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Identification and characterization of Swiss grapevine cultivars using microsatellite markers

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Microsatellite analysis with up to 12 markers was performed on 463 grapevine samples mostly collected from Swiss cultivar collections, viticulturists, winegrowers and private collectors, using an optimized and fast method based on quick DNA extraction, six-plex PCR and automated fragment analysis. Several already published genetic profiles were confirmed, misnamed plants were identified, and additional new profiles are presented in this study. Some of the misnamed plants could be named correctly, while cultivar allocation of others needs confirmation. We found that 'Briegler' seems to be a synonym for 'Bondola nera', possibly the German name for a cultivar grown in Southern Switzerland. In the case of 'Erlenbacher Schwarz' we found types with two different profiles. The ones from Eastern Switzerland are identical to 'Hitzkircher', while the type collected in Western Switzerland is different. Further data collection is necessary to elucidate which type is the true-to-type cultivar. Also an old and rare cultivar named 'Mörchel' was shown to be identical to 'Trollinger' (syn. 'Schiava Grossa', 'Gross-Vernatsch' or 'Frankenthal Noir'). Several 'Chasselas' and 'Muscat' types were allocated into synonymous groups with identical profiles.
***Key words**: Vitis vinifera*, grape, microsatellites, Swiss cultivars, genetic profile.

***Identifizierung und Charakterisierung von Schweizer Rebsorten mittels Mikrosatellitenanalyse.** 463 Proben von Weinreben aus Schweizer Sortensammlungen, von Weinbauinstituten, Weinbauern und privaten Sammlern wurden mittels Mikrosatellitenanalyse an bis zu 12 Markern untersucht, wobei eine optimierte und schnelle Methode, die auf rascher DNA-Extraktion basierte, sechsfache PCR und automatisierte Fragmentanalyse angewandt wurden. Einige bereits veröffentlichte genetische Profile wurden bestätigt, falsch bezeichnete Sorten wurden identifiziert und zusätzliche neue Profile erstellt. Einige der falsch bezeichneten Sorten konnten richtig benannt werden, während einige andere Sortenzuweisungen noch einer Bestätigung bedürfen. 'Briegler' scheint ein Synonym für 'Bondola nera' zu sein, wahrscheinlich der deutsche Name für eine Sorte aus der Südschweiz. Bei 'Erlenbacher Schwarz' wurden Typen mit zwei unterschiedlichen Profilen gefunden. Die aus der Ostschweiz entsprechen 'Hitzkircher', während die Typen aus der Westschweiz unterschiedlich sind. Weitere Daten müssen erhoben werden, um zu klären, welcher Typ der sortentypische ist. Die alte und seltene Sorte 'Mörchel' erwies sich als identisch mit 'Trollinger' (syn. 'Schiava Grossa', 'Gross-Vernatsch' oder 'Frankenthal Noir'). Einige Chasselas- und Muscat-Typen wurden synonymen Gruppen mit identischen Profilen zugeordnet.*
Key words: *Vitis vinifera*, Rebe, Mikrosatelliten, Schweiz, Sorten, genetisches Profil

***Identification et caractérisation de variétés de vignes suisses au moyen de l'analyse de microsatellites.** 463 échantillons de vignes en provenance des collections de variétés de vignes suisses, d'instituts d'œnologie, de viticulteurs et de collectionneurs privés ont été examinés au moyen de l'analyse de microsatellites en tenant compte de jusqu'à 12 marqueurs. À cette fin, on a utilisé une méthode optimisée et rapide basée sur l'extraction rapide de l'ADN, la PCR sextuple et l'analyse de fragments automatisée. Quelques profils génétiques déjà publiés ont été confirmés, des variétés mal désignées ont été identifiées et de nouveaux profils supplémentaires ont été établis. Il a été possible de désigner correctement quelques variétés mal désignées, tandis que d'autres attributions de variétés doivent encore être confirmées. Il semble que 'Briegler' soit synonyme de 'Bondola nera', probablement le nom allemand d'une variété du sud*

de la Suisse. Des types avec deux profils différents ont été trouvés pour 'Erlenbacher Schwarz'. Ceux provenant de l'est de la Suisse correspondent à 'Hitzkircher', tandis que les types provenant de l'ouest de la Suisse sont différents. Il est nécessaire de saisir encore plus de données afin de déterminer quel type est celui typique pour la variété. La variété ancienne et rare 'Mörchel' s'est révélée être identique au 'Trollinger' (syn. 'Schiava Grossa', 'Gross-Vernatsch' ou 'Frankenthal Noir'). Quelques types de Chasselas et de Muscat ont été attribués aux groupes synonymes présentant des profils identiques.

