Turkish Journal of Agriculture and Forestry

Volume 41 | Number 2 Article 1

1-1-2017

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Turkish Journal of Agriculture and Forestry
http://journals.tubitak.gov.tr/agriculture/
Research Article
Turk J Agric For
(2017) 41: 93-102

doi:10.3906/tar-1611-27

Characterization of morphological traits of local and global persimmon varieties and genotypes collected from Turkey

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Received: 14.11.2016 • **Accepted/Published Online:** 08.02.2017 • **Final Version:** 03.05.2017

Abstract: Genetic variations are highly important in terms of plant breeding. These variations occur either spontaneously or artificially by mutations and sexual hybridizations in order to achieve specific breeding objectives. In this study, persimmon genetic resources collected from Turkey and preserved ex situ with commercial cultivars in a germplasm orchard located at Çukurova University, Turkey, were characterized based on their morphological traits. The collection was composed of traditional genotypes and local accessions together with global varieties. For the morphological characterization, 59 morphological and agronomic traits were investigated: 9 related to plant growth, 5 to leaf characteristics, 7 to flower traits, 32 to fruit traits, and 6 to seed traits. Moreover, the data obtained in this process were subjected to similarity coefficient, principal component, and cluster analyses to demonstrate the overall phenotypic relationships among these genotypes. The cumulative proportion of variation reached 39.04% with the first three PCA axes. The first component was based on shoot length, trunk surface structure, flowering time of female flowers, fruit length, and diameter. The twelve factor scores represented 74.75% of the total multivariate variation, and cluster analysis indicated that the similarity index of the population consisting of the investigated genotypes ranged between 81.09% and 17.32%.

Key words: Germplasm resources, *Diospyros kaki*, collection, multivariate analysis

1. Introduction

Persimmon (*Diospyros kaki* L.) belongs to the family Ebenaceae, which contains six genera and nearly 400 species. There are approximately 200 species in the genus *Diospyros*, only four of which have pomological significance. *Diospyros kaki* is one of these four and is the most important commercially cultivated species. The basic chromosome number of *Diospyros kaki* is 15, but the cultivars have 2n = 2x = 30, 4x = 60, or 6x = 90, indicating that they are either tetraploid or hexaploid. *D. kaki* is also referred to as the Japanese or oriental persimmon (Ray, 2002).

Persimmon is a deciduous subtropical fruit crop that is predominantly cultivated in subtropical and temperate regions around the world. Persimmon originated from China but it has been cultivated and produced mostly in Japan (Tuzcu et al., 1994). Although the exact date of the introduction of persimmon to Anatolia is unknown, it is clear that it dates back to rather old times (Yıldız et al., 2007; Ercisli and Akbulut, 2009). Persimmon was introduced to Turkey from Russia via the Black Sea region. It is assumed that both this species and its congener, *D. lotus* L., originated from the same region. Persimmon varieties with commercial value were first introduced to Turkey in 1967 by the Ministry of Agriculture, followed by some selection studies in various parts of Turkey, thus creating a rich persimmon germplasm collection (Onur, 1990; Tuzcu and Seker, 1996). Persimmon is spread in subtropical climatic regions of Turkey. In Turkey, persimmon is rarely cultivated in orchards established by grafting and selecting particular plants and is instead usually cultivated from seedlings. In the last decade, attempts have been made at commercial production and several orchards have been established, especially in the Mediterranean region of the country (Onur, 1990; Özcan, 1994). Turkey's persimmon production was 33,725 t from orchards planted in 2015 (http://www.turkstat.gov.tr). Currently, persimmon is abundantly grown in Hatay, along the coastline of the Eastern Mediterranean, but is also grown in regions of the Black Sea, Marmara, Aegean, and Southeast Anatolia, where average temperatures are somewhat cooler.

Germplasm collections are a source of genetic diversity to support plant breeding and botanical research as well as to support conservation efforts (Naval et al., 2010). These variations occur either spontaneously or artificially by mutations and sexual hybridizations in order to achieve

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specific breeding objectives. The value of plant genetic resources is expressed as the wealth of plant material. Therefore, it is crucial to register genetic resources, establish new orchards with collected plants, and present the plant material to breeders for new varietal development. For this purpose, persimmon genetic resources were collected from Turkey and were preserved ex situ with commercial cultivars in a germplasm orchard located at Çukurova University. The collection includes accessions from selections made in several regions of Turkey and other genotypes introduced from Italy, Israel, Japan, France, the United States, Pakistan, and Iran. The total number of persimmon cultivars and genotypes has now reached 48.

Principal component analysis (PCA) is a method that can be used to identify patterns in a data set and to eliminate redundancy in univariate analyses when multicollinear data are involved. PCA essentially restructures data sets containing many correlated variables into smaller sets of components of the original variables. With PCA a large number of independent variables can be systematically reduced to a smaller, conceptually more coherent set of variables. These principal components can be described as a linear combination of the original variables. PCA can be applied in horticultural sciences to yield and quality components, taxonomic similarity, and association between genetic and environmental attributes (Iezzoni and Pritts, 1991).

The aim of the existing study was to evaluate the morphological variation among these 48 persimmon genotypes that originated from Turkey, Italy, Israel, Japan, France, the United States, Pakistan, and Iran.

2. Materials and methods

2.1. Plant material

This study was conducted during 2010 and 2011. The plant material consisted of 48 accessions belonging to the persimmon germplasm collection of the Agriculture Faculty of Çukurova University. Three trees per accession were studied. Most of these varieties were introduced from Italy, but some were from Israel, Japan, the United States, France, Pakistan, and Iran. An additional 11 accessions were collected from 6 provinces in 3 different regions of Turkey (Mediterranean, ME; Marmara, MR; Black Sea, BS). *D. lotus* L. and *D. virginiana* L. were used as reference outgroups. The origins of the accessions are presented in Table 1. Accessions were evaluated based on a total of 59 morphological and agronomic characters (9 plant growth, 5 leaf, 7 flower, 32 fruit, and 6 seed) by using a modified UPOV (International Union for the Protection of New Varieties of Plants) descriptor list (UPOV, 2004) (Table 2).

