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Fruit quality parameters and molecular analysis of apple germplasm resources from Van Lake Basin, Turkey

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Abstract: The objective of this study was to determine some fruit quality characters and genetic variability of native apple germplasm resources from Van Lake Basin, eastern Turkey. With respect to fruit quality characters, apple genotypes had a range of 46.00–94.99 mm for fruit diameter, 43.04–310.99 g for fruit weight, 0.71–1.13 for fruit shape index, 3.99–14.05 kg cm^{-2} for fruit flesh firmness, 9.0%–14.4% for soluble solids content, and 0.15%–1.75% for titratable acidity. Five genotypes revealed no alternate bearing and nine genotypes showed partial alternate bearing. The genetic variability was characterized by random amplified polymorphic DNA (RAPD) for 35 native apple genotypes belonging to the basin and two standard apple cultivars. The average level of polymorphism across genotypes was 89.29% as revealed by RAPD. The highest genetic similarity was detected between the G10 and G11 (79.31%) genotypes and the similarity rate varied between 38% and 79% among genotypes. According to the dendrogram derived from RAPD data, the G3, G23, G28, and G24 genotypes formed a cluster. These results implied that the Van Lake Basin may be one of the native expansion areas of the genus *Malus*.

Key words: Apple, fruit characterization, genetic variability, random amplified polymorphic DNA

1. Introduction

Apple (*Malus domestica* Borkh.) is an important fruit species widely spread in the cold and mild climates of temperate regions in the world (Harris et al., 2002). Approximately 25–47 species belonging to the genus *Malus* have been cultivated all over the world (Robinson et al., 2001). Anatolia is one of the origin centers and native spreading areas of the apple (Ercisli, 2004). The apple genetic resources in Anatolia show a wide variability, including numerous local genotypes (Özrenk et al., 2010; Muradoğlu et al., 2011).

The production of fruits requires the ability to distinguish one cultivar from another in nurseries and orchards. Assessment performed on the basis of morphological traits may prove misleading due to substantial similarities in the appearances of trees and fruits. New cultivars are constantly being introduced, which may cause further difficulties in their identification. The possibility of erroneous cultivar determination meant that molecular techniques were needed to allow precise identification of genotypes (Eroğul, 2009; Bayazit et al., 2011; Turkoglu et al., 2012; Ozyurt et al., 2013).

Characterization of genetic resource collections has also been greatly facilitated by the availability of a number of molecular marker systems. Morphological traits were among the earliest markers used in germplasm management, but they have a number of limitations, including low polymorphism, low heritability, late expression, and vulnerability to environmental influences (Smith and Smith, 1992). On the other hand, DNA markers do not have such limitations. They can be used to detect variation at the DNA level and have proven to be effective tools for distinguishing between closely related genotypes. Different types of molecular markers have been used to assess the genetic diversity in crop species, but no single technique is universally ideal. Therefore, the choice of the technique depends on the objective of the study, financial constraints, skills, and available facilities (Kafkas et al., 2008; Pavlovic et al., 2012). The random amplified polymorphic DNA (RAPD) technique determines genetic diversity and relationships among different fruit species and cultivars, including apples (Koc et al., 2009; Erturk and Akcay, 2010; Smolik et al., 2011; Ansari and Khan, 2012).

This study aimed to identify the fruit quality characteristics of local apple genotypes cultivated in the Van Lake Basin in terms of fruit breeding objectives and also to determine the genetic diversity among the genotypes by using RAPD.

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2. Materials and methods

2.1. Study area and plant material

The Van Lake Basin is situated at 1648 m a.s.l. in eastern Turkey. The area has a continental climate with warm summers and cold and long winters. With its sensitivity to climatic changes, this area is located in a transitional zone between different vegetation types (Wick et al., 2003). This study was conducted in native apple populations of the Gevaş, Edremit, and Central Van districts of the Van Lake Basin. Within the native apple population, 137 genotypes were evaluated, and 35 genotypes were selected among them for future breeding efforts. In order to determine genetic variability among the 35 promising genotypes, RAPD analysis was performed in comparison with two standard apple cultivars (Golden Delicious and Starking Delicious). The study lasted 3 years and the data of 3 years are presented.

2.2. DNA isolation

DNA isolation was conducted in compliance with CTAB+PVP protocol, based on a method that was adopted with some modifications from Chen and Ronald (1999). Fresh and fully opened young leaf tissues were used for each genotype. The leaf sample was ground via liquid nitrogen. The ground sample (0.3 g) was then transferred to a 2-mL tube. In the same tube, 700 µL of CTAB buffer (2% w/v CTAB, 1.42 M NaCl, 20 mM EDTA, 100 mM Tris-HCl, pH 8.0, 2% polyvinylpyrrolidone PVP-40) (Doyle and Doyle, 1990) and 7 µL of RNase A were added. To the pure DNA obtained, approximately 50 µL of TE buffer solution was added and the DNA was solved. The obtained genomic DNA was monitored by conduction in agarose gel and its concentration was determined by spectrophotometer.

2.3. RAPD analysis

Ten-mer primers (Operon A01, A02, A08, A09, A13, A14, A18) were used in the RAPD analysis (Zhou and Li, 2000; Goulão et al., 2001; Royo and Itoiz, 2004; Ansari and Khan, 2012). The PCR mixture contained 10 mM Tris-HCl, 50 mM KCl, 2 mM $MgCl_2$, 0.1% Triton, 120 µL dNTP, 0.4 µL primer, 25 ng template DNA, and 0.5 U Taq DNA polymerase (Liu et al., 2004). The following amplification program was used in the polymerase chain reaction: DNA denaturation for 4 min at 94 °C; 40 cycles of primer connecting and polymerization for 60 s at 94 °C, 90 s at 36 °C, and 120 s at 72 °C; and a last amplification stage carried out for 10 min at 72 °C. PCR products were separated based on their molecular weight by running for 3 h in 1.5% agarose gel. The bands were made visible under UV light after they were stained with ethidium bromide and the various genotype fingerprints were determined based on band existence (1) or band absence (0) (Zhou and Li, 2000; Goulão et al., 2001).

