ANALYSIS OF GRAPE ROOTSTOCKS BY SSR MARKERS

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Abstract

Aims: The aim of this work was to determine the SSR profile of 96 *Vitis* accessions (mainly rootstocks) at 19 loci to find genetic relatedness between them.

Methods and results: The molecular markers used in the last 30 years are not or less affected by the environment, making them a valuable tool for the determination of genetic distances. Based on our former experiences, an SSR analysis was carried out on 96 grape accretions, mainly rootstocks. DNA was extracted from young leaves and analyses were carried out at 19 microsatellite loci. The loci were selected to cover all of the linkage groups to get a more accurate genotyping of each grape rootstock. Results of the SSR analysis and the resulting dendrogram showing genetic relatedness are presented.

Conclusions: Based on the results, it can be established, that most of the selected loci showed appropriate polymorphism for the assessment of genetic relatedness. The rootstocks derived from Teleki's seedlings showed high similarity. A low genetic distance was also detected between the accessions originated from the cross between Börner and Georgikon 28. Finally, the *Vitis sylvestris* accessions showed close relatedness with the *Vitis vinifera* L. varieties.

Significance and impact of the study: Our results indicate a high level of polymorphism between grape rootstock accessions. Strong differences were detected between the so-called Teleki 5C (T5C) and Teleki-Kober 5BB (T5KBB) "clones", suggesting that they are not real clones but different genotypes with highly similar morphological features.

Key words: simple sequence repeats (SSR), microsatellite, grape, rootstock

Résumé

But: Le but de notre travail a été de déterminer des profils SSR de 96 lots *Vitis* (majoritairement des porte-greffes) dans 19 « loci » pour trouver des relations génétiques entre eux.

Méthodes et résultats: Étant donné que les marqueurs moléculaires utilisés il y a 30 ans étaient moins influencés par le milieu, ils représentent de bons outils pour déterminer les distances génétiques. En utilisant nos précédentes expériences, nous avons réalisé des recherches pour les 96 lots de la vigne qui étaient pour la plupart des porte-greffes.
L'ADN a été extrait des jeunes feuilles. Nous avons réalisé des analyses dans 19 microsatellites loci. Les loci ont été choisis pour couvrir chacun des groupes de liens, pour obtenir une image plus précise du génome des porte-greffes. Les résultats de l'analyse SSR et des relations génétiques sont présentés par dendrogramme.

Conclusion: Nous avons pu constater que les loci ont montré un polymorphisme convenable. Les porte-greffes des plants de semis de Teleki ont montré une grande similitude. De plus, nous avons trouvé quelques différences entre les lots du croisement de Börner et de Georgicon 28. Les lots de *Vitis sylvestris* ont montré une forte similitude avec ceux de *Vitis vinifera.*

Importance et impact de l'étude: Nos résultats montrent un polymorphisme certain entre les différents porte-greffes. Nous avons cependant pu constater une importante différence entre les clones de T5C et de TK5BB. En conséquence, ce ne sont pas des clones réels, mais ils ont des génotypes différents avec des propriétés morphologiques relativement similaires.

Key words: répétitions simples (SSR), microsatellite, vigne, porte-greffes

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INTRODUCTION

Rootstocks are used in most grape growing areas of the world to control grape phylloxera and to adapt to soil characteristics.

The rootstock variety, similarly to the scion variety, has become a « production tool » for grape growing, determining the phylloxera resistance, nutrient uptake, lifetime, soil requirements, drought-, salt- and lime tolerance of the grafts, and the primary growth and lifetime of the stocks. It also influences the quality and quantity of crop, and the economic viability of grape growing. Although the main features, such as phylloxera resistance and lime- or drought tolerance, differ among rootstocks, rootstock identification is very difficult because many of them are closely related and have similar morphological characters.

The clone selection and cross breeding of grape rootstocks dates back more than a hundred years. Nevertheless, none of the rootstocks has all of the features required to meet production demands. Zsigmond Teleki, a vintner in the 1880s, experienced this in his own vineyards, which led him to search for new rootstock types (Bakonyi, Kocsis, 2004). Because of the embargo on import of vine-stocks, he bought grape seeds from France, from a famous *Vitis berlandieri* breeder named Euryale Rességuier. His aim was to breed rootstocks with high lime tolerance (Németh, 1975). Up until now, the origin of the 40 000 Teleki's seedlings derived from the seeds brought from France has not been completely established. So, the species from which the world most widespread *Berlandieri* x *Riparia* rootstocks (Teleki 5C, Teleki Kober 5BB, and Teleki Fuhr SO4) originated is still unknown. Teleki sorted his seedlings into 10 groups (Table 1).

The correct identification of rootstocks is possible by isoenzymes (Boursiquot and Parra, 1992), if the time of sampling and the followed procedure is standardized; however, the discrimination of similar rootstocks by isoenzyme analysis can fail because of the limited polymorphism (Walker and Liu, 1995)

Microsatellite markers (also known as SSRs, VNTRs, STMSs or STRs) are highly polymorphic DNA sequences comprised of mononucleotides, dinucleotides, trinucleotides or tetranucleotides that are repeated in tandem arrays and distributed throughout the genome (Jeffreys *et al*., 1985). They can provide a suitable tool for grape rootstock identification, phylogenetic studies or marker-assisted selection (MAS). Here are a few examples of successful application of microsatellite markers to rootstock identification:

(1) A representative group of rootstock accessions and cultivars of the *Vitis* species commonly used in rootstock breeding (*V. vinifera*, *V. berlandieri*, *V. riparia*, and *V. rupestris*) and conserved in the largest European germplasm banks of *Vitis* have been analyzed using sequence-tagged microsatellite sites (STMS) and amplified fragment length polymorphism (AFLP) markers (de Andrés *et al*., 2007). The STMS analysis allowed assigning a microsatellite genotype to most of the rootstock cultivars, highlighting numerous misclassified accessions in the studied collections, and the AFLP analysis provided information on the genetic relationships within and between hybrid groups (de Andrés *et al*., 2007).

(2) The screening of a *Vitis riparia* genomic library for the presence of (GA)n SSRs has allowed the identification of 18 new markers applicable to the genotyping of a range of *Vitis* species (Sefc *et al*., 1999).

Table 1. The origin and classification of Teleki's varieties based on morphological characters (after Bakonyi and Kocsis, 2004).

Group n°	Type	Internode	Colour of tip	Flower type	Variety name
1 2 3	*Vinifera*	Not propagated due to low vigour			
4A	-	necked	bronze	hermaphrodite	Binova
				male	SO4
5A	*Riparia*	necked	bronze	female	5BB
				male	G.K.67
			green	female	G.K.62
				male	5C
6A	-	necked	green	female	G.K.1
7B	-	downy	bronze	male	125 A, 127
				female	125 AA
8B	*Belandieri*	downy	bronze	female	Cosmo 2, 10, G.K.10
				male	Durlach 50, 52, G.K.9
9B	-	downy	green	female	Barr 503, 513
10A	*Rupestris*	necked	bronze	male	T.10A

