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Pomological Evaluation of Apple (*Malus* x *domestica* Borkh) Germplasm in Morocco

Youssef Khachtib, Said Bouda, Youssef Ait Bella and Abdelmajid Haddioui
Laboratory of Biotechnologies and Valorization of Plant Genetic Ressources, Faculty of Sciences and Techniques, Sultan Moulay Slimane University, B.P. 523, Béni Mellal, Morocco

ABSTRACT

To evaluate the pomological diversity of apple (*Malus* x *domestica* Borkh) germplasm in Morocco, 34 fruit characteristics of 30 apple cultivars were studied. Fruit weights were higher in cultivars 'Delicious1', 'Azougar', 'Starking 4' and 'Golden 4' cultivars and lower in case of 'Lahlou', 'Talhlout' and 'Amlale' cultivars".The highest titratable acidity value was highest in 'Lahlou' (1.19%) and lowest in 'Delicious 3' (0.20%). Soluble solid content was significantly higher in cultivars 'Ahmri 2', 'Delicious 3' and 'Starking 1', which implies that they are suitable for processing. Principal components analysis separated all cultivars into three distinct groups independently of their geographical origin. In addition, multivatiate analyses showed that fruit weight, length of stalk, number of seeds and titratable acidity, but not soluble solid content had important roles in grouping of cultivars. This work sheds light on mislabelled cultivars, and could be helpful to recognize the exact number of Moroccan apple cultivars.

Key words: Cultivars, diversity, *Malus* x *domestica*, Morocco, pomology

Author for correspondence: Said Bouda; e-mail: saidbouda@yahoo.fr

Introduction

Cultivated apple is a crop with great economic value. Over the past centuries, humans use it as food, medical purposes, refreshing agent and as an ornamental tree (Pieroni et al., 2003; Lotito & Balz, 2004; Ceferelli et al., 2006; Iannaccone et al., 2007). There are more than 7,500 known apple cultivars around the world (Kellerhals, 2009). However, a small number of them dominate the global production, which over time, can lead to greater erosion of the genetic diversity of this species by the loss of many native cultivars. Nevertheless, some local or autochthonous apple cultivars are used as donors of genes in apple breeding programs. These genes code for interesting traits with high agronomic value, such as harvesting maturity, tolerance of abiotic factors, resistance to pests and disease, flavour, storage properties and so on (Ognjanov et al., 1998; Bignami et al., 2003; Ognjanov, 2005; Marić et al., 2007). For the purpose of assessing the enormous genetic variability of apples, many apple genetic resources evaluation and conservation programs have been started at the international scale (Vujanić-Varga et al., 1994; Hokanson et al., 1996; Zhi-Qin, 1999; Pereira-Lorenzo et al., 2003; Ercisli, 2004; Holland et al., 2006; Mratinić & Fotirić-Akšić 2011, 2012; Balik et al., 2012; Al-Halabi &Muzher, 2015; Ganopoulos et al., 2018).

In Morocco, during the last few years, the cultivation of apple has expanded greatly, making it the second most important tree fruit crop of the Rosaceae family in terms of cultivated area after almond tree and the first in terms of production. Today, apple crop covers an area of more than 49,000 ha and the total production is around 830,000 tons (FAO, 2017). Nevertheless, the global apple production involves only a few introduced cultivars like 'Golden Delicious' and 'Starking Delicious', which represent more than half of total production (MAFRDWF, 2017). Besides this, in large-scale production the role of local cultivars and landraces that have accumulated a great number of adaptations over a hundred of years has become completely insignificant in front of the introduced ones, which can lead to genetic erosion of apple germplasm over time. However, abnormal climate conditions (irregular annual precipitation, high temperatures and low humidity during summer) in Morocco could negatively affect the quality of fruit. Thus, it is necessary to take measures to preserve local apple cultivars with good biological and agronomic characteristics in different regions of Morocco that could serve as valuable resource for breeding programs. There are only two apple collections in Morocco, one at experimental station in Ain Taoujdate in the Saïs plains and a second experimental station at Annoceur in a mountain area of province Sefrou. These collections mostly consist of introduced cultivars. Given the lack of information in the literature on local apple resources, the objectives of this study were to analyse and evaluate the apple genetic resources of Morocco. The results of this study will be helpful to identify the exact number of cultivars so as to draw up an inventory of apple cultivars in Morocco, and to select the best cultivars.

Materials and Methods

Plant Material

A total of 30 cultivars were considered in this study (Table 1). They were collected from commercial farms in the most important fruit regions in Morocco, especially around the High and Middle Atlas Mountains in the North and centre of the country where climatic conditions are suitable for the cultivation of this tree) (Fig. 1), during the period 2017-2018 over several collection trips.

Pomological Traits

Thirty-four pomological traits (Table 2) were measured to evaluate the studied cultivars. The most important fruit traits, such as fruit shape, fruit weight (NS), number of seeds (NS) and length of stalk (LS), were evaluated using the descriptors of the International Board for Plant Genetic Resources (IBPGR, 1982) and the International Union for the Protection of New Varieties of Plants (UPOV, 2005). A digital refracto meter and pH meter were used respectively to measure soluble solid content (SSC, æ%Brix) and pH. Titratable acidity (TA, malic acid %) was determined by titrating apple juice with 0.1M NaOH. Analyses of the fruits were done on a sample of 50 fruits per cultivar harvested from five different trees.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) to detect significant differences between the studied cultivars for measured pomological traits using SPSS® software version 24. Coefficients of variation (CV) were determined as indicators of variability. Correlations between the traits were determined using the Pearson correlation coefficient.Qualitative traits were evaluated following the descriptors lists and scores (IBPGR, 1982; UPOV, 2005). For example, for trait: aperture of locules, we use the following score. 1: Closed or slightly open; 2: Moderately open; 3: Fully open The use of this number code makes it possible to perform correlation analysis on the data. Relationships among the accessions were investigated using principal components analysis (PCA) using XLSTAT® software (version 2014.1). Cluster analysis was performed using unweighted pair-group average (UPGMA) method with squared Euclidean distance (STATISTICA ® software version 5).

