Comparative ampelographic and genetic analysis of grapevine cultivars from Algeria and Morocco

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Abstract

Background and Aims: North Africa has a long history of viticulture and a wide diversity of grape cultivars. Ampelographic studies have been made of grapevine cultivars grown all over the world, but only a few describe those of Algeria and Morocco. Many Maghrebi cultivars held in germplasm banks or found growing wild in this region have recently been subjected to microsatellite profiling by different researchers, though little comparative analysis has been undertaken. The aim of the present work was to clarify the identity of the grapevine cultivars growing in the Maghreb via ampelographic and single-nucleotide polymorphism analysis.

Methods and Results: Seventy-one accessions were studied through the ampelographic construction of their mean leaves, via genotypic analysis using single-nucleotide polymorphism markers, and the comparison of these results with previously reported single sequence repeat marker profiles and ampelographic data for other grapevine material from the Maghreb.

Conclusion: New synonyms and homonyms were detected between Maghrebi cultivars. Some misinterpretations and errors of identification made during the making of the studied germplasm collections were identified.

Significance of the Study: This study helps clarify the confusion over the identity of Algerian and Moroccan grapevine cultivars and provides a general picture of grapevine diversity in the Maghreb.

Keywords: *germplasm collection, homonym, North Africa, SNP, synonym,* Vitis vinifera, *wild population*

Introduction

North Africa has a long history of viticulture and a great diversity of grape cultivars. In fact, the north of Algeria, Morocco and Tunisia are within the area of distribution of the original wild species *Vitis vinifera* L. ssp. *sylvestris* (Gmelin) Hegi from which present day cultivated grapes (*Vitis vinifera* L. spp. *sativa*) were domesticated (This et al. 2006). Cultivated vines were brought into the region by Phoenicians and Carthaginians (Isnard 1951, McGovern 2004) and these likely hybridised among themselves and with wild forms over centuries of viticultural history. Viticulture became consolidated in Northern Africa under Roman influence (McGovern 2004, This et al. 2006). Centuries later, Islam enhanced the expansion of table rather than winemaking cultivars (Isnard 1951, Aldebert and Orsat 1959), bringing new cultivars from Eastern regions (Fregoni 1991). More recently, European influence in the region promoted grapevine cultivation in Algeria, with colonists making their own wine (Föex 1891, Johnson 1990). The arrival of phylloxera in Europe at the end of the 19th century, however, led to a great increase in the area cultivated to the grapevine in Algeria, with French vine growers planting large vineyards. Many of the cultivars planted were those grown at that time in France (Föex 1891), while others were brought from Spain (Isnard 1951, Levadoux et al. 1971). Today, information held by the Organisation Internationale de la Vigne et du Vin (OIV) (http://www.oiv.int/) Internationale de la Vigne et du Vin 2009) for the period 1986–2007 shows that Algeria and Morocco were responsible for a mean 0.42% and 0.41%, respectively, of the world's entire grape production. In Algeria, 59.41% of this production was destined for table consumption, 40.47% for winemaking and 0.10% for raisin production. In Morocco, these figures were 76.40, 23.24 and 0.36%, respectively.

Many ampelographic studies have been made of grapevine cultivars from all over the world, but only a few have described those of Algeria and Morocco (Föex 1891, Isnard 1951, Vidal 1951, Levadoux et al. 1971), the most recent being a collection of the descriptions made by Galet since 1952 under the title *Dictionaire Encyclopédique des Cépages* (Galet 2000). In recent years, however, several molecular studies on North African cultivars have been made, identifying the accessions held in germplasm banks through the study of DNA polymorphisms. As a consequence, many of the Maghrebi cultivars have now been profiled by nuclear and chloroplast microsatellite [simple sequence repeats (SSR)] analysis (El Oualkadi et al. 2009, 2011,

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Laiadi et al. 2009, Riahi et al. 2010, Zinelabidine et al. 2010). Unfortunately, these studies were published over a short period of time that made it difficult for their authors to compare their results. Thus, much confusion regarding the true number of cultivars continues to exist, the consequence of the existence of synonyms, homonyms, errors of identification and the difficulty in transcribing Arab words into the Latin alphabet.

Recently, single-nucleotide polymorphisms (SNPs – another type of molecular marker) have been used to identify grapevine cultivars, to construct genetic maps and to perform parentage analysis (Cabezas et al. 2011, Ibanez et al. 2012, Zinelabidine et al. 2012). In the genome, SNPs are more abundant than SSRs, and further, they have the advantage of being bi-allelic, co-dominant, robust and of allowing for high-throughput genotyping and automation. Importantly, their allele binning is easy (bi-allelic and based on nucleotide sequence instead of amplicon length), which makes these markers particularly suitable for comparing the data obtained by different laboratories.

The aim of the present work was to clarify the identity of the grapevine cultivars growing in the Maghreb via ampelographic and SNP analysis, and to compare the results obtained with previously published SSR marker profiles and ampelographic data. This information was used to detect synonyms, homonyms and possible errors of identification in previous reports.

Materials and methods

Plant material

The Algerian material used in this study included 34 accessions (two plants per accession) (codes A1–A34; Table 1) of the germplasm collection belonging to the M'zej Edchiche Institut Téchnique d'Arboriculture Fruitière (ITAF), (Ministère de l'Agriculture), Skikda (northeastern Algeria). The Moroccan material included 37 accessions (two plants per accession) and wild plants (codes M1–M37; Table 1); these were either maintained as part of the grapevine collection of the Société du Développement Agricole (SODEA) de Meknés ($n = 19$), found growing in vineyards in the Demnate region ($n = 11$), or found growing spontaneously in non-cultivated areas in Oum-er-Rbia, Ouaoumana and El Ksiba ($n = 7$). Different leaf samples were taken from the same plants for the ampelographic and molecular analysis.

Ampelographic characterisation

After blooming, 10–11 fully expanded leaves from nodes eight to nine of green shoots were collected from each accession. Measurement of the variables required for reconstructing an average leaf for each plant was taken following the method of Martinez and Grenan (1999) (Figure 1a). Image analysis of digital photographs was performed with analySIS 3.0 software (Soft Imaging System GmbH, Münster, Germany). The number of teeth between the major veins was also recorded following the proposal of the same authors (Figure 1b).

The variables measured (lengths and angles) were used to calculate the following relationships: Rel.1:L1d/L; Rel.2:L1g/L; Rel.3:A + B + G; Rel.4:A′ + B′ + G′; Rel.5:a + b + g; Rel.6:a′ + b′ + g′; Rel.7:(S1d + S2d)/(L1d + L2d); Rel.8:(S1g + S2g)/(L1g + L2g); Rel.9:S1d/L1d; Rel.10:S1g/L1g; Rel.11:S2d/L2d; Rel.12: S2g/L2g (Martinez and Grenan 1999).

DNA analysis

DNA was isolated from young frozen leaves using the DNeasyTM Plant Mini Kit (Qiagen, Valencia, CA, USA). The genotype of most of the grapevine cultivars examined was determined with a set of 48 selected SNPs (Table 1). Genotyping was performed at CEGEN (http://www.cegen.es), using the SNPlex high-throughput genotyping platform (Applied Biosystems, Foster City, CA, USA), according to Cabezas et al. (2011). The results obtained were compared with the Instituto de Ciencias de la Vid y el Vino database, which includes the genotypes of more than 6000 grapevine samples.

Data analysis

Principal component analysis (PCA) of the raw data from the above-defined leaf relationships was performed using SAS statistical software v.9.1 (SAS Institute, Cary, NC, USA). This analysis avoids problems caused by differences in leaf size because of growing conditions. SNP data were analysed using GenAlEx (Peakall and Smouse 2006, 2012).

Results

The average leaf of every cultivar studied was constructed. Figures 2 and 3 show the mean leaves constructed for the Algerian and Moroccan cultivars, respectively. The first three axes determined in PCA explained 88% of the variation between cultivars in terms of leaf morphology. Axis 1 (Prin 1) explained 49.5% of the variation, with variables related to the depth of the lateral sinuses (Rel. 7, Rel. 8, Rel. 9, Rel. 10, Rel. 11 and Rel. 12) having the greatest weight. Axis 2 (Prin 2) explained 25.28% of the variation, with variables related to the angles formed by the main veins (Rel. 3, Rel. 4, Rel. 5 and Rel. 6) showing the greatest weight. Finally, the third axis (Prin 3) explained 13.55% of the variation, with variables indicating the orbicular or cuneiform shape of the leaf (Rel. 1 and Rel. 2) having the greatest weight.