2.2. Variables related to trees

Observations of the trees and 1-year-old shoots were made during the dormant season; those for the 1-year-old shoots were made based on the middle third of the shoot. Shoot length, shoot thickness, shoot color (sunny side), internode length, and bud shape were measured for 10 shoots from 3 trees for each accession.

2.3. Variables related to leaves

Observations of leaves were made in summer on fully developed leaves from the middle third of a shoot from the current season. The measurements were performed for 10 leaves from 3 trees for each accession.

2.4. Variables related to flowers

Observations of the flowers were based on fully developed flowers at full flowering. The measurements were performed for 10 flowers from 3 trees for each accession.

2.5. Variables related to fruits and seeds

Observations of the fruit were performed using fruits at the time of harvest maturity. The measurements (Table 2) were made on 15 fruits from 3 trees for each accession. For small length and width measures (mm), a digital caliper (Mitutoyo CD-15CPX, Mitutoyo America Corporation, USA) was used. The fruit samples were weighed on a precision scale (max. 12 kg, d = 1 g). The total soluble solids (TSS) content was determined using a portable refractometer [FG-103/113 (0%–32%), Soif Ltd., China] based on a few drops of juice. The total titratable acidity (TA) was determined by neutralization to pH 8.1 of an aliquot of 5 mL of juice with 0.1 N sodium hydroxide (NaOH) using a digital burette and pH meter. Seeds obtained from 45 fruits for each genotype were investigated for seed variables.

2.6. Statistical analysis

Statistical analyses were conducted using SAS (SAS Institute Inc., 2006). The data for 59 quantitative characters were analyzed to determine means, standard deviations, and minimum and maximum values of persimmon accessions for agromorphological traits using the TABULATE procedure of SAS. Data were then subjected to PCA using PRINCOMP procedures. Cluster analysis (UPGMA, Euclid), similarity coefficients, and dendrograms were generated using StatGraphics (v.16) statistical software.

3. Results and discussion

3.1. Means, standard deviations, and minimum and maximum values

Descriptive statistics for the 59 agromorphological characters included means for all traits and their minimum and maximum values, as well as the standard deviations (Table 3). Fruit size exhibited the greatest standard deviation (43.64), followed by yield per tree (34.32), showing the maximum variation in the data recorded. Maximum variations were recorded for fruit size, fruit yield per tree, the period from flower formation to fruit maturity, fruit length and diameter, and sepal width,

Table 1. Origins of persimmon accessions.

No.	Cultivar and selections	Scientific name	Origin	Type of astringency	Germplasm source
1	Shakoku	*Diospyros kaki* L.	France	PCA	CU
2	*Diospyros lotus*	*Diospyros lotus*	France	PCA	CU
3	*Diospyros virginiana*	*Diospyros virginiana*	Israel	PCA	CU
4	Seedless Mardan	*Diospyros kaki* L.	Pakistan	PCA	CU
5	Yesil Hurma	*Diospyros oleifera*	Selection from Adana-ME-Turkey	PCA	CU
6	07 TH 13	*Diospyros kaki* L.	Selection from Antalya-ME-Turkey	PCA	CU
7	07 TH 14	*Diospyros kaki* L.	Selection from Antalya-ME-Turkey	PVA	CU
8	07 TH 17	*Diospyros kaki* L.	Selection from Antalya-ME-Turkey	PVA	CU
9	07 TH 18	*Diospyros kaki* L.	Selection from Antalya-ME-Turkey	PVA	CU
10	31 TH 01	*Diospyros kaki* L.	Selection from Hatay-ME-Turkey	PVA	CU
11	31 TH 03	*Diospyros kaki* L.	Selection from Hatay-ME-Turkey	PCA	CU
12	55 TH 05	*Diospyros kaki* L.	Selection from Samsun-BS-Turkey	PVA	CU
13	Fatsa - 1	*Diospyros kaki* L.	Selection from Ordu-BS-Turkey	PVA	CU
14	Sarı Yenen	*Diospyros kaki* L.	Selection from Istanbul-MR-Turkey	PCA	CU
15	Cekirdekli	*Diospyros kaki* L.	Selection from Adana-ME-Turkey	PVA	CU
16	Saijo	*Diospyros kaki* L.	Israel	PCA	CU
17	Hachiya	*Diospyros kaki* L.	Italy	PCA	CU
18	Guilbecky	*Diospyros kaki* L.	Italy	PCA	CU
19	BST - 29	*Diospyros kaki* L.	Italy	PCA	CU
20	Fennio	*Diospyros kaki* L.	Italy	PCA	CU
21	Lycopersicon	*Diospyros kaki* L.	Italy	PCA	CU
22	Farmacista Honorati	*Diospyros kaki* L.	Italy	PCA	CU
23	Fujiwara O'Gosho	*Diospyros kaki* L.	USA	PCNA	CU
24	Triumph	*Diospyros kaki* L.	Israel	PCA	CU
25	Vainiglia	*Diospyros kaki* L.	Pakistan	PVNA	CU
26	Aman Kaki-1	*Diospyros kaki* L.	Pakistan	PVNA	CU
27	Sirin Hurma	*Diospyros kaki* L.	Iran	PVA	CU
28	Nishimura wase	*Diospyros kaki* L.	Italy	PVA	CU
29	Mikatani O'Gosho	*Diospyros kaki* L.	Italy	PVNA	CU
30	Mandarino	*Diospyros kaki* L.	Italy	PVNA	CU
31	Bruniquel	*Diospyros kaki* L.	Italy	PVNA	CU
32	Aman Kaki-2	*Diospyros kaki* L.	Italy	PVNA	CU
33	Koshu Hyakume	*Diospyros kaki* L.	Japan	PVA	CU
34	Mizushima O'Gosho	*Diospyros kaki* L.	Italy	PVNA	CU
35	Chienting	*Diospyros kaki* L.	USA	PVA	CU
36	Jiro C - 24276	*Diospyros kaki* L.	Italy	PCNA	CU
37	Kawabata O'Gosho	*Diospyros kaki* L.	Italy	PCNA	CU
38	Giant Fuyu	*Diospyros kaki* L.	Israel	PCNA	CU
39	Tipo Kaki	*Diospyros kaki* L.	Pakistan	PVNA	CU
40	Shogatsu	*Diospyros kaki* L.	Italy	PVNA	CU
41	Giboshi	*Diospyros kaki* L.	Italy	PVNA	CU
42	Thiene	*Diospyros kaki* L.	Italy	PVNA	CU
43	Moro	*Diospyros kaki* L.	Italy	PVNA	CU
44	Brazzale	*Diospyros kaki* L.	Italy	PVNA	CU
45	Kirakaki	*Diospyros kaki* L.	Italy	PVNA	CU
46	Akouman Kaki	*Diospyros kaki* L.	Italy	PVNA	CU
47	Kurokuma	*Diospyros kaki* L.	Italy	PVNA	CU
48	Hyakume	*Diospyros kaki* L.	Italy	PVNA	CU

