RAPD and pomological data results were in overall agreement. Differences in groupings based on molecular and morphological traits have been reported for many fruit species, because of several biological (incongruence between data set, few loci tested, hybridization, lineage sorting) and technical (marker scoring) issues (Takeda et al. 1998; Viyajan et al. 2006). However, it has been reported that RAPD data support hypothetical origins, adaptation history, and previous classification by isozymes or pomological traits (Badenes et al. 2003).

Both morphological and molecular traits are being used to characterize *Crataegus* species (e.g., Albarouki and Peterson 2007). However, it is a difficult task to separate accessions into species, due to individual variations of hawthorn plants and the high number of species. Hybridization (Phipps 2005),

polyploidy, and apomixis (Christensen 1992; Lippert 1995) contributed to the number of new species and, therefore, taxonomic complexity. Dickinson et al. (2007) suggested that a better understanding of the modes of reproduction and the uses of flow cytometry and molecular markers would help us reveal more in-depth *Crataegus* taxonomy. Therefore, the results presented here may contribute to this area.

Our results are also important for the horticultural value of the *Crataegus*. Although Turkey has numerous *Crataegus* species and many geographical areas with diverse wild growing *Crataegus* accessions, hawthorn is still an underutilized crop in Turkey. Indeed, it is difficult to classify the Turkish *Crataegus* accessions as wild or domesticated. Some of them are truly wild meaning it is very unlikely that they have ever been through the domestication process (e.g., A-3). Some of them, however, (e.g., B-3 and B-7) can be classified wild as they are not grown in orchards. They were sampled from places where these trees are in home gardens (usually as a single trees) or on the borders of other orchards. To our knowledge, there are no hawthorn orchards in the region where the accessions presented in the study were sampled. However, hawthorn fruits are marketed during fall in many regions of Turkey. Therefore, these accessions are different from the truly wild accession (such as A3), as it is apparent they have been tree to domestication process. There have been recent (e.g., Türkoğlu et al. 2005) studies to characterize Turkish *Crataegus* accessions with superior horticultural characteristics. Some of accessions presented here have comparable horticultural characteristics to previously identified Turkish (Asma and Birhanlı 2003) and global (Guo and Jiao 1995) *Crataegus* accessions. Therefore, some of the *Crataegus* accessions presented in this work have a potential for utilization as a horticultural crop.

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