Figure 4 shows the PCA distribution plot for the studied plants with respect to the variables analysed. The accessions to the right of the graph on Prin 1 are those with shallow lateral sinuses, including accession Oum-er-Rbia 1 (M28), and the cultivars Bouchouka (M7), El Farryali (M15), Laadari (M20), Bouzouga (M11), Tagulayt (M34) and Oualgdid (M25), all from Morocco. On the left on Prin 1 lie the cultivars with deeper lateral sinuses, such as Amokrane (A12), Carignan (M12), Louali (A27), Muscat el Adda (A30), Bezzoul el Khadem (A15), Farana (M19), El Karim (M16) and Sidi Taybi (M33). Muscat de Berkaim (A28), with the most open vein angles, is located at the back of the graph on Prin 2, while El-Ksiba 2 (M18), Farana (M19) and Bezzoul el Khadem (A15), with the most closed angles, are located in the foreground. The bottom of the graph on Prin 3 is occupied by Ouaoumana 2 (M27), Farana Blanc (A20), Oum-er-Rbia 1 (M28), Bouchouka Blanc (M7) and Rarjij (M31), all plants with longer leaves, i.e. those in which the relationship between L1g or L1d with respect to L is small. The upper part of the graph is occupied by Muscat Sefrou (M24), Sultanina Fandouk (A32), El-Ksiba 1 (M17), Bouzouga (M11), Muscat de Fandouk1 (A29) and Muscat de Berkaim (A28), the leaves of which are orbicular in shape. The remaining cultivars are distributed in intermediate positions.

Given the above PCA distribution of the accessions and the mean leaf data (Figures 2 and 3), the Moroccan cultivars were found to show (at least in *grosso* modo) more variation in terms of leaf morphology than those of Algeria, which generally were characterised by deep lateral sinuses.

In the samples studied, SNP1399_81 was found to be monomorphic and SNP analysis of 58 cultivar samples (34 Algerian and 24 Moroccan) revealed a total of 39 non-redundant genotypes (Table 2). Most redundancy was found among accessions of the same country, but two matching pairs were found between accessions from different countries: Aïn el Kelb (A10) with Muscat Sefrou (M24), and Muscat de Fandouk 1 (A29) with Muscat Doukkala (M23). A total of 23 different genotypes

Table 1. The Algerian and Moroccan cultivars studied in the present work.

Accession name	Code	Berry colour	Origin‡	Country	SNP analysis
Aberkane	A1	B†	ITAF	Algeria	Yes
Adadi	A2	G	ITAF	Algeria	Yes
Adari des Bibans	A3	G	ITAF	Algeria	Yes
Ahchichene	A4	G	ITAF	Algeria	Yes
Ahmar de Mascara	A5	R	ITAF	Algeria	Yes
Ahmar Mechtras2	A6	P	ITAF	Algeria	Yes
Ahmar Mechtras3	A7	P	ITAF	Algeria	Yes
Ahmed dra el Mizen	A8	G	ITAF	Algeria	Yes
Aïn el Couma	A9	G	ITAF	Algeria	Yes
Aïn el Kelb	A10	G	ITAF	Algeria	Yes
Amellal	A11	G	ITAF	Algeria	Yes
Amokrane	A12	G	ITAF	Algeria	Yes
Aneb el Cadi	A13	G	ITAF	Algeria	Yes
Baladi	A14	G	ITAF	Algeria	Yes
Bezzoul el Khadem	A15	B	ITAF	Algeria	Yes
Boghni	A16	G	ITAF	Algeria	Yes
Bouaber des Aures	A17	B	ITAF	Algeria	Yes
Bouni	A18	G	ITAF	Algeria	Yes
Cherchelli	A19	G	ITAF	Algeria	Yes
Farana Blanc	A20	G	ITAF	Algeria	Yes
Farana de Mascara	A21	G	ITAF	Algeria	Yes
Farana Noir	A22	B	ITAF	Algeria	Yes
Ghanez	A23	G	ITAF	Algeria	Yes
Kabyl Aldebert	A24	B	ITAF	Algeria	Yes
Lakhzine	A25	G	ITAF	Algeria	Yes
Lekhdari	A26	G	ITAF	Algeria	Yes
Louali	A27	G	ITAF	Algeria	Yes
Muscat de Berkain	A28	G	ITAF	Algeria	Yes
Muscat de Fandouk1	A29	G	ITAF	Algeria	Yes
Muscat el Adda	A30	B	ITAF	Algeria	Yes
Sbaa Tolba	A31	G	ITAF	Algeria	Yes
Sultanine Fandouk	A32	G	ITAF	Algeria	Yes
Tadelith	A33	B	ITAF	Algeria	Yes
Tizi Ouinine	A34	G	ITAF	Algeria	Yes
Abbou	M1	B	SODEA	Morocco	Yes
Abbouhou	M2	B	Demnate	Morocco	Yes
Aguyar	M3	B	Demnate	Morocco	Yes
Arbia	M4	B	SODEA	Morocco	Yes
Azizi El Hor	M5	G	SODEA	Morocco	No
Bezoul el Aouda	M6	B	SODEA	Morocco	Yes
Bouchouka blanc	M7	G	Demnate	Morocco	Yes
Boujlida	M8	G	SODEA	Morocco	Yes
Boukhanzir	M9	G	SODEA	Morocco	No
Bouqseb	M10	G	SODEA	Morocco	Yes
Bouzouga	M11	B	SODEA	Morocco	Yes
Carignan	M12	B	SODEA	Morocco	Yes
Djinani	M13	G	SODEA	Morocco	Yes
El Biod	M14	G	SODEA	Morocco	Yes
El Farryali	M15	B	Demnate	Morocco	No
El Karim	M16	G	SODEA	Morocco	Yes
El-Ksiba1	M17	Nd	Wild (El-Ksiba)	Morocco	No

Table 1. *Continued*

Accession name	Code	Berry colour	Origin‡	Country	SNP analysis
El-Ksiba2	M18	Nd	Wild (El-Ksiba)	Morocco	No
Farana	M19	G	SODEA	Morocco	Yes
Laadari	M20	G	Demnate	Morocco	No
Laaderi	M21	B	SODEA	Morocco	Yes
Maccabeo	M22	G	SODEA	Morocco	Yes
Muscat Doukkala	M23	G	SODEA	Morocco	Yes
Muscat Sefrou	M24	G	SODEA	Morocco	Yes
Oualgdid	M25	B	Demnate	Morocco	Yes
Ouaoumana1	M26	Nd	Wild (Ouaoumana)	Morocco	No
Ouaoumana2	M27	Nd	Wild (Ouaoumana)	Morocco	No
Oum-er-Rbia1	M28	Nd	Wild (Oum-er-Rbia)	Morocco	No
Oum-er-Rbia3	M29	Nd	Wild (Oum-er-Rbia)	Morocco	No
Oum-er-Rbia4	M30	Nd	Wild (Oum-er-Rbia)	Morocco	No
Rarjij	M31	B	Demnate	Morocco	No
Sbaa Lebnat	M32	G	SODEA	Morocco	Yes
Sidi Taybi	M33	B	SODEA	Morocco	Yes
Tagulayt	M34	G	Demnate	Morocco	Yes
Tanakert	M35	B	Demnate	Morocco	Yes
Tinouine	M36	B	Demnate	Morocco	Yes
Tyliote	M37	G	Demnate	Morocco	No

†Berry colour: B, black, P, pink; R, red; G, green; Nd, not determined. ‡Origin: ITAF, Germplasm collection of the M'zej Edchiche Institut Téchnique d'Arboriculture Fruitière (Skikda, Algeria); SODEA, Germplasm collection of the Société du Développement Agricole (Meknés, Morocco).