Table 2. Modified UPOV descriptors used for morphological characterization in persimmon.

No.	Traits	Abbreviation	Range
1	Tree vigor	TV	1 (weak), 3 (medium), 5 (strong), 7 (very strong)
2	Tree habit	TH	1 (upright), 2 (semiupright), 3 (spreading), 4 (drooping)
3	Shoot length (1 year old)	SL	Measured in centimeters (cm)
4	Shoot thickness (1 year old)	ST	Measured in millimeters (mm)
5	Internode length (1 year old)	IL	Measured in centimeters (cm)
6	Shoot color (1 year old, sunny side)	SHC	1 (gray brown), 2 (yellow brown), 3 (brown), 4 (red brown)
7	Bud shape	BS	1 (triangular), 2 (broad ovate), 3 (circular)
8	Tendency of side branching	SBT	1 (high), 2 (medium), 3 (low)
9	Trunk surface structure	TS	1 (smooth), 2 (rough), 3 (very rough)
10	Leaf blade length (mm)	LL	Measured in centimeters (cm)
11	Leaf blade width (mm)	LW	Measured in centimeters (cm)
12	Leaf blade shape	LS	1 (elliptic), 2 (ovate), 3 (obovate)
13	Leaf blade: shape of base	LBS	1 (narrow acute), 2 (broad acute), 3 (obtuse), 4 (rounded)
14	Leaf blade: shape of apex	LAS	1 (acuminate), 2 (acute), 3 (obtuse)
15	Sex expression of flowers	FLS	1 (female only), 2 (female and male), 3 (female, male, hermaphrodite)
16	Time of flowering of female flower (80% open)	FLT	1 (early), 2 (medium), 3 (late)
17	Female flower: diameter of corolla (mm)	COD	Measured in millimeters (mm)
18	Female flower: diameter of calyx (mm)	CAD	Measured in millimeters (mm)
19	Female flower: shape of calyx viewed from above	CAS	1 (circular), 2 (rounded rhombic), 3 (rhombic), 4 (regular cruciform), 5 (irregular cruciform)
20	Female flower: number of calyxes	CAN	1 (four), 2 (more than four)
21	The period from flower formation to fruit maturity	PFM	Measured in days
22	Fruit harvest time	FHT	1 (early), 2 (medium), 3 (late)
23	Fruit size	FRS	Measured in grams (g)
24	Fruit length	FRL	Measured in millimeters (mm)
25	Fruit diameter	FRD	Measured in millimeters (mm)
26	Fruit shape	FRS	1 (narrow elliptic), 2 (elliptic), 3 (circular), 4 (oblate), 5 (transverse broad oblong), 6 (ovate), 7 (broad ovate), 8 (very broad ovate)
27	Fruit: shape in cross-section	FCS	1 (circular), 2 (irregular rounded), 3 (square)
28	Fruit: shape of apex in longitudinal section	FAS	1 (acuminate), 2 (obtuse), 3 (rounded), 4 (truncate), 5 (retuse)
29	Fruit: grooving at apex	FAG	1 (absent or weak), 2 (moderate), 3 (strong)
30	Fruit: shallow concentric cracking around apex	FSC	1 (absent or weak), 2 (moderate), 3 (strong)
31	Fruit: cracking of apex	FAC	1 (absent or weak), 2 (moderate), 3 (strong)
32	Fruit: longitudinal grooving	FLG	1 (absent or very shallow), 3 (shallow), 5 (medium), 7 (deep)
33	Fruit: wrinkles at calyx end	FWC	1 (absent to very few), 3 (few), 5 (medium), 7 (many)
34	Fruit: calyx attachment	FCA	1 (level), 2 (slightly depressed), 3 (strongly depressed)
35	Fruit: groove at calyx end	FCG	1 (absent), 9 (present)
36	Fruit: calyx size compared with fruit diameter	CS	3 (small), 5 (medium), 7 (large)
37	Fruit: attitude of calyx	CA	1 (erect), 2 (semierect), 3 (horizontal)
38	Fruit: width of sepal	SW	Measured in millimeters (mm)
39	Fruit: length of stalk	SL	Measured in millimeters (mm)
40	Fruit: thickness of stalk	ST	Measured in millimeters (mm)
41	Fruit: color of skin at harvest period	HSC	1 (green yellow), 2 (yellow orange), 3 (orange), 4 (red orange)
42	Fruit: color of skin at maturity period	MSC	1 (orange), 2 (dark orange), 3 (red orange), 4 (red), 5 (brown)
43	Fruit: skin structure	FSS	1 (very bright), 2 (bright), 3 (matte)
44	Fruit: color of flesh at harvest period	HFC	1 (yellow), 2 (orange yellow), 3 (orange), 4 (red orange), 5 (brown orange), 6 (brown)
45	Fruit: color of flesh at maturity period	MFC	1 (yellow), 2 (orange yellow), 3 (orange), 4 (red orange), 5 (red), 6 (brown), 6 (dark brown)
46	Fruit: presence of brown specks in flesh	FBS	1 (always absent), 2 (sometimes present), 3 (always present)
47	Fruit: color of flesh around seeds	FCS	1 (orange), 2 (brown), 3 (dark brown)
48	Fruit: classification on the basis of a combination of pollination types	PT	1 (pollination variant), 2 (pollination constant)
49	Fruit: astringency	A	1 (astringency), 2 (nonastringent)
50	Fruit: total soluble solids	TSS	Measured in °Brix
51	Fruit: total acid	TA	Measured in g/L of malic acid
52	Fruit: flavor	FF	1 (very low), 2 (low), 3 (medium), 4 (good), 5 (very high)
53	Tree yield (kg)	TY	Measured in yield per tree (kg)
54	Seed: presence of seeds	S	1 (present), 2 (absent)
55	Seed: seed weight	SW	Measured in grams (g)
56	Seed: shape in lateral view	SLV	1 (narrow elliptic), 2 (ovate), 3 (broad ovate), 4 (semibroad elliptic), 5 (semioblate)
57	Seed: color	SC	1 (green brown), 2 (medium brown), 3 (dark brown)
58	Seed: number of seeds	SN	Measured in seed number per fruit
59	Seed: tendency of parthenocarpy	SP	1 (low), 2 (high)