2.4. Data analysis

Similarity between apple genotypes was detected by RAPD and calculated using the Jaccard coefficient. Cluster analysis was carried out based on a similarity matrix and using the UPGMA algorithm to generate the corresponding dendrogram. These calculations and scaling with 2 or 3 dimensions were performed using NTSYS software (Labate, 2000).

2.5. Fruit quality characteristics

The pomological analyses of some fruit quality characters, such as fruit weight (g), fruit volume (cm^3), fruit mass density (g cm^{-3}), fruit flesh firmness (kg cm^{-2}), fruit height (mm), fruit diameter (mm), and fruit shape index (%), were determined for each apple genotype. All investigated genotypes were defined as cylindrically waisted, conic, ovoid, cylindrical, ellipsoid, globose, or obloid according to fruit shape index. In the fruit juice, pH, soluble solids content (%), and titratable acidity (%) were detected. For fruit analyses, ten fruits from different tree branches were randomly collected. Harvest time was determined according to statement of the tree owner and apple harvest parameters (Karaçalı, 2012).

2.6. Alternate bearing and tree characteristics

Alternate bearing was evaluated based on the records of 3 years. It was defined as follows: "absent" for the genotypes that yielded every year, "existent" for the genotypes that yielded 1 year but did not yield the next year, and "partial" for the genotypes that successively yielded for 2 years but did not yield in the third year. Stem circumference (cm), tree height (m), and crown width (m) were also calculated.

3. Results

3.1. Genetic relationships as revealed by RAPD data

Genetic variability and relationships among 35 native apple genotypes (Figure 1) and two apple cultivars (Golden Delicious (G18) and Starking Delicious (G17)) were tested using RAPD analyses. The template DNA attained for each genotype was monitored by running in agarose gel (Figure 2) and concentrations were determined with the help of a spectrophotometer (Table 1). Results revealed that the DNA concentrations varied between 11.55 µg mL^{-1} (VANEL-010) and 23.32 µg mL^{-1} (VANEL-134). The visible bands were also monitored (Figure 3). A total of 56 fragments were amplified from 7 primers; 50 fragments were polymorphic (89.29%) (Table 2). The genotype that had the lowest mean similarity with the other genotypes was G24 (0.3518), while the one having the highest mean similarity was G10 (0.5810) (Figure 4). According to the dendrogram (Figure 5), the similarity percentage among the genotypes varied between 0.38 and 0.79. While all the remaining genotypes showed branching under a group at the same level, G3-G23-G28-G24 formed a second group. Examining the scaling with two dimensions (Figure 6) and

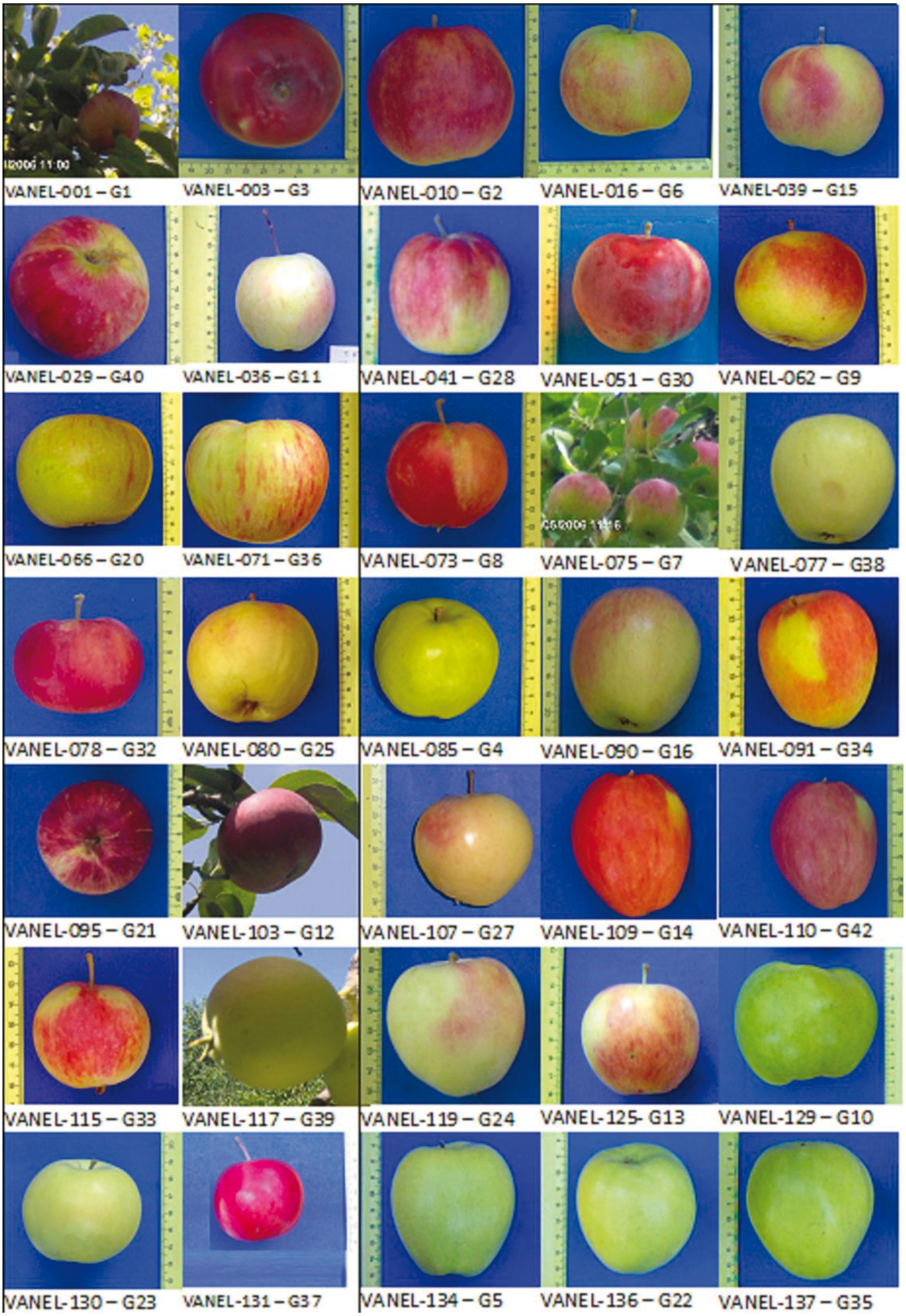

Figure 1. The fruit images of apple genotypes.