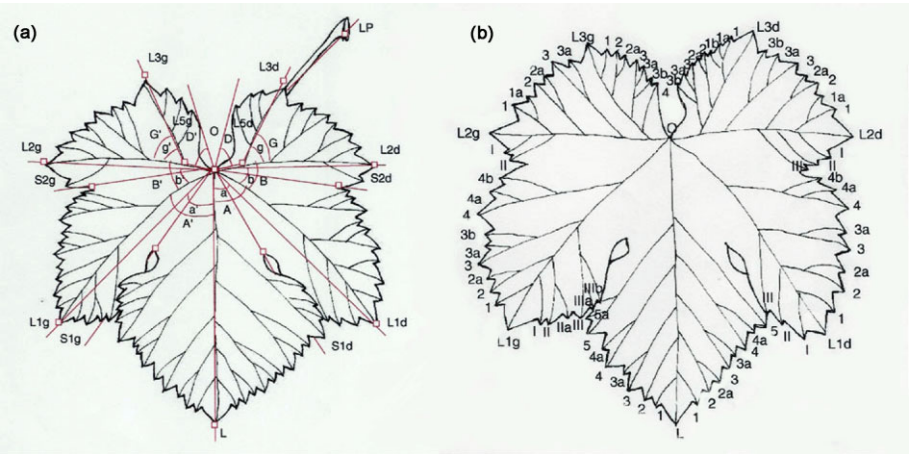

Figure 1. Construction of mean leaves (based on the method of Martinez and Grenan 1999): (a) lengths and angles measured in real leaves; (b) number of teeth in a real leaf.

were observed among the Algerian samples, and 18 among the Moroccan samples. The total probability of identity for multi-locus genotypes for the 48 SNPs, calculated from the 39 non-redundant genotypes, was $3.2 \cdot 10^{-16}$.

Discussion

Viticulture in the Maghreb has experienced great changes over its history, a consequence of the different political and cultural influences to which the region has been subjected. At the end of the protectorate in Morocco, the country's vineyards covered more than 52 000 ha (37 000 ha planted with European cultivars and 15 000 ha with indigenous cultivars) (Vidal 1951). Economically important plantations existed in several regions, including Doukkala, Haouz, Benslimane, Essaouira and Moulouya Khémisset. Presently, local cultivars occupy 59.5% of the total Moroccan vineyard area given over to table grape production. The cultivar Doukkala occupies 41.1%, followed by Abbou with an area of 6%. The most common of the introduced cultivars is Muscat d'Italie, which occupies 9.9% of the total area under vineyards, followed by Valency which occupies 8.6%, and the cultivar Muscat of Alexandria with 6.9% (Ezzahouani 2002). The most important winemaking grape cultivars grown in Morocco are Cinsaut, Carignan, Alicante Bouschet, Grenache Noir and Cabernet Sauvignon. These cultivars occupy 72% of the total area of winegrape vineyards, which have enjoyed some recovery through partnership agreements between national and foreign (mainly French) wine companies (Ezzahouani 2002).

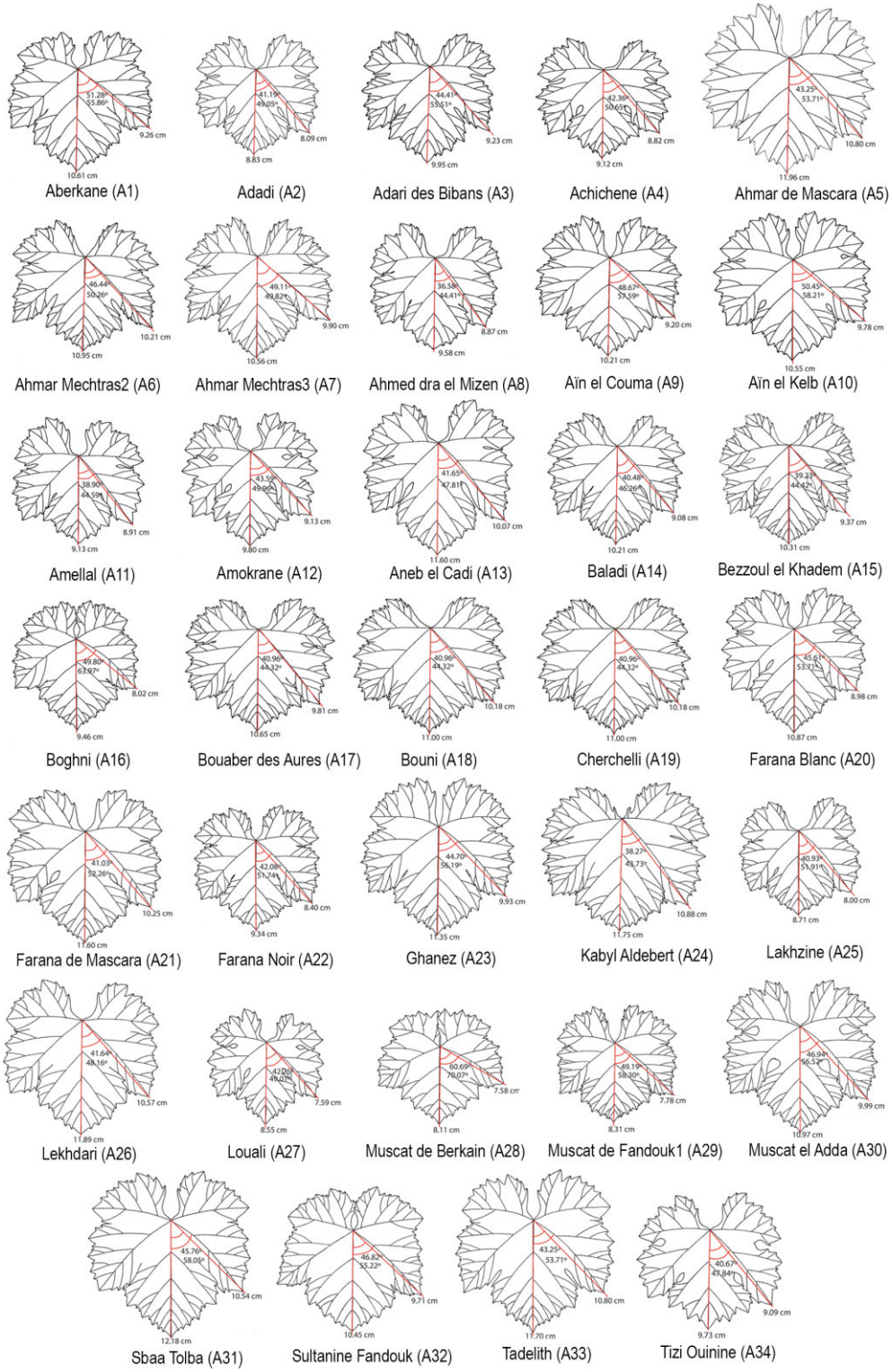

Figure 2. Mean leaves of the Algerian cultivars (A1 to A34).

Less information is available for Algeria. The only information on the extension of land under vineyards, and of the cultivars grown, is provided by the Organisation Internationale de la Vigne et du Vin (2009) (originally provided by the ITAF), by Isnard (1951), and by Levadoux et al. (1971). According to the ITAF, some 94 025 ha were given over to vineyards in 2013. The only information available on the cultivars grown (and their relative proportion) is now many years old (Isnard 1951, Levadoux et al. 1971). Although grapevine cultivation is thought to be in recession in Algeria, the conservation of the country's grapevine genetic resources is both scientifically and economically important.