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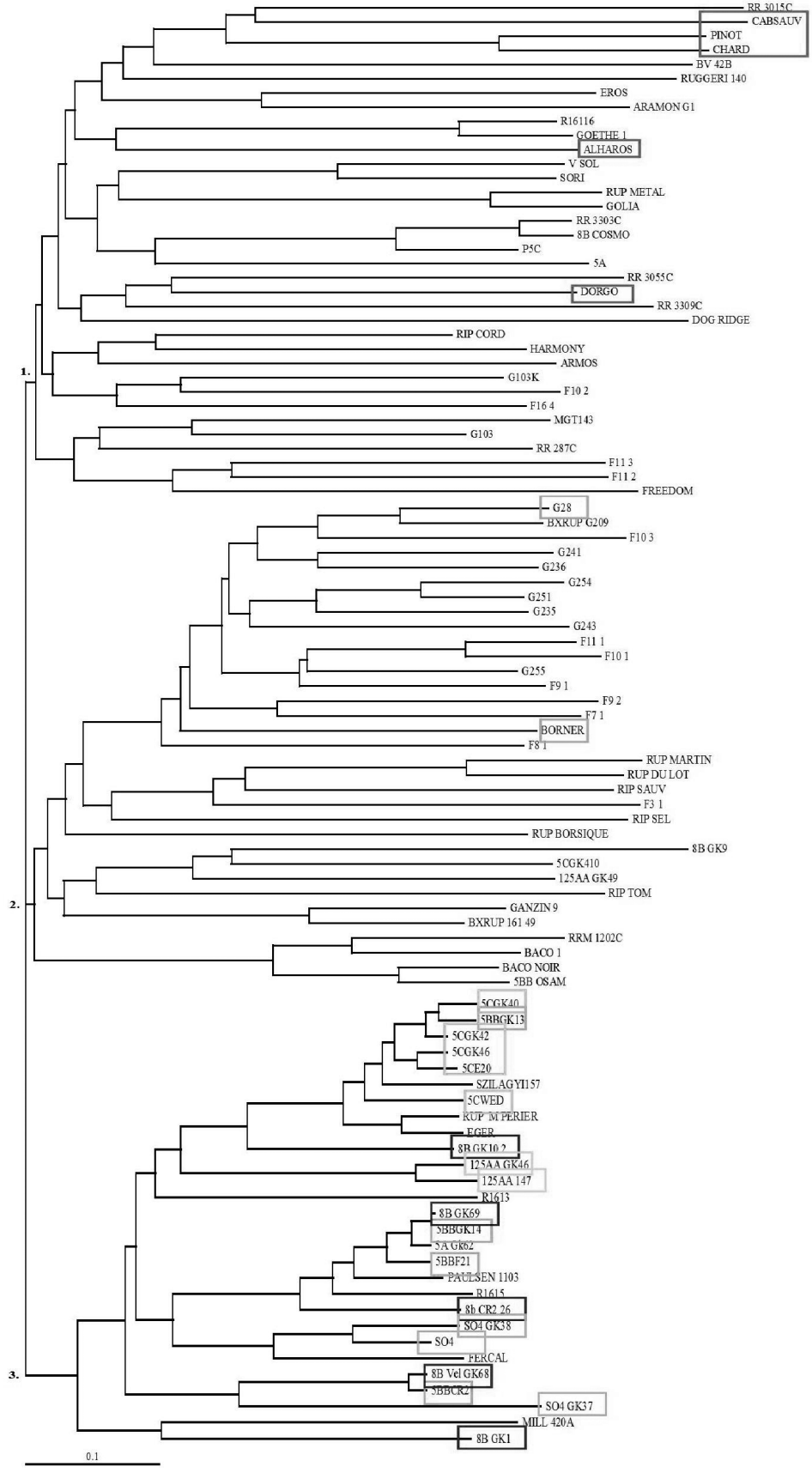


Figure 1. Dendrogram based on the microsatellite analysis results of 96 varieties at 19 loci.

Table 2. List of the analyzed *Vitis* accessions.

N°	Accession name	Cultivar code	Genetic origin	Accession origin
1	Teleki 5C GK40	5CGK40	*V. berlandieri x V. riparia*	clone of Gm 6, sel. By Georgikon Faculty
2	Teleki 5C GK42	5CGK42	*V. berlandieri x V. riparia*	clone of Gm 10, sel. By Georgikon Faculty
3	Teleki 5C E20	5CE20	*V. berlandieri x V. riparia*	Kecskemet, Hungary
4	Teleki 5C G46(64)	5CGK46	*V. berlandieri x V. riparia*	clone of Gm 6, sel. By Georgikon Faculty
5	Teleki 5C G41 (74)	5CGK410	*V. berlandieri x V. riparia*	clone of Gm 10, sel. By Georgikon Faculty
6	Teleki 5C WED (103)	5CWED	*V. berlandieri x V. riparia*	Wadenswill, Switzerland
7	Teleki-Kober 5BB GK14	5BBGK14	*V. berlandieri x V. riparia*	clone sel. by K. Bakonyi
8	Teleki-Kober 5BB GK13	5BBGK13	*V. berlandieri x V. riparia*	clone sel. by K. Bakonyi
9	Teleki 8B Velence GK68	8B_Vel_GK68	*V. berlandieri x V. riparia*	collected by D. Pálffy, Velence Hungary
10	Teleki 8B GK69	8B_GK69	*V. berlandieri x V. riparia*	collected by K. Bakonyi, Cserszegtomaj, Hungary
11	Teleki 5A GK62	5A_Gk62	*V. berlandieri x V. riparia*	collected by K. Bakonyi, Somló, Hungary
12	Teleki-Kober 5BB (F21)	5BBF21	*V. berlandieri x V. riparia*	Freiburg, Germany
13	Teleki-Kober 5BB CR2 (18)	5BBCR2	*V. berlandieri x V. riparia*	Romania
14	Ősamerika	5BB_OSAM	*V. berlandieri x V. riparia*	Kecskemet, Hungary
15	Teleki-Fuhr SO4 (133)	SO4	*V. berlandieri x V. riparia*	Cserszegtomaj, Hungary
16	Teleki-Kober 125AA GK46	125AA_GK46	*V. berlandieri x V. riparia*	clone, sel. by Georgikon Faculty
17	Teleki-Kober 125 AA GK49	125AA_GK49	*V. berlandieri x V. riparia*	clone, sel. by Georgikon Faculty
18	Teleki-Kober 125AA (147)	125AA_147	*V. berlandieri x V. riparia*	Cserszegtomaj, Hungary
19	Teleki 8B GK9	8B_GK9	*V. berlandieri x V. riparia*	clone, sel. by Georgikon Faculty
20	Teleki 8B GK10/2	8B_GK10_2	*V. berlandieri x V. riparia*	clone, sel. by Georgikon Faculty
21	Teleki 8B Cosmo 2	8B_COSMO	*V. berlandieri x V. riparia*	Kecskemet, Hungary
22	Teleki 8B GK1	8B_GK1	*V. berlandieri x V. riparia*	clone, sel. by Georgikon Faculty
23	MILLARDET ET GRASSET 420 A	MILL_420A	*V. berlandieri x V. riparia*	Kecskemet, Hungary
24	Erős	EROS	*V. berlandieri x V. riparia*	unknown
25	Teleki 5A	5A	*V. berlandieri x V. riparia*	collected by K. Bakonyi, Villany, Hungary
26	Eger	EGER	*V. berlandieri x V. riparia*	Eger, Hungary
27	Szilágyi 157	SZILAGYI157	*V. berlandieri x V. riparia*	Pecs, Hungary
28	2/49 Goethe 1	GOETHE_1	*V. vinifera x V. berlandieri*	unknown
29	4/1 Teleki P5C	P5C	*V. berlandieri x V. riparia*	Pecs, Hungary
30	Teleki 8B CR2-26	8b_CR2_26	*V. berlandieri x V. riparia*	Romania
31	Ganzin 9	GANZIN_9	*V. vinifera x V. rupestris*	collection of Georgikon Faculty
32	2/35 Riparia Tomentosa	RIP_TOM	*Vitis riparia*	collection of Georgikon Faculty
33	Riparia Selecta	RIP_SEL	*Vitis riparia*	collection of Georgikon Faculty
34	Riparia Sauvage	RIP_SAUV	*Vitis riparia*	collection of Georgikon Faculty
35	Riparia Cordifolia	RIP_CORD	*Vitis riparia*	collection of Georgikon Faculty
36	2/10 Rupestris du Lot	RUP_DU_LOT	*Vitis rupestris*	collection of Georgikon Faculty
37	Rupestris Metalica	RUP_METAL	*Vitis rupestris*	collection of Georgikon Faculty
38	2/40 Rupestris Martin	RUP_MARTIN	*Vitis rupestris*	collection of Georgikon Faculty
39	Rupestris Martin de Perier	RUP_ M_PERIER	*Vitis rupestris*	collection of Georgikon Faculty
40	Rupestris Borsique	RUP_BORSIQUE	*Vitis rupestris*	collection of Georgikon Faculty
41	Paulsen 1103	PAULSEN_1103	*V. berlandieri x V. rupestris*	collection of Georgikon Faculty
42	Ruggeri 140	RUGGERI_140	*V. berlandieri x V. rupestris*	collection of Georgikon Faculty
43	161-49 C	BXRUP_161_49	*V. berlandieri x V. rupestris*	collection of Georgikon Faculty
44	G209	BXRUP_G209	*V. berlandieri x V. rupestris*	collection of Georgikon Faculty
45	2/27 287 C	RR_287C	*V. riparia x V. rupestris*	collection of Georgikon Faculty
46	2/28 3309 C	RR_3309C	*V. riparia x V. rupestris*	collection of Georgikon Faculty
47	2/41 Mourveder 1202 C	RRM_1202C	*V. riparia x V. rupestris*	collection of Georgikon Faculty
48	3/4 3015 C	RR_3015C	*V. riparia x V. rupestris*	collection of Georgikon Faculty
49	3/2 3055 C	RR_3055C	*V. riparia x V. rupestris*	collection of Georgikon Faculty

