Vitis **54** (Special Issue), 81–86 (2015)

Pedigree analysis of the Spanish grapevine cultivar 'Hebén'

L. H. Zinelabidine[1)], J. Cunha[2), 3)], J. E. Eiras-Dias[2)], F. Cabello[4)], J. M. Martínez-Zapater[1)] and J. Ibáñez[1)]

[1)] Instituto de Ciencias de la Vid y del Vino (CSIC, Universidad de La Rioja, Gobierno de La Rioja), Spain
[2)] Instituto Nacional de Investigação Agrária e Veterinária (INIAV), Portugal
[3)] Universidade Nova de Lisboa, Instituto de Tecnologia Química e Biológica (UNL, ITQB), Portugal
[4)] Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), Spain

Summary

The use of Single Nucleotide Polymorphism (SNP) markers allows genetic identification and parentage analysis of grapevine cultivars. Ancient cultivars like 'Hebén' were widely cultivated in the Iberian Peninsula along its history and likely contributed to the origin of varieties which are still cultivated today. The goal of our study was to search for possible first-degree relationships between the female variety 'Hebén' and other Iberian and Mediterranean cultivars. For this purpose, we used a set of 261 SNP markers which allowed identifying 23 trios and 37 parent-offspring relationships supported by high overall likelihood ratios (LOD scores). The results shed light on the relationships among several cultivars from Spain and Portugal, and demonstrated that 'Hebén' is a major founder of current varieties in the Iberian Peninsula viticulture, and contributed to spread the chlorotype A in this region.

K e y w o r d s : genetic relationships, historical genetics, single nucleotide polymorphism, *Vitis vinifera*.

Introduction

The Iberian Peninsula has large grapevine diversity: National grapevine catalogues include 222 different varieties in Spain and 511 in Portugal (Lacombe *et al*. 2011). Nevertheless, in terms of cultivated surface only a few cultivars are important. In Spain, the country with the largest vineyard surface, only two varieties ('Airén' and 'Tempranillo') account for almost half of the total area (about 470,000 ha, Cabello *et al*. 2011). The trend to cultivate only certain varieties has contributed to the disappearance of many local cultivars, but recently this trend is starting to change, and some wineries, grape growers and consumers are looking for 'new', local products. In this sense, the knowledge of the genetic origin of local varieties, mainly conserved in germplasm banks, may provide an added value to these products. From a historical point of view this knowledge also contributes to understand the origin and development of the viticulture in a given region. In addition, from a scientific point of view, this information may provide a sound basis for the study of the inheritance of certain traits, as well as for selecting or discarding varieties in breeding programs or in association mapping panels.

In this work the old female variety 'Hebén' was selected after several reports indicating its possible important role in the Iberian Peninsula genetic network (Lacombe *et al*. 2013). 'Hebén' is a winegrape cultivar, already described in the 16th century (Herrera 1513) as a white variety of grapevine producing large and sparse bunches of grapes with big seeds. It was grown in the Andalusian region (Southern Spain) (García de los Salmones 1914), but currently it is hardly cultivated in the provinces of Cordoba, Granada, Badajoz, Guadalajara, Toledo and Cadiz (Spain) (Cabello *et al*. 2011). In Portugal it is known as 'Mourisco Branco', and it was first cited in the 18th century (Alarte 1711). Another synonym is 'Gibi', which was considered as an Arabic table grape original from Northern Africa that was once grown in southern France and throughout the Iberian Peninsula (Galet 2000). It could have been introduced in Europe sometime during the Al-Andalus period, between the 8th and 15th centuries. In Spain, 'Hebén' is known as 'Ben', 'Even', 'Edenes', 'Heven', 'Heven Jaen', 'Jeven', 'Laco Blanco', 'Panseras', 'Pansero' or 'Torrontes' (Cabello *et al*. 2011).

Nowadays, molecular markers allow identifying the putative parents of grapevine varieties. The discovery of the pedigree of 'Cabernet Sauvignon' in 1997 (Bowers and Meredith 1997), based on microsatellite data, opened the way to similar analyses in different regions, including the Iberian Peninsula (Lopes *et al*. 2006, Ibañez *et al*. 2009). More recently, SNP markers have been shown to be very efficient for parentage analysis (Zinelabidine *et al*. 2012, Ibañez *et al*. 2012).