Several authors have recently published microsatellite profiles for many of the cultivars examined in the present work, insome cases using the same accessions examined here [those of the ITAF (Algeria), and the SODEA and Demnate (Morocco) collections]. The present work compiles and compares all the microsatellite and ampelographic data published for North

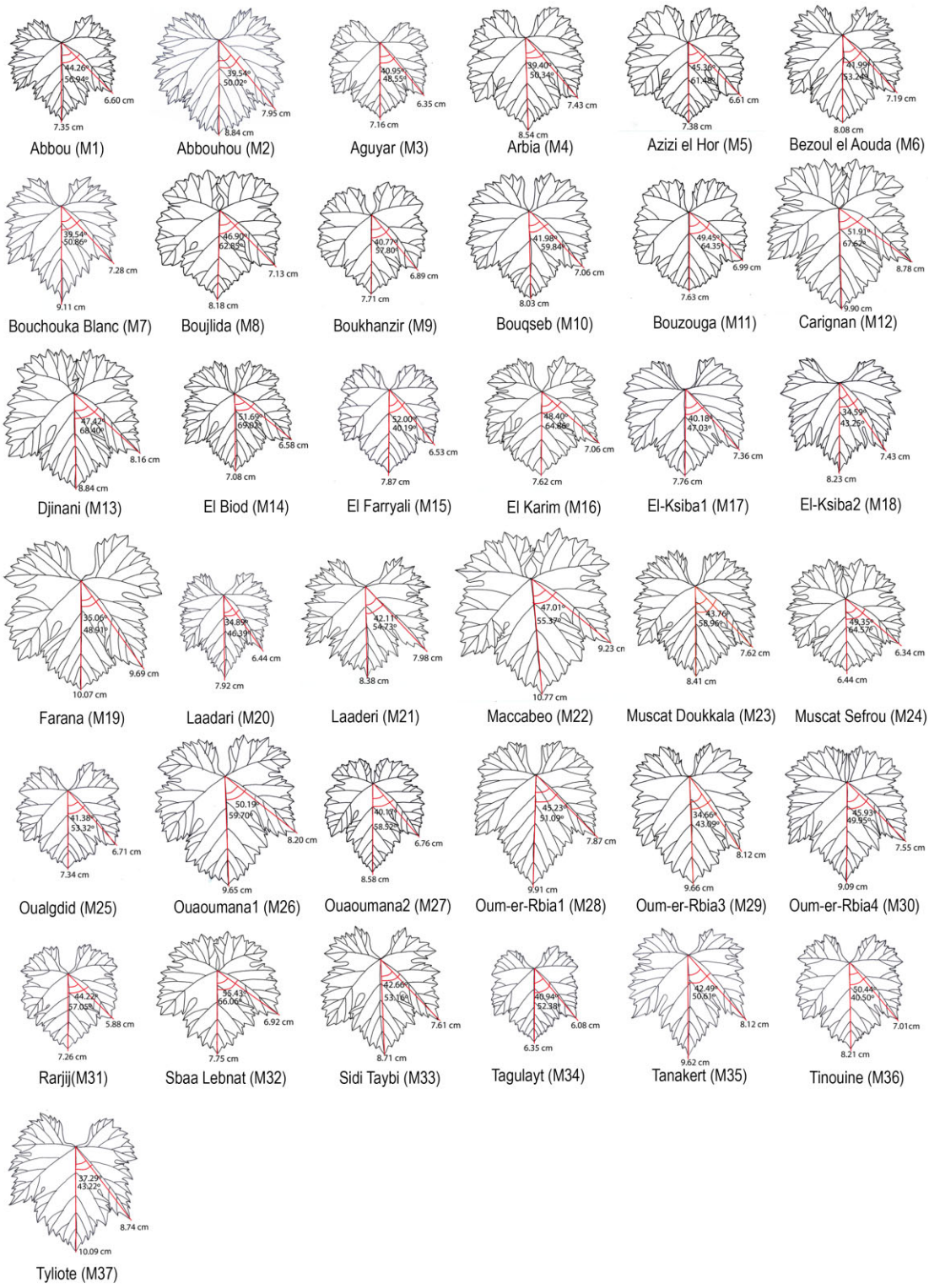

Figure 3. Mean leaves of the Moroccan cultivars and wild plants (M1 to M37).

African grape cultivars, and along with the ampelographic and SNP results obtained, provides a greater understanding of the true identity behind the names given to cultivars in different areas. Supporting Information Table S1 provides a comprehensive summary of the comparisons made and conclusions reached. Samples are grouped according to their SNP genotypes and ordered according to their codes (Table 1), except in those cases in which homonyms or similar names appear; these are grouped together for better understanding. Where synonyms, homonyms, similar names and possible sampling and/or collection errors come together, proper identification can be complicated. For example, the cultivars Ahmed dra el Mizen (A8), Amellal (A11) and Tizi Ouinine (A34) (GEN_SNP_2313, Supporting Information Table S1), all turned out to be the same cultivar. The same happened for Amokrane (A12) and Louali (A27), (GEN_SNP_2308, Supporting Information Table S1). Another example is the complex use of 'Farana', which includes several Algerian and Moroccan cultivars (GEN_SNP_2220,

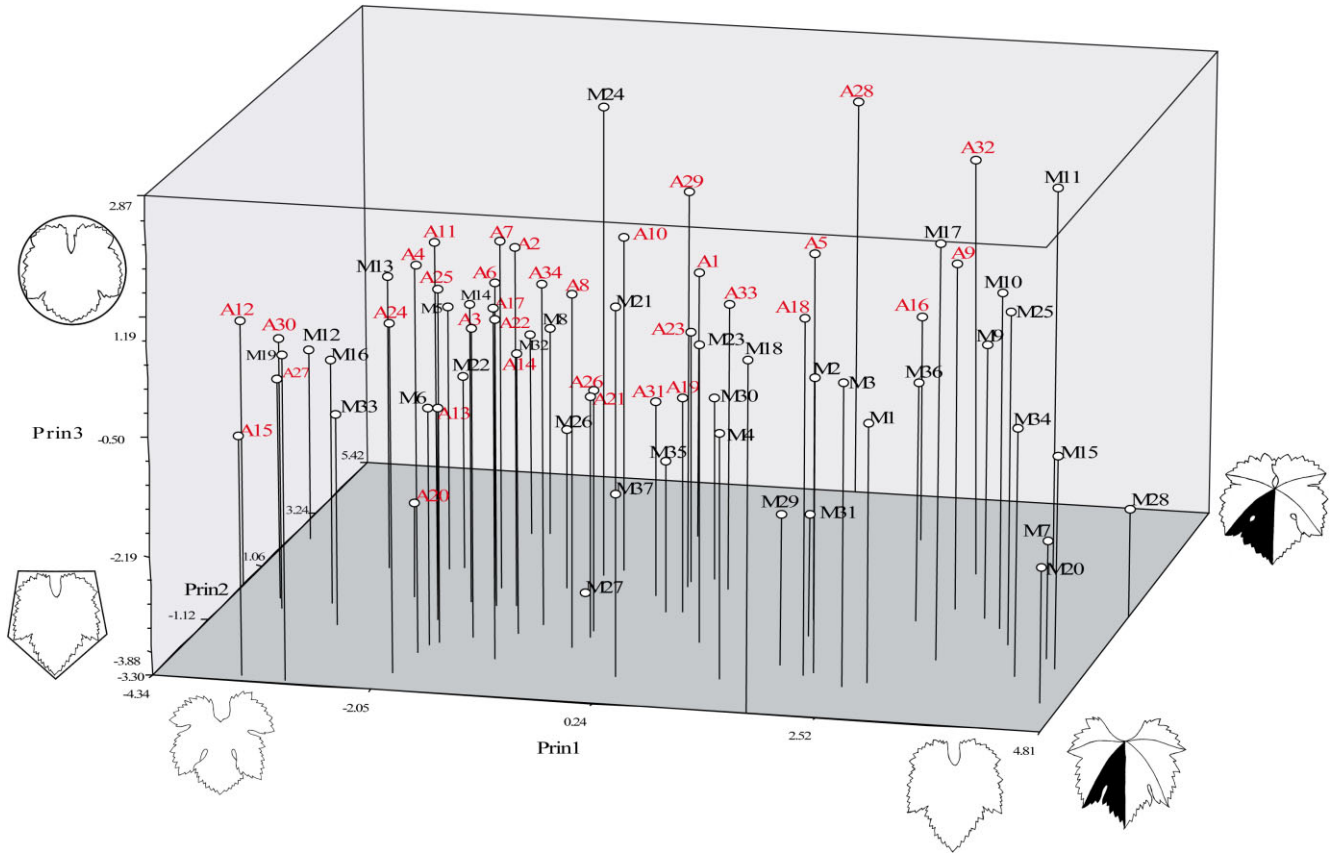

Figure 4. Principal component analysis showing the projection of the 34 Algerian (A1 to A34) and 37 Moroccan (M1 to M37) grape cultivars on the axes defined by the first three principal coordinates.