Results

Pomological description

The results of pomological evaluation are summarized in the Tables 3 and 4. The analysis of variance showed significant differences between cultivars for all the measured traits. The majority of cultivars showed yellow-green ground color (GC) (77.8%) followed by a yellow colour (11.5%), while the color of flesh (CF) was cream in most of the studied cultivars (39.5%) followed by yellowish (38%) and greenish (21.1%) (Table 3). The level of the aperture of locules (AL) showed evident differences among cultivars, with a dominance of locules moderately opened (78.3%). Fruit shape was predominantly ovoid (41.2%), followed by a conic (23.4%), ellipsoid (13%) and globose (10%).

Number of seeds (NS) varied significantly among cultivars; the lowest NS were recorded in ‘Delicious2’ cultivar (3.26), while the highest NS were recorded in ‘Lahlou’ (9) with general mean of 6.44 (Table 4). Titratable acidity (TA) exhibited the highest coefficient of variation (CV=62.74%), and its variation among cultivars ranged from 0.20 % malic acid in Delicious3 to 1.19% in ‘Lahlou’ cultivar, while the lowest CVs were observed in area of russet on cheeks, AROC(3.97%) and ratio height/diameter, RHD (6.28%). Moreover, 22 out of 34 traits reached CV values more than 15.00%, which revealed a high variation among the cultivars. The cultivar ‘Delicious1’ had the highest size of fruit (25.76 mm) and ‘Amlale’ the lowest (15.64 mm) with general mean of 20.29 mm. The remaining cultivars had intermediate values with significant differences. In addition, fruit weight (FW) ranged from 52.07g in ‘Talhlout’ to 229.34g in ‘Delicious1’ with an average of 119.09g and a CV of 36.87%. Length of stalk (LS) showed significant degree of variation among the cultivars, minimum LS was observed in ‘Labiad’ (11.31 mm) cultivar while maximum LS was observed in ‘Golden4’ cultivar (30.79 mm). With a difference of more than 7æ%Brix between studied cultivars, SSC showed a wide range, from 11.63% in ‘Lahlou’ to 18.80% in ‘Starking1’ cultivars. This variation could be used to design improved and efficient breeding programs.

Table 1. Geographical and meteorological conditions of the collected apple cultivars. Local (Loc) and international (Int) varieties indicated in column 1.

Cultivars	Geographical Origin	Longitude West	Latitude North	Altitude (m)	Average maximum temp (C°)	Average minimum temp (C°)
Delicious1 (Int)	Asni (1)	-7.98	31.25	1163	23.5	7.4
Oumlile2 (Loc), Ahmri2 (Loc)	Ourika (2)	-7.71	31.36	1421	26.8	12.2
Ahmri1 (Loc), Oumlile1 (Loc) Gala2 (Int), Mticha (Loc)	Ait Bouguemez (3)	-6.37	31.69	2059	23.7	4.2
Labiad (Loc)	Ait M'hamed (4)	-6.49	31.87	1629	22.4	5.5
Amlale (Loc)	Zaouiat Ahansal (5)	-6.10	31.84	1751	21.2	4.5
Oumlile beldi (Loc), Azougar beldi (Loc), Starking2 (Int), Azougar (Loc)	Ikoumine (6)	-6.10	31.89	1547	20	4.5
Lahlou (Loc)	Imi nwarge (7)	-6.16	31.99	1192	24	7
Delicious2 (Int)	Tagoutite (8)	-6.23	32.04	1280	24.2	7.3
Talhlout (Loc)	Ouaouizeght (9)	-6.35	32.17	1022	24.2	7.3
Starking1 (Int)	Outrbat (10)	-5.36	32.15	2247	25.5	6.2
Starkimson2 (Int), Golden2 (Int)	Imilchil (11)	-5.63	32.15	2146	19.1	3
Gala 1 (Int)	Boutfarda(12)	-5.84	32.37	1473	22.2	6.5
Lahmar1 (Loc)	Tizi-Nisly (13)	-5.75	32.43	1395	26.7	11.4
Zarbana (Loc)	Bounwal (14)	-6.00	32.47	1079	26.7	11.4
Golden1 (Int), Starkimson1 (Int)	Ait ayach (15)	-4.95	32.68	1531	21.8	7.5
Golden4 (Int), Starking4 (Int)	Khenifra (16)	-5.50	32.92	1314	23.5	8.4
Starking 3 (Int)	Azrou(17)	-5.23	33.43	1234	21.4	6.1
Golden3 (Int), Delicious3 (Int) Lahmar2 (Loc)	Imouzzer Kandar (18)	-5.04	33.75	1210	23.5	6.5