Mots clés : *Vitis vinifera*, vigne, microsatellites, Suisse, variétés, profil génétique

Despite the relatively small size of the country, many different grapevine cultivars are grown in Switzerland, as a result of historically strong influences of surrounding regions. Samples of these grapevine cultivars were collected in order to identify and genetically characterize them, and to arrange the results in a database. The basis for the construction of any database is the reliability of the data included. This means that the analyzed plants must be true-to-type representatives of a cultivar. That might sound obvious, but misnamed grapevine plants are found even in cultivar collections. Misnamed cultivars have a negative impact on research, grapevine breeding and the organization of grapevine collections (This and Dettweiler, 2003). Errors in nomenclature are then propagated worldwide through material exchange. It is known that about 5% of the types in the world grapevine collections are misnamed and hence not true-to-type (Dettweiler, 1992). Therefore, identification and true-to-type assignment of cultivars in a database is a prerequisite for any parental analysis or other studies.

When analyzing typical and historical Swiss grapevine cultivars, we faced the above mentioned difficulties. Many cultivars were introduced to different areas over a long period of time and were given either similar or totally different names. Also, due to limited travelling possibilities in ancient times, ampelographers were forced to rely on descriptions, and so errors were passed on from one report to another. There is not much information in ampelographic books about historical Swiss cultivars. Several diploma theses were conducted at our institute on the subject (Balmer, 2000; Greuter and Wunderlin, 1998). Recently, a book about the history of old grapevine cultivars has been published that includes many Swiss grapevine cultivars (Aeberhard, 2005). Several names of historical Swiss cultivars are mentioned as synonyms in literature, but errors regarding synonyms can be found. For instance, 'Lafnetscha' and 'Completer' often are mentioned as or suspected to be synonyms (Ambrosi et al., 1994; Eggenberger and Lennert, 1996; Hillebrand et al., 1998), but this was proven incorrect; they are two different but related cultivars (Vouillamoz et al., 2004). Other mentioned synonyms are, e.g. 'Briegler' - 'Hitzkircher' (as formerly named in cultivar collection in Au, Switzerland), 'Hitzkircher' - 'Grosser blauer Mörsch' (Aeberhard, 2005), 'Schwarzer Erlenbacher' - 'Gänsfüsser' - 'Argant' (Ambrosi et al., 1994). It is of great importance that cultivars are clearly characterized and possible synonyms and naming errors are found. Genetic methods such as microsatellite analysis enable clarification if two plants are identical or related.

In the present study, special emphasis was placed on old Swiss cultivars focusing on those cultivated in the „historical vineyard" at the wine production museum in Au, Switzerland. These vines were originally planted by W. Eggenberger of the University of Applied Sciences of Wädenswil in 1978. Several old varieties can be found there, such as 'Elbling weiss', 'Elbling rot', 'Mörchel', 'Completer', 'Erlenbacher Schwarz', 'Briegler', 'Thuner blau', 'Räuschling rot', and 'Räuschling weiss'. Many of these cultivars are very rare. For example, it is supposed to be the only planting of 'Mörchel' in Switzerland (Aeberhard, 2005).

The central geographical situation and the intensive trading connections of Switzerland over hundreds of years led to a melting pot of different and rare grape varieties from all over Europe. In order to safeguard the genetic diversity in grapevine, Pro Specie Rara and SKEK (Schweizerische Kommission zur Erhaltung von Kulturpflanzen) are running several programs. One measure is a so-called positive-list of all (historical) grapevines in Switzerland that are worth safeguarding. These cultivars will be planted in collections in different areas of Switzerland. An inventory of all existing cultivar collections is under way.

Especially for rare cultivars it is therefore very important to try to find many different, but originally independent types of the same cultivar and so to find the true-to-type cultivar and their corresponding genetic profiles.