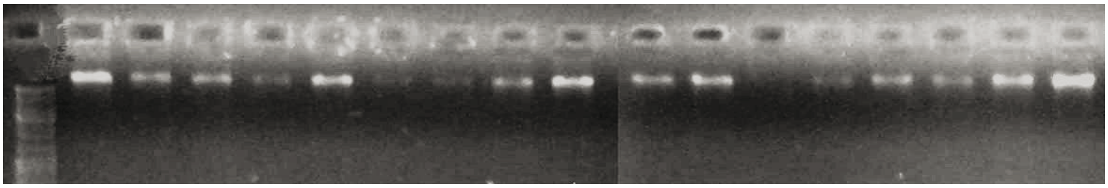

Figure 2. The template DNA images of some genotypes.

Table 1. The concentration of each template DNA.

No.	RAPD name	Genotype name	DNA (µg mL^{-1})	No.	RAPD name	Genotype name	DNA (µg mL^{-1})
1	G1	VANEL-001	16.31	20	G23	VANEL-130	20.68
2	G2	VANEL-010	11.55	21	G24	VANEL-119	21.48
3	G3	VANEL-003	12.41	22	G25	VANEL-080	22.43
4	G4	VANEL-085	20.27	23	G27	VANEL-107	18.89
5	G5	VANEL-134	23.32	24	G28	VANEL-041	20.48
6	G6	VANEL-016	22.74	25	G30	VANEL-051	17.61
7	G7	VANEL-075	21.83	26	G32	VANEL-078	19.22
8	G8	VANEL-073	17.68	27	G33	VANEL-115	21.51
9	G9	VANEL-062	21.59	28	G34	VANEL-091	20.01
10	G10	VANEL-129	22.49	29	G35	VANEL-137	21.65
11	G11	VANEL-036	22.60	30	G36	VANEL-071	22.67
12	G12	VANEL-103	22.30	31	G37	VANEL-131	21.10
13	G13	VANEL-125	21.79	32	G38	VANEL-077	20.08
14	G14	VANEL-109	22.56	33	G39	VANEL-117	21.44
15	G15	VANEL-039	21.69	34	G40	VANEL-029	21.45
16	G16	VANEL-090	22.50	35	G42	VANEL-110	22.42
17	G20	VANEL-066	22.30	36	G17	Starking D.	22.32
18	G21	VANEL-095	22.44	37	G18	Golden D.	22.37
19	G22	VANEL-136	19.75				

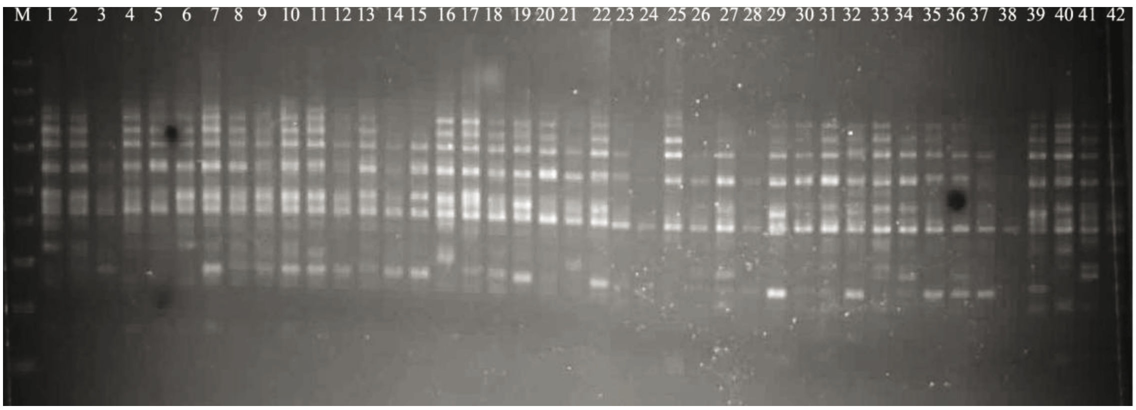

Figure 3. RAPD amplification patterns generated with primer OPA1. M- Marker.

Table 2. The polymorphic band numbers.

No.	Primers	Total band number	Polymorphic band number	Polymorphic band percentage (%)
1	Operon A01	12	11	91.66
2	Operon A02	11	9	81.81
3	Operon A08	5	4	80.00
4	Operon A09	8	8	100.00
5	Operon A13	9	9	100.00
6	Operon A14	3	2	66.66
7	Operon A18	8	7	87.50
	Total	56	50	89.29

three dimensions (Figure 7), it was observed that these 4 genotypes (G3-23-28-24) were located far from the others and from one another. In addition, it was remarkable that genotypes G25 and G38 showed branching by themselves in the other big group; they united with the rest of the group at the level of approximately 44% and they could be probable intermediate forms of *Malus* species.