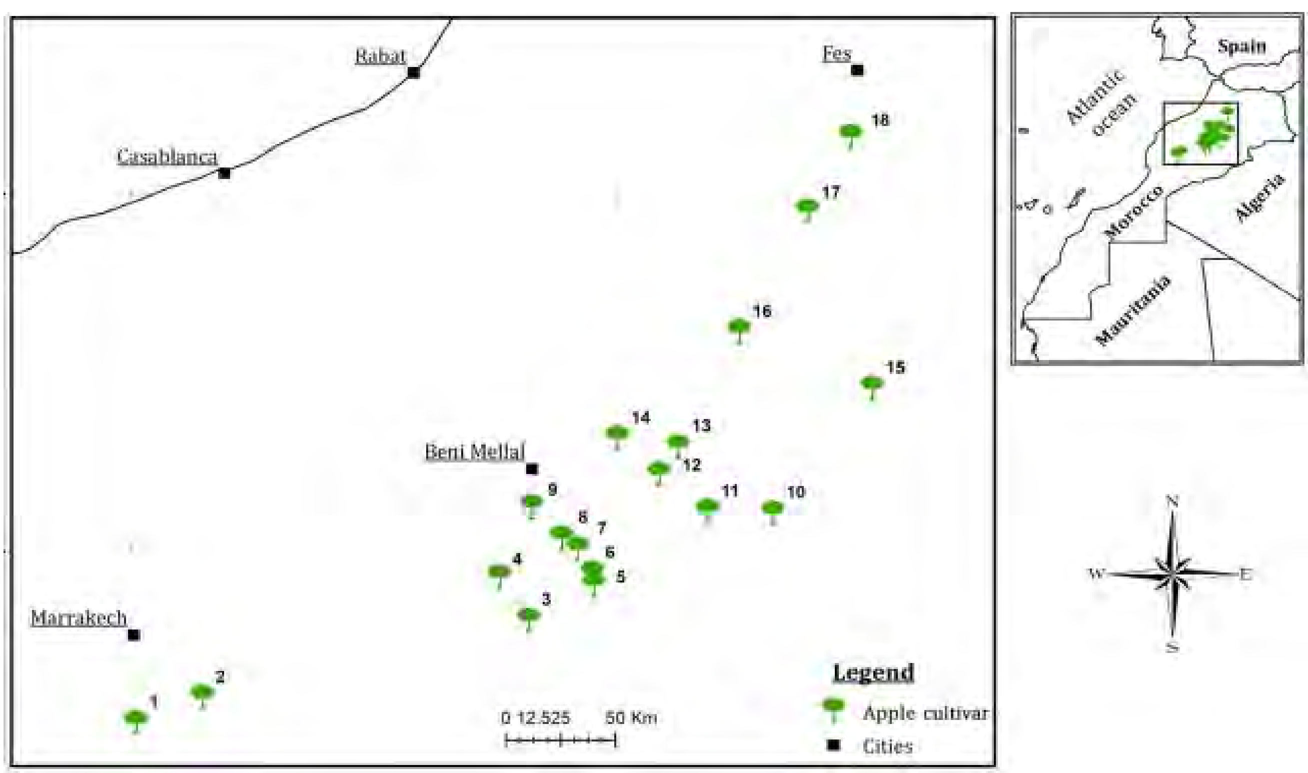

Figure 1. The locations of apple (Malus × domestica Borkh) cultivars collected in the North and Center of Morocco

Table 2. Pomological traits measured in the study.

	Trait (Unit)	Abbreviation
Qualitative	Fruit shape	FS
	Fragrance	F
	Greasiness of skin	GS
	Ground color	GC
	Over color	OC
	Pattern of over color	POC
	Relative area of over color	RAOC
	Area of russet around stalk attachment	ARAS
	Area of russet on cheeks	AROC
	Area of russet around eye basin	ARAE
	Color of flesh	CF
	Aperture of locules	AL
	Texture	T
Quantitative	Fruit weight (g)	FW
	Size of Fruit (mm)	SF
	Height of Fruit (mm)	HF
	Diameter of Fruit (mm)	DF
	Ratio height/diameter	RHD
	Number of lenticels	NL
	Size of lenticels (mm)	SL
	Length of stalk (mm)	LS
	Thickness of stalk (mm)	TS
	Depth of stalk cavity (mm)	DSC
	Width of stalk cavity (mm)	WSC
	Size of eye unit (mm)	SE
	Depth of eye basin (mm)	DEB
	Width of eye basin (mm)	WEB
	Number of seeds	NS
	Seeds Width (mm)	SW
	Seeds length (mm)	SeL
	Length of sepal (mm)	Lsp
	Soluble solid content (ºBrix)	SSC
	pH	pH
	Titratable acidity (%)	TA

Correlations between the characters

In order to highlight the strength and direction of association between the traits, Pearson correlation analysis was carried out (Table 5). Correlation coefficients among the majority of traits were found significant. Fruit weight showed positive correlations with size of fruit (r = 0.97), size of eye (r = 0.84), size of lenticels (r = 0.60), height of fruit (r = 0.96) and fragrance (r = 0.56). Also, length of stalk was positively and significantly correlated with ratio height/diameter (r = 0.74) and length of sepal (r = 0.58). In contrast, titratable acidity was negatively correlated with size of lenticels (r = - 0.50), and positively correlated with fruit shape (r = 0.46). The pH showed significant negative correlation with aperture of locules (r = -0.57), number of seeds (r = -0.56) and seeds width (r = -0.51).