The present study describes the current situation of the efforts to name, characterize and identify Swiss cultivars. The results of this study contribute to the charac-

terization of true-to-type grape cultivars. They will enable the clear identification of unknown, rare or misnamed plants by comparing their genetic profile to the database.

Materials and Methods

Plant material

A total of 463 grapevine leaf samples were collected from several sites, mostly in Switzerland (Table 1). Cultivar collections as Rheinhof/Frümsen, Sortengarten Au and the collection of Agroscope ACW Changins in Pully contain types from different parts of Switzerland. Of the 463 cultivars that were finally analyzed, the largest part came from collections in Au and Agroscope ACW Wädenswil (38.7%). In total, 373 types have been sampled from cultivar collections, 33 from a private collection in Berne, 44 from nurseries and vineyards, and ten from private gardens (Table 1). One type is an unknown wild grape found in an ancient vineyard. Types from vineyards and individual gardens came from seven different cantons from all over Switzerland. Twenty-eight types were from Germany or Austria, 22 of them from a 'Gutedel'/'Chasselas' collection in Badenweiler, Germany. The aim was to find out if 'Chasselas' was identical with some of the Muscat cultivars, e.g. 'Muskat Gutedel'. We also compared the results to other Muscat profiles.

Cultivars were named according to the French and German names, generally known synonyms are: 'Chasselas' = syn. 'Gutedel'; 'Pinot noir' = syn. 'Blauburgunder'; 'Gouais blanc' = syn. 'Gwäss' = syn. 'Heunisch weiss'; 'Savagnin blanc' = syn. 'Païen' = syn. 'Heida' = syn. 'Traminer weiss'. 'Cornalin' was named 'Cornalin du Valais' according to Vouillamoz et al. (2003) to avoid confusion with 'Cornalin d'Aoste' which is a synonym of 'Humagne rouge' (Vouillamoz et al., 2003).

Tab. 1: Collection sites (mostly in Switzerland) and number of analyzed grape cultivar accessions

Collection site	Type	No of accessions
Sortengarten Au, Wädenswil	Cultivar collection	146
Agroscope ACW, Wädenswil	Cultivar collection	33
Agroscope ACW, Changins, Pully	Cultivar collection	45
Rheinhof, Frümsen	Cultivar collection	121
Geilweilerhof (D)	Cultivar collection	5
Gutedelgarten Badenweiler (D)	Cultivar collection	22
Klosterneuburg (A)	Cultivar collection	1
M. Aeberhard, Berne	Private collection	33
Rebschule Auer, Hallau	Nursery	3
Rebschule Meier, Würenlingen	Nursery	6
S. Haldemann, Minusio	Vineyard	4
Ph. Constantin, Salgesch	Vineyard	2
O. Kalt, Tegerfelden	Vineyard	4
X. DeWerra, Granges	Vineyard	21
J.M. Chanton, Visp	Vineyard	3
J. Wildisen, Hitzkirch	Vineyard	2
M. Weber, Erlenbach	Vineyard	1
Private Person	Private gardens	10
P. Rey, Muhen	Unknown wild grape	1
Total		463

DNA extraction, PCR and sample analysis

Generally, methods were as described in Frei et al. (2004). Extraction of DNA had started using a common method (Thomas and Scott, 1993), with some modifications. For some of the samples, a quick DNA extraction method was applied, using the Extract-N-Amp™ Plant PCR kit (Sigma). Thirty-two types were analyzed using both DNA extraction methods, and the results were always identical (data not shown). Several types were analyzed for most cultivars, which is important when trying to identify the true-to-type profile of a cultivar.

All cultivars were analyzed at six marker sites internationally proposed for grapevine cultivar characterization: VVS2 (Thomas and Scott, 1993), VVMD5, VVMD7 (Bowers et al., 1996), VVMD27 (Bowers et al., 1999), VrZAG62 and VrZAG79 (Sefc et al., 1999). It is generally accepted that these six markers are sufficient to clearly distinguish between different cultivars (Regner et al., 2001). These markers have also been chosen to establish a standard set of microsatellite reference alleles in the EU Project GenRes CT96 No81 (This et al., 2004). Some of the cultivars were analyzed at six additional markers (VVS4 (Thomas and Scott, 1993), VVMD6, VVMD8 (Bowers et al., 1996), VrZAG21, VrZAG 67 and VrZAG112 (Sefc et al., 1999)).