Table 3. Means, standard deviations, and minimum and maximum values of persimmon accessions for agromorphological traits.

Traits	Minimum	Maximum	Mean	St. dev.
Tree vigor	3.00	7.00	6.38	1.10
Tree habit	2.00	3.00	2.85	0.36
Shoot length (1 year old)	12.48	36.98	19.32	4.81
Shoot thickness (1 year old)	3.28	5.36	4.22	0.45
Internode length (1 year old)	2.03	4.00	2.83	0.44
Shoot color (1 year old, sunny side)	1.00	3.00	1.92	1.01
Bud shape	1.00	2.00	1.35	0.48
Tendency of side branching	1.00	1.00	1.00	0.00
Trunk surface structure	2.00	3.00	2.04	0.20
Leaf blade length (mm)	6.98	13.78	9.93	1.62
Leaf blade width (mm)	3.15	8.65	5.98	1.12
Leaf blade shape	1.00	2.00	1.52	0.50
Leaf blade: shape of base	1.00	4.00	2.38	0.87
Leaf blade: shape of apex	1.00	3.00	1.60	0.54
Sex expression of flowers	1.00	2.00	1.19	0.39
Time of flowering of female flower (80% open)	1.00	3.00	1.38	0.57
Female flower: diameter of corolla (mm)	8.86	19.29	15.79	2.12
Female flower: diameter of calyx (mm)	10.97	42.53	27.28	6.46
Female flower: shape of calyx viewed from above	2.00	5.00	3.25	0.96
Female flower: number of calyxes	1.00	1.00	1.00	0.00
Period from flower form. to fruit matur. (days)	166	260.00	176.38	12.84
Fruit harvest time	1.00	3.00	1.08	0.35
Fruit size	5.20	239.13	95.84	43.64
Fruit length	21.09	76.32	55.95	10.46
Fruit diameter	17.20	74.26	49.09	9.62
Fruit shape	2.00	8.00	3.85	1.30
Fruit: shape in cross-section	1.00	3.00	1.52	0.77
Fruit: shape of apex in longitudinal section	2.00	5.00	3.52	0.99
Fruit: grooving at apex	1.00	3.00	1.94	0.78
Fruit: shallow concentric cracking around apex	1.00	2.00	1.15	0.36
Fruit: cracking of apex	1.00	2.00	1.04	0.20
Fruit: longitudinal grooving	1.00	7.00	2.67	1.72
Fruit: wrinkles at calyx end	1.00	5.00	2.33	1.26
Fruit: calyx attachment	1.00	3.00	1.96	0.58
Fruit: groove at calyx end	1.00	9.00	1.17	1.15
Fruit: calyx size compared with fruit diameter	3.00	7.00	6.54	0.94
Fruit: attitude of calyx	2.00	3.00	2.13	0.33
Fruit: width of sepal	11.80	53.06	46.01	7.18
Fruit: length of stalk	3.50	14.55	9.70	1.86
Fruit: thickness of stalk	1.70	4.71	3.24	0.64
Fruit: color of skin at harvest period	1.00	4.00	1.56	0.77
Fruit: color of skin at maturity period	1.00	5.00	3.04	1.74
Fruit: skin structure	2.00	3.00	2.04	0.20
Fruit: color of flesh at harvest period	2.00	6.00	4.19	1.83
Fruit: color of flesh at maturity period	3.00	7.00	5.15	1.87
Fruit: presence of brown specks in flesh	1.00	3.00	1.77	0.59
Fruit: color of flesh around seeds	1.00	3.00	1.71	0.50
Clas. on the basis of a combination of pol. typ.	1.00	2.00	1.42	0.50
Fruit: astringency	1.00	2.00	1.27	0.45
Fruit: total soluble solids	0.00	21.60	15.15	4.08
Fruit: total acid	0.00	0.40	0.22	0.08
Fruit: flavor	1.00	5.00	3.85	0.68
Tree yield (kg)	5.00	190.00	52.55	34.32
Seed: presence of seeds	1.00	2.00	1.06	0.24
Seed: seed weight	0.00	1.33	0.82	0.32
Seed: shape in lateral view	0.00	5.00	3.52	1.43
Seed: color	0.00	2.00	1.85	0.50
Seed: number of seeds	0.00	8.00	4.00	2.23
Seed: tendency of parthenocarpy	1.00	2.00	1.19	0.39

which indicated that the genotypes used were diverse in origin. The average value recorded for fruit weight was 95.84 g, and the average fruit yield per tree was 52.55 kg. The variations present among the persimmon accessions for fruit weight and fruit yield per tree illustrated the scope of variation for the improvement in yield and yield-related traits. However, the variability in the period from flower formation to fruit maturity indicated early and late fruiting genotypes. Several researchers reported for different plant species that the highest variability that could be used for potential improvement was in yield and yield-related traits (Badenes et al., 1998; Naval et al., 2010; Nawab et al., 2013). Badenes et al. (1998) also indicated that variation was observed to be higher for traits related to phenology and fruit quality in peach genotypes.