Classification

To evaluate the association among the studied apple cultivars, PCA has been previously used. The bi-plot axes (Fig. 2), generated based on principal components PC1 and PC2 were able to explain more than 46 % of the total variance. PC1 was strongly associated with HF, SE FW and SF. PC2 was strongly associated with TA, seed width (SW), AL, Area of russet around eye basin (ARAE) and LS. The PCA bi-plot showed a high pomological variation among the studied cultivars, and they were distributed into three groups independently of their geographical origin. The first group (1) consists of 5 cultivars and is mainly composed of the local cultivars characterized by a low FW, high TA, long LS, high NS and a big ARAE. The second group (2) contains 9 cultivars and is composed of introduced and local cultivars. The members of the second group have short LS, low NS, medium to low TA, small ARAE and closed or slightly open locules. The third group includes 16 cultivars and is constituted mainly of the introduced cultivars, it was differentiated from other group by large HF, large SE, high FW and large SF.

The cluster analysis (Fig. 3) revealed the separation of two main clusters based on the measured variables of the sampled cultivars, but not on their geographical area. The first cluster (I) was split into two sub-clusters. Sub-cluster I-A included 9 cultivars namely 'Zarbana', 'Gala 1', 'Delicious 3', 'Lahmar 2', 'Oumlile 2', 'Azougar beldi', 'Lahlou', 'Talhloute' and 'Amlale' characterized by low values for FW, HF, DF, size of fruit SF and higher values of LS and SeL. Sub-cluster I-B consisted of 17 cultivars namely 'Golden 1', 'Starking 1', 'Ahmri 2', 'Starking 2', 'Lahmar 1', 'Oumlilie beldi', 'Starkimson 1', 'Ahmri 1', 'Labiad', 'Maticha', 'Starkimson 2', 'Delicious 2', 'Golden 2', 'Golden 3', 'Gala 2', 'Oumlile 1' and 'Starking 3', which were distinguished from other cultivars by medium values for the majority of traits such as FW, SF, NS and T. The second main cluster is represented by four cultivars, 'Delicious 1', 'Azougar', 'Starking 4' and 'Golden 4' where all the cultivars have intermediate SSC, high FW, large SF and low TA values. The comparisons of result obtained by the UPGMA reveal possible synonyms and homonymswithin the studied cultivars. However, the cultivars 'Lahlou', 'Talhlout' and 'Amlale' which are frequently considered distinct from each other, were placed in the same cluster (I-A) on the dendrogram. Also 'Oumlile 1' and 'starking 3' cultivars, often considered to be different, were grouped

Table 3. List of qualitative traits and states characterized, most frequent state in bold with frequency in next column.

Trait	States characterized	Frequency (%)	CV (%)
Fruit shape	Cylindrical waisted - Conic - **Ovoid** - Cylindrica l- Ellipsoid - Globose - Obloid	41.2 **	36.87
Fragrance	Fragrance-free - **Fragrant** - Very fragrant	67.7**	21.98
Greasiness of skin	**Absent or weak** - Moderate - Strong	58.2 **	43.21
Ground color	Not visible - Whitish yellow - Yellow - Whitish green - **Yellow green** - Green	77.8 **	16.58
Pattern of over color	Only solid flush - **Solid flush with defined stripes** - Only stripes	73.9 **	24.23
Relative area of over color	Absent or very small - Small - Medium - Large - **Very large**	36.7 **	53.84
Over color	Absent - Orange - **Pink** - Red - dark red - purple - Brow	45.5 **	26.24
Area of russet around stalk attachment	Absent or small - **Medium** - Large	45.1 **	23.53
Area of russet on cheeks	**Absent or small** - Medium - Large	99.2 **	3.97
Area of russet around eye basin	**Absent or small** - Medium - Large	93.1 **	22.09
Color of flesh	White - **Cream** - Yellowish - Greenish - Pinkish - Reddish	39.5 **	24.81
Aperture of locules	Closed or slightly open - **Moderately open** - Fully open	78.3 **	11.80

Level of ANOVA significance: **: $p < 0.01$

in the same cluster (I-B). On the other hand,'Delicious 1', 'Delicious 2' and 'Delicious 3' cultivars, usually considered to be synonyms, were placed in three separate clusters (II, I-B and I-A, respectively).

Discussion

For the first time the pomological variability of Moroccan apple cultivars was evaluated in this study. The results showed a high diversity within the analyzed apple cultivars. Thus, nearly 62% of measured traits present coefficient of variation more than 15%.