PCR reaction was performed with the Qiagen Multiplex PCR kit, using a final PCR volume of 10 µl (5 µl of 2x Qiagen multiplex PCR mastermix, 1 µl of 5x Q-Solution, 1 µl of 10x primer mix containing 2 µM of each F and R primer (six-plex), 1 µl of pure H_2O and 2 µl of template DNA, diluted 1:10 with pure H_2O). PCR was done on a Techne Genius thermocycler (Witec AG, Littau, Switzerland) under the following cycling conditions: 15 min at 95 °C (for initial denatura-

tion), followed by 40 cycles of 40 sec at 94 °C, 90 sec at 57 °C and 90 sec at 72 °C; then 30 min at 60 °C and final hold at 10 °C (FREY et al., 2004).
A mastermix containing 15 µl formamide and 0.5 µl of fluorescent GeneScan^{TM}-500 ROX^{TM} standard dye (Applied Biosystems) per sample was mixed and 15 µl were pipetted in each well of a 96 well plate. Then, 1 µl of the 1:10 diluted PCR product was added. After centrifugation, heat denaturation for 2 min at 96 °C and rapid cooling in the freezer followed. The plates were then transferred to a 3100 Genetic Analyzer (Applied Biosystems) and run on 50 cm capillaries with a high resolution polymer (POP-6; Applied Biosystems). The data produced by the Genetic Analyzer were imported into the software GeneMapper^{TM} version 3.0 (Applied Biosystems) and automatically sized and analyzed. Bins were created based on the first results and autobinning was performed with the rest of the data. The values were rounded to the nearest base and then exported into the spreadsheet program Excel (Microsoft). The program Identity version 1.0 (WAGNER and SEFC, 1999) was used to compare and find identical profiles among the results.

Results and Discussion

High genetic variability was found among the analyzed grapevine cultivars, which is in agreement with earlier studies for grapevine cultivars from Central Europe, e.g. by SEFC et al. (1999). From the 463 types analyzed, 195 different profiles could be identified. Most of the profiles could be assigned to a cultivar, while in a few cases plants remain unidentified. Profiles of several, mostly well known, cultivars could be confirmed from literature (Table 2). Nine profiles were identical to true-to-type profiles of the European Vitis database (THIS et al., 2004) and 15 profiles were found to be identical compared to several publications (GRANDO and FRISINGHELLI, 1998; SEFC et al., 1997; SEFC et al., 2000; THIS et al., 2004; VOUILLAMOZ et al., 2003; VOUILLAMOZ et al., 2004). The profiles were compared at six to nine marker sites, depending on the markers analyzed in each study. Table 2 provides additional allele lengths at more marker sites.
To enable direct comparison of the allele lengths between this and previous studies, a parallel shift of base pairs (bp) was necessary. Allele lengths in this study were generally 0 to 3 bp shorter compared to VOUILLAMOZ et al. (2003 and 2004), 0 to 2 bp shorter compared to SEFC et al. (1997 and 2000), and 0 to 3 bp shorter compared to THIS et al. (2004); but they were 0 to 2 bp longer compared to GRANDO and FRISINGHELLI (1998). A particular situation was observed for the markers VVMD6 and VVMD8. Six bp had to be added to allele lengths found in this study in order to be able to compare them to allele lengths mentioned in VOUILLAMOZ et al. (2003 and 2004). At the same marker sites, the lengths had to be minimized by 2 bp when compared to GRANDO and FRISINGHELLI (1998).
The allele lengths of cultivars from this study were shown to be identical in most marker sites compared to literature profiles, with a difference of one allele at one marker each in 'Merlot', 'Muscat blanc a petits grains', 'Silvaner', 'Himbertscha', and 'Plantscher' (Table 2). The first three showed a difference at VVMD27, a 2 and 1 bp shorter allele, respectively (in this study, after the parallel shift), while 'Himbertscha' and 'Plantscher' were heterozygous in this study at VVS4 or VVMD8, respectively. These differences are probably due to the use of different methods, i.e. capillary analysis vs. polyacrylamide gel readings. For 'Humagne Rouge', we confirmed a heterozygous allele at marker VVMD 8, as mentioned by VOUILLAMOZ et al. (2003), while its Italian synonym 'Cornalin d'Aoste' is homozygous at this site. These results show that a profile or a database from literature can be adapted to other results or be used for comparison with unknown profiles, after a parallel shift of known numbers of base pairs, for the purpose of comparing, characterizing or identifying unknown grapevine cultivars.