3.2. Principal component analysis

PCA is a useful statistical technique for providing a better comprehension of the relationships, correlations, and significance among variables studied. When applied to germplasm collections, PCA shows the structure of the collection by identifying the most relevant variables, relationships among accessions, and possible outliers (Martínez-Calvo et al., 2013).

The first twelve factor scores (PC axes) contained 74.75% of the cumulative variation (Table 4). The first PC explained 19.82%, the second 11.92%, the third 7.30%, the fourth 6.77%, and the fifth 5.40% of the morphological variation, making 50%. The cumulative proportion of variation reached 51.21% in the first five axes.

The results of PCA are presented in Table 4. The variables with the most important contributions to PC1 with positive coefficients were fruit flavor, TSS, fruit length, and width of sepal, and the most important contributions with negative coefficients were trunk surface structure and shoot length. For PC2, the most important variables with positive coefficients were for the fruit's shape of cross-section and presence of seeds and those with negative coefficients were seed color and seed number. Variables with the highest scores in PC3 with positive coefficients were presence of seeds and the period from flower formation to fruit maturity and the variable with the highest score and a negative coefficient was seed color. Fruit shape of apex in longitudinal section, wrinkles at the calyx end, and grooving at the apex were highly positively correlated with PC4, and leaf blade length and period from flower formation to fruit maturity showed a strong negative correlation with PC4. The traits showing the strongest positive correlation with PC5 were calyx attachment and fruit size; those with the strongest negative correlations were internode length and tree habit.

The 48 persimmon accessions are represented in the space defined by the first and second principal components (Figure 1) and in that defined by the first and third (Figure 2). Both of these figures show that the genotypes could be divided into five different groups of trees similar to each other. Based on all the examined agromorphological traits, and especially fruit characteristics, the first subgroup, formed by *D. lotus* and *D. virginiana*, was separated from the rest of the persimmon accessions and is shown on the right side in Figures 1 and 2. These species are used more often as rootstock than for their fruits. Similar results were obtained by Ray (2002), indicating that these species have small edible fruits of inferior quality; thus, they are used as rootstocks.

The second subgroup, formed by Yesil Hurma (*D. oleifera*), was discriminated from all other accessions based on the period from flower formation to fruit maturity (days), time of flowering of female flower (80% open), fruit harvest time, and fruit characteristics such as skin structure, flavor, and color of skin when fresh. Among all the examined genotypes, Yesil Hurma was the latest maturing accession and separated from the other genotypes due to the rough and matte texture of the fruit skin, and it is located on the right-hand side in Figures 1 and 2.

The third subgroup, formed by BST29 and Fennio, was discriminated from all other accessions based on fruit size and is shown on the upper left side of the figures. Fennio and BST29 are the accessions with the largest fruit among all examined genotypes. The fourth subgroup, formed by Seedless Mardan and Aman Kaki 2, was separated from all other accessions based on seedlessness and a high tendency towards parthenocarpy, and this subgroup also appears on the left side in the figures. The last subgroup was formed by the rest of the accessions and appears closely spaced on the left side of the figures. Fruit characteristics such as fruit size, flavor, color of skin when fresh, TSS, and shape of cross-section are the most important variables for classification into this subgroup. The results of the present investigation concur with those of Martínez-Calvo et al. (2013), who studied 27 persimmon cultivars based on multivariate analysis with 37 variables, using PCA and cluster analysis. Badenes et al. (1998) reported that PCA was useful for evaluating morphological, phenological, and fruit quality traits of 55 apricot cultivars, including the most important clones grown in Spain, France, and Italy.

3.3. Cluster analysis

The 59 variables from PCA were used in clustering, and the resulting clusters are presented in Figure 3. The accessions were divided into six main clusters, and subclusters were identified within those clusters. In the morphological dendrogram, the majority of accessions were found in close proximity to each other and did not show differences regarding fruit morphology or other characters. The first main group consisted of *Diospyros lotus* and *Diospyros virginiana* and these two genotypes

Table 4. Results of the principle component (PC) analysis (for the first 12 PCs) of persimmon genotypes collected from Turkey for 59 agromorphological traits.