3.2. Fruit quality and tree characteristics

Some fruit and tree characteristics of the selected apple genotypes (Figure 1) were determined based on data from 2005–2007 (Tables 3 and 4). Apple genotypes had a range of 46.00–94.99 mm for fruit diameter, 38.29–81.42 mm for fruit height, 43.04–310.99 g for fruit weight, 58.00–416.33 cm^3 for fruit volume, 0.71–1.13 for fruit shape index, 0.64–0.90 g cm^{-3} for fruit mass density, 3.99–14.05 kg cm^{-2} for fruit flesh firmness, 9.0%–14.4% for soluble solids content, 0.15%–1.75% for titratable acidity, and 3.14–4.65 for pH value. Their fruits had different characteristics from one another in size, shape, and color (Table 3). On the other hand, fruit shape index varied from 0.71 to 1.13. Fruit shape was globose for 20 genotypes, obloid for 4 genotypes, cylindrically waisted for 3 genotypes, conic for 3 genotypes, ellipsoid for 2 genotypes, ovoid for 2 genotypes, and cylindrical for 1 genotype (Table 3). Based on the records of 3 years, alternate bearing was partially present for 9 genotypes and existent for 21 genotypes. Five genotypes (G5, G9, G10, G28, and G36) lacked this tendency completely. Stem circumference of genotypes varied between 30 and 135 cm. Tree height varied from 4 m to 8 m, and crown width ranged from 2 m to 10 m (Table 4).

4. Discussion

In this study, the level of polymorphism across genotypes was 89.29% as revealed by RAPD. Ur-Rahman et al. (1997) used 20 primers from Operon A01 to A20 and attained 215 bands in *M. hupehensis* (of which 129 (60%) were polymorphic) and 271 bands in *M. toringoides* (of which 107 (39.48%) were polymorphic). Goulão et al. (2001) scanned 41 apple cultivars (*Malus* × *domestica* Borkh.) by using RAPD and AFLP markers. RAPD analysis was conducted with 35 primers. A total of 362 bands were attained and 208 bands (57.5%) were polymorphic. Muzher et al. (2007) determined the highest similarity between Golden Delicious/Dershawi cultivars by RAPD (76.7%) and Khlati/Dershawi cultivars by AFLP (72.9%) among six apple cultivars. To determine the genetic polymorphism among a *Malus sieversii* population, Yan et al. (2008) used 39 primers and attained a total of 469 bands, 210 of which (45%) were polymorphic. The high levels of polymorphism in our study demonstrate that there is considerable richness in terms of apple genetic resources.

The apple genotypes showed a range of 46.00–94.99 mm for fruit diameter, 43.04–310.99 g for fruit weight, and 3.99–14.05 kg cm^{-2} for fruit flesh firmness (Table 3). Similar studies reported fruit diameters varying from 35.4 mm to 91 mm for apple genotypes or selections from various areas (Bongers et al., 1994; Balta and Uca, 1996; Hampson et al., 2004; Miller et al., 2004; Aygün and Ülgen, 2009; Özrenk et al., 2010; Karadeniz et al., 2013). In related references for apple genotypes, fruit weight values ranged from 17 g to 327 g (Tolmacheva, 1991; Lei et al., 1996; Erdoğan and Bolat, 2002; Koike et al., 2003; Pirlak et al., 2003; Karlıdağ and Eşitken, 2006; Aygün and Ülgen, 2009; Bostan, 2009; Karadeniz et al., 2013) and fruit flesh firmness values ranged from 3.21 to 8.98 kg (Oğuz and Aşkın, 1993; Crosby et al., 1994; Scalzo et al., 2001; Soylu et al., 2003; Balta and Kaya, 2007; Serdar et al., 2007; Özrenk et al., 2010). Accordingly, apple genotypes of the Van Lake Basin seem to have higher values in terms of fruit diameter, fruit weight, and the fruit flesh firmness than those reported by many other references.