GEN_SNP_1475 and GEN_SNP_2311, Supporting Information Table S1). The present work shows that several old cultivars grown both in Spain and in the Maghreb countries, especially in Morocco (where they still grow but under different names), include Ahmeur bou Ahmeur, Airen, Cañocazo, Beba, Cayetana Blanca, Dominga, Ohanes, Planta Fina and Planta Mula (Supporting Information Table 1). This is probably the result of cultural and material exchange between North Africa and the Iberian Peninsula over many centuries. There are also cultivars of wide distribution outside the Maghreb, such as several Muscats, and Sultanina, that were also found in the Moroccan and Algerian collections. Finally, there are several cultivars (Aberkane, Achichene, Adadi, Amellal, Aneb el Cadi, Bezzoul el Khadem, Taferielt, Agueyer, Abbouhou, Bouqseb, Bouchouka and Bouzouga) for which no synonyms were found outside of the region; these cultivars are probably native to the Maghreb.

The molecular profiles for Ouaoumana 1 and Ouaoumana 2 (wild grapevine samples from Morocco) reported by Zinelabidine et al. (2010) were identical, but different to any other wild plants from different locations in Morocco. No matches were seen with the profiles of other North African materials reported by other authors (El Oualkadi et al. 2009, Laiadi et al. 2009, Riahi et al. 2010). Figure 3 shows the mean leaves for Ouaoumana 1 (M26) and Ouaoumana 2 (M27) to be similar in terms of lateral sinus depth and vein angles, even though Ouaoumana 2 (M27) has more cuneiform leaves. This great similarity in their leaves, and the above-mentioned molecular results, show that they are the same genotype.

The three wild plants found at Oum-er-Rbia (M28, M29 and M30) had clearly different leaves to one another and to plants from the other locations. The wild plant M28 had more cuneiform leaves, M29 more closed lateral sinuses and superimposed lobules, and M30 a closed petiolar sinus and U-shaped lateral sinuses.

In terms of their vein angles, M17 and M18 from El-Ksiba also showed leaves that differed from one another, and from those of the other cultivars studied. This suggests that they represent different cultivars; however, it would appear that they are similar at the molecular level because 8 of the 11 microsatellites analysed by Zinelabidine et al. (2010) coincide.

The present results highlight the need for collaboration between countries if problems of homonyms and synonyms are to be resolved. They also show the need to combine ampelographic and molecular results. Cultivars with similar leaf or bunch morphology might be difficult to distinguish by ampelographic means, but be clearly distinguishable by molecular techniques. For example, Bouchouka Blanc (M7) and Laadari (M20), which have leaves of similar morphology, are clearly shown by molecular methods to be different cultivars. Combining these techniques can also help confirm identity. For example, Amokrane (A12) and Louali (A27) have similar leaf morphologies, but leaves may vary greatly in size (because of the properties of the soil and water availability, or even because their parent plants belong to different clones). Molecular analysis shows them to be the same cultivar.

Conversely, some cultivars show identical molecular profiles for the markers analysed, but have different ampelographic characteristics, even to the extent that the grapes of one might be red and those of the other green. This was seen for the Pinot cultivars (Pinot Noir, Pinot Blanc and Pinot Gris) and for Muscat de Frontignan Rouge and Muscat de Frontignan Blanc.

Table 2. SNP genotypes for the 34 Algerian and 24 Moroccan accessions analysed.