Misnamed plants

The assigned names of 58 analyzed grapevine types were unknown or wrong (Table 3). Compared to the 463 analyzed types, this corresponds to a proportion of 12.5%. If we only take into account the 23 misnamed cultivars from cultivar collections (not counting the obviously propagated material) and compare it to the total of 373 types from cultivar collections, the percentage drops to 6.2% of falsely named plants. This number is close to the presumed number of about 5% of misnamed plants in cultivar collections (Dettweiler, 1992). A total of 44 individual misnamed plants as well as 12 cultivars of unknown or uncertain status could be correctly identified by comparing their profile to the database. Seven cultivars still remain unidentified (Table 3). We found that even in cultivar collections, the situation is not always consistent. Of three plants of supposedly the same cultivar according to the name tag, all three can be wrong as in the case of 'Humagne Blanc' which

Tab. 2: Grape cultivar profiles analyzed, compared and confirmed with literature data, including allele lengths at additional marker sites. Numbers in bold are different to literature but have been confirmed several times in this study. In literature, the allele length is +2bp (a), or +1 bp (b), respectively, compared to the results in this table. Numbers in italics (c) are homozygous in literature, while heterozygous in this study. The markers that were compared are underlined.

DNA No	Cultivar name	Coll. site[1]	Literature confirmation[2]	VVS2		VVMD5		VVMD7		VVMD27		VrZAG62		VrZAG79		VVS4		VVMD6		VVMD8		VrZAG21		VrZAG67		VrZAG112	
320	Aligoté	CC	Sefc 00 (6/6)	131	135	225	237	237	237	178	188	194	196	242	244	167	172	189	199	135	141	199	205	137	151	239	241
151	Cabernet franc	WG	Th 04 (6/6) Sefc 97 (9/9)	137	146	223	237	261	180	188	194	204	246	258	166	174	199	206	141	152	190	199	137	137	228	241	
164	Cabernet Sauvignon	WG	Th 04 (6/6) Sefc 97 (9/9)	137	150	229	237	237	174	188	188	194	246	246	167	174	206	206	137	152	199	205	124	137	228	233	
262	Chardonnay cl. 29	CC	Th 04 (6/6)	135	141	231	235	237	241	180	188	188	196	242	244	167	172	199	208	135	141	199	205	137	151	239	239
123	Completer	CC	Vou 04 (9/9)	137	154	225	229	231	237	178	184	194	196	244	258	167	167	199	208	135	137	190	199	137	148	241	241
82	Comalin du Valais	CC	Vou 03 (9/9)	131	137	223	225	245	261	184	188	194	194	238	246	168	174	206	206	135	137	190	199	201	124	148	241	261	
172	Gewürztraminer	CC	Th 04 (6/6)	150	150	229	235	241	255	188	188	188	194	244	250	167	174	199	206	135	137	199	205	124	130	233	239
544	Goron rouge	CC	Vou 03 (6/6)	131	150	225	225	237	245	188	188	194	194	246	258												
488	Humagne blanc	CC	Vou 04 (6/6)	131	150	223	233	241	251	184	188	188	200	238	246												
329	Humagne rouge	CC	Vou 03 (9/9)	131	137	223	225	245	255	184	188	194	194	238	244	166	168	199	206	135	152	199	213	130	148	233	261
535	Himbertscha	CC	Vou 04 (8/9)	131	131	223	233	231	241	184	188	188	196	238	250	*172c*	174	206	206	135	137	190	199	124	137	228	239
117	Lafnetscha	CC	Vou 04 (9/9)	131	154	225	233	237	251	178	184	194	200	238	258	167	174	199	206	137	137	190	199	124	148	235	241
272	Madeleine Royale	CC	Th 04 (6/6)	150	154	225	233	241	245	180	188	188	194	244	258	167	172	199	208	137	152	201	205	137	151	228	239
94	Merlot	CC	Th 04 (5/6)	137	150	223	233	237	245	**186a**	190	194	194	258	258	167	174	199	206	137	152	199	199	130	137	228	241
299	Muscat blanc a.p.g.	CC	Th 04 (5/6)	131	131	225	233	231	247	178	**192b**	186	196	250	254	167	174	206	208	135	135	205	205	124	137	233	233
433	Nebbiolo	CC	Vou 04 (9/9)	154	154	229	233	245	247	184	190	194	200	242	250	167	167	206	208	135	162	190	190	124	162	239	241
204	Petit rouge d'Aoste	WG	Vou 03 (9/9)	131	137	223	225	245	245	188	188	194	204	244	246	167	174	206	208	135	137	201	201	124	153	233	261
576	Plantscher	CC	Vou 04 (8/9)	144	152	229	237	237	247	182	192	196	204	236	258	166	174	189	208	137	*152c*	199	205	137	148	228	241
77	Pinot noir	CC	Th 04 (6/6)	135	150	225	235	237	241	184	188	188	194	238	244	167	172	199	199	135	137	199	205	124	151	239	241
135	Rieslaner	CC	GF 98 (6/6)	150	150	223	223	241	247	180	192	188	204	242	248	167	167	206	208	137	137	199	205	124	151	239	241
56	Riesling	CC	Sefc 97 (9/9)	141	150	223	231	247	255	180	188	194	204	242	244	167	167	206	208	137	141	201	205	137	151	239	241
209	Sauvignon blanc	WG	Sefc 97 (9/9)	131	150	225	229	237	255	174	188	188	194	244	246	167	167	199	206	137	137	203	205	124	148	233	239
133	Scheurebe	CC	GF 98 (6/6)	141	150	223	235	245	247	188	192	188	204	244	248	167	167	206	208	141	162	201	205	137	158	239	239
103	Silvaner	CC	Th 04 (5/6) Sefc 97 (9/9)	150	152	223	229	241	245	188	**192b**	188	204	248	250	167	167	189	206	135	137	199	205	124	158	237	239