The global appreciation and acceptability observed in the apple cultivars is affected strongly by sweetness and acidity (Bignami et al., 2003). In the studied cultivars SSC ranged between 11.63 and 18.80 % and TA ranged from 0.20 to 1.19% malic acid. Similar findings have been reported previously for apple cultivars from Syria (SSC ranged from 11.8 to 19.1% and TA from 0.2 to 1.5% malic acid), Italy (SSC ranged from 11.9 to 18.5% and TA from 0.12 to 1.29% malic acid) and Spain (SSC ranged from 10 to18.1% and TA from 0.17 to 1.73% malic acid) (Bignami et al., 2003; Al-Halabi & Muzher, 2015; Reig et al., 2015). Lower soluble solids of local apple cultivars were recorded in Pakistan (11.80-14.50%) and Turkey (10.5-15%) (Ali et al., 2004; Bostan, 2009). However, higher interval of variation of this parameter was found in apple cultivars from Serbia (12.55 to 19.24%) and India (11.80 to 20.03%) (Mir et al., 2017). The SSC of most of the apple cultivars ranged between 11.0 and 16.1 % (Sebek, 2013). Therefore, over 16 % of SSC could be accepted as high level in apple fruits. In this study, 'Gala 1' (16.20%), 'Ahmri 1' (16.07%), 'Delicious 3' (16.97%), 'Ahmri 2' (16.63%) and 'Starking 1'(18.80%) were classified as high-SSC content cultivars, implying that they can be commercially used in production of apple juice, concentrate, spirits, jam and also for drying. Besides this, fruit weight is another character to be taken in consideration because it is a good indicator of yield, fruit quality and therefore of consumer preference (Gao et al., 2011). The studied cultivars had fruit weight varying from 52.07 to 229.34 g. Similar results have been reported for the apple cultivars grown in Bosnia and Herzegovina (97.9-219.58 g) (Gasi et al., 2011) and Spain (Reig et al., 2015). Daymar et al (2007) reported lower value for Iranian apple (71-165 g), while higher values (91.68-274.37 g) were revealed for Indian apples (Mir et al., 2017).

Table 4. Descriptive statistics for the quantitative traits considered in the studied cultivars of apple. Mean values presented for each variety, as well as overall mean and coefficient of variation (CV) for each trait across varieties. *All F values are significant at p<0.01.

	FW	NL	SL	LS	TS	SF	HF	DF	RHD	SE	DSC	WSC	DEB	WEB	NS	SW	SeL	LSp	T	SSC	PH	TA
Zarbana	86.71	3.24	5	17.71	2.12	19.58	51.62	61.86	0.83	5	9.53	23.81	4.60	24.48	6.48	4.26	8.67	6.23	4.84	13.67	3.64	0.54
Golden 1	147.57	5.72	6.12	24.71	1.77	21.64	64.33	69.22	0.93	5.52	15.90	28.84	6.03	27.07	7.06	4.54	8.43	5.74	5	15.37	3.71	0.54
Starkimson 1	124.97	5.32	5.28	20.69	2.36	20.92	59.03	67.50	0.87	5.48	13.18	32.09	7.24	25.54	6.84	4.14	7.64	6.36	3.72	13.97	3.82	0.44
Delicious 1	229.34	5.16	5.72	21.44	2.78	25.76	76.02	84.23	0.90	6.96	18.08	38.64	10.55	34.86	3.4	4.38	7.84	6.35	1.96	12.53	4.26	0.56
Starkimson 2	115.23	4.72	5	20.83	2.37	20.16	59.01	65.22	0.91	6.16	14.41	30.65	7.78	25.49	6.42	3.81	7.21	6.79	4.92	12.97	3.96	0.42
Golden 2	120.41	5.48	4.68	28.88	1.62	20.37	59.97	65.07	0.92	6.32	15.59	31.22	8.89	27.95	8.18	4.47	8.24	5.98	5	13.77	3.66	0.29
Starking 1	140.05	4.36	4.76	23.79	2.31	21.63	63.88	70.08	0.91	6.32	14.66	33.32	8.07	25.56	6.4	3.89	7.19	6.76	4.36	18.80	3.96	0.42