Code	Name	SNP Genotype number	Proposed name†	SNP1003_336	SNP1015_67	SNP1027_69	SNP1035_226	SNP1079_58	SNP1119_176	SNP1127_70	SNP1157_64	SNP1215_138	SNP1229_219	SNP1323_155	SNP1347_100	SNP1349_174	SNP1399_81	SNP1411_565	SNP1445_218	SNP1453_40	SNP1471_179	SNP1513_153	SNP191_100	SNP197_82	SNP227_191	SNP259_199
A01	Aberkane	GEN_SNP_2412	ABERKANE	AA	AG	CC	TT	AG	AC	GT	AT	CC	CC	CC	GG	AA	AA	TT	AG	AA	TT	TT	CC	AC	CC	TT
A02	Adadi	GEN_SNP_2902	—	ND	AG	ND	CT	ND	ND	ND	ND	CC	CC	ND	ND	ND	AA	TT	ND	ND	TT	TT	CC	ND	AC	ND
A03	Adari des Bibans	GEN_SNP_2310	ACHICHANE	CC	AG	CT	TT	AG	AC	GT	AT	CC	CC	AC	AG	AA	AA	AT	AG	AG	TT	CT	CC	AC	AA	AT
A04	Ahchichene	GEN_SNP_2310	ACHICHANE	CC	AG	CT	TT	AG	AC	GT	AT	CC	CC	AC	AG	AA	AA	AT	AG	AG	TT	CT	CC	AC	AA	AT
A05	Ahmar de Mascara	GEN_SNP_0473	AHMEUR BOU AHMEUR	AC	AA	CT	CT	AA	AA	GG	AT	CT	CG	CC	GG	AG	AA	TT	AG	GG	CT	TT	CC	AC	AA	AT
A06	Ahmar Mechtras II	GEN_SNP_0051	FRAOULA KOKKINI	AA	AG	CC	CT	AG	CC	GG	TT	CC	CG	AC	AG	AG	AA	TT	AG	AA	TT	TT	CC	AC	AA	AT
A07	Ahmar Mechtras III	GEN_SNP_0051	FRAOULA KOKKINI	AA	AG	CC	CT	AG	CC	GG	TT	CC	CG	AC	AG	AG	AA	TT	AG	AA	TT	TT	CC	AC	AA	AT
A08	Ahmed Draa el Mizen	GEN_SNP_2313	AMELLAL	AC	AG	CT	CT	GG	AA	TT	TT	CC	CC	AC	AG	AG	AA	TT	AA	AG	TT	TT	CC	CC	AA	AT
A09	Aïn el Couma	GEN_SNP_2413	AIN EL BOUMA	CC	AG	CC	CC	ND	AA	GG	TT	CC	CC	CC	AG	AA	AA	AT	GG	AA	TT	CT	CC	CC	AC	TT
A10	Aïn el Kelb	GEN_SNP_2088	BEBA	AC	AA	TT	CT	AA	AA	GG	TT	CC	CC	CC	AG	GG	AA	TT	GG	AG	TT	TT	CC	CC	AA	AT
A11	Amellal	GEN_SNP_2313	AMELLAL	AC	AG	CT	CT	GG	AA	TT	TT	CC	CC	AC	AG	AG	AA	TT	AA	AG	TT	TT	CC	CC	AA	AT
A12	Amokrane	GEN_SNP_2308	—	AC	GG	CC	CT	GG	AA	GG	TT	CT	CC	CC	GG	AG	AA	TT	AG	AA	TT	TT	CC	CC	AC	TT
A13	Aneb el Cadi	GEN_SNP_2314	—	AA	AA	CT	CT	AG	AC	GG	TT	CT	CC	AC	AG	AG	AA	TT	GG	AG	TT	TT	CC	CC	AA	TT
A14	Baladi	GEN_SNP_0021	—	AA	AG	CT	CT	AG	AC	GG	TT	CC	CC	AC	AG	AA	AA	TT	GG	AG	TT	CT	CC	CC	ND	AT
A15	Bezzoul el Khadem	GEN_SNP_2312	BEZOUL EL KHADEM D'ALGÉRIE	AA	AG	CC	CT	GG	CC	GG	AT	CT	CC	AC	AA	AA	AA	TT	GG	GG	TT	TT	CC	AA	AA	AT
A16	Boghni	GEN_SNP_2414	—	AC	GG	CC	CT	AA	AA	GT	TT	TT	CC	AA	GG	AA	AA	TT	AA	AA	TT	TT	CC	AA	AA	AA
A17	Bouaber des Aures	GEN_SNP_2309	KABYLE ALDEBERT	CC	AG	CT	CT	GG	AC	GG	TT	CC	CC	AC	GG	AA	AA	TT	GG	AA	CT	TT	CC	AC	AA	TT
A18	Bouni	GEN_SNP_2114	DOMINGA	AC	AG	CT	CC	AG	AC	GG	TT	CT	CC	AA	GG	AA	AA	TT	GG	AA	TT	CT	CC	CC	AA	AT
A19	Cherchelli	GEN_SNP_2220	—	CC	AG	CT	TT	AA	CC	GT	TT	CC	CC	CC	AA	AG	AA	TT	GG	AG	TT	CT	CC	CC	AA	TT
A20	Farana Blanc	GEN_SNP_2220	PLANTA FINA	CC	AG	CT	TT	AA	CC	GT	TT	CC	CC	CC	AA	AG	AA	TT	GG	AG	TT	CT	CC	CC	AA	TT
A21	Farana de Mascara	GEN_SNP_2220	PLANTA FINA	CC	AG	CT	TT	AA	CC	GT	TT	CC	CC	CC	AA	AG	AA	TT	GG	AG	TT	CT	CC	CC	AA	TT
A22	Farana Noir	GEN_SNP_2311	TAFERIELT	CC	AG	CT	CT	ND	AA	GG	TT	CC	CC	AC	GG	AG	AA	TT	GG	GG	TT	TT	CT	AA	AA	AT
A23	Ghanez	GEN_SNP_0608	OHANES	AC	AG	CT	ND	AA	AA	GG	AT	CT	CC	AC	GG	AG	AA	TT	GG	AA	TT	CT	CC	CC	AA	AT
A24	Kabyle Aldebert	GEN_SNP_2309	KABYLE ALDEBERT	CC	AG	CT	CT	GG	AC	GG	TT	CC	CC	AC	GG	AA	AA	TT	GG	AA	CT	TT	CC	AC	AA	TT
A25	Lekzine	GEN_SNP_2310	—	CC	AG	CT	TT	AG	AC	GT	AT	CC	CC	AC	AG	AA	AA	AT	AG	AG	TT	CT	CC	AC	AA	AT
A26	Lakhdari	GEN_SNP_2315	—	AC	AG	CC	CT	GG	AA	GT	TT	CT	CC	CC	GG	AG	AA	TT	AA	AA	TT	TT	CC	CC	AA	TT
A27	Louali	GEN_SNP_2308	LOUALI	AC	GG	CC	CT	GG	AA	GG	TT	CT	CC	CC	ND	AG	AA	TT	AG	AA	TT	TT	CC	CC	AC	TT
A28	Muscat de Berkain	GEN_SNP_0799	MUSCAT FLEUR D'ORANGER	AC	GG	CC	TT	AA	AC	GT	AT	CC	CC	CC	GG	AA	AA	AT	AG	AG	CT	CC	CT	AC	AA	AT
A29	Muscat de Fandouk	GEN_SNP_2153	MUSCAT OF ALEXANDRIA	AC	GG	CC	CT	AG	AC	GT	TT	CT	CC	AC	GG	AA	AA	AT	GG	AG	CT	TT	CC	CC	AA	AT
A30	Muscat el Adda	GEN_SNP_2059	MOSCATO D'ADDA	AA	GG	CT	TT	AA	AC	GG	TT	CT	CC	CC	GG	AA	AA	AA	AG	AG	CT	CT	CT	AC	AC	AA
A31	Sbaa Tolba	GEN_SNP_2220	—	ND	ND	ND	TT	AA	CC	GT	TT	CC	CC	CC	AA	AG	AA	TT	GG	AG	TT	CT	CC	CC	AA	TT
A32	Sultanine Fandouk	GEN_SNP_2126	SULTANINA	AC	AG	CT	CT	ND	CC	GG	TT	CT	CG	AC	AG	AG	AA	AT	AG	AA	TT	CT	ND	ND	ND	AA
A33	Tadelith	GEN_SNP_0608	—	ND	AG	CT	ND	ND	AA	GG	AT	ND	CC	AC	ND	ND	AA	TT	ND	AA	ND	CT	CC	CC	AA	AT
A34	Tizi Ouinine	GEN_SNP_2313	—	AC	AG	CT	CT	GG	AA	TT	TT	CC	CC	AC	AG	AG	AA	TT	AA	AG	TT	TT	CC	CC	AA	AT
M01	Abbou	GEN_SNP_2307	AGUEYER	CC	AG	CC	CT	AG	CC	GG	TT	CC	CC	CC	AG	AG	AA	TT	AG	AA	CT	TT	CC	CC	AA	AT
M02	Abouhou2	GEN_SNP_2317	ABOUHOU	CC	AG	CC	CT	AG	CC	GG	TT	CC	CC	AC	AG	AA	AA	TT	AA	AA	TT	TT	CC	CC	AA	AT
M03	Aguyar1	GEN_SNP_2307	AGUEYER	CC	AG	CC	CT	AG	CC	GG	TT	CC	CC	CC	AG	AG	AA	TT	AG	AA	CT	TT	CC	CC	AA	AT
M04	Arbia	GEN_SNP_1158	PLANTA MULA	CC	AG	CC	TT	AG	AC	GT	TT	CC	CG	CC	AG	AA	AA	AA	AA	AA	CT	CT	CC	AC	AC	AT
M06	Bezoult Aouda	GEN_SNP_0527	BEZOUL EL KHADEM	AC	AG	CC	CT	AG	AC	GG	TT	CT	CC	AC	GG	AA	AA	TT	AA	AA	CT	TT	CC	AC	AA	AT
M07	Bouchouka Blanc	GEN_SNP_2316	BOU CHOUKKA	AC	AG	CC	CC	AA	AC	GG	TT	CT	CC	AC	AG	AG	AA	TT	GG	AG	CT	TT	CC	CC	AA	AT
M08	Boujlida	GEN_SNP_0966	CAÑOCAZO	AC	GG	CT	TT	AA	AC	GT	TT	CC	CC	CC	AG	AG	AA	TT	AG	AG	TT	TT	CC	AC	CC	AT
M10	Bouqseb	GEN_SNP_2306	BOU QSOB	AA	AA	CC	CT	AG	AA	GG	TT	CT	CC	CC	GG	AG	AA	TT	AG	AG	TT	TT	CC	AC	AA	TT
M11	Bouzouga	GEN_SNP_2421	BOUZOUGA	AC	AG	CC	TT	AA	AC	GG	TT	CC	CC	AC	GG	AA	AA	TT	AG	AA	TT	TT	CC	AC	AA	TT
M12	Carignan	GEN_SNP_0540	CARIGNAN	AC	AG	CC	CT	GG	CC	GG	TT	CT	CC	CC	AA	AG	AA	AT	AG	AG	TT	CT	CC	AC	AA	AT
M13	Djinani	GEN_SNP_1089	CAYETANA BLANCA	CC	AA	CT	CT	AA	AC	GG	TT	CC	CC	CC	AG	AG	AA	TT	AG	GG	TT	TT	CC	CC	AA	AT
M14	El Biod	GEN_SNP_0885	AIREN	AC	GG	CT	CT	AA	AA	GG	TT	CC	CC	CC	AG	GG	AA	TT	AG	AA	TT	TT	CC	CC	AA	AT
M16	El Karim	GEN_SNP_0885	AIREN	AC	GG	CT	CT	AA	AA	GG	TT	CC	CC	CC	AG	GG	AA	TT	AG	AA	TT	TT	CC	CC	AA	AT
M19	Feranna	GEN_SNP_1475	—	CC	GG	CT	TT	GG	AC	GT	TT	CT	CC	CC	AG	GG	AA	AA	AG	AA	TT	CC	CC	CC	AC	AT
M21	Laaderi	GEN_SNP_2307	—	CC	AG	CC	CT	AG	CC	GG	TT	CC	CC	CC	ND	AG	AA	TT	AG	AA	CT	TT	CC	CC	AA	AT
M22	Maccabeo	GEN_SNP_1504	VIURA	CC	GG	TT	TT	AG	AC	GT	TT	CT	CC	CC	AA	AG	AA	AT	AG	GG	TT	CT	CC	AC	AA	TT
M23	Muscat Doukala	GEN_SNP_2153	MUSCAT OF ALEXANDRIA	AC	GG	CC	CT	AG	AC	GT	TT	CT	CC	AC	GG	AA	AA	AT	GG	AG	CT	TT	CC	CC	AA	AT
M24	Muscat Sefrou	GEN_SNP_2088	BEBA	AC	AA	TT	CT	AA	AA	GG	TT	CC	CC	CC	AG	GG	AA	TT	GG	AG	TT	TT	CC	CC	AA	AT
M25	Oulgdid	GEN_SNP_2317	—	CC	AG	CC	CT	AG	CC	GG	TT	CC	CC	AC	AG	AA	AA	TT	AA	AA	TT	TT	CC	CC	AA	AT
M32	Sbaa Bnet	GEN_SNP_0479	OLIVETTE BARTHELET	AC	AA	CT	TT	AA	AA	GG	TT	CC	CC	AC	GG	AG	AA	TT	GG	AA	TT	CT	CC	CC	AA	TT
M33	Sidi Taybi	GEN_SNP_0527	BEZOUL EL KHADEM	AC	AG	CC	CT	AG	AC	GG	TT	CT	CC	AC	GG	AA	AA	TT	AA	AA	CT	TT	CC	AC	AA	AT
M34	Tagleyate2	GEN_SNP_2316	—	AC	AG	CC	CC	AA	AC	GG	TT	CT	CC	AC	AG	AG	AA	TT	GG	AG	CT	TT	CC	CC	AA	AT
M35	Tanakarte2	GEN_SNP_2415	—	AC	AG	CC	TT	AG	CC	GG	AT	CC	CC	AC	GG	AA	AA	TT	AG	AA	TT	TT	CC	CC	AA	TT
M36	Tinionine2	GEN_SNP_2424	—	AC	GG	CC	CT	AG	AC	GG	TT	CT	CC	AC	AG	AG	AA	TT	AG	AA	TT	TT	CC	AC	AA	AT