50	3303 C	RR_3303C	*V. riparia x V. rupestris*	collection of Georgikon Faculty
51	42 B Millardet et de Grasset	BV_42B	*V. vinifera x V. berlandieri*	collection of Georgikon Faculty
52	Fercal	FERCAL	*V. vinifera x V. berlandieri*	Kecskemet, Hungary
53	Georgikon 28	G28	*TK 5BB x V. vinifera*	new rootstock by Georgikon Faculty, Hungary
54	2/34 1616 Couderc	R16116	*V. longii (Solonis) x V. riparia*	collection of Georgikon Faculty
55	3/20 1613 Couderc	R1613	*V. longii x cv. Othello*	collection of Georgikon Faculty
56	2/45 1615 Couderc	R1615	*V. longii x V. riparia*	collection of Georgikon Faculty
57	143 Mgt	MGT143	*V. vinifera X V. riparia*	collection of Georgikon Faculty
58	Sori	SORI	*V. longii x V. riparia*	Geisenheim, Germany
59	Harmony	HARMONY	*V. longii x V. rip. x V. cand.*	collection of Georgikon Faculty
60	Freedom	FREEDOM	*V. champinii x 1613 C*	collection of Georgikon Faculty
61	Dog Ridge	DOG_RIDGE	*V. riparia x V. candicans*	collection of Georgikon Faculty
62	2/19 Gólia	GOLIA	*V. berl. x V. rip. x V. rup.*	collection of Georgikon Faculty
63	Vitis longii (Solonis)	V_SOL	*Vitis longii (Solonis)*	collection of Georgikon Faculty
64	Aramon G1	ARAMON_G1	*V. vinifera x V. rupestris*	collection of Georgikon Faculty
65	Baco Noir	BACO_NOIR	*V. vinifera x V. riparia*	collection of Georgikon Faculty
66	Alháros	ALHAROS	*V. sylvestris*	collected by A. Terpo, Hungary
67	Dorgó	DORGO	*V. sylvestris*	collected by A. Terpo, Hungary
68	Baco 1	BACO_1	*V. vinifera V. riparia*	collection of Georgikon Faculty
69	Amos	ARMOS	*V. berl. x V. rip. x V. rup.*	collection of Georgikon Faculty
70	G251	G251	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
71	G241	G241	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
72	G243	G243	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
73	G255	G255	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
74	G235	G235	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
75	G236	G236	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
76	G254	G254	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
77	G103 K	G103K	*V. berl. x V. rip. x V. rup.*	crossing made by Georgikon Faculty, Hungary
78	G203	G103	*V. berl. x V. rip. x V. rup.*	crossing made by Georgikon Faculty, Hungary
79	Börner	BORNER	*V. riparia x V. cinerea*	Kecskemét, Hungary
80	F3/1	F3_1	*V. berl. x V. rip. x V. vin. x V. rup.*	crossing made by Georgikon Faculty, Hungary
81	F7/1	F7_1	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
82	F8/1	F8_1	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
83	F9/1	F9_1	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
84	F9/2	F9_2	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
85	F10/1	F10_1	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
86	F10/2	F10_2	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
87	F10/3	F10_3	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
88	F11/1	F11_1	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
89	F11/2	F11_2	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
90	F11/3	F11_3	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
91	F16/4	F16_4	*V. berl. x V. rip. x V. vin. x V. cin.*	crossing made by Georgikon Faculty, Hungary
92	Teleki-Fuhr SO4 GK.37	SO4_GK37	*V. berlandieri x V. riparia*	clone, sel. By Georgikon Faculty
93	Teleki-Fuhr SO4 GK.38	SO4_GK38	*V. berlandieri x V. riparia*	clone, sel. By Georgikon Faculty
94	Cabernet sauvignon	CABSAUV	*V. vinifera*	Badacsony, Hungary
95	Chardonnay	CHARD	*V. vinifera*	Badacsony, Hungary
96	Pinot noir	PINOT	*V. vinifera*	Badacsony, Hungary

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Table 3 - List of the analyzed SSR loci.

Linkage group[a]	SSR locus name	Annealing T°C	Linkage group[a]	SSR locus name	Annealing T°C
1	VMC8A7	64 °C	2	VMC7G3	60 °C
3	VVMD28	62 °C	4	VrZag21	62 °C
5	VrZag79	60 °C	6	VMC4G6	50 °C
7	VVMD7	50 °C	8	VMC1F10	57 °C
9	VMC1C10	60 °C	10	VrZag25	67 °C
11	VVS2	60 °C	12	VMC2H4	57 °C
13	VMC3D12	57 °C	14	VMCNG1E1	58 °C
15	VMC5G8	58 °C	16	VVMD5	53 °C
17	Scu06vv	60 °C	18	VVIM10	57 °C
19	VMC5E9	58 °C			

[a]Linkage groups are numbered according to Adam-Blondon *et al*. (2004)

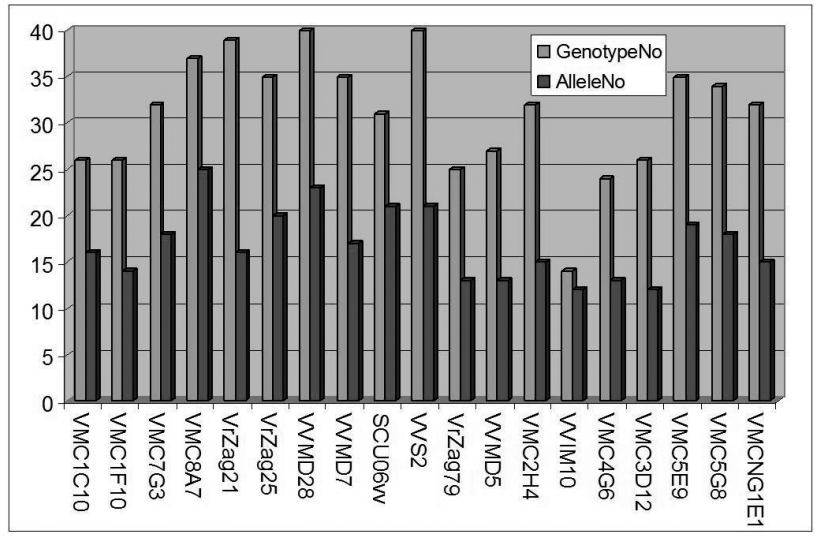


Figure 2. Genotype and allele number of microsatellite loci based on the microsatellite analysis results.