Lahmar 1	138.09	4.6	5.44	22.36	2.70	21.78	59.98	71.02	0.84	6.96	16.48	36.08	9.10	30.52	7.74	4.26	7.97	6.52	4.24	14.03	4.27	0.30
Gala 1	74.45	3.04	5.4	25.86	2.10	17.15	48.68	55.21	0.88	4.44	13.38	23.65	5.87	18.17	7.3	4.37	8.26	6.74	6.52	16.20	3.83	0.38
Lahlou	55.24	3	3	17.81	2.16	16.37	39.18	54.40	0.73	3.8	10.49	22.92	5.53	20.66	9	4.85	8.46	4.76	3	11.63	3.29	1.19
Amlale	57.29	3.2	4.7	24.43	1.80	15.64	46.97	50.59	0.93	4.1	10.69	18.63	4.94	19.36	5.85	4.27	8.18	7.00	5	12.80	3.51	0.74
Oumlile beldi	136.61	3.68	4.88	13.91	2.77	22.58	57.47	73.24	0.79	5.16	14.22	32.58	5.13	29.59	7.2	4.70	8.17	5.51	2.16	14.03	3.40	0.62
Azougar beldi	69.353	3	16.90	2.15	17.39	50.90	56.28	0.90	3.6	11.46	19.52	3.47	22.17	8.7	4.68	9.93	6.87	7	14.53	3.18	1.14	
Starking 2	137.96	4	5.4	24.30	2.13	21.98	65.58	71.15	0.92	6	14.99	34.36	9.16	27.43	6.4	4.36	8.31	6.20	5	12.60	4.01	0.43
Azougar	193.07	4	5.2	21.07	2.20	23.75	71.95	78.37	0.92	7	17.12	37.86	10.87	30.33	6.5	4.58	8.67	7.67	5	12.73	4.01	0.41
Delicious 2	117.26	3.52	4.56	21.39	2.00	20.08	60.29	64.95	0.93	5.96	13.35	30.91	9.52	27.07	3.26	4.19	7.64	6.79	4.76	12.37	4.13	0.27
Labiad	119.91	5	5.8	11.31	2.67	21.22	56.11	69.13	0.81	5.8	13.04	34.43	6.97	29.01	7.6	4.61	7.79	5.06	4.6	15.83	2.95	1.03
Ahmri 1	129.40	3.24	5.56	20.00	2.27	21.27	59.72	68.61	0.87	5.72	14.66	33.17	8.53	27.19	6.54	4.29	7.83	6.21	4.6	16.07	4.11	0.31
Oumlile 1	105.26	5.5	5.6	20.85	2.07	19.06	54.85	60.29	0.91	4.9	14.44	28.83	6.98	25.39	7.4	4.29	8.12	6.35	5	12.93	4.06	0.32
Gala 2	124.75	3.4	5.2	25.08	2.21	20.93	61.16	66.28	0.92	5.4	18.33	29.80	8.07	28.58	5.6	4.35	7.90	6.66	4	15.50	3.59	0.53
Maticha	123.50	3	5	14.62	2.56	20.83	57.34	69.12	0.83	5.4	14.57	34.10	6.35	28.93	7.6	4.34	8.04	6.13	5	12.80	3.52	0.52
Golden 3	120.86	6.16	5.88	28.37	1.72	20.27	60.74	64.47	0.94	5.76	15.99	31.35	8.32	25.96	6.48	4.28	8.59	7.29	5	12.93	4.31	0.23
Delicious 3	75.30	6.4	5	26.29	2.21	17.32	49.22	55.52	0.89	4.8	11.09	23.35	6.61	22.04	4.9	2.28	4.66	6.27	5	16.97	4.26	0.20
Lahmar 2	73.21	6.2	5	22.99	2.12	17.36	49.24	56.01	0.88	4.8	10.69	24.31	5.01	21.96	5.1	2.72	5.38	5.39	4	12.53	4.10	0.22
Starking 3	97.04	3.8	4.7	27.75	2.17	18.97	53.39	60.38	0.89	6.2	11.72	29.39	7.44	25.38	7.35	4.03	7.58	7.02	5	14.43	4.07	0.27
Golden 4	182.70	6.2	6.9	30.79	1.97	23.84	69.40	78.23	1.02	6.8	18.24	29.10	9.40	29.94	6.15	4.42	8.89	7.28	5	13.27	4.16	0.25
Starking 4	205.00	4.3	5.6	25.66	2.36	24.62	72.76	80.04	0.91	6.9	17.10	39.21	9.52	30.60	7	4.38	8.21	6.83	3.4	15.70	4.09	0.22
Ahmri 2	138.56	5.28	5.96	25.40	2.38	21.29	63.19	68.94	0.92	6.12	15.70	33.26	8.02	26.33	5.9	4.13	7.87	6.90	3.52	16.63	4.04	0.38
Oumlile 2	81.76	5.8	5.7	28.62	2.06	17.90	52.69	56.88	0.93	5	13.52	27.23	4.84	22.15	7.45	4.12	8.59	6.47	5	12.57	3.84	0.24
Talhlout	52.07	3.4	3.4	13.40	1.89	17.16	43.04	53.15	0.81	5	9.07	24.95	6.11	21.76	1.3	2.61	4.86	5.42	5.1	11.93	4.35	0.27
Mean	119.10	4.46	5.11	22.24	2.20	20.29	57.92	65.51	0.89	5.58	14.06	29.92	7.30	26.05	6.44	4.15	7.84	6.38	4.56	14.07	3.87	0.47
CV(%)	36.87	25.72	16.49	22.26	13.51	12.38	14.89	13.05	6.28	16.68	18.48	18.01	26.03	14.58	25.05	14.32	14.17	10.60	22.88	12.38	9.21	62.74
F value*	74.24	38.88	18.10	33.76	37.56	68.57	59.63	46.75	6.72	28.50	35.36	61.22	37.57	48.31	19.19	22.90	45.68	16.75	73.53	8.81	19.29	12.70