Traits	PC axis											
	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8	Prin9	Prin10	Prin11	Prin12
Eingenvalues	11.69	7.03	4.31	3.99	3.19	2.94	2.35	2.29	1.85	1.62	1.55	1.30
Explained proportion of variation (%)	19.82	11.92	7.30	6.77	5.40	4.98	3.99	3.87	3.13	2.74	2.62	2.21
Cumulative proportion of variation (%)	19.82	31.74	39.04	45.81	51.21	56.19	60.17	64.05	67.18	69.92	72.55	74.75
Variables	Eigenvectors											
Tree vigor	–0.01	0.00	0.05	–0.04	0.16	0.23	0.23	0.06	–0.23	–0.02	0.08	–0.01
Tree habit	0.15	–0.08	0.06	0.05	–0.26	0.10	–0.30	0.01	–0.09	–0.01	–0.04	0.13
Shoot length (1 year old)	–0.22	–0.01	–0.02	0.02	0.12	0.21	0.14	0.06	–0.10	0.08	0.06	–0.04
Shoot thickness (1 year old)	–0.02	0.14	–0.09	0.24	–0.21	0.13	0.13	0.09	–0.19	–0.08	–0.01	–0.07
Internode length (1 year old)	0.05	0.16	–0.16	0.01	–0.27	0.06	0.10	0.00	0.04	–0.03	0.23	0.10
Shoot color (1 year old, sunny side)	0.03	–0.10	0.00	–0.10	0.15	0.23	–0.17	0.32	0.11	–0.04	–0.09	–0.02
Bud shape	0.02	0.12	–0.02	0.17	–0.06	–0.15	–0.08	0.23	–0.01	–0.08	–0.23	–0.44
Tendency of side branching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trunk surface structure	–0.24	–0.08	–0.02	0.10	0.18	0.04	0.05	–0.07	0.11	–0.08	–0.01	0.05
Leaf blade length (mm)	0.05	0.15	–0.18	–0.24	–0.05	–0.09	0.05	–0.30	–0.11	–0.01	–0.02	–0.03
Leaf blade width (mm)	0.15	0.15	–0.15	–0.13	–0.07	0.04	0.08	–0.24	0.10	0.02	–0.07	0.08
Leaf blade shape	0.03	0.03	0.09	0.09	–0.06	0.17	0.22	0.14	0.38	–0.14	–0.11	–0.03
Leaf blade: shape of base	0.13	0.04	0.00	0.10	–0.05	0.28	0.26	0.13	0.06	0.06	–0.12	0.29
Leaf blade: shape of apex	0.09	0.08	–0.12	–0.01	0.01	–0.12	–0.02	0.22	0.08	–0.02	0.05	0.41
Sex expression of flowers	0.03	0.01	–0.09	0.17	0.06	–0.31	–0.08	0.15	–0.29	–0.12	0.22	–0.03
Time of flowering of female flower (80% open)	–0.19	–0.01	–0.07	–0.03	0.16	0.01	–0.05	0.09	0.09	0.03	–0.33	–0.06
Female flower: diameter of corolla (mm)	0.16	0.06	0.17	–0.10	0.17	0.00	0.01	0.20	0.11	0.16	–0.06	0.05
Female flower: diameter of calyx (mm)	0.20	–0.15	0.03	–0.07	–0.03	0.06	–0.06	–0.06	0.11	–0.02	0.17	0.07
Female flower: shape of calyx from above	–0.02	–0.05	0.05	0.01	0.10	0.16	–0.26	–0.07	–0.28	–0.25	0.00	0.34
Female flower: number of calyx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Period from flower form. to fruit matur. (days)	–0.04	0.11	0.27	–0.23	0.02	–0.18	0.09	–0.03	–0.13	0.10	0.18	0.08
Fruit harvest time	–0.21	0.04	0.19	–0.14	0.16	–0.12	0.09	–0.03	–0.02	0.05	0.06	0.08
Fruit size	0.18	0.18	–0.06	–0.03	0.29	0.02	0.03	0.01	0.04	–0.04	0.08	–0.12
Fruit length	0.23	0.17	0.02	0.06	0.17	–0.02	–0.01	0.02	0.02	0.04	0.12	–0.04
Fruit diameter	0.21	0.06	–0.01	–0.17	0.20	0.05	0.02	0.12	–0.01	–0.03	0.02	0.06
Fruit shape	0.06	0.20	–0.17	0.07	0.13	–0.08	0.07	–0.11	–0.01	–0.17	–0.22	0.21
Fruit: shape in cross-section	0.00	0.30	–0.06	0.07	–0.02	0.07	–0.01	–0.22	–0.04	–0.04	–0.09	0.05
Fruit: shape of apex in longitudinal section	0.02	0.09	0.17	0.32	–0.15	0.09	–0.04	–0.05	0.01	0.12	0.20	0.00
Fruit: grooving at apex	0.08	0.02	0.20	0.28	–0.05	0.08	0.10	0.04	0.05	–0.01	0.17	–0.12
Fruit: shallow concentric cracking around apex	0.07	–0.10	0.16	–0.10	0.15	0.23	–0.05	–0.05	–0.06	0.21	–0.03	–0.12
Fruit: cracking of apex	0.04	–0.07	0.09	–0.01	0.02	0.15	0.08	0.11	0.10	–0.40	0.19	0.19
Fruit: longitudinal grooving	0.07	–0.01	–0.02	0.23	0.10	–0.14	–0.03	0.09	0.15	0.39	–0.10	0.22
Fruit: wrinkles at calyx end	0.04	0.11	0.07	0.30	–0.01	–0.07	–0.12	–0.16	0.24	0.25	0.01	0.01
Fruit: calyx attachment	0.14	0.08	–0.02	0.19	0.32	0.03	–0.01	–0.04	0.09	0.00	0.07	0.10
Fruit: groove at calyx end	0.02	0.12	–0.13	–0.06	0.08	0.06	0.12	–0.17	0.24	0.05	0.42	–0.18
Fruit: calyx size compared with fruit diameter	–0.05	–0.22	0.17	–0.04	–0.18	–0.03	–0.10	0.00	–0.05	0.27	0.04	0.14
Fruit: attitude of calyx	0.02	0.04	–0.15	0.10	0.08	–0.18	0.22	0.30	–0.29	0.09	0.08	0.00
Fruit: width of sepal	0.23	0.05	0.07	–0.14	–0.06	–0.12	–0.06	0.08	–0.05	0.12	0.13	0.04
Fruit: length of stalk	0.20	0.02	–0.04	–0.10	–0.05	–0.08	–0.06	0.12	0.08	0.04	–0.09	–0.14
Fruit: thickness of stalk	0.14	0.19	0.07	–0.01	0.14	0.00	–0.10	0.14	–0.14	–0.01	0.04	–0.08
Fruit: color of skin at harvest period	–0.11	–0.02	–0.08	0.06	–0.12	–0.22	0.24	0.24	–0.03	0.05	–0.03	0.20
Fruit: color of skin at maturity period	0.12	–0.23	0.11	–0.11	–0.12	–0.09	0.18	0.00	0.11	–0.07	0.00	–0.07
Fruit: skin structure	–0.18	0.05	0.19	–0.12	0.17	–0.12	0.10	–0.03	0.03	0.12	0.04	0.08
Fruit: color of flesh at harvest period	0.15	–0.23	0.13	0.07	0.06	–0.12	0.20	–0.08	–0.01	–0.06	–0.02	–0.02
Fruit: color of flesh at maturity period	0.16	–0.23	0.13	0.05	0.04	–0.10	0.21	–0.07	–0.02	–0.07	0.01	–0.02
Fruit: presence of brown specks in flesh	0.15	–0.13	0.04	0.06	0.08	–0.13	–0.23	–0.13	–0.01	–0.01	0.00	0.08
Fruit: color of flesh around seeds	0.15	–0.13	0.16	0.17	0.01	0.00	0.09	–0.17	–0.14	–0.08	–0.18	–0.07
Clas. on the basis of a combination of pol. typ.	–0.14	0.13	–0.19	–0.15	–0.07	–0.04	–0.21	0.12	0.22	0.06	0.06	0.05
Fruit: astringency	0.11	–0.07	0.04	0.04	0.17	–0.16	–0.21	–0.04	0.13	–0.26	0.03	–0.02
Fruit: total soluble solids	0.23	0.06	0.05	–0.08	–0.14	–0.01	0.08	–0.05	–0.05	–0.04	–0.18	0.02
Fruit: total acid	0.17	0.03	0.01	–0.17	–0.01	–0.02	0.20	–0.05	–0.06	0.19	–0.20	0.04
Fruit: flavor	0.25	0.05	–0.02	–0.05	–0.16	–0.02	0.00	0.08	0.00	0.01	–0.10	0.02
Tree yield (kg)	–0.02	0.03	0.04	–0.22	–0.18	0.20	–0.09	0.23	0.01	0.07	0.15	–0.08
Seed: presence of seeds	–0.06	0.24	0.28	–0.09	–0.10	–0.10	0.04	0.00	0.00	–0.10	–0.05	0.03
Seed: seed weight	0.15	–0.11	–0.22	–0.08	0.07	0.22	0.01	–0.01	–0.21	0.11	–0.05	–0.12
Seed: shape in lateral view	0.02	–0.12	–0.24	0.13	0.04	0.11	0.00	–0.13	–0.14	0.27	0.09	0.04
Seed: color	0.06	–0.26	–0.28	0.05	0.11	0.06	–0.05	0.02	0.03	0.09	0.08	0.00
Seed: number of seeds	–0.07	–0.25	–0.20	–0.06	–0.02	–0.14	0.17	–0.04	0.14	–0.03	–0.06	0.05
Seed: tendency of parthenocarpy	–0.09	0.21	0.21	0.07	0.04	0.17	–0.06	–0.07	–0.10	0.11	–0.18	0.10