(3) Eleven microsatellites isolated from grapevine (*Vitis vinifera* L.) have been used to study the degree of conservation of these sequences across different *Vitis* species. The results demonstrate the possibility of extending the use of microsatellite markers to wild germplasm and inter-specific hybrids (Di Gaspero *et al*., 2000).

The DNA extracted from cambium tissues of grape rootstocks (*Vitis spp*., *Muscadinia rotundifolia* SMALL) has been found to be suitable for molecular analysis (Lin and Walker, 1997). Its quality is equivalent to that of DNA extracted from leaf tissues, although the yield is higher from leaves. In addition, the use of cambium tissue allows DNA extractions during dormancy or from grafted rootstocks where leaves are not available.

Microsatellites can provide data for mapping as well. The first genetic linkage map of grape derived from rootstock parents was constructed using 188 progeny from a cross of Ramsey (*V. champinii*) x Riparia Gloire (*V. riparia*) (Lowe and Walker, 2006).

The aim of this work was to determine the SSR profile of 96 *Vitis* accessions (mainly rootstocks) at 19 loci.

MATERIALS AND METHODS

1. Plant material and DNA extraction

Young leaves of 96 *Vitis* accessions (listed in Table 2) were collected in 2008 in the collection of the University of Pannonia in Cserszegtomaj (Hungary).

Total genomic DNA was extracted using the DNeasy Plant Mini Kit (Qiagen), following the manufacturer's instructions. The amount and quality of DNA was determined spectrophotometrically. The DNA was diluted to a concentration of 10 ng/µl for use in polymerase chain reaction (PCR) assays.

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Table 4. Results of the microsatellite analysis of 96 cultivars at 19 loci. Data in base pairs. 0 = null allele/no amplification. 1/4

cultivar code	cultivar name	VMC1C10		VMC1F10		VMC7G3		VMC8A7		VrZag21		VrZag25		VVMD28		VVMD7		SCU06vv		VVS2	
5CGK40	Teleki 5C GK40	144	150	196	196	114	126	158	158	193	201	237	237	215	251	229	263	203	203	143	147
5CGK42	Teleki 5C GK42	144	150	196	196	114	126	158	160	201	203	237	237	215	251	229	263	203	203	143	147
5CE20	Teleki 5C E20	144	150	196	196	114	126	160	162	201	203	237	237	215	251	229	263	179	203	143	147
5CGK46	Teleki 5C G46(64)	144	150	196	196	114	126	160	166	201	203	237	237	215	251	229	263	179	203	143	147
5CGK410	Teleki 5C G41 (74)	144	150	196	196	0	0	160	166	203	203	226	226	217	217	231	231	0	0	147	149
5CWED	Teleki 5C WED (103)	144	150	184	196	114	126	150	160	191	201	223	237	215	251	229	263	179	203	143	147
5BBGK14	Teleki-Kober 5BB GK14	144	150	184	196	120	126	0	0	201	209	223	237	215	251	231	263	169	169	139	147
5BBGK13	Teleki-Kober 5BB GK13	144	150	184	196	114	126	158	158	201	203	237	237	215	251	229	263	203	203	143	147
8B_Vel_GK68	Teleki 8B Velence GK68	144	150	196	196	114	126	158	160	201	209	237	237	215	251	229	263	169	169	139	147
8B_GK69	Teleki 8B GK69	144	150	184	196	120	126	149	160	201	209	223	237	215	251	231	263	169	169	139	147
5A_Gk62	Teleki 5A GK62	144	150	184	196	120	126	149	160	201	209	237	237	215	251	231	263	169	169	139	147
5BBF21	Teleki-Kober 5BB (F21)	144	150	184	196	0	0	158	160	201	209	223	237	215	251	231	263	169	169	139	147
5BBCR2	Teleki-Kober 5BB CR2 (18)	144	150	196	196	114	126	160	160	201	209	237	237	215	251	229	263	169	169	139	147
5BB_OSAM	Ősamerika	144	168	184	196	120	138	149	158	201	209	221	235	243	257	237	263	163	169	131	143
SO4	Teleki-Fuhr SO4 (133)	144	150	196	196	114	126	157	160	195	209	237	249	215	235	231	263	169	169	143	145
125AA_GK46	Teleki-Kober 125AA GK46	140	144	196	196	114	120	160	166	195	209	233	237	215	251	229	249	203	203	139	145
125AA_GK49	Teleki-Kober 125 AA GK49	110	146	196	196	114	120	150	160	203	203	225	241	215	269	229	229	0	0	149	149
125AA_147	Teleki-Kober 125AA (147)	140	144	196	196	114	120	150	162	195	209	233	249	215	251	229	249	203	203	139	145
8B_GK9	Teleki 8B GK9	110	150	196	196	114	114	150	162	193	203	241	241	217	217	231	231	0	0	145	153
8B_GK10_2	Teleki 8B GK10/2	140	144	196	196	114	126	150	160	201	203	233	237	235	243	229	263	169	169	143	147
8B_COSMO	Teleki 8B Cosmo 2	124	144	196	198	116	118	160	160	191	203	249	249	239	245	243	257	183	183	121	161
8B_GK1	Teleki 8B GK1	140	144	190	200	114	126	158	160	189	203	247	247	215	235	0	0	169	175	157	157
MILL_420A	MILLARDET ET GRASSET 420	144	150	190	200	114	116	158	160	209	213	225	241	243	245	229	261	175	183	125	135
EROS	Erős	150	156	190	200	120	126	150	160	199	213	229	239	249	259	241	247	179	179	131	135
5A	Teleki 5A	150	150	196	196	122	122	149	160	197	211	223	237	235	249	253	257	183	187	137	139
EGER	Eger	144	150	196	196	114	126	150	160	201	203	237	237	215	251	229	229	149	149	143	147
SZILAGYI157	Szilágyi 157	144	150	190	196	114	125	149	160	201	203	237	237	215	251	229	263	203	203	143	147
GOETHE_1	2/49 Goethe 1	144	164	180	190	116	118	150	162	197	197	225	249	219	257	247	255	173	177	143	143
P5C	4/1 Teleki P5C	124	144	196	198	114	126	158	160	191	203	233	249	215	251	243	257	183	183	121	161
8b_CR2_26	Teleki 8B CR2-26	144	150	194	196	116	118	150	160	201	209	223	237	239	245	231	263	169	169	139	147
GANZIN_9	Ganzin 9	144	150	196	198	120	120	120	120	203	211	239	239	215	231	249	259	169	179	137	139
RIP_TOM	2/35 Riparia Tomentosa	144	150	196	196	110	120	150	160	190	217	237	237	217	233	305	305	0	0	137	143
RIP_SEL	Riparia Selecta	172	172	194	194	114	116	150	160	191	191	265	265	215	215	323	323	0	0	141	141
RIP_SAUV	Riparia Sauvage	144	156	204	204	114	116	152	160	190	217	174	189	215	215	229	245	167	167	129	143
RIP_CORD	Riparia Cordifolia	144	144	194	196	126	130	149	174	209	209	249	249	215	243	249	263	173	173	135	143
RUP_DU_LOT	2/10 Rupestris du Lot	144	168	196	200	0	0	156	166	197	205	251	251	215	247	243	245	167	167	129	143
RUP_METAL	Rupestris Metalica	150	154	194	196	118	144	148	160	207	217	233	249	215	245	249	259	195	195	137	137
RUP_MARTIN	2/40 Rupestris Martin	144	168	194	194	116	120	152	162	197	205	247	247	215	247	243	245	167	169	129	143
RUP_ M_PERIER	Rupestris Martin de Perier	144	150	196	196	114	126	149	160	201	203	237	237	215	251	229	229	203	203	143	147
RUP_BORSIQUE	Rupestris Borsique	146	146	196	200	116	120	141	160	203	203	249	249	215	215	0	0	167	167	131	141
PAULSEN_1103	Paulsen 1103	144	150	190	196	120	126	162	166	201	209	223	237	215	251	231	263	169	179	139	147
RUGGERI_140	Ruggeri 140	146	152	190	190	108	114	162	166	199	207	237	237	233	233	229	255	177	183	135	141
BXRUP_161_49	161-49 C	144	150	196	198	114	120	149	160	203	211	247	247	215	231	249	259	169	179	137	139
BXRUP_G209	G209	132	142	196	196	114	132	149	160	205	209	237	237	215	215	229	241	169	169	131	139
RR_287C	2/27 287 C	144	156	202	204	118	120	160	166	205	209	231	247	227	241	237	249	169	179	135	139
RR_3309C	2/28 3309 C	144	144	198	198	114	118	159	162	201	209	233	249	219	219	255	259	185	201	127	147
RRM_1202C	2/41 Mourveder 1202 C	144	168	196	206	120	120	162	172	205	209	235	235	215	215	237	237	163	163	133	133
RR_3015C	3/4 3015 C	168	168	202	204	110	116	151	154	193	205	237	237	235	245	237	259	171	177	131	141
RR_3055C	3/2 3055 C	124	140	194	194	116	126	140	162	201	201	249	249	245	257	0	0	0	0	123	137