Recently, Lacombe *et al*. (2013) published a large list of possible first-degree relationships among grapevine varieties based on the genotype of 20 microsatellite loci. Among all the listed pedigrees, 28 involved 'Hebén' as one of the parents, with LOD values (likelihood ratios) ranging from 19 to 41. Furthermore, 'Hebén' display putative parent-offspring relationships with 45 additional genotypes. In the present work, we have used SNP markers to detect and confirm first degree relationships between 'Hebén' and different cultivars especially from Spain and Portugal.

Material and Methods

P l a n t m a t e r i a l : All Spanish and Portuguese accessions genetically related to the ancient *Vitis vinifera* variety 'Hebén' were collected from the Instituto de Cien-

Correspondence to: Dr. J. Ibáñez, Instituto de Ciencias de la Vid y del Vino (CSIC, Universidad de La Rioja, Gobierno de La Rioja), C/ Madre de Dios 51, 26004 Logroño, Spain. E-mail: javier.ibanez@icvv.es

cias de la Vid y del Vino (ICVV) grapevine collection, at Finca La Grajera (Logroño, Spain), the *Vitis* Germplasm Bank at El Encín (IMIDRA, Madrid, Spain) and from the Colecção Ampelográfica Nacional (CAN) of Instituto Nacional de Investigação Agrária (INIA, Portugal) (Tab. 1). Prime names are proposed mostly according to the *Vitis* International Variety Catalogue (*V*IVC, www.vivc.de).

DNA analysis: DNA was isolated from young frozen leaves using the DNeasy® Plant Mini Kit (Qiagen, Valencia, CA). SNP genotyping services were provided by the Spanish "Centro Nacional de Genotipado" (CEGEN) (www.cegen.org) using previously identified SNPs (Cabezas *et al*. 2011) and SNPlex or Veracode genotyping platforms, according to Zinelabidine *et al*. (2012).

Parentage analysis: A search for compatible trios (parents and offspring) and duos (parent-offspring) combinations among the SNPs profiles of grapevines was carried out, using Cervus 3.0 software (Kalinowski *et al*. 2007). The analysis was performed with the ICVV database, which includes 1,117 genotypes, mostly corresponding to Iberian cultivars and *sylvestris* plants, but also there are many European and Maghrebian grapevine varieties. In case of doubt, historical data, the number of mismatches and the LOD scores were used for parentage assignment.

Results and Discussion

The parentage analysis was based on a large set of grapevine genotypes, mostly from Spain and Portugal. Initially, a set of 336 SNPs was used, but after removing failed and non polymorphic SNPs, data for 261 SNPs were obtained. The genotype set included trios previously described using SSRs (Bowers *et al*. 1999, Cabezas *et al*. 2003, Ibáñez *et al*. 2009), which were used as control in the parentage analysis (Zinelabidine *et al*. 2012). Based on such control data, up to 3 mismatches were allowed for considering a trio, and up to 1 mismatch for a duo.

A number of potential parent-progeny combinations were identified, and those which could be directly related with 'Hebén' were selected: the possible trios (parents and offspring) where one of the varieties involved was 'Hebén' and all the cultivars that share at least one allele per locus with 'Hebén' and, therefore, maintain a putative parent-offspring relationship (duos). 'Hebén' parents could not be found, as no compatible trio with 'Hebén' as offspring was detected. Thus it is possible that one of the compatible duos includes one of 'Hebén' parents. All the other duos must correspond to other 'Hebén' progenies.

A total of 23 trios, and 37 duos were found involving 'Hebén' (Tabs 2 and 3). Some of the trios had been previously described by other authors (Tab. 2), but most of them are reported for the first time, and all were supported by high LOD scores. Given that 'Hebén' carries female flowers, it must be the female parent in all the crosses, and all its descendants (59 or 60 only in this work) will carry the 'Hebén' chlorotype A (García-Muñoz *et al*. 2011), largely contributing to its spread in the Iberian Peninsula.