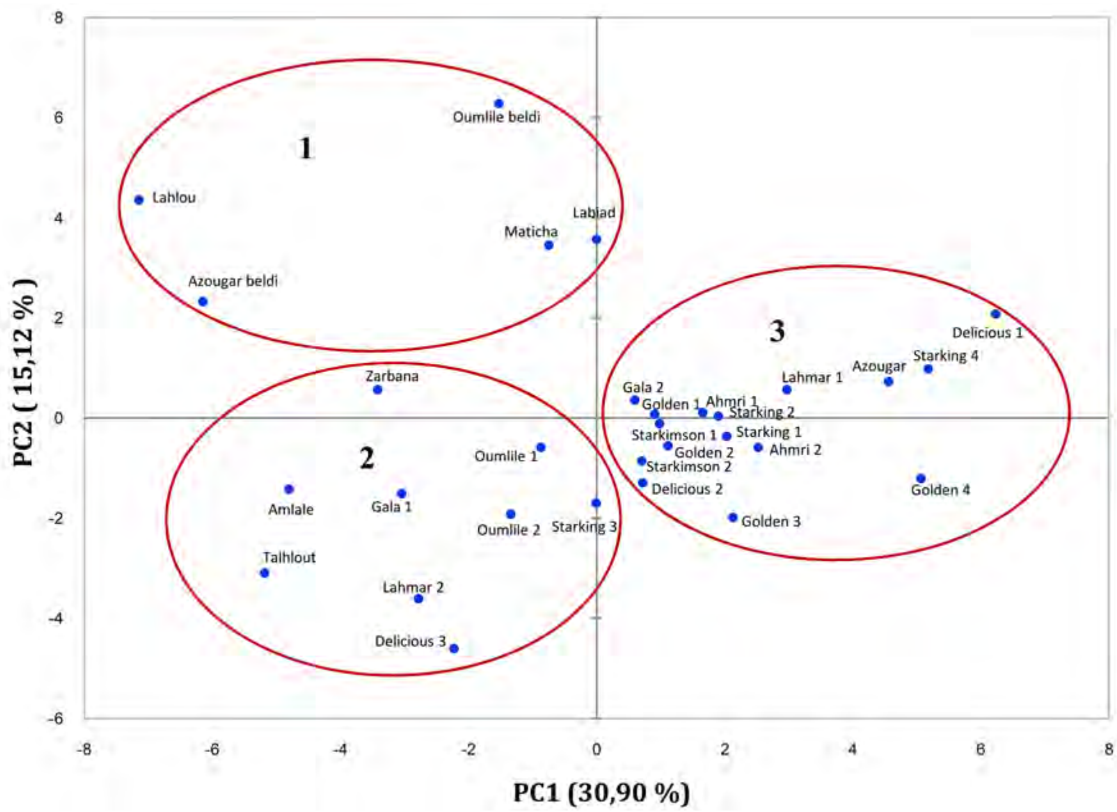

Figure 2. Scatter plot for the studied apple (M.domestica) cultivars based on PC1/PC2.

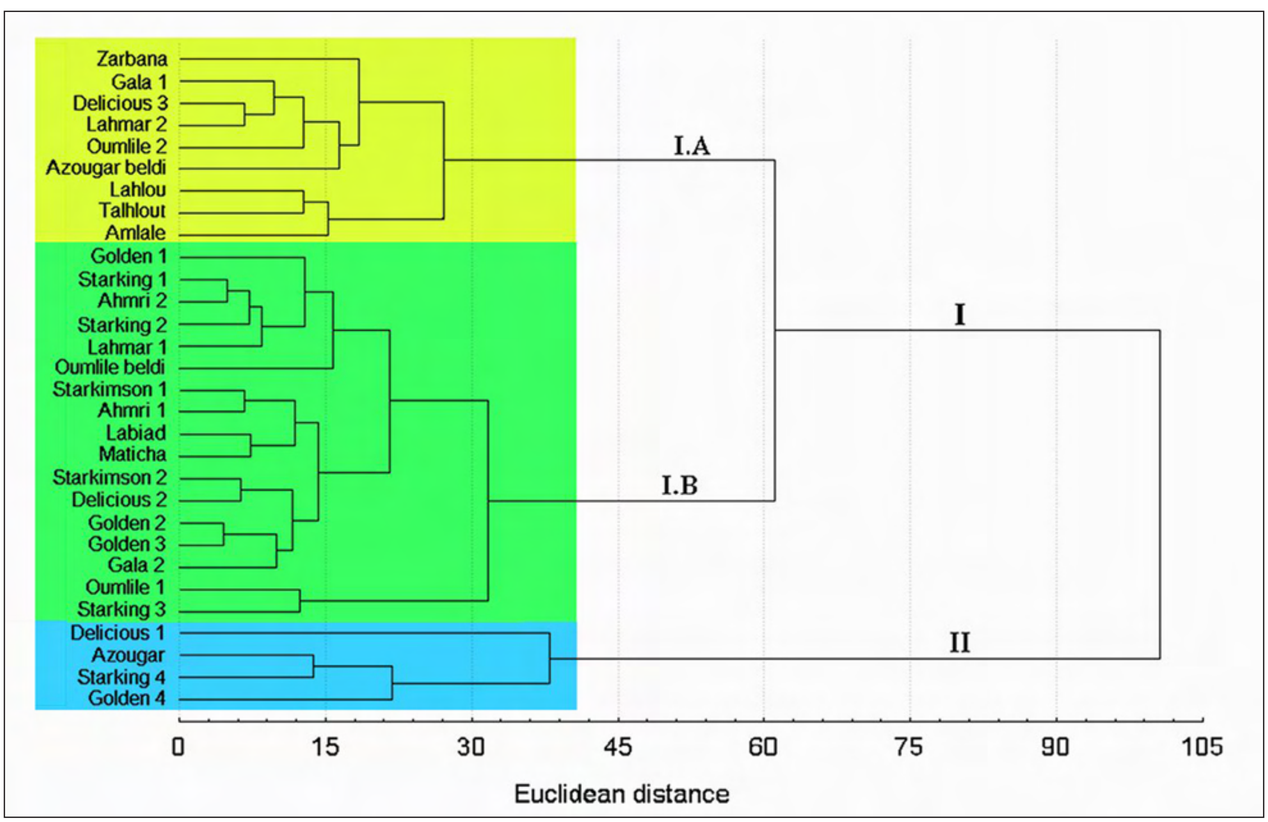

Figure 3. UPGMA cluster analysis of the studied apple (*M. domestica*) cultivars based on the pomological traits using Euclidean distances

Table 5. Matrix of correlations between some pomological traits considered in the studied cultivars.