2. DNA amplification

Microsatellite (SSR) analysis was performed at 19 loci (Table 3). The primers were chosen from each chromosome to give well-defined heterozygosis (Costantini *et al.*, 2007).

PCRs were carried out in a total volume of 25 μl containing 12,5 μl of Hot Start Master Mix (Qiagen), 0,2 μM of each primer, and 50 ng of template DNA, using the following thermal profile: (1) 94 °C for 45 min; (2) 35 cycles of 94 °C for 1 min, annealing temperature (Table 3) for 1 min, 73 °C for 1 min; (3) 73 °C for 7 min.

One primer of each primer pair was fluorescently labeled with 6-FAM (6-carboxyfluorescein) on the 5' end of the DNA chain. The PCR products were run on a PE-Applied Biosystems 3100 Automated Capillary DNA Sequencer, and the size of the DNA fragments was determined using the GeneScan 2.0 software (Applied Biosystems).

3. SSR analysis and dendrogram

The PowerMarker v. 3.25 was used for the calculation of summary statistics of the microsatellite marker data and the creation of the dendrogram (Liu and Muse, 2005).

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Table 4. Results of the microsatellite analysis of 96 cultivars at 19 loci. Data in base pairs. 0 = null allele/no amplification. 2/4

cultivar code	cultivar name	VMC1C10		VMC1F10		VMC7G3		VMC8A7		VrZag21		VrZag25		VVMD28		VVMD7		SCU06vv		VVS2	
RR 3303C	3303 C	124	144	196	198	116	118	158	160	191	203	249	249	239	245	243	257	183	183	121	161
BV 42B	42 B Millardet et de Grasset	150	168	204	204	114	116	159	159	197	205	249	249	241	267	229	237	173	173	133	141
FERCAL	Fercal	144	150	194	196	118	120	149	160	195	209	237	249	243	257	231	263	169	169	143	143
Georgikon 28	G28	134	144	178	190	114	132	149	159	205	209	223	237	215	251	0	0	169	169	131	139
R16116	2/34 1616 Couderc	144	164	178	190	116	115	149	160	197	207	225	249	219	257	247	255	173	177	143	143
R1613	3/20 1613 Couderc	140	144	194	196	120	126	158	162	201	201	237	237	235	243	229	249	175	175	139	145
R1615	2/45 1615 Couderc	144	150	194	196	120	126	155	164	195	203	223	239	215	251	231	263	169	169	139	147
MGT143	143 Mgt	144	156	192	196	116	120	160	160	201	209	233	249	227	241	241	241	173	173	131	141
SORI	Sori	150	150	194	196	120	122	160	162	205	205	245	245	243	243	249	249	195	209	141	141
HARMONY	Harmony	144	144	191	196	128	130	158	162	205	205	235	249	233	243	253	263	173	173	135	135
FREEDOM	Freedom	144	144	190	196	114	114	160	173	207	207	233	251	195	195	305	305	221	221	135	135
DOG RIDGE	Dog Ridge	150	154	196	200	128	146	158	162	193	193	231	249	247	251	231	249	173	173	139	139
GOLIA	2/19 Gólia	150	154	194	196	118	144	160	162	207	217	249	249	215	245	249	259	183	195	137	137
V SOL	Vitis longii (Solonis)	150	150	194	196	120	122	158	160	205	211	243	257	243	247	249	249	195	195	141	155
ARAMON G1	Aramon G1	156	168	192	198	110	118	158	160	197	205	239	247	259	259	241	247	171	177	135	141
BACO NOIR	Baco Noir	144	168	194	196	120	138	158	160	195	207	221	237	243	257	237	263	163	169	131	143
ALHAROS	Alháros	150	156	190	196	124	132	149	160	193	193	229	243	249	263	247	255	171	173	131	135
DORGO	Dorgó	144	144	204	206	116	126	162	162	203	203	235	249	243	259	253	263	167	167	131	143
BACO 1	Baco 1	144	168	196	196	120	138	162	172	205	209	235	249	243	257	237	237	163	169	131	143
ARMOS	Amos	144	150	192	194	114	126	156	182	195	209	225	225	243	243	239	263	173	173	127	127
G251	G251	144	144	190	190	120	132	160	160	205	217	237	237	215	215	229	229	169	169	131	149
G241	G241	134	144	194	196	106	114	160	160	197	205	235	251	237	283	229	229	199	199	131	147
G243	G243	134	140	178	190	120	132	150	160	197	205	221	237	215	283	229	229	169	169	129	131
G255	G255	134	140	178	190	114	132	141	160	197	205	235	249	215	237	229	243	161	169	131	149
G235	G235	150	154	194	196	120	132	160	170	205	217	233	249	215	237	229	229	169	169	131	149
G236	G236	134	144	178	190	108	114	160	160	205	217	235	249	237	283	241	243	169	169	129	131
G254	G254	144	144	178	190	120	132	162	173	205	217	235	235	215	215	229	229	169	169	131	151
G103K	G103 K	144	150	202	204	114	126	160	160	201	201	241	257	243	243	249	253	179	179	131	135
G103	G203	144	144	192	196	120	130	160	160	199	209	231	247	243	243	241	249	173	189	135	141
BORNER	Börner	140	144	200	200	114	120	160	160	197	217	249	249	215	283	229	243	175	191	129	149
F3 1	F3/1	140	156	192	200	114	116	160	160	178	190	237	237	247	283	229	237	167	169	129	143
F7 1	F7/1	144	144	190	200	114	114	160	160	209	217	251	251	215	237	229	241	169	169	129	131
F8 1	F8/1	144	144	190	196	114	120	160	160	197	209	249	249	219	219	229	229	169	171	157	157
F9 1	F9/1	134	144	178	190	114	114	150	158	197	197	235	249	215	237	229	243	169	169	139	149
F9 2	F9/2	144	158	190	190	114	114	160	160	197	209	251	251	215	237	229	229	169	169	197	197
F10 1	F10/1	134	140	194	198	114	120	162	162	205	217	235	251	215	237	229	243	169	169	139	149
F10 2	F10/2	134	150	178	190	114	120	162	162	209	209	257	257	237	243	241	253	203	203	131	139
F10 3	F10/3	134	144	178	190	108	114	154	164	205	205	233	239	237	237	241	241	161	169	139	139
F11 1	F11/1	134	140	178	190	114	120	160	166	205	205	235	249	215	237	229	243	169	169	139	149
F11 2	F11/2	124	144	0	0	126	132	160	166	201	211	235	235	243	243	0	0	171	171	135	141
F11 3	F11/3	144	144	192	200	126	132	152	162	197	197	0	0	237	241	0	0	0	0	139	139
F16 4	F16/4	134	144	190	196	126	132	160	166	205	205	235	239	215	243	241	253	169	179	131	139
SO4 GK37	Teleki-Fuhr SO4 GK.37	132	142	180	190	114	126	158	158	201	209	233	233	197	197	229	229	169	169	139	147
SO4 GK38	Teleki-Fuhr SO4 GK.38	144	150	194	196	114	126	162	164	195	209	235	251	215	235	231	263	0	0	143	145
CABSAUV	Cabernet sauvignon	156	168	204	208	116	132	167	167	199	201	237	237	233	233	237	237	0	0	137	149
CHARD	Chardonnay	144	156	196	208	116	116	156	156	199	205	0	0	217	227	237	241	0	0	135	141
PINOT	Pinot noir	156	156	190	208	116	132	146	156	199	205	237	237	217	217	237	241	0	0	135	149