'Hebén' is the mother of many Portuguese cultivars. The white cultivar 'Hebén' proved to be a key genotype for many Portuguese grape varieties since it appears in several trios and duos. In five of these trios 'Alfrocheiro' is the male parent, and gave place to four varieties presently cultivated in Portugal: 'Trincadeira das Pratas', 'Tinta Grossa', 'Castelão Branco' and 'Malvasia Fina', with LOD scores ranged between 70.86 and 79.89 (Tab. 2) (Cunha *et al*. this issue). 'Alfrocheiro' and 'Hebén' are also the parents of the cultivar 'Allarén', a minor Spanish variety. Other crosses with 'Hebén' gave place to other Portuguese cultivars: 'Rabigato Moreno' and 'Côdega do Larinho' are descents of 'Rabigato' and are planted in Douro region. 'Moscatel Nunes', a cultivar from the Peninsula de Setúbal, arose from a cross between 'Hebén' and `Muscat of Alexandria'. It could be the same cultivar as 'Nuno Gomes', for which Lacombe *et al*. (2013) reported the same pedigree, since both have name similarities, have Muscat flavor and match for the four common microsatellite markers used by Lacombe *et al*. (2013) and Veloso *et al.* (2010). Other 'Hebén' Portuguese descendants 'Boal Espinho', 'Malvasia', 'Trincadeira Branca', 'Roupeiro Branco','Padeiro de Basto', 'Larião', and 'Malvasia Babosa' came from different geographical origins (Cunha *et al*. 2013), suggesting that the cultivar was widespread in historical times.

Additionally, 'Hebén' exhibited a close relationship with other four Portuguese varieties sharing at least one allele at each of the 261 SNP loci used: 'Almafra', 'Gouveio Real', 'Lourela' and 'Perrum' (Tab. 3).

'Hebén' is the parent of several Spanish cultivars. In the Spanish side many duos and only some trios were detected, the opposite of what happened in the Portuguese case, probably because some of the parent varieties are not available anymore. The genetic origin of eight cultivars could be determined with high LOD scores, ranging between 76.4 and 95.3. Among the trios, and apart from 'Allarén' cited above, only in two cases the second parent was also a Spanish or Iberian variety: 'Mandón' is an offspring of 'Graciano' (and 'Hebén'), and 'Verdejo de Salamanca' is an offspring of 'Listán Prieto'. In the other cases the male parent is a foreign variety, like 'Muscat of Alexandria', which is the parent of 'Moscatel de Angüés'. A cross between 'Hebén' and 'Manseng Noir' ('Ferrón' in Spain) led to the variety 'Señá'. 'Ferrón' was first mentioned in 1914 in the region of Orense as 'Ferrol' (García de los Salmones 1914) and is cultivated in Galicia, Spain. SNP results also confirmed that the cultivars 'Xarello' and 'Viura' arise from crosses between 'Hebén' and 'Brustiano Faux' (Lacombe *et al*. 2013). In contrast, for variety 'Gorgollasa', reported as the offspring of 'Hebén' and 'Monastrell' based on 20 microsatellites (one mismatch) (García-Muñoz *et al*. 2011 and Lacombe *et al*. 2013), the SNP data confirmed 'Hebén' as a compatible parent (Tab. 3), but not 'Monastrell', which was excluded as a parent of this variety. Finally, two additional trios involved 'Hebén': together with the Moroccan cultivar 'Bou Qseb' to give place to the Spanish variety 'Montua' (in Portugal 'Diagalves') and with the Spanish variety 'Monastrell', to give place to the Moroccan variety 'Cot de Cheragas' (Tab. 2). These results, and the genetic origin of the Portuguese 'Larião', are in agreement with the existence of grapevine material exchange between the Iberian Peninsula and the Maghreb region previously pro-