Table 2. *Continued*

Code	SNP269_308	SNP325_65	SNP425_205	SNP447_244	SNP555_132	SNP579_187	SNP581_114	SNP593_149	SNP613_315	SNP697_296	SNP819_210	SNP829_281	SNP873_244	SNP879_308	SNP895_382	SNP945_88	SNP947_288	Vvi_10113	Vvi_10329	Vvi_10353	Vvi_10992	Vvi_12882	Vvi_1617	Vvi_9227	Vvi_9920
A01	AA	AA	AA	CT	AA	TT	AG	CT	CC	AA	AA	AG	CT	AG	TT	AG	AG	AA	TT	GG	AA	TT	AC	TT	GG
A02	AG	ND	AA	CT	AA	ND	AG	ND	CC	AA	ND	AG	CT	ND	AT	ND	ND	AA	ND	GG	AA	TT	AC	ND	GG
A03	AG	AT	AA	CT	AA	TT	AG	TT	CC	AA	AT	GG	CT	AG	AT	AA	AG	AA	CT	GG	AA	TT	CC	TT	AG
A04	AG	AT	AA	CT	AA	TT	AG	TT	CC	AA	TT	GG	CT	AG	AT	AA	AG	AA	CT	GG	AA	TT	CC	TT	AG
A05	AG	AA	AA	CT	AA	CT	AG	TT	CC	AG	AT	GG	CT	AA	AA	AG	GG	AA	CT	GG	AT	TT	CC	TT	AG
A06	AG	AA	AA	CT	AC	TT	AG	CT	CT	AA	TT	GG	CC	AG	AA	GG	GG	AA	CT	GG	TT	TT	AC	TT	AA
A07	AG	AA	AA	CT	AC	CT	AG	CT	CT	AA	TT	GG	CT	GG	AA	GG	GG	AA	CT	GG	AA	TT	AC	AT	GG
A08	GG	AT	AA	CT	AA	CT	AG	TT	CC	AA	AT	GG	CT	AG	AA	GG	GG	AA	CC	AG	AA	CT	ND	TT	AG
A09	AA	AT	AA	CT	AC	TT	AG	TT	CC	AA	TT	AG	CT	GG	AA	GG	AG	AA	CC	AG	AA	CT	ND	AT	GG
A10	AG	AA	AA	CC	AA	CC	AG	CT	CT	AA	TT	GG	CT	AG	AA	GG	AG	AA	CT	GG	TT	TT	AA	AT	GG
A11	GG	AT	AA	CT	AA	CT	AG	TT	CC	AA	AT	GG	CT	GG	AA	GG	GG	AA	CT	GG	AA	TT	AC	AT	GG
A12	AG	AT	AA	TT	AC	TT	AG	TT	CC	AG	TT	GG	CT	AA	AT	GG	GG	AA	CT	GG	AT	TT	AC	AT	GG
A13	AA	AT	AA	CC	AC	TT	AG	TT	CC	AA	AA	GG	CT	GG	AT	GG	GG	AA	TT	GG	AA	TT	AC	AT	AA
A14	AA	AA	AA	CC	AC	TT	AG	TT	CC	AA	AA	GG	CT	AG	AT	AG	AG	AA	TT	AG	AA	CT	AC	AT	GG
A15	AA	AA	AA	CT	AC	TT	AG	CT	CT	AA	AT	GG	CC	AA	TT	AG	AG	AT	AT	AG	AT	TT	AA	TT	AG
A16	AG	AA	AA	CT	AC	TT	AG	CT	CT	AA	AT	GG	CT	AA	AA	AG	GG	AA	ND	AG	AA	TT	AA	TT	AG
A17	AA	AA	AA	TT	AA	TT	AG	TT	CT	AA	AT	AA	CT	AA	TT	AG	GG	AA	CT	GG	AA	TT	CC	TT	AG
A18	AA	AA	AA	TT	AC	TT	AG	CC	CT	AA	AT	GG	CC	AA	AT	GG	GG	AA	CT	GG	AA	TT	AC	AT	GG
A19	AG	AA	AA	CT	AA	CT	AG	CT	CT	AA	AT	AG	CT	AG	AT	AA	GG	AA	TT	AG	AT	TT	AC	AA	AG
A20	AG	AA	AA	CT	AA	CT	AG	CT	CT	AA	AT	AG	CT	AG	AT	AA	GG	AA	TT	GG	AT	TT	AC	AA	AG
A21	AG	AA	AA	CT	AA	CT	AG	CT	CT	AA	AT	AG	CT	AG	AT	AA	GG	AA	CC	AG	AT	TT	AC	AA	AG
A22	GG	AT	AA	TT	AA	TT	AG	CT	CT	AG	AT	AG	TT	AG	AA	AG	GG	AA	CC	AG	AT	TT	AC	TT	GG
A23	AA	AA	AA	CT	AA	TT	ND	TT	CT	AA	AT	AG	CC	AG	AT	AG	AG	AA	CT	GG	AT	TT	AC	TT	GG
A24	AA	AA	AA	TT	AA	TT	AG	TT	CT	AA	AT	AG	CT	AA	TT	AG	GG	AA	CT	GG	AT	TT	AC	TT	GG
A25	AG	AT	AA	CT	AA	TT	AG	TT	CC	AA	TT	GG	CT	AA	AT	AG	AG	AA	CC	AG	AT	TT	AA	TT	AG
A26	AG	AT	AA	CT	AC	TT	GG	TT	CT	AG	AT	AG	CC	AG	AT	GG	AG	AA	TT	AG	AT	TT	AC	AT	AG
A27	AG	AT	AA	TT	AC	TT	AG	TT	CC	AG	TT	AG	CT	AA	AT	GG	AG	AA	CC	AG	AT	TT	AC	AT	GG
A28	AG	AA	AA	CC	AC	TT	AG	CC	CC	AA	TT	AA	TT	AA	AA	AA	GG	AA	CT	AG	AT	TT	AC	AT	GG
A29	AA	AA	AA	CT	CC	TT	AG	CT	CC	AA	AT	AG	CT	AA	AA	AG	GG	AA	CT	AG	AT	TT	AC	AT	GG
A30	AA	AA	AA	TT	CC	TT	AG	CT	CC	AA	AA	AG	CT	AA	AT	AG	GG	AA	CT	AG	AT	TT	AC	AT	GG
A31	AG	AA	AA	CT	AA	CT	AG	CT	CT	AA	AT	AG	ND	GG	ND	ND	GG	AA	CT	GG	AT	TT	AC	AA	AG
A32	ND	AA	ND	ND	AA	TT	AG	CT	CT	AA	TT	GG	CT	AA	ND	AG	AG	AA	TT	AG	AT	TT	CC	TT	GG
A33	ND	ND	AA	CT	AA	TT	ND	TT	CC	AA	AT	GG	CT	GG	AA	AG	GG	AA	CT	GG	AA	ND	AC	AT	GG
A34	GG	AT	AA	CT	AA	CT	AG	TT	CC	AA	AT	AG	CT	GG	AA	AG	GG	AA	CT	GG	AA	TT	AC	AT	GG
M01	AG	AA	AA	TT	AC	TT	GG	TT	CC	AA	AT	AG	CC	GG	AT	AG	GG	AA	TT	AG	TT	TT	AC	TT	AG
M02	AG	AA	AA	TT	AC	TT	GG	TT	CC	AA	AT	AG	CC	GG	AT	AG	GG	AA	TT	AG	TT	TT	AC	TT	AG
M03	AG	AA	AA	TT	AC	TT	AG	TT	CC	AA	AT	AG	CC	GG	AT	AG	GG	AA	TT	AG	TT	TT	AC	TT	AG
M04	AG	AA	AA	CT	AA	CT	AG	TT	CT	GG	TT	AG	TT	GG	AT	AG	GG	AA	TT	GG	AT	TT	AC	ND	AG
M06	AA	AA	AA	TT	AA	TT	AG	TT	CC	AA	AT	GG	ND	AA	TT	AG	GG	AA	CC	AG	AT	TT	AC	TT	AG
M07	AG	AA	AA	TT	AC	TT	AG	CT	CT	AA	AT	GG	CC	GG	TT	AA	GG	AA	CC	AG	AA	TT	AC	TT	AG
M08	AG	AT	AA	CC	AA	CT	AG	TT	CT	AG	TT	AG	CT	GG	AA	AG	GG	AA	CT	GG	AA	TT	AC	AA	GG
M10	AG	AA	AA	CT	AA	TT	AG	TT	CC	AG	AA	AG	CC	AG	TT	AG	AG	AA	CC	GG	AA	TT	AC	TT	AG
M11	AA	AA	AA	CT	AA	TT	AG	TT	CC	AA	AA	AG	CC	AA	TT	AG	AG	AA	CT	AG	AA	TT	AA	TT	AG
M12	GG	AA	AA	CC	AC	CT	AG	CC	CC	AA	AT	AG	TT	AG	AT	AG	AG	AA	TT	AG	AT	TT	CC	AT	AG
M13	GG	AA	AA	CC	AA	CT	AG	CT	CT	GG	AA	GG	CC	AG	AT	AG	AG	AA	CT	GG	AT	TT	AC	AT	GG
M14	GG	TT	AA	CT	AA	TT	AG	CT	CT	AG	AT	AG	CT	GG	AT	AG	AG	AA	CT	GG	AT	TT	AC	AT	GG
M16	GG	TT	AA	CT	AA	TT	AG	CT	CT	AG	AT	AG	CT	GG	AT	AG	AG	AA	CT	GG	TT	TT	AC	AT	GG
M19	AG	AA	AC	CT	AA	TT	GG	TT	CC	AA	AT	GG	TT	AA	AT	AA	AA	AA	TT	GG	AA	TT	AC	AT	AA
M21	AG	AA	AA	TT	AC	TT	AG	TT	CC	AA	AT	AG	CC	GG	AT	AG	GG	AA	TT	AG	AT	TT	AC	AT	AG
M22	AG	AT	AC	CC	AC	TT	AG	CC	TT	AG	AT	AG	CT	AG	AT	AG	GG	AA	CT	GG	AA	TT	AC	AT	AG
M23	AA	AA	AA	CT	CC	TT	AG	CT	CC	AA	AT	GG	CT	AA	AT	AG	AG	AA	CT	AG	AT	TT	AC	TT	AA
M24	AG	AA	AA	CC	AA	CC	AG	CT	CC	AA	TT	GG	CT	AA	AA	GG	AG	AA	CT	GG	TT	TT	AA	AT	GG
M25	AG	AA	AA	TT	AC	TT	GG	TT	CC	AA	AT	AG	CC	AA	AT	AG	GG	AA	TT	AG	TT	TT	AC	TT	AG
M32	AG	AA	AA	CT	AA	CT	AG	CC	CT	AA	TT	GG	CT	AG	AT	GG	GG	AA	CC	GG	AT	TT	AA	TT	GG
M33	AA	AA	AA	TT	AA	TT	AG	TT	CC	AA	AT	GG	CT	AA	TT	AG	GG	AA	CC	GG	AT	TT	AC	TT	AG
M34	AG	AA	AA	TT	AC	TT	AG	CT	CT	AA	AT	GG	CT	GG	AA	AG	GG	AA	CC	GG	AA	TT	AC	TT	AG
M35	AG	AA	AA	CT	AA	CT	GG	TT	CT	AA	AT	GG	CC	AA	AT	AG	GG	AA	CT	GG	AT	TT	AA	TT	GG
M36	AG	AA	AA	CT	AA	TT	AG	CT	CC	AA	AT	AG	CC	AA	AT	AG	AG	AA	CT	GG	AT	TT	AC	TT	GG