[1] CC: Cultivar collection; WG: winegrower

[2] Literature citations: GF 98: GRANDO and FRISINGHELLI, 1998; Sefc 97: SEFC et al., 1997; Sefc 00: SEFC et al., 2000; Th 04: THIS et al., 2004; Vou 03: VOUILLAMOZ et al., 2003; Vou 04: VOUILLAMOZ et al., 2004.

Number of identical marker sites vs. compared marker sites are given in parenthesis. Compared to Th 04: some discrepancies in MD27. Compared to Vou 03 and Vou 04: Wherever there was no identical match, it was always heterozygous in this study vs. homozygous in literature, i.e. one allele was always consistent. Details are described in the text

turned out to be 'Lafnetscha ', or two out of three can be wrong ('Silvaner') and the third one is correct, as in the case of 'Gwäss' (Table 3). So it is important to analyze repetitions of the same cultivar, especially if they seem to be ampelographically different, and if they will be propagated or used as examples in cultivar collections.

Profiles of Swiss grapevine cultivars

To identify the true-to-type profile of Swiss cultivars, it is important to analyze types from different origins. This reduces the chances to include a misnamed cultivar in the database. An interesting example where we successfully confirmed profiles is the case of 'Completer' and 'Lafnetscha', two ancient Swiss cultivars believed to be synonyms. As shown by VOUILLAMOZ et al. (2004), these varieties belong to two different cultivars. We analyzed 16 plants named 'Completer' from five collection sites and 11 plants named 'Lafnetscha' from four collection sites. We found the correct profiles for all 'Completer' and for six 'Lafnetscha', while three 'Lafnetscha' turned out to be 'Completer', one was 'Gouais blanc'/'Heunisch weiss' and one was 'Heida' (Table 3). Interestingly, the 'Heida' came from the same site as two correctly named 'Lafnetscha'.