Table 1

Grapevine accessions included in this study

Variety Name[a]	Accession Name	Institution[b]	Nº Accesion	Country of origin	Color[c]	Nº Variety *V*IVC
Ahmeur Bou Ahmeur	Flame Tokay	ESP217	5067	Algeria	P	140
Airen	Airén	ESP217	5000	Spain	W	157
Alarije	Malvasía	ESP217	5101	Spain	W	213
Albillo Real de Granada	Borba	ESP080	BGVCAM0948	Spain	W	248
Alfrocheiro	Albarín Negro	ESP217	5001	Portugal	B	277
Allarén	Allarén	ESP080	BGVCAM0934	Spain	W	325
Almafra	Almafra	PRT051	52313	Portugal	W	5191
Amaral	Amaral	PRT051	52908	Portugal	B	818
Beba	Beba de Jaén	ESP217	5332	Spain	W	22710
Boal Espinho	Boal Espinho	PRT051	52017	Portugal	W	14154
Bou Qsob	Bouqseb	Sodea Meknes	-	Morocco	W	1593
Brustiano Faux	Unknown	ESP217	6063		W	41642
Castelao Branco	Castelão Branco	PRT051	52615	Portugal	W	2321
Castillo de Arcos	Castillo de Arcos	ESP080	BGVCAM2247	Spain	W	2328
Cayetana Blanca	Blanca Cayetana	ESP217	5026	Spain	W	5648
Cot de Cheragas	Cheragua	Sodea Meknes	-	Morocco	B	5169
Côdega do Larinho	Côdega de Larinho	PRT051	51317	Portugal	W	2743
Corazón de Cabrito	Corazon de Cabrito	ESP080	BGVCAM2227	Spain	W	232
Derechero de Muniesa	Miguel de Arco	ESP217	5113	Spain	B	3525
Eperó de Gall	Eperó de Gall	ESP080	BGVCAM0893	Spain	B	3919
Ferral	Ferral	ESP217	5359	Spain	B	4105
Folgasao	Folgasão	ESP217	5069	Portugal	W	4178
Forcallat Tinta	Forcallat Negra	ESP217	5072	Spain	B	4192
Fumat	Fumat	ESP080	BGVCAM1880	France	R	4289
Gorgollasa	Gorgollasa	ESP080	BGVCAM1135	Spain	B	4904
Gouveio Real	Gouveio Real	PRT051	50616	Portugal	W	4927
Graciano	Graciano	ESP217	5086	Spain	B	4935
Hebén	Hebén	ESP080	BGVCAM0848	Spain	W	5335
Jeronimo	Jerónimo de Tudela	ESP217	5370	Spain	P	5692
Lariao	Larião	PRT051	51113	Portugal	W	6757
Listan Prieto	Listán Prieto	ESP080	BGVCAM1590	Spain	B	6860
Lourela	Lourela	PRT051	50708	Portugal	B	6914
Malvar	Malvar	ESP080	BGVCAM1141	Spain	W	7254
Malvasia	Malvasia	PRT051	52714	Portugal	W	22968
Malvasia Babosa	Malvasia Babosa	PRT051	40603	Portugal	W	14139
Malvasía Común	Malvasía Común	ESP080	BGVCAM0831	Spain	W	213
Malvasia Di Sardegna	Malvasía de Sitges	ESP217	5102	Spain	W	7266
Malvasia Fina	Gual	ESP217	5088	Portugal	W	715
Mandon	Mandón	ESP080	BGVCAM1921	Spain	B	7326
Manseng Noir	Ferrón	ESP217	5066	France	B	7340
Merseguera	Messeguera	ESP217	5112	Spain	W	7660
Miguel de Arco	Miguel de Arco	ESP080	BGVCAM2685	Spain	B	7710
Molinera	Castellano Morado	ESP217	5341	Spain	R	7900
Moll	Pensal Blanco	ESP080	BGVCAM2682	Spain	W	9113
Mollar Cano	Mollar Cano	ESP217	5115	Spain	B	7901
Monastrell	Monastrell	ESP217	5116	Spain	B	7915
Montua	Eva	ESP217	5064	Spain	W	2520
Moscatel de Angüés	Moscatel de Angüés	ESP080	BGVCAM2090	Spain	W	40885
Moscatel Nunes	Moscatel Branco	PRT051	53015	Portugal	W	15680
Muscat Of Alexandria	Moscatel de Alejandría	ESP217	5381	Greece	W	8241
Naparo	Naparo	ESP217	5131	Spain	B	8345
Padeiro de Basto	Padeiro de Basto	PRT051	50806	Portugal	B	17360
Pedro Ximenes	Pedro Ximénez	ESP217	5143	Spain	W	9080
Perrum	Perrum	ESP217	5146	Portugal	W	
Planta Fina	Planta Fina de Pedralba	ESP217	5155	Spain	W	9542
Quigat	Quigat	ESP080	BGVCAM0900	Spain	W	9854