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18
G1	1.0000																	
G2	0.6957	1.0000																
G3	0.3684	0.4000	1.0000															
G4	0.5926	0.6923	0.2857	1.0000														
G5	0.5185	0.6800	0.3333	0.6452	1.0000													
G6	0.5862	0.6207	0.3000	0.6389	0.6875	1.0000												
G7	0.5333	0.5667	0.3333	0.6216	0.5278	0.6154	1.0000											
G8	0.6154	0.7200	0.3214	0.6471	0.6452	0.6857	0.6216	1.0000										
G9	0.5652	0.6818	0.3043	0.6667	0.6667	0.6452	0.5588	0.7500	1.0000									
G10	0.7273	0.6667	0.2963	0.7000	0.5667	0.6875	0.6667	0.6250	0.6429	1.0000								
G11	0.5517	0.6429	0.3214	0.6571	0.6563	0.6944	0.6316	0.7059	0.6774	0.7931	1.0000							
G12	0.4400	0.5417	0.5333	0.5185	0.5000	0.4194	0.4194	0.5385	0.5217	0.5217	0.5926	1.0000						
G13	0.6364	0.6818	0.3478	0.6129	0.5000	0.5588	0.5429	0.6667	0.6296	0.7037	0.6250	0.6190	1.0000					
G14	0.6500	0.5455	0.4667	0.5200	0.4400	0.4138	0.4643	0.4800	0.6000	0.6190	0.4815	0.6316	0.6316	1.0000				
G15	0.5238	0.4348	0.4706	0.3750	0.4444	0.3824	0.4545	0.5172	0.4615	0.4815	0.4375	0.5789	0.4615	0.6875	1.0000			
G16	0.5172	0.5517	0.3077	0.6176	0.6129	0.6111	0.5128	0.5714	0.5313	0.6897	0.6286	0.4000	0.5313	0.3929	0.3871	1.0000		
G17	0.4688	0.5484	0.3214	0.6389	0.5882	0.5897	0.5750	0.5128	0.5455	0.7333	0.6053	0.5000	0.5143	0.4483	0.4242	0.6111	1.0000	
G18	0.4643	0.6154	0.3462	0.5556	0.5455	0.5128	0.5385	0.5556	0.5313	0.6667	0.6571	0.6250	0.5625	0.5000	0.4194	0.4865	0.6857	1.0000
G20	0.6087	0.6522	0.2727	0.5625	0.5517	0.5000	0.5143	0.5806	0.5862	0.6296	0.5758	0.5000	0.5714	0.5000	0.4615	0.4412	0.5938	0.6333
G21	0.4800	0.5833	0.3636	0.5000	0.4839	0.5882	0.4474	0.5455	0.6071	0.5517	0.6061	0.5909	0.5517	0.5238	0.5000	0.4706	0.4595	0.5938
G22	0.5200	0.4444	0.4444	0.4545	0.5357	0.4571	0.4857	0.4118	0.4000	0.5769	0.5152	0.5000	0.4000	0.5000	0.5652	0.4242	0.5000	0.5000
G23	0.4500	0.4286	0.5385	0.3333	0.4000	0.3030	0.2941	0.3793	0.4167	0.3462	0.3125	0.5000	0.4167	0.6000	0.6471	0.3000	0.3030	0.3333
G24	0.2917	0.3333	0.4667	0.3030	0.3571	0.3529	0.2368	0.3438	0.3333	0.2759	0.3235	0.3810	0.3214	0.3684	0.4762	0.2353	0.3143	0.3030
G25	0.4545	0.4348	0.3529	0.5000	0.5000	0.3750	0.3636	0.4483	0.3333	0.5200	0.4194	0.4286	0.3846	0.3500	0.4286	0.4643	0.4516	0.4000
G27	0.5652	0.5417	0.3333	0.5484	0.5357	0.5455	0.4857	0.5484	0.6154	0.6538	0.6667	0.4783	0.4483	0.5500	0.5652	0.5161	0.4571	0.5000
G28	0.4000	0.3810	0.5385	0.3448	0.4167	0.3125	0.3030	0.3000	0.3750	0.3462	0.3226	0.4444	0.3200	0.5333	0.5000	0.3103	0.3125	0.3448
G30	0.5217	0.5000	0.3529	0.4815	0.5833	0.4828	0.5357	0.5600	0.5455	0.5909	0.5000	0.4348	0.4348	0.5000	0.6111	0.5185	0.4667	0.5200
G32	0.5200	0.4444	0.3810	0.5806	0.5714	0.4857	0.5588	0.4848	0.5357	0.6296	0.5938	0.5000	0.4333	0.5714	0.5417	0.5484	0.6250	0.5313
G33	0.6818	0.5200	0.3043	0.5152	0.5517	0.5588	0.5000	0.6129	0.5926	0.6667	0.6250	0.5217	0.6923	0.6000	0.5833	0.5313	0.4722	0.5152
G34	0.6522	0.5600	0.3333	0.5938	0.5862	0.6364	0.5278	0.5938	0.6667	0.6207	0.6061	0.5000	0.6071	0.5714	0.5000	0.6129	0.5429	0.5000
G35	0.5417	0.5200	0.4286	0.4848	0.5714	0.4857	0.4722	0.5806	0.5357	0.5517	0.5455	0.5909	0.5357	0.5238	0.5417	0.4545	0.5294	0.5313
G36	0.5714	0.5455	0.3889	0.4516	0.4815	0.4839	0.5000	0.4667	0.5185	0.5769	0.5161	0.5238	0.5000	0.6111	0.5000	0.3750	0.5862	0.5172
G37	0.5217	0.5000	0.5556	0.5000	0.4333	0.4571	0.4857	0.4545	0.5185	0.5357	0.5152	0.5714	0.4483	0.5789	0.5000	0.3429	0.5000	0.5000
G38	0.3846	0.4231	0.4706	0.4375	0.4643	0.3243	0.3514	0.3529	0.4815	0.4286	0.4118	0.4167	0.3333	0.4091	0.3600	0.4063	0.5313	0.4375
G39	0.5000	0.5333	0.3600	0.6176	0.6129	0.4872	0.5128	0.4474	0.4848	0.6333	0.5833	0.5357	0.4848	0.4815	0.4333	0.5882	0.7059	0.5278
G40	0.4194	0.4516	0.2963	0.5429	0.5806	0.5000	0.5263	0.5000	0.4118	0.5152	0.4359	0.4000	0.4118	0.3448	0.4000	0.6061	0.5405	0.4211
G42	0.6316	0.5238	0.3750	0.5185	0.6667	0.4828	0.4194	0.4643	0.4583	0.4800	0.4333	0.5263	0.4583	0.6250	0.6111	0.4815	0.4667	0.4138
ORT	0.5325	0.5446	0.3782	0.5349	0.5401	0.5130	0.4918	0.5349	0.5388	0.5810	0.5519	0.5068	0.5161	0.5199	0.4908	0.4886	0.5186	0.5081

	G20	G21	G22	G23	G24	G25	G27	G28	G30	G32	G33	G34	G35	G36	G37	G38	G39	G40	G42
G20	1.0000																		
G21	0.6071	1.0000																	
G22	0.5556	0.4828	1.0000																
G23	0.4167	0.4583	0.5238	1.0000															
G24	0.3846	0.4615	0.4000	0.5882	1.0000														
G25	0.4400	0.3214	0.5455	0.4444	0.3333	1.0000													
G27	0.5556	0.6538	0.5385	0.4545	0.4583	0.4783	1.0000												
G28	0.3200	0.4167	0.4762	0.6429	0.4444	0.3889	0.4762	1.0000											
G30	0.5909	0.5455	0.5909	0.5294	0.3333	0.5263	0.5714	0.5625	1.0000										
G32	0.4828	0.4667	0.6400	0.4348	0.3333	0.5217	0.6400	0.4545	0.5909	1.0000									
G33	0.6538	0.5517	0.5556	0.4783	0.3704	0.4400	0.6154	0.4348	0.6190	0.5357	1.0000								
G34	0.5517	0.6429	0.4828	0.4583	0.3103	0.3704	0.5926	0.4167	0.5217	0.6296	0.6667	1.0000							
G35	0.5926	0.5172	0.5769	0.5000	0.3333	0.5217	0.4643	0.4545	0.6190	0.5556	0.6538	0.6923	1.0000						
G36	0.6400	0.4815	0.4800	0.3810	0.2917	0.3478	0.4800	0.4000	0.6316	0.5200	0.5833	0.5385	0.7273	1.0000					
G37	0.5769	0.5357	0.4815	0.3913	0.4000	0.3600	0.5385	0.4762	0.5238	0.4643	0.5000	0.4828	0.5769	0.7143	1.0000				
G38	0.4815	0.4138	0.4615	0.3636	0.3750	0.3913	0.4615	0.4500	0.5000	0.5000	0.3793	0.4643	0.5000	0.5217	0.5833	1.0000			
G39	0.5806	0.4286	0.6207	0.3448	0.2727	0.5185	0.4688	0.3571	0.5000	0.6552	0.5313	0.5625	0.6000	0.5714	0.5161	0.6071	1.0000		
G40	0.4545	0.4000	0.5333	0.3103	0.2059	0.5385	0.3939	0.3214	0.5769	0.5161	0.4545	0.5313	0.5667	0.4333	0.3529	0.4667	0.7097	1.0000	
G42	0.4583	0.4400	0.5714	0.5625	0.3500	0.5263	0.5000	0.5000	0.6471	0.6190	0.5909	0.5652	0.5455	0.5000	0.4348	0.4091	0.5385	0.5000	1.0000
ORT	0.5300	0.5076	0.5042	0.4329	0.3518	0.4340	0.5249	0.4111	0.5311	0.5305	0.5461	0.5470	0.5395	0.5099	0.4952	0.4376	0.5254	0.4603	0.5082