	FS	FW	P	AROC	ARAE	SL	LS	TS	SF	HF	DF	RHD	SE	DSC	WSC	DEB	WEB	AL	NS	SW	SeL	Lsp	T	PH	TA
FW	-0.50**																								
F	-0.32	0.56**																							
AROC	0.37*	-0.22	-0.11																						
ARAE	0.50**	-0.03	-0.13	0.12																					
SL	-0.59**	0.60**	0.49**	-0.44*	-0.24																				
LS	-0.47**	0.17	0.03	-0.26	-0.44*	0.45*																			
TS	-0.01	0.38*	0.29	0.06	0.32	0.10	-0.48**																		
SF	-0.42*	0.97**	0.59**	-0.22	0.07	0.57**	0.06	0.45*																	
HF	-0.59**	0.96**	0.51**	-0.35	-0.09	0.63**	0.29	0.25	0.93**																
DF	-0.43*	0.97**	0.58**	-0.16	0.07	0.55**	0.04	0.48**	0.99**	0.93**															
RHD	-0.60**	0.37*	0.11	-0.58**	-0.38*	0.54**	0.74**	-0.43*	0.27	0.55**	0.24														
SE	-0.61**	0.84**	0.46**	-0.32	-0.28	0.56**	0.28	0.27	0.84**	0.84**	0.83**	0.38*													
DSC	-0.50**	0.85**	0.44*	-0.19	-0.09	0.65**	0.39*	0.20	0.81**	0.87**	0.81**	0.52**	0.72**												
WSC	-0.52**	0.85**	0.54**	-0.12	-0.07	0.49**	-0.00	0.51**	0.88**	0.82**	0.88**	0.10	0.86**	0.73**											
DEB	-0.59**	0.78**	0.45*	-0.19	-0.41*	0.44*	0.32	0.14	0.74**	0.79**	0.73**	0.40*	0.87**	0.73**	0.79**										
WEB	-0.30	0.89**	0.51**	-0.15	0.09	0.47**	-0.04	0.49**	0.93**	0.85**	0.93**	0.17	0.81**	0.77**	0.87**	0.72**									
AL	0.31	-0.14	-0.26	0.32	0.71**	-0.28	-0.47**	0.22	-0.12	-0.19	-0.08	-0.30	-0.49**	-0.12	-0.19	-0.45*	-0.07								
NS	-0.03	-0.05	-0.03	0.36*	0.23	0.00	0.05	0.07	-0.04	-0.07	-0.01	-0.15	-0.16	0.09	-0.01	-0.24	-0.04	0.34							
SW	-0.10	0.37*	0.15	0.24	0.27	0.14	-0.06	0.13	0.38*	0.34	0.40*	0.01	0.12	0.44*	0.28	0.14	0.36*	0.44*	0.61**						
SeL	-0.14	0.28	0.10	0.12	0.23	0.15	0.09	-0.03	0.27	0.30	0.29	0.21	0.04	0.38*	0.12	0.03	0.23	0.40*	0.63**	0.92**					
Lsp	-0.58**	0.34	0.04	-0.44*	-0.25	0.31	0.55**	-0.16	0.2	0.47**	0.24	0.74**	0.38*	0.43*	0.16	0.41*	0.14	-0.14	-0.03	0.13	0.33				
T	-0.14	-0.44*	-0.31	-0.24	-0.22	-0.13	0.14	-0.54**	-0.46**	-0.30	-0.47**	0.32	-0.31	-0.26	-0.47**	-0.27	-0.49**	0.00	0.16	-0.09	0.13	0.32			
PH	-0.44*	0.2	0.20	-0.37*	-0.44*	0.32	0.47**	-0.13	0.22	0.32	0.18	0.40*	0.49**	0.24	0.27	0.53**	0.15	-0.57	-0.56**	-0.51**	-0.43*	0.40*	-0.06		
TA	0.46**	-0.24	-0.13	0.42*	0.37*	-0.50**	-0.54**	0.19	-0.21	-0.30	-0.17	-0.42*	-0.51**	-0.27	-0.32	-0.45*	-0.16	0.56**	0.40*	0.46**	0.42*	-0.32	0.03	-0.82**	

Significance level: *: $p<0.05$; **: $p< 0.01$

Usually, the apple cultivars are given local names by farmers based on their fruit characteristics (fruit shape, skin color, size and flavour) which could lead to the problem of mislabelling. Cluster analysis based on pomological characters was a useful tool in this study to classify and identify synonyms and homonyms into the studied apple cultivars which were in agreement in Spanish and Hungarian apples (Pereira et al., 2003; Király et al., 2015). In addition, cluster analysis allows the grouping of individuals by the discriminating characteristics and not by their geographic area which might be helpful for farmers in the selection of superior apple cultivars. The principal components analysis depicted high performance in classifying apple cultivars which can be used as a gene pool carrying important genes for desired traits in the future breeding programs. This finding is in concordance with previous studies evaluating apple germplasm in Syria, Spain and Bosnia and Herzegovina (Al-Halabi &Muzher, 2015; Pereira-Lorenzo et al., 2003; Gaši et al., 2011).

Conclusion

The present study of apple fruits demonstrated that the studied cultivars were different based on most of the characters. However, three groups of cultivars were separated from each other. This separation into three different groups mostly is linked to fruit characteristics such as size of fruit, fruit weight. titratable acidity, length of stalk and area of russet around eye basin. In addition, five cultivars including ‘Gala 1’, ‘Ahmri 1’, ‘Delicious 3’, ‘Ahmri 2’ and Starking 1 showed high values of soluble solids content suggesting that they can be suitable for processing. Also, based on the results of hierarchical cluster analysis, we have detected two groups of synonyms and homonyms involving five cultivars. These results would help to identify the exact number of apple cultivars on the national scale in Morocco. The present study offers important findings that could be useful for conducting an efficient breeding program for the industrial use, management and conservation of apple genetic resources in Morocco.

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