Tab. 1, continued

Variety Name[a]	Accession Name	Institution[b]	Nº Accesion	Country of origin	Color[c]	Nº Variety *V*IVC
Rabigato	Rabigato	PRT051	52014	Portugal	W	9857
Rabigato Moreno	Rabigato Moreno	PRT051	50917	Portugal	W	9859
Roupeiro Branco	Roupeiro	PRT051	51314	Portugal	W	17716
Seña	Señá	ESP080	BGVCAM1688	Spain	B	11483
Sabro	Sabro	ESP080	BGVCAM2234	Portugal	W	
Sumoll	Sumoll	ESP217	5180	Spain	B	12072
Tarragoní	Tarragoní	ESP080	BGVCAM1288	Spain	B	12266
Tinta Grossa	Tinta Grossa	PRT051	52906	Portugal	B	40711
Torralba	Torralba	ESP080	BGVCAM1085	Spain	B	12580
Trepat	Trepat	ESP217	5199	Spain	B	12633
Trincadeira Branca	Trincadeira Branca	PRT051	51012	Portugal	W	14130
Trincadeira Das Pratas	Trincadeira Das Pratas	PRT051	52216	Portugal	W	15688
Trousseau Noir	María Ordoña	ESP217	5105	France	B	12668
Turruntés	Torrontés	ESP217	5194	Spain	W	12581
Verdejo de Salamanca	Verdejo	ESP217	5208	Spain	W	40923
Verdil	Verdiel	ESP217	5211	Spain	W	12965
Vijiriega Comun	Vijiriega Común	ESP217	5213	Spain	W	13075
Vinhao	Sousón	ESP217	5177	Portugal	B	13100
Viura	Viura	ESP217	5216	Spain	W	13127
Xarello	Xarello	ESP217	5218	Spain	W	13270

[a] In bold, confirmed names for the corresponding genotypes at the ICVV database.
[b] Institution: ESP080: IMIDRA; ESP217: ICVV; PRT051: INIA.
[c] Color: B: Black; P: Pink; R: Red; W: White.

Table 2

Summary of the trios (parents and offspring) found where 'Hebén' is involved

Offspring	Country of origin	Parent 1	Parent 2	SNP compared	SNP mismatches	Trio LOD score	Literature[a]
Cot de Cheragas	Morocco	Hebén	Monastrell	241	0	87.46	3
Boal Espinho	Portugal	Hebén	Malvasia Fina	212	2	83.86	
Castelao Branco	Portugal	Hebén	Alfrocheiro	220	0	71.52	
Côdega do Larinho	Portugal	Hebén	Rabigato	214	1	70.55	
Lariao	Portugal	Hebén	Ahmeur Bou Ahmeur	192	2	70.18	
Malvasia	Portugal	Hebén	Amaral	221	0	74.45	2,3
Malvasia Babosa	Portugal	Hebén	Malvasia Di Sardegna	250	0	70.46	
Malvasia Fina	Portugal	Hebén	Alfrocheiro	252	3	70.86	3
Moscatel Nunes	Portugal	Hebén	Muscat of Alexandria	215	1	73.37	3
Padeiro de Basto	Portugal	Hebén	Vinhao	216	1	66.34	3
Rabigato Moreno	Portugal	Hebén	Rabigato	213	0	82.06	
Roupeiro Branco	Portugal	Hebén	Folgasao	215	2	53.24	
Tinta Grossa	Portugal	Hebén	Alfrocheiro	222	0	74.68	3
Trincadeira Branca	Portugal	Hebén	Trousseau Noir	209	0	64.57	
Trincadeira Das Pratas	Portugal	Hebén	Alfrocheiro	245	0	79.89	
Allarén	Spain	Hebén	Alfrocheiro	241	0	78.63	
Mandon	Spain	Hebén	Graciano	240	2	76.44	1,3
Montua	Spain	Hebén	Bou Qsob	253	1	94.41	3
Moscatel De Angüés	Spain	Hebén	Muscat of Alexandria	240	0	80.77	
Seña	Spain	Hebén	Manseng Noir	238	0	79.93	
Verdejo de Salamanca	Spain	Hebén	Listan Prieto	238	0	95.3	
Viura	Spain	Hebén	Brustiano Faux	241	1	78.76	1,3
Xarello	Spain	Hebén	Brustiano Faux	239	1	80.29	3

[a] 1 = García-Muñoz *et al.* 2011; 2 = Lacombe *et al.* 2007; 3 = Lacombe *et al.* 2013.