RESULTS AND DISCUSSION

The results of microsatellite analysis are summarized in table 4.

Based on these results, it can be established that most of the loci showed appropriate polymorphism (Table 5). The total number of alleles per locus ranged from 12 to 25, and the number of genotypes ranged from 15 to 40 (Figure 2). The VVIM10 locus showed the worst result, presenting 12 and 15 alleles per locus and genotypes, respectively. The VVMD28 and VVS2 loci both showed good results with 40 genotypes and 23 and 21 alleles per locus, respectively. The highest allele number (25) was detected in VMC8A7.

The heterozygosity of the loci in the analyzed population ranged from 0.1771 to 0.9032. The lowest heterozygosity (0.1771) was detected at the VVIM10 locus and the highest heterozygosity (0.9032) was detected at the VMC5G8 locus (Figure 3).

The distance matrix (not presented) was calculated using the shared alleles method (distance is defined as one minus half the average number of shared alleles per locus) and the dendrogram (Figure 1) was constructed using the neighbor-joining method (Saitou and Nei, 1987). In this figure, three clusters can be easily distinguished. All of the *Vitis sylvestris* (ALHAROS and DORGO) and *Vitis vinifera* (Cabernet-sauvignon, Pinot noir and Chardonnay) accessions are in the upper cluster with different rootstocks. In the middle cluster, we can find

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Table 4. Results of the microsatellite analysis of 96 cultivars at 19 loci. Data in base pairs. 0 = null allele/no amplification. 3/4

No.	cultivar code	cultivar name	VrZAG79		VVMD5		VMC2H4		VVIM10		VMC4G6		VMC3D12		VMC5E9		VMC5G8		VMCNG1E	
1	5CGK40	Teleki 5C GK40	256	256	233	263	197	219	364	364	124	124	204	208	200	202	294	304	88	88
2	5CGK42	Teleki 5C GK42	256	256	233	263	197	219	364	364	124	124	204	208	200	202	294	304	88	88
3	5CE20	Teleki 5C E20	256	256	233	233	197	219	364	364	124	124	204	208	200	202	294	304	88	88
4	5CGK46	Teleki 5C G46(64)	256	256	233	263	197	219	364	364	124	124	204	208	200	202	294	304	88	88
5	5CGK410	Teleki 5C G41 (74)	0	0	0	0	207	207	364	364	128	128	0	0	200	202	294	304	0	0
6	5CWED	Teleki 5C WED (103)	256	256	0	0	197	219	364	364	124	124	204	208	200	202	294	304	88	88
7	5BBGK14	Teleki-Kober 5BB GK14	0	0	233	263	205	219	364	364	124	124	208	212	200	202	302	304	84	84
8	5BBGK13	Teleki-Kober 5BB GK13	256	256	233	263	0	0	364	364	124	124	204	208	200	202	294	304	88	88
9	8B_Vel_GK68	Teleki 8B Velence GK68	252	252	233	263	205	219	364	364	124	124	208	212	202	210	302	304	88	88
10	8B_GK69	Teleki 8B GK69	248	256	233	263	205	219	364	364	124	124	208	212	200	202	302	304	84	84
11	5A_Gk62	Teleki 5A GK62	248	256	233	263	0	0	364	364	124	124	208	212	200	202	302	304	84	84
12	5BBF21	Teleki-Kober 5BB (F21)	248	256	233	263	205	219	364	364	124	124	208	212	200	202	302	304	80	84
13	5BBCR2	Teleki-Kober 5BB CR2 (18)	252	252	233	263	205	219	364	364	124	124	208	212	202	210	302	304	88	88
14	5BB_OSAM	Ősamerika	242	252	231	263	197	197	364	364	124	138	206	212	202	212	302	304	88	92
15	SO4	Teleki-Fuhr SO4 (133)	252	252	233	263	197	219	364	364	124	124	208	212	202	210	284	294	84	84
16	125AA_GK46	Teleki-Kober 125AA GK46	256	256	223	263	205	219	364	364	124	124	204	208	202	210	284	294	88	88
17	125AA_GK49	Teleki-Kober 125 AA GK49	244	256	0	0	0	0	364	364	126	126	0	0	202	210	294	304	0	0
18	125AA_147	Teleki-Kober 125AA (147)	0	0	223	263	205	219	364	364	124	124	204	208	202	210	284	294	88	88
19	8B_GK9	Teleki 8B GK9	244	256	223	263	0	0	294	400	110	128	0	0	202	202	288	306	0	0
20	8B_GK10_2	Teleki 8B GK10/2	256	256	223	263	197	219	364	364	124	124	208	212	200	202	284	302	88	88
21	8B_COSMO	Teleki 8B Cosmo 2	252	252	249	261	197	223	364	364	124	124	204	204	196	208	284	300	84	102
22	8B_GK1	Teleki 8B GK1	252	252	235	235	0	0	364	364	124	124	0	0	200	202	294	304	88	88
23	MILL_420A	MILLARDET ET GRASSET 420	252	252	235	235	207	211	364	364	124	124	200	208	200	204	300	300	80	86
24	EROS	Erős	240	252	231	249	197	221	364	366	138	138	206	210	192	208	300	302	80	88
25	5A	Teleki 5A	252	254	249	261	201	219	364	364	134	134	202	204	196	208	298	300	84	90
26	EGER	Eger	256	256	0	0	197	197	364	364	124	124	0	0	200	202	294	304	88	88
27	SZILAGYI157	Szilágyi 157	256	256	233	233	197	219	364	364	124	124	204	208	200	202	294	304	88	88
28	GOETHE_1	2/49 Goethe 1	252	252	261	265	199	219	364	364	116	124	202	202	202	212	300	302	90	92
29	P5C	4/1 Teleki P5C	252	252	249	261	197	223	364	364	124	124	202	204	196	208	284	300	84	104
30	8b_CR2_26	Teleki 8B CR2-26	250	256	233	263	205	219	364	364	124	124	208	212	200	202	302	304	84	84
31	GANZIN_9	Ganzin 9	252	252	249	263	205	213	364	364	118	124	206	212	188	202	304	304	84	95
32	RIP_TOM	2/35 Riparia Tomentosa	0	0	0	0	213	213	364	366	120	126	0	0	190	190	308	308	0	0
33	RIP_SEL	Riparia Selecta	0	0	0	0	209	215	364	366	110	128	0	0	202	204	304	304	84	84
34	RIP_SAUV	Riparia Sauvage	246	252	223	227	209	215	364	374	128	128	194	208	202	212	314	320	94	120
35	RIP_CORD	Riparia Cordifolia	252	252	249	263	205	219	364	364	124	132	202	204	202	206	300	304	84	88
36	RUP_DU_LOT	2/10 Rupestris du Lot	234	234	223	263	209	215	364	374	120	120	194	208	208	212	302	304	94	94
37	RUP_METAL	Rupestris Metalica	254	258	249	249	197	207	364	364	0	0	200	202	192	206	286	302	102	102
38	RUP_MARTIN	2/40 Rupestris Martin	234	234	223	261	209	215	364	374	120	120	194	194	208	212	302	304	94	94
39	RUP_ M_PERIER	Rupestris Martin de Perier	256	256	0	0	197	197	364	364	124	124	0	0	200	202	294	304	88	88
40	RUP_BORSIQUE	Rupestris Borsique	0	0	0	0	205	219	364	364	124	132	0	0	178	198	0	0	0	0
41	PAULSEN_1103	Paulsen 1103	248	256	233	263	205	219	364	364	124	124	208	212	200	202	302	304	84	84
42	RUGGERI_140	Ruggeri 140	242	256	243	265	197	217	364	364	116	116	208	208	194	194	302	302	86	94
43	BXRUP_161_49	161-49 C	252	254	249	261	205	213	364	364	118	124	206	212	190	202	302	304	84	94
44	BXRUP_G209	G209	248	248	0	0	205	225	364	364	122	122	0	0	202	208	304	314	88	88
45	RR_287C	2/27 287 C	256	258	249	263	205	215	346	364	124	124	204	210	202	212	284	300	80	84
46	RR_3309C	2/28 3309 C	256	256	0	0	0	0	364	366	116	122	0	0	198	200	294	306	0	0
47	RRM_1202C	2/41 Mourveder 1202 C	242	252	0	0	0	0	364	364	138	138	0	0	202	212	0	0	0	0
48	RR_3015C	3/4 3015 C	234	234	223	223	197	215	354	366	122	138	206	220	194	226	306	310	80	86
49	RR_3055C	3/2 3055 C	248	256	0	0	219	219	364	364	122	122	0	0	192	196	282	300	0	0