Figure 4. Similarity coefficient (Jaccard) with RAPD markers in each genotype.

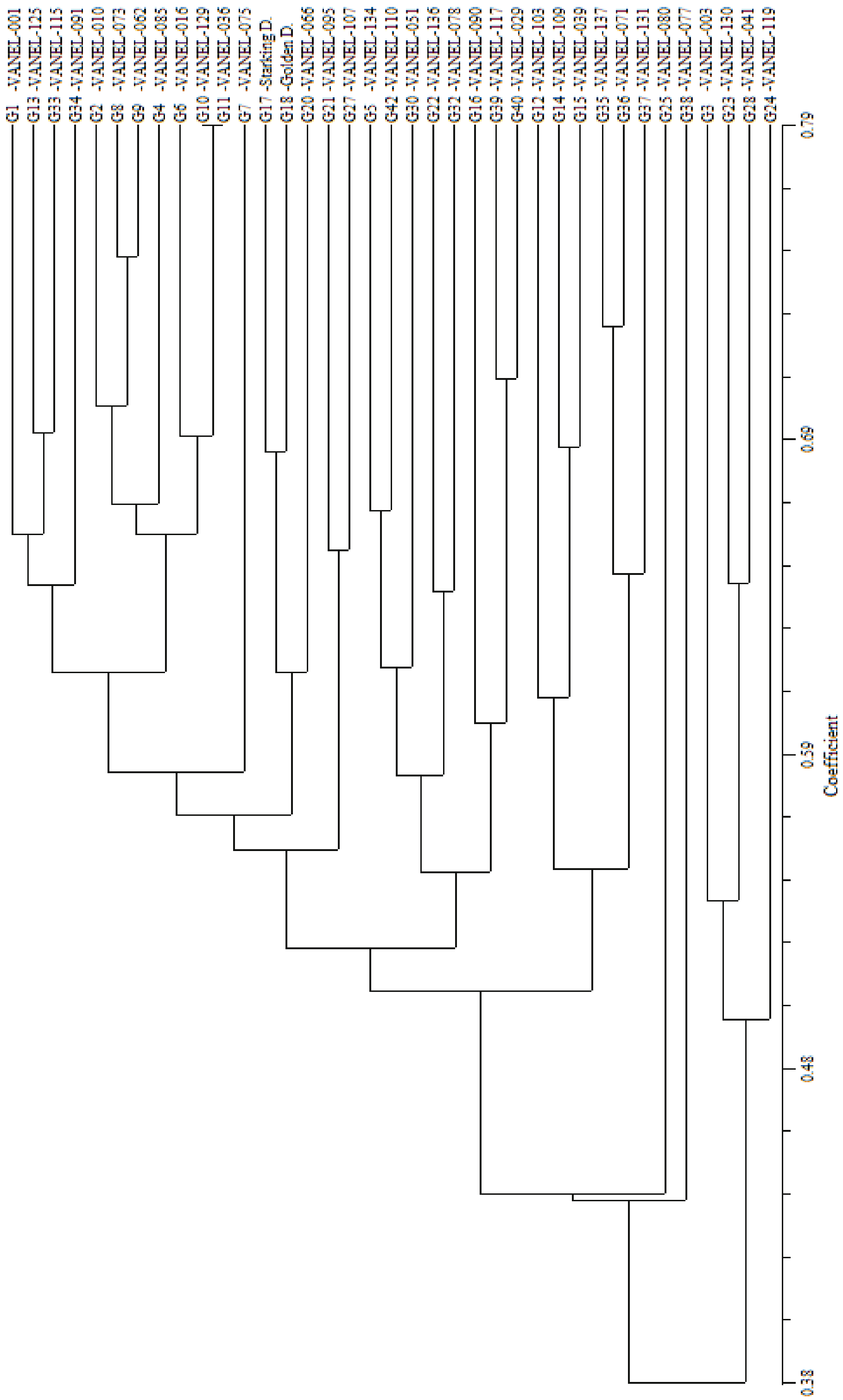

Figure 5. The dendrogram showing the similarity rates between the genotypes.

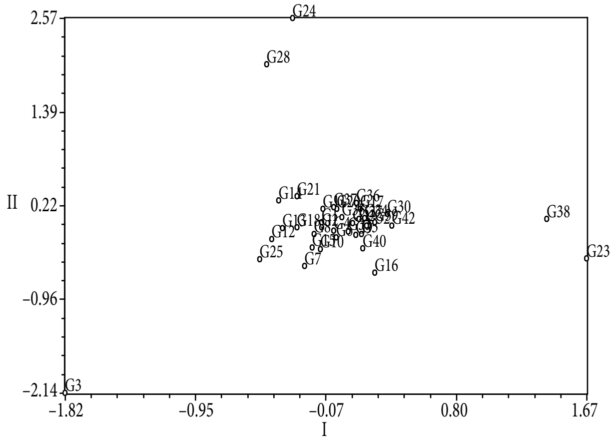

Figure 6. Two-dimensional scaling related to the genetic similarity.