Table 3

Summary of duos (parent-offspring) found where 'Hebén' is involved

Cultivar 1	Country of origin	Cultivar 2	SNP compared	SNP mismatches	Pair LOD score	Literature[a]
Fumat	France	Hebén	237	1	28.32	
Almafra	Portugal	Hebén	215	1	15.26	
Gouveio Real	Portugal	Hebén	215	0	21.94	
Lourela	Portugal	Hebén	214	0	17.69	
Perrum	Portugal	Hebén	211	1	26.12	3
Airen	Spain	Hebén	241	1	34.13	3
Alarije	Spain	Hebén	235	0	30.88	2[b],3[b]
Albillo Real de Granada	Spain	Hebén	202	0	28.75	
Beba	Spain	Hebén	246	0	41.74	3
Castillo De Arcos	Spain	Hebén	241	1	27.84	
Cayetana Blanca	Spain	Hebén	245	0	24.49	3
Corazón De Cabrito	Spain	Hebén	240	1	30.22	
Derechero De Muniesa	Spain	Hebén	239	1	23.42	
Eperó de Gall	Spain	Hebén	237	1	20.32	3
Ferral	Spain	Hebén	233	1	33.44	
Forcallat Tinta	Spain	Hebén	201	0	30.95	3
Gorgollasa	Spain	Hebén	240	0	25.37	1[b],3[b]
Jeronimo	Spain	Hebén	225	0	32.93	3
Malvar	Spain	Hebén	234	0	37.33	3[b]
Malvasía Común	Spain	Hebén	239	1	20.55	
Merseguera	Spain	Hebén	244	1	30.62	3[b]
Miguel De Arco	Spain	Hebén	235	1	24.94	3
Molinera	Spain	Hebén	230	0	32.89	3
Moll	Spain	Hebén	239	0	29.24	3
Mollar Cano	Spain	Hebén	250	1	20.86	3
Naparo	Spain	Hebén	221	0	28.57	
Pedro Ximenes	Spain	Hebén	249	0	31.87	3,4
Planta Fina	Spain	Hebén	214	0	35.44	3
Quigat	Spain	Hebén	244	0	30.73	3
Sabro	Spain	Hebén	237	1	20.37	3
Sumoll	Spain	Hebén	237	0	37.26	3
Tarragoní	Spain	Hebén	243	0	33.57	3
Torralba	Spain	Hebén	223	1	27.19	
Trepat	Spain	Hebén	238	0	31.81	3
Turruntés	Spain	Hebén	221	1	26.44	
Verdil	Spain	Hebén	229	0	24.96	
Vijiriega Comun	Spain	Hebén	244	0	26.63	3

[a] 1 = García-Muñoz *et al.* 2011; 2 = Lacombe *et al.* 2007; 3 = Lacombe *et al.* 2013; 4 = Vargas *et al.* 2007.
[b] Full pedigree reported.

posed in several works (Zinelabidine *et al*. 2010, Ghaffari *et al*. 2013). A large number of Iberian varieties descent of 'Hebén' has been found in this work (Tabs 2 and 3) what, added to the additional trios and duos reported by Lacombe *et al*. (2013), reveals its large impact in the Iberian viticulture in terms of its contribution to the varietal patrimony. In the present work, out of a total of 332 Iberian varieties analyzed (data not shown), 'Hebén' showed first order genetic relationships with 60 of them. In addition, some of the Spanish varieties directly related to 'Hebén' are currently very relevant in terms of cultivated surface. 'Airén', 'Cayetana Blanca', 'Viura', 'Xarello' and 'Pedro Ximenes' accounted in 2009 for more than 350,000 ha representing one third of the Spanish vineyard surface (Cabello *et al*. 2011). In the case of the Portuguese varieties related to 'Hebén', they are less relevant (less than 1,000 ha), except in the case of 'Malvasia Fina', which is cultivated in 5,500 ha (Böhm 2011).

Conclusion

The set of 261 SNP markers is a powerful tool for parentage analysis in grapevine. This study sheds light on the genetic relationships among cultivars from the Iberian Peninsula and demonstrates the close parentage relationships among Spanish and Portuguese varieties. The results allowed to uncover 13 new pedigrees and to confirm 10 previously proposed with higher LOD values. Besides, 23 proposed parent-offspring relationships between 'Hebén' and

other varieties were confirmed and 14 additional relationships were uncovered. Altogether these results demonstrate the very predominant role of the female cultivar 'Hebén' in the Iberian genetic network, which has contributed to the spread of the chlorotype A, the most frequent chlorotype in Western Europe.