Georgikon 28 (G28) and Börner (BORNER) with different crossbred accessions (F10_3, G241, G236, G254, G251, G235, G243, F11_1, F10_1, G255, F9_1, and F9_2). In the pedigree of these hybrids both Georgikon 28 and Börner are present. Most of the rootstocks derived from Teleki's seedlings are found in the lower cluster, with the *Vitis riparia* Gloire de Montpellier rootstock, which is supposed to be a parent of Teleki 5C E20 (this study).

The history and origin of the rootstocks derived from the seedlings of Zsigmond Teleki is described in the introduction. The explained common origin may be the reason that in this study quite high similarity was detected between the Teleki 5C and the Teleki Kober 5BB accessions. The distance ranged from 0.0556 to 0.7692 with an average of 0.4031. On the other hand, strong differences were detected between the so-called « clones » of Teleki 5C and Teleki Kober 5BB, suggesting that they are not real clones Similarly, the inability of the SSR method to detect clonal variability between these

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Table 4. Results of the microsatellite analysis of 96 cultivars at 19 loci. Data in base pairs. 0 = null allele/no amplification. 4/4

No.	cultivar code	cultivar name	VrZag79		VVMD5		VMC2H4		VV1M10		VMC4G6		VMC3D12		VMC5E9		VMC5G8		VMCNG1E	
50	RR_3303C	3303 C	252	254	249	261	197	223	364	364	124	124	204	204	196	208	284	302	84	102
51	BV_42B	42 B Millardet et de Grasset	252	256	223	223	201	211	352	352	132	132	210	222	206	214	298	302	102	104
52	FERCAL	Fercal	238	252	233	263	197	219	364	364	124	124	208	208	202	210	284	294	84	84
53	Georgikon 28	G28	248	248	229	263	205	225	364	364	122	122	200	212	202	208	304	314	88	88
54	R16116	2/34 1616 Couderc	252	252	261	265	201	219	364	364	116	124	202	202	202	212	300	302	90	92
55	R1613	3/20 1613 Couderc	248	252	223	263	197	219	364	364	124	124	208	212	200	202	284	294	84	84
56	R1615	2/45 1615 Couderc	248	256	233	263	205	219	364	364	124	124	208	212	200	202	302	304	84	84
57	MGT143	143 Mgt	242	256	231	261	205	213	354	366	124	124	202	206	190	200	300	314	84	88
58	SORI	Sori	258	258	0	0	197	219	364	364	124	124	202	206	202	210	298	300	80	90
59	HARMONY	Harmony	252	254	225	249	201	219	364	364	122	122	200	202	202	216	292	304	0	0
60	FREEDOM	Freedom	0	0	0	0	0	0	366	368	124	124	0	0	270	270	292	304	98	98
61	DOG_RIDGE	Dog Ridge	236	252	261	261	215	217	366	366	122	134	194	194	196	196	276	302	94	94
62	GOLIA	2/19 Gólia	254	258	249	249	197	207	364	364	120	120	200	202	192	206	288	302	104	104
63	V_SOL	Vitis longii (Solonis)	256	256	263	263	197	219	364	364	124	132	202	206	200	208	298	300	80	90
64	ARAMON_G1	Aramon G1	242	252	231	249	197	213	364	364	138	138	210	234	192	194	300	312	80	92
65	BACO_NOIR	Baco Noir	242	252	231	263	197	221	364	364	124	138	206	212	202	212	302	304	88	92
66	ALHAROS	Alháros	248	258	225	249	215	219	364	364	124	124	200	202	190	204	298	310	90	92
67	DORGO	Dorgó	248	256	237	263	197	215	364	364	122	122	210	212	198	202	302	304	88	96
68	BACO_1	Baco 1	242	252	231	263	197	197	364	364	138	138	206	206	202	212	302	304	88	92
69	ARMOS	Amos	254	254	249	249	215	215	364	364	124	146	228	228	196	202	300	304	84	92
70	G251	G251	248	252	229	263	205	209	364	364	122	122	194	200	202	202	304	314	88	88
71	G241	G241	248	252	227	229	205	225	364	364	122	122	194	200	202	208	304	314	88	90
72	G243	G243	248	252	263	263	209	225	364	364	130	130	208	212	202	208	304	304	88	92
73	G255	G255	248	252	227	263	205	205	364	364	124	124	194	200	202	208	302	304	88	90
74	G235	G235	248	252	227	263	205	209	364	364	122	122	194	200	202	208	304	304	88	88
75	G236	G236	248	252	227	263	205	225	364	364	122	122	194	212	202	208	304	320	88	90
76	G254	G254	248	252	229	263	205	209	364	364	122	122	194	200	202	202	304	314	88	90
77	G103K	G103 K	252	252	233	249	199	219	364	364	124	132	200	204	196	206	298	304	80	84
78	G103	G203	252	256	231	263	205	221	364	364	124	124	202	206	200	202	304	314	88	88
79	BORNER	Börner	252	252	227	261	205	209	364	364	124	130	194	208	202	208	304	320	90	90
80	F3_1	F3/1	234	252	237	263	205	215	352	352	128	128	194	212	208	212	302	320	90	104
81	F7_1	F7/1	248	252	229	263	203	205	364	392	130	130	194	212	202	202	312	320	88	88
82	F8_1	F8/1	0	0	0	0	0	0	364	392	128	132	0	0	202	208	0	0	0	0
83	F9_1	F9/1	252	252	227	263	205	225	364	364	130	130	194	212	202	208	302	304	88	120
84	F9_2	F9/2	252	252	0	0	0	0	340	340	124	124	0	0	202	202	304	304	90	90
85	F10_1	F10/1	252	252	227	229	205	205	362	362	124	124	194	212	202	208	304	314	88	88
86	F10_2	F10/2	252	252	229	249	219	225	364	364	132	132	200	204	202	206	298	314	84	84
87	F10_3	F10/3	248	248	229	229	205	225	364	364	122	122	200	212	202	208	304	312	88	88
88	F11_1	F11/1	252	252	227	227	205	205	362	362	124	124	194	212	202	208	304	314	88	88
89	F11_2	F11/2	0	0	0	0	0	0	366	368	124	124	0	0	198	198	0	0	0	0
90	F11_3	F11/3	0	0	0	0	0	0	366	368	124	124	0	0	0	0	0	0	0	0
91	F16_4	F16/4	248	252	233	263	225	225	364	364	122	122	200	204	196	208	302	304	80	80
92	SO4_GK37	Teleki-Fuhr SO4 GK.37	252	252	0	0	205	205	364	364	124	124	0	0	202	210	300	304	88	88
93	SO4_GK38	Teleki-Fuhr SO4 GK.38	252	252	233	263	197	219	364	364	124	124	208	212	202	210	284	294	84	84
94	CABSAUV	Cabernet sauvignon	242	242	0	0	213	221	362	366	124	134	200	220	194	218	322	322	106	124
95	CHARD	Chardonnay	238	240	0	0	201	201	354	354	124	128	206	222	192	218	312	314	96	124
96	PINOT	Pinot noir	234	240	0	0	201	201	354	354	124	124	206	222	192	200	312	314	124	124