Table 4 shows the genetic profiles of 27 cultivars, analyzed at 6 or 12 marker sites, respectively. True-to-typeness has been estimated according to the number of types analyzed, compared to literature, or of confirmed origin (e.g., cultivars that have been bred by Agroscope ACW Changins). If

Tab. 3: Falsely named grape cultivar accessions from different collection sites that were identified with the grapevine database

Given name	No of access.	No of coll. sites	Correct name/ Identical profile
Ancellotta	1	1	Cabernet Franc
	1	1	Diolinoir
Äugstler weiss	5	4	Madeleine Angevine[1]
	1	1	Scheurebe
Bondola bianca	1	1	Muscat bl. à p.g.
Bondola nera	1	1	Madeleine Royale
Chasselas noir	2	2	Muscat bl. à p.g.
Durize	1	1	Gamay
Eyholz roter	1	1	Doral
	1	1	Completer
Gänsfüsser	1	1	Douce Noire[2]
Garanoir	1	1	Gamaret
	1	1	Pinot noir
Gutedel rot	1	1	Räuschling
Gwäss/Gouais blanc	2	1	Silvaner
Heunisch weiss	1	1	Muscat bl. à p.g.
Humagne blanc	3	1	
	1	1	Lafnetscha
Klepferelsässer	1	1	Elbling[1]
Lady Downes Seedling	2	2	Trollinger
Lafnetscha	1	1	Gouais bl. / Heunisch w.
	1	1	Heida
	3	1	Completer
Landot	1	1	Chasselas
Léon Millot	1	1	Maréchal Foch
Magliasina	1	1	Isabella
Maréchal Foch	1	1	Millot Foch
Muskateller rot	1	1	Silvaner
Erlenbacher Schwarz	1	1	Traminer
Roter Königsgutedel	1	1	Carminoir[2]
Seibel 13053	1	1	Chasselas
Triumph vom Elsass	1	1	Maréchal Foch
Viognier	1	1	Cornalin du Valais
Unknown cultivars, identified with database			
„Alte Rebe“	1	1	Cornalin du Valais
„Di 1“	1	1	Balsamina nera
„Di rot“	1	1	Gutedel rot
„Di blau“	1	1	Seibel 13053
„Grobe aus A“	1	1	Elbling rot
„Kü A“	1	1	Heida
„Kü B“	1	1	Muscat bl. à p.g.
„Kü C“	1	1	Heunisch weiss
„Kü D“	1	1	Barbrassa[2]
„Kü E + F“	1	1	Maréchal Foch
„Zen weiss“	1	1	Humagne blanc
„Zen rot“	1	1	Léon Millot
Falsely or unnamed, unidentified cultivars			
„Sherlock“	1	1	No identical profile
„Findling Muhen“	1	1	No identical profile

[1] These names might be synonyms, [2] identification J. Vouillamoz, pers. comm.

only one or a few types could be analyzed, the true-to-typeness is supposed, but will have to be confirmed by analyzing more types. Two known synonym groups (’Heida’ / ’Savagnin blanc’ / ’Paÿen’ / ’Weisser Traminer’ and ’Heunisch weiss’ / ’Gwäss’ / ’Gouais blanc’) were confirmed with types from four and five collection sites, respectively. For five cultivars bred by Agroscope ACW Changins (’Charmont’, ’Doral’, ’Diolinoir’, ’Gamaret’ and ’Garanoir’), a genetic profile was established. These profiles can be added to the identification files of the cultivars. A unique profile was determined for several historical Swiss cultivars.

Finding the true-to-type profile for rare cultivars sometimes turned out to be difficult. Historical cultivars are often only grown at one or a few sites or originate all from the same site. Both types of ’Eyholzer rot’ from the cultivar collections in Frümsen and Au were misnamed and turned out to be ’Completer’ and ’Doral’, respectively. Only the two types from a vineyard in Valais and the cultivar collection of Agroscope ACW Changins, Pully, showed the same profile which was unique and therefore was assigned the true-to-type profile. ’Ancellotta’, from two different collection sites (collected from a vineyard and a nursery, respectively), is a cultivar that had been introduced by Agroscope ACW Changins from Italy, showed two false profiles. One turned out to be ’Diolinoir’, while the other was a ’Cabernet Franc’.

We were not able to clearly assign the genetic profile of all cultivars. Of six types of ’Äugstler weiss’ from three type sites (Au, Agroscope ACW Wädenswil and Frümsen), none could be assigned a typical profile. One type of ’Äugstler weiss’ was identical to ’Scheurebe’, and five were identical to ’Madeleine Angevine’. This suggests that ’Äugstler weiss’ is not a unique cultivar, but might be a synonym of ’Madeleine Angevine’. Another possibility is that the types of ’Äugstler weiss’ found so far in Switzerland originated from one plant that was confused with a ’Madeleine Angevine’ in the past. In the case of ’Gänsfüsser’, we had two types with two different, unique profiles. According to the experience of a versed ampelographer, the ’Gänsfüsser’ in the cultivar collection Au is the true-to-type one. It was also identical with ’Argant’. The „false“ ’Gänsfüsser’ turned out to be identical to ’Douce Noire’ (J. VOUILLAMOZ, pers. comm.).