Acknowledgements

L. H. Zinelabidine was supported by a fellowship from the Agencia Española de Cooperación Internacional. J. Cunha was supported by a Post-doctoral fellowship "Fundação para a Ciência e Tecnologia" (SFRH/BPD/ 74895/2010). LHZ and JC were supported by COST action FA1003 "East-West Collaboration for Grapevine Diversity Exploration and Mobilization of Adaptive Traits for Breeding", from European Cooperation in the Field of Scientific and Technical Research, through the funding of short scientific missions at the ICVV.

References

Alarte, V. (Silvestre Gomes de Moraes); 1711: Agricultura das Vinhas, e Tudo o que Pertence a ellas, até Perfeito Recolhimento do Vinho, e Relação das suas Virtudes, e da Cêpa, Vides, Folhas e Borras. Lisboa: Officina Real Deslandesiana.

Böhm, J.; 2011: Atlas das Castas da Península Ibérica. Historia, Terroir, Ampelografia. Lisbon, Dinalivro.

Bowers, J.; Boursiquot, J. M.; This, P.; Chu, K.; Johansson, H.; Meredith, C.; 1999: Historical genetics: the parentage of 'Chardonnay', 'Gamay', and other wine grapes of Northeastern France. Science **285**, 1562-1565.

Bowers, J. E.; Meredith, C. P.; 1997: The parentage of a classic wine grape, 'Cabernet Sauvignon'. Nat. Genet. **16**, 84-87.

Cabello, F.; Ortiz, J.; Muñoz-Organero, G.; Rodríguez-Torres, I.; Benito, A.; Rubio, C.; García-Muñoz, S.; Sáiz, R.; 2011: Variedades de Vid en España, Madrid, Comunidad de Madrid and Editorial Agrícola.

Cabezas, J. A.; Cervera, M. T.; Arroyo-Garcia, R.; Ibáñez, J.; Rodríguez-Torres, I.; Borrego, J.; Cabello, F.; Martínez-Zapater, J. M.; 2003: 'Garnacha' and 'Garnacha Tintorera': Genetic Relationships and the Origin of Teinturier Varieties Cultivated in Spain. Am. J. Enol. Vitic. **54**, 237-245.

Cabezas, J. A.; Ibañez, J.; Lijavetzky, D.; Vélez, D.; Bravo, G.; Rodríguez, V.; Carreño, I.; Jermakow, A. M.; Carreño, J.; Ruiz-Garcia, L.; Thomas, M. R.; Martínez-Zapater, J. M.; 2011: A 48 SNP set for grapevine cultivar identification. BMC Plant Biol. **11**, 153.

Cunha, J.; Teixeira-Santos, M.; Brazão, J.; Fevereiro, P.; Eiras-Dias, J. E.; 2013: Portuguese *Vitis vinifera* L. germplasm: accessing its diversity and strategies for conservation. In: D. Poljuha, B. Sladonja (Eds): The mediterranean genetic code - grapevine and olive. Intech **6**, 125-144.

Galet, P.; 2000: Dictionnaire Encyclopédique des Cépages. Hachette, Paris.

García de los Salmones, N.; 1914: Memoria General de las Sesiones del Congreso y Ponencias Presentadas. Imprenta Provincial, Pamplona.

García-Muñoz, S.; Lacombe, T.; De Andrés, M. T.; Gaforio, L.; Muñoz-Organero, G.; Laucou, V.; This, P.; Cabello, F.; 2011: Grape varieties (*Vitis vinifera* L.) from the Balearic Islands: genetic characterization and relationship with Iberian Peninsula and Mediterranean Basin. Genet. Resour. Crop. Evol. **59**, 589-605.

Ghaffari, S.; Hasnaoui, N.; Zinelabidine, L. H.; Ferchichi, A.; Martínez-Zapater, J. M.; Ibáñez, J.; 2013: Genetic identification and origin of grapevine cultivars (*Vitis vinifera* L.) in Tunisia. Am. J. Enol. Vitic. **64**, 538-544.