« clones » has been reported several times (This *et al*., 2006 ; Sefc *et al*., 1998 ; Moncada *et al*., 2006 ; Moncada and Hinrichsen, 2007 ; Regner *et al*., 2006 ; Wolf *et al*., 2003).

It is surprising that two of the analyzed Teleki rootstocks (Teleki Kober 5BB GK14 and Teleki Kober 8B GK69) showed identical genotypes. One possible explanation for this can be (1) an identical genetic origin (being derived from the same cross), but the likelihood of this is very low because of the high number of loci studied. Another explanation could be related to (2) problems with passport data or bank management, such as those reported by de Andrés *et al*. (2007), or with mistakes in DNA analysis if they show phenotypic differences that cannot be related with somatic mutation. There may be differences at the two loci (VrZAG79 and VMC8A7) for which SSR analysis was not possible (no amplification in Teleki Kober 5BB GK14 - either failed or corresponded to null allele). Unless genetic differences between both of these accessions can be identified by increasing the number of genotyped loci, which would

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Table 5. Statistical results of the analyzed SSR loci.

Locus	Number of alleles	Heterozigosity		Probability of Identity (PI)	Estimated frequency of Null Alleles
		expected	observed		
VMC1C10	16	0,764648	0,812500	0,127883	-0,027117
VMC1F10	14	0,786537	0,694737	0,099171	0,051385
VMC7G3	18	0,838363	0,903226	0,080525	-0,035283
VMC8A7	25	0,812188	0,757895	0,077725	0,029960
VrZag21	16	0,886610	0,781250	0,044264	0,055846
VrZag25	20	0,855478	0,510638	0,058724	0,185849
VVMD28	23	0,871419	0,760417	0,043185	0,059315
VVMD7	17	0,875062	0,744444	0,046581	0,069660
SCU06vv	21	0,827889	0,352941	0,064547	0,259834
VVS2	21	0,903592	0,812500	0,032588	0,047852
VrZag79	13	0,767509	0,511628	0,140288	0,144770
VVMD5	13	0,846056	0,810811	0,068514	0,019092
VMC2H4	16	0,857355	0,845238	0,065192	0,006524
VVIM10	12	0,366482	0,177083	0,426934	0,138603
VMC4G6	13	0,678892	0,221053	0,161956	0,272703
VMC3D12	12	0,867853	0,870130	0,059849	-0,001219
VMC5E9	19	0,816953	0,894737	0,076965	-0,042810
VMC5G8	18	0,837097	0,901099	0,071969	-0,034839
VMCNG1E	15	0,792304	0,440476	0,106597	0,196299

confirm our first hypothesis, the most probable explanation is the second one.

In this study, the rootstock variety Paulsen 1103 (*V. berlandieri* x *V. rupestris*) is very close to the Teleki Kober 5BB rootstocks, which are supposed to derived from crosses between *V. berlandieri* and *V. riparia*. There may be similarity because of the similar origin. The origin of the rootstocks bred by Zsigmond Teleki are not clear, but they were selected for good lime and drought tolerance, and Paulsen 1103 was selected in southern Italy (by Paulsen in 1895) for its strong drought tolerance and its ability to grow well on lime-based soils as well. The similar economical features can be traced back to the similar genetic background.

A low distance was also detected between accessions with complex gene pool (*V. berlandieri* x *V. riparia* x *V. vinifera* x *V. cinerea*). Most of them originated from the cross between Börner and Georgikon 28. The parent-offspring relation cannot be justified in any cases, probably because they went through a long selection period, when mutations can have occurred.

The *Vitis sylvestris* accessions (ALHAROS and DORGO) showed closer relatedness with the *Vitis vinifera* varieties (Figure 3). This rejects the possibility of a *V. sylvestris* x *V. riparia* hybrid origin, but does not exclude the possibility of a *V. vinifera* x *V. sylvestris* hybrid origin for these accessions. On the other hand, recent microsatellite (SSR) analyses have shown clear distinctions between wild and cultivated individuals (This *et al*., 2006), so this aspect needs further analysis.

The possible parent-offspring combinations were considered when two genotypes shared at least one allele per locus. A possible parent for the following five rootstocks was found: T5C GK42, T5C E20, T5C GK46, T5C WED, and SZILÁGYI 157. This possible parent is the Riparia Gloire de Montpellier rootstock, which was selected in Montpellier, France by Viala in 1880. This rootstock is male flowered and was one of the first to be used after the phylloxera crisis in Europe. It also provides enough iron to its scions in limestone-based soils (Németh, 1975). The first four possible offsprings are the Teleki rootstocks (T5C GK42, T5C E20, T5C GK46, and T5C WED), and the fifth (SZILÁGYI 157) is a rootstock selected in Pécs, Hungary by János Szilágyi, from *V. berlandieri* x *V. riparia* seedlings from France (Bakonyi and Kocsis, 2004). All of the base material for selection in these five accessions were originated from France and were selected later, as Riparia Gloire de Montpellier occurred, which make it more possible to be a parent.

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