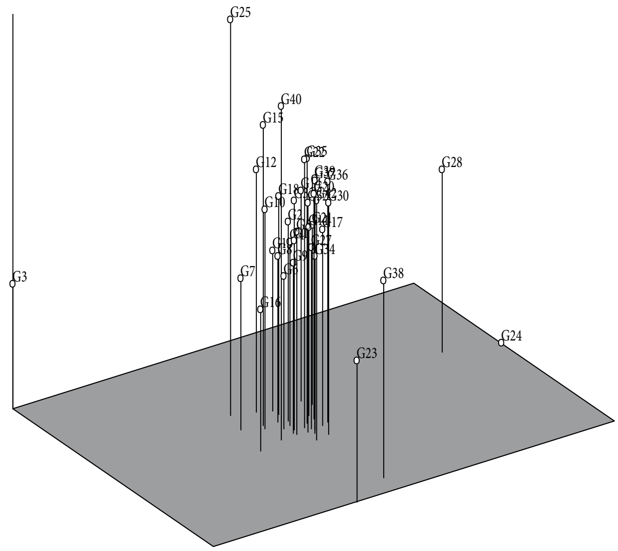

Figure 7. Three-dimensional scaling related to the genetic similarity.

In our study, fruit mass density varied between 0.64 and 0.90 g cm^{-3}. Some studies recorded fruit mass density between 0.40 and 1.35 g cm^{-3} (Akça and Şen, 1991; Edizer and Bekar, 2007; Mitropoulos and Lambrinos, 2007). Mitropoulos and Lambrinos (2007) stated that high fruit density is an important quality parameter with regard to increasing fruit storage time. Our genotypes had the following values: 9.0%–14.40% soluble solids content, 0.15%–1.75% titratable acidity, and pH of 3.14–4.65. Koike et al. (2003) detected soluble solids content between 14.7% and 16.7% in Fuji apples, depending on the years. Hampson et al. (2004) reported soluble solids contents from 11.8% to 18.1% for Braeburn and 14.1% to 16.6% for Golden Delicious; they observed titratable acidity varying from 0.51% to 1.21% for the same apple cultivars grown in different regions. The ranges of titratable acidity and soluble solids content were 0.21%–0.87% and 11.5%–14.5% for apple genotypes grown in Çoruh Valley (Erdoğan and Bolat, 2002), 0.7%–1.2% and 10.6%–13.0% for Demir apples grown in Rize Province (Aygün and Ülgen, 2009), and 0.29%–0.33% and 11.6%–12.8% for Piraziz apples from the Piraziz district of Giresun Province (Karadeniz et al., 2013). Many researchers also detected pH values ranging from 3.15 to 4.89 for apple genotypes (Akça and Şen, 1991; Balta and Uca, 1996; Soylu et al., 2003; Bostan, 2009). Regarding soluble solid content, titratable acidity, and pH values, apple genotypes of the Van Lake Basin had similar findings when compared to those of the related references.

In this study, fruit shape index ranged from 0.71 to 1.13. It was globose for 20 genotypes and the remaining genotypes had other shapes (Table 3). Fruit shape index has been reported as ovoid for Gold Rush (Janick, 2001), oblong for Nicogreen, short globose conical for Nicoter, globose for SuperMac, oblong conical for Zari (Luby and Bedford, 2008), and obloid for the local Altınçekirdek variety (Akçay and Hamarat, 1997). Findings of many related studies revealed fruit shape index values that ranged from 0.67 to 0.98 (Bongers et al., 1994; Akçay and Hamarat, 1997; Miller et al., 2004). Although the majority of native apple genotypes from the Van Lake Basin had globose fruits, other fruit shapes were also seen. As regards fruit shape index, the findings of this study might be recognized as genetic diversity and can contribute to a wide character pool for fruit breeders and researchers. Ercisli (2004) stated that wild apple germplasm resources are critical in maintaining genetic diversity in the gene pool.

While alternate bearing was not observed in five genotypes (G5, G9, G10, G28, and G36), it was partial for 9 genotypes and existent for 21 genotypes (Table 4). Apple genotypes without alternate bearing have also been reported in several references (Eltez, 1983; Akçay and Hamarat, 1997; Janick, 2001; Soylu et al., 2003; Luby and Bedford, 2006). It is known that alternate bearing is a common problem for most apple varieties. Therefore, apple cultivars need to be bred to have regular bearing characters. In this study, genotypes that did not show alternate bearing might contribute to breeding efforts and be valuable for industrial needs, as well.

Consequently, since the apple genotypes investigated in this research have a wide diversity of fruit characteristics

Table 3. Some fruit quality characteristics of apple genotypes. Data are the means of values obtained for 3 years.