†Proposed names in capital letters according to VIVC (www.vivc.de). ND, not detected.

The accessions Ghanez (A23) and Tadelith (A33) had identical SNP profiles (SNP genotype number: GEN_SNP_0608; proposed name: Ohanes), and their mean leaves were similar (Figure 2) – even clustering close to one another in PCA (Figure 4). The fact that they have different coloured grapes, however, is enough to consider them different cultivars. The reporting of contradictory results in previous studies (Supporting Information Table S1) suggests that Tadelith might be a colour sport of Ohanes, or that sampling errors were made (either in previous studies or in the present work). These results underscore the need for experts to undertake sampling.

The techniques used in the present work have certain advantages. For example, the construction of mean leaves allows the variability in morphology between leaves of the same accession to be examined. Experience tells us that when sampling is properly performed, the leaves of plants from the same cultivar are similar (with the exception of the Spanish cultivar Godello), and that when mean leaves are being constructed, the coefficients of variation for the variables measured are usually low. The technique also allows for statistical comparisons to be made. In the present study, PCA was used, which permits the simultaneous comparison of many variables. The three-dimensional display of the results obtained (i.e. for the first three axes) shows the distribution of the different accessions in terms of leaf lateral sinus, the angle formed between the main veins and the shape of the leaf (more orbicular or more cuneiform). Figure 4 shows the accessions with similar leaves in these respects to be distributed close to one another, while others with different characteristics in one or more respects to lie more distant from the corresponding axes. The construction of mean leaves also allows comparisons to be made between leaves in terms of single variables.

In grapevine molecular analyses, SNP markers are not widely used while SSRs are commonly employed. In the present work, the genotyping results of SSR analyses and SNP analyses were compared (Supporting Information Table S1). The main difficulty in SSR data comparison is the different allele binning used by different authors, which in many cases precludes large-scale comparisons. Reaching definite conclusions about the identity of some alleles is therefore impossible. This is not the case when comparing SNP data because of the bi-allelic nature of SNPs. This makes comparisons much easier.

Conclusion

In the present work, the mean leaves of the main Moroccan and Algerian grapevine cultivars were constructed. SNP analysis and comparison of published microsatellite and ampelographic data highlighted the existence of new synonyms and homonyms. The existence of some errors of identification, misinterpretations and collection or sampling errors is suggested. Together, the present results contribute towards a better understanding of grapevine diversity in the Maghreb.

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Supporting information

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Table S1. Comprehensive summary of all the microsatellite and ampelographic data published for North African grape cultivars, compared with the ampelographic and SNP results obtained in the present work.