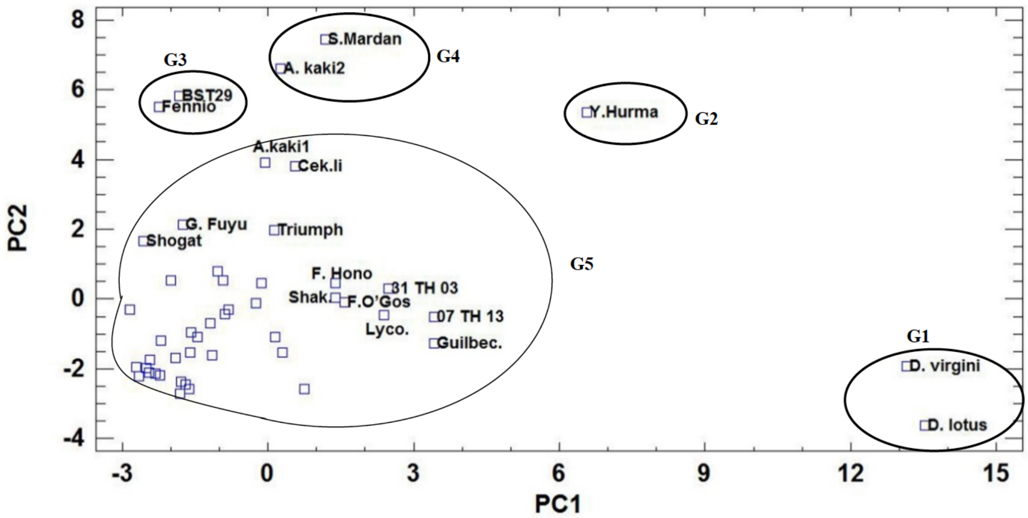

Figure 1. Representation of the accessions in the space defined by the first two principal components.

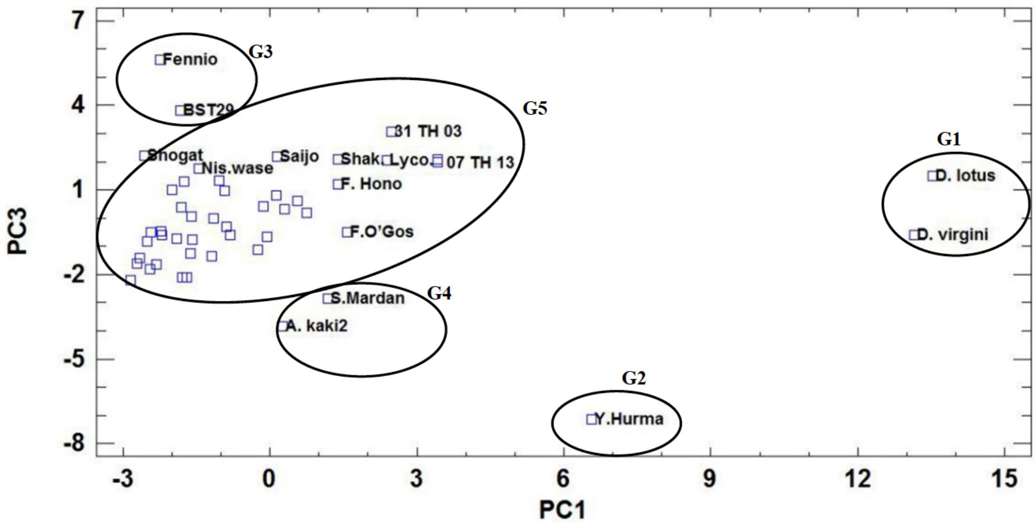

Figure 2. Representation of the accessions in the space defined by the first and third principal components.