Herrera, A. 1513: Agricultura General. Edición Facsimil (1981). Servicio de Publicaciones del Ministerio 268 de Agricultura y Pesca, Madrid.

Ibañez, J.; Vargas, A. M.; Palancar, M.; Borrego, J.; de Andres, M. T.; 2009: Genetic relationships among table-grape varieties. Am. J. Enol. Vitic. **60**, 35-42.

Ibañez, J.; Muñoz-Organero, G.; Zinelabidine, L. H.; de Andrés, M. T.; Cabello, F.; Martínez-Zapater, J. M.; 2012: Genetic origin of the grapevine cultivar 'Tempranillo'. Am. J. Enol. Vitic. **63**, 549-553.

Kalinowski, S. T.; Taper, M. L.; Marshall, T. C.; 2007: Revising how the computer program *Cervus accommodates* genotyping error increases success in paternity assignment. Mol. Ecol. **16**, 1099-1106.

Lacombe, T.; Boursiquot, J. M.; Laucou, V.; Dechesne, F.; Vares, D.; This, P.; 2007: Relationships and genetic diversity within the accessions related to 'Malvasia' held in the Domaine de Vassal grape germplasm repository. Am. J. Enol. Vitic. **58**, 124-131.

Lacombe, T.; Audeguin, L.; Boselli, M.; Bucchetti, B.; Cabello, F.; Chatelet, P.; Crespan, M.; D'Onofrio, C.; Eiras-Dias, J.; Ercisli, S.; Gardiman, M.; Grando, M. S.; Imazio, S.; Jandurova, O.; Jung, A.; Kiss, E.; Kozma, P.; Maul, E.; Maghradze, D.; Martinez, M. C.; Muñoz, G.; Patkova, J. K.; Pejić, I.; Peterlunger, E.; Pitsoli, D.; Preiner, D.; Raimondi, S.; Regner, F.; Savin, G.; Savvides, S.; Schneider, A.; Spring, J. L.; Szoke, A.; Veres, A.; Boursiquot, J. M.; Bacilieri, R.; This, P.; 2011: Grapevine European Catalogue: Towards a Comprenhensive List. Vitis **50**, 65-68.

Lacombe, T.; Boursiquot, J. M.; Laucou, V.; Vecchi-Staraz, M.; Péros, J. P.; This, P.; 2013: Large-scale parentage analysis in an extended set of grapevine cultivars (*Vitis vinifera* L.). Theor. Appl. Genet. **126**, 401-414.

Lopes, M. S.; Dos Santos, M. R.; Dias, J. E.; Mendonca, D.; Machado, A. D.; 2006: Discrimination of Portuguese grapevines based on microsatellite markers. J. Biotechnol. **127**, 34-44.

Sefc, K. M.; Steinkellner, H.; Glössl, J.; Kampfer, S.; Regner, F.; 1998: Reconstruction of a grapevine pedigree by microsatellite analysis. Theor. Appl. Genet. **97**, 227-231.

Vargas, A. M.; Velez, M. D.; de Andres, M .T.; Laucou, V.; Lacombe, T.; Boursiquot, J. M.; Borrego, J.; Ibáñez, J.; 2007: 'Corinto Bianco': a seedless mutant of 'Pedro Ximenes'. Am. J. Enol. Vitic. **58**, 540−543.

Veloso, M. M.; Almandanim, M. C.; Baleiras-Couto, M.; Pereira, H. S.; Carneiro, L. C.; Fevereiro, P.; Eiras-Dias, J.; 2010: Microsatellite database of grapevine (*Vitis vinifera* L.) cultivars used for wine production in Portugal. Ciência Téc. Vitiv. **25**, 53-61.

Zinelabidine, L. H; Haddioui, A.; Bravo, G.; Arroyo-García, R.; Martínez-Zapater, J. M.; 2010: Genetic origins of cultivated and wildgrapevines from Morocco. Am. J. Enol. Vitic. **61**, 83-90.

Zinelabidine, L. H.; Haddioui, A.; Rodriguez, V.; Cabello, F.; Eiras-Dias, J. E.; Martínez- Zapater, J. M.; Ibañez, J.; 2012: Identification by SNP Analysis of a Major Role for 'Cayetana Blanca' in the Genetic Network of Iberian Peninsula Grapevine Varieties. Am. J. Enol. Vitic. **63**, 121-126.