RAPD name	Fh (mm)	Fd (mm)	Fsi	Fff (kg cm^{-2})	Ssc (%)	Ta (%)	pH	Fw (g)	Fv (cm^3)	Fmd (g cm^{-3})
G36	77.63	94.99	0.82 (ob)	7.08	12.17	1.75	3.23	310.99	416.33	0.75
G10	61.79	78.77	0.79 (gl)	14.05	13.20	0.74	3.27	202.67	253.33	0.80
G5	76.96	73.38	1.05 (cw)	9.29	11.93	0.28	4.13	192.60	256.67	0.75
G9	61.76	77.12	0.80 (gl)	6.98	14.40	0.80	4.21	158.80	205.67	0.78
G28	64.71	72.03	0.90 (cy)	7.55	10.97	0.26	4.35	143.84	186.67	0.77
G20	68.44	87.38	0.78 (ob)	9.64	10.25	1.38	3.16	218.70	308.00	0.73
G30	62.86	71.21	0.88 (gl)	7.48	11.10	0.21	4.12	137.80	188.00	0.73
G2	61.45	70.82	0.87 (gl)	8.48	11.80	0.30	4.06	145.66	180.00	0.81
G8	59.55	69.30	0.86 (gl)	6.36	9.55	0.91	3.34	123.68	173.50	0.72
G23	55.70	67.75	0.82 (gl)	6.17	12.75	0.22	4.17	111.72	142.00	0.79
G13	47.90	60.43	0.79 (gl)	8.85	9.00	0.20	4.32	97.73	152.00	0.64
G40	55.22	64.80	0.85 (gl)	7.44	13.00	0.27	4.11	94.72	140.00	0.68
G33	52.92	61.26	0.86 (gl)	6.63	11.85	0.18	4.27	91.65	122.00	0.76
G1	46.00	52.90	0.87 (gl)	5.42	13.00	1.46	3.19	75.75	100.00	0.76
G38	44.28	55.00	0.81 (cn)	6.51	12.00	1.19	3.14	61.86	80.00	0.77
G27	58.67	61.34	0.96 (cn)	5.35	12.10	0.90	3.41	101.40	124.00	0.82
G25	60.23	72.48	0.83 (gl)	4.69	11.40	0.27	4.20	130.06	190.00	0.68
G12	57.10	65.10	0.88 (ob)	3.99	12.00	0.15	4.22	95.30	125.00	0.76
G4	56.74	65.00	0.87 (gl)	6.31	11.80	0.52	3.38	103.18	136.00	0.76
G11	59.90	64.55	0.93 (gl)	8.57	10.50	0.19	4.65	103.10	136.00	0.76
G21	55.80	62.00	0.90 (gl)	4.21	11.00	0.15	4.44	78.26	110.00	0.71
G3	54.86	66.87	0.82 (gl)	4.80	12.50	0.24	4.10	69.06	94.00	0.73
G32	41.90	59.00	0.71 (ob)	8.66	10.50	1.20	3.30	65.10	85.00	0.77
G39	48.63	56.73	0.86 (gl)	8.32	11.50	0.15	3.80	64.00	84.00	0.76
G42	51.90	46.00	1.13 (el)	7.62	12.80	0.40	3.89	48.00	71.00	0.68
G37	38.29	47.20	0.81 (gl)	8.50	11.50	0.17	4.47	43.04	58.00	0.74
G35	81.42	77.33	1.05 (cw)	8.59	12.50	0.31	3.94	216.34	310.00	0.70
G22	80.05	78.34	1.02 (cw)	9.19	12.40	0.32	3.98	175.30	202.00	0.90
G16	70.56	71.15	0.99 (ov)	9.11	10.80	0.89	3.85	148.44	205.00	0.73
G6	58.15	70.08	0.83 (gl)	8.62	12.50	0.29	4.11	146.25	184.00	0.79
G15	52.89	62.55	0.85 (gl)	10.14	12.50	0.27	4.20	91.80	118.50	0.77
G7	63.33	65.84	0.96 (gl)	12.72	11.20	0.53	3.45	140.00	200.00	0.70
G34	66.44	61.11	1.09 (ov)	9.24	12.50	0.34	4.13	119.11	134.00	0.89
G24	53.10	57.72	0.92 (cn)	9.12	11.20	0.26	4.21	86.23	132.00	0.66
G14	55.84	47.26	1.18 (el)	9.30	13.80	0.28	4.43	58.00	75.00	0.77
Average	58.94	66.14	0.89	7.86	11.83	0.51	3.92	121.43	162.22	0.75
Maximum	81.42	94.99	1.13	14.05	14.40	1.75	4.65	310.99	416.33	0.90
Minimum	38.29	46.00	0.71	3.99	9.00	0.15	3.14	43.04	58.00	0.64

Fff: Fruit flesh firmness, Fh: fruit height, Fd: fruit diameter, Fsi: fruit shape index, Fw: fruit weight, Fv: fruit volume, Fmd: fruit mass density, Ssc: soluble solids content, Ta: titratable acidity, cw: cylindrically waisted, cn: conic, ov: ovoid, cy: cylindrical, el: ellipsoid, gl: globose, ob: obloid.

Table 4. Some tree characteristics of apple genotypes.

RAPD name	Alternate bearing	Stem circumference (cm)	Crown width (m)	Tree height (m)
G36	Absent	35	2	4
G10	Absent	50	5	4
G5	Absent	35	4	6
G9	Absent	100	4	4
G28	Absent	60	6	7
G20	Existent	35	4	4
G30	Existent	90	4	7
G2	Existent	135	10	8
G8	Existent	55	5	6
G23	Existent	50	5	7
G13	Existent	65	3	5
G40	Existent	85	4	5
G33	Existent	85	4	6
G1	Existent	80	7	8
G38	Existent	60	5	4
G27	Existent	60	4	6
G25	Existent	50	10	8
G12	Existent	65	5	8
G4	Existent	80	5	8
G11	Existent	95	6	6
G21	Existent	110	6	8
G3	Existent	80	4	4
G32	Existent	70	5	4
G39	Existent	30	3	3
G42	Existent	37	3	5
G37	Existent	35	4	7
G35	Partial	95	5	5
G22	Partial	85	3	5
G16	Partial	45	3	4
G6	Partial	76	6	7
G15	Partial	60	4	6
G7	Partial	65	6	8
G34	Partial	35	3	6
G24	Partial	40	3	5
G14	Partial	50	2.5	5

and alternate bearing tendency, they might contribute to further breeding efforts and also the conservation of genetic diversity in the gene pool. Additionally, the high percentage of polymorphism revealed that similarity levels among the apple genotypes were quite low. The genetic variation of fruit characteristics supported this. The results suggest that the Van Lake Basin may be one of the native expansion areas of the genus *Malus*.

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