remained outside of the main cluster of accessions based on their morphologic differences related to fruits, leaves, trees, flowers, and phenology. The second main group consisted of only Yesil Hurma (*Diospyros oleifera*), which showed a similarity of 22.07% to the rest of the *Diospyros kaki* genotypes. These genotypes were determined to show 17.32% similarity to the other accessions. In addition, the accessions BST-29 and Fennio were very similar (%) in terms of fruit characteristics and especially fruit size. Seedless Mardan and Aman Kaki showed separation from the other genotypes due to morphologic differences related to seedlessness and high tendency towards parthenocarpy. Another very similar group included the accessions Giant Fuyu and Shogatsu, which are similar in flower and fruit characteristics. Similar results were obtained in PCA using the first two and the first and third principal components.

Cluster analysis placed the majority of the genotypes selected from Turkey together, showing a high level of morphological relatedness. Among the accessions studied, based on the morphological distances obtained, there were no clear groupings divided by the type of astringency of the flesh. Similarly, Yonemori et al. (2008) examined 61 accessions, including five PCNA accessions, and observed that four of the PCNA accessions were grouped together and one grouped with accessions showing other astringency types. At the same time, Du et al. (2009) studied a total of 28 accessions, including 13 PCNA varieties, and based on the genetic distances provided, the groupings were not

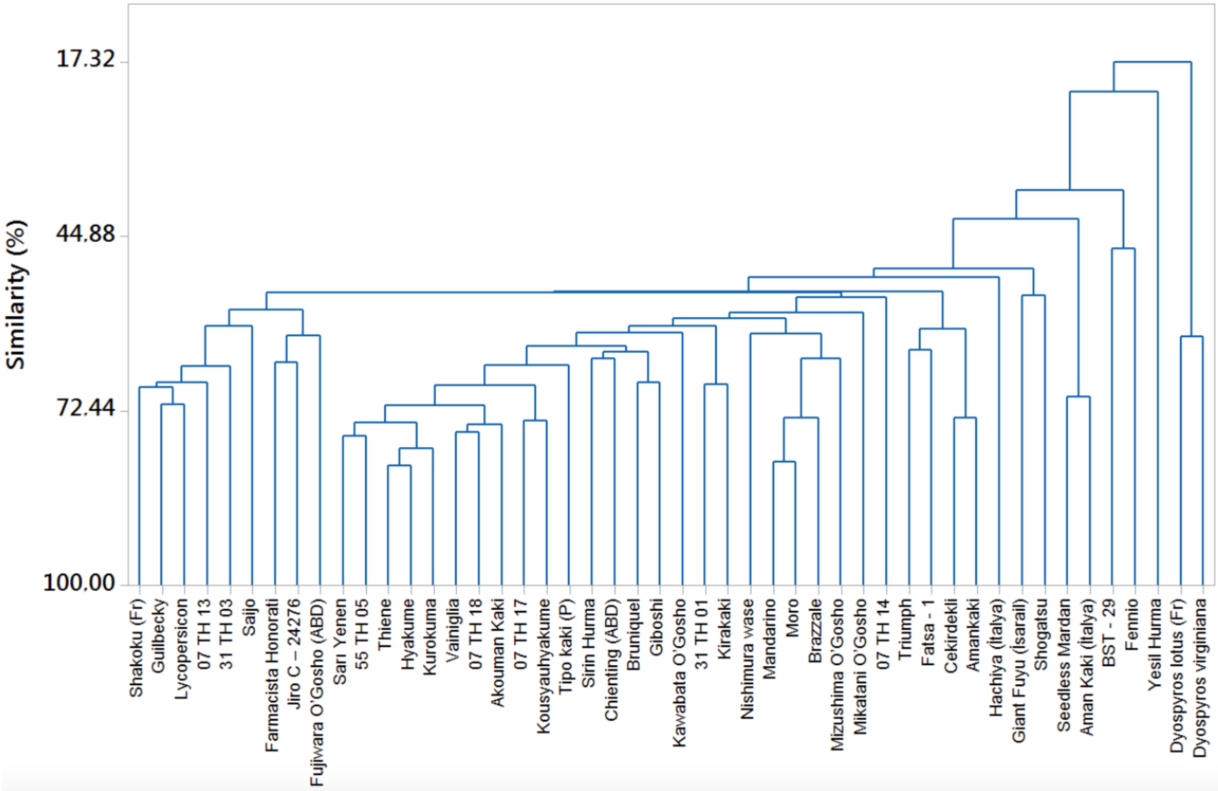

Figure 3. Dendrogram of persimmon accessions collected from Turkey obtained from cluster analysis of 59 agromorphological traits using average method.

associated with the astringency type. Local varieties seem to have developed as random seedlings or bud mutations. In Turkey, local varieties nearly all belong to the PVA or PCA groups. The varieties known to be of Japanese origin generally belong to the PCNA group. None of the selected types in Turkey belong to the PCNA group. The results of the present investigation concur with those of Bellini and Giordani (2005), who studied European persimmon. Similar results were reported by Bellini et al. (2003), who created a dendrogram of 27 Italian persimmon cultivars based on their morphological characters.

3.4. Conclusions

Survey, collection, identification, classification, and evaluation studies of genetic resources have great importance in terms of using genotypes. The value of plant genetic resources is expressed by its usability in breeding. Characterization studies would allow us to point out the variability pattern and the most significant variables and to establish groups of accessions with similar traits. In this study, we characterized 11 selected (local) and 37 introduced (global) plant materials in terms of 59 morphological traits. The results of the present study are important for planning future studies of germplasm resources. This study will be useful for taxonomical studies and other breeding studies such as the development of cultivars with late or early ripening, nonastringent fruits, seedless fruits, large fruits, and fruits with deeper color. The results will allow the establishment of criteria for further uses of the plant material and are important for choosing suitable parental material for breeding programs.

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