Tab. 4: Profiles of grape cultivars found in Switzerland, analyzed at 6 or 12 microsatellite marker sites, respectively.

Cultivar name	Acc/ sites[1]	True-to-typeness[2]	Comments	VVS2		VVMD5		VVMD7		VVMD27		VrZAG62		VrZAG79		VVS4		VVMD6		VVMD8		VrZAG21		VrZAG67		VrZAG112	
Amigne	2/2	AB	Old CH, VS	131	131	223	231	241	255	178	188	188	194	248	250	172	174	199	206	137	152	199	205	124	137	228	241
Arvine (Petite)	3/3	AB	Old CH, VS	131	150	235	235	255	261	184	188	194	194	238	250	167	172	206	208	135	135	190	199	124	137	228	241
Arvine Grande	1	AD	Old CH, VS	131	131	223	235	245	255	184	188	194	194	250	250												
Balsamina nera	2/2	C		123	154	225	249	241	249	184	207	188	190	244	258												
Bondola nera	5/5																										
Briegler	10/5	AB	**Syn-new**	131	135	223	235	237	237	188	188	188	194	246	250	174	174	199	206	137	137	199	201	151	153	233	241
Charmont	2/2	AB	CreationACW	131	135	225	235	241	245	184	188	188	204	244	250	167	167	199	206	135	137	199	205	151	151	239	239
Doral	3/3	AB	CreationACW	131	141	225	235	241	245	180	188	188	204	242	258	167	172	199	206	137	141	199	199	151	151	239	239
Diolinoir	4/4	AB	CreationACW	131	135	225	229	237	247	184	188	194	200	238	258	167	172	199	206	135	135	199	201	151	162	239	241
Elbling blau	3/2	C		135	150	225	235	237	247	184	188	194	204	238	244	167	174	199	199	135	141	199	199	137	151	239	239
Elbling rot/weiss	5/4	AB		141	150	235	237	247	255	178	188	194	204	236	244	167	174	199	208	135	141	199	205	137	148	239	239
Erlenbacher Schwarz (W)	2/2	CD		135	154	225	235	233	237	184	188	188	194	238	244												
Ermitage, syn. Marzanne	1	A		131	131	223	229	237	251	188	190	196	200	244	250	167	174	206	208	137	137	190	199	137	151	228	235
Eyholzer Roter	2/2	BC		131	154	229	229	237	245	188	188	194	194	246	250	167	174	208	208	135	137	190	205	124	124	239	241
Gamaret B13	2/2	AB	CreationACW	131	150	225	231	237	255	180	180	194	194	242	258	167	167	189	199	137	137	199	199	137	148	239	239
Gamay	2/2	AB		131	135	231	235	237	247	180	188	194	204	242	244	167	172	199	208	137	141	199	205	137	151	239	239
Gänsfüsser, syn. Argant	3/2	AB		131	141	223	225	251	253	178	192	192	204	250	254	167	174	189	206	137	141	199	199	148	148	228	233
Garanoir B28	1	AB	CreationACW	135	150	225	235	247	255	180	188	194	194	244	244												
Heida	2/2																										
Savagnin blanc/ Païen	1	AB	Syn	150	150	229	235	241	255	188	188	188	194	244	250	167	174	199	206	135	137	199	205	124	130	233	239
Traminer weiss	1																										
Heunisch Blau/ noir	2/2	AB		137	150	223	235	241	251	178	190	188	200	244	248	166	166	206	208	135	137	194	199	151	151	228	233
Heunisch weiss	1																										
Heunisch dreifarbig	1																										
Gwäss	2/2	AB	Syn	131	141	231	237	237	247	178	180	196	204	236	242	167	167	189	208	135	141	201	205	137	137	239	241
Gouais blanc	1																										
Hitzkircher	4/3																										
Erlenbacher Schwarz (E)	4/2	B	**Syn-new**	135	154	223	229	237	237	184	188	188	194	244	246	167	174	199	206	135	137	190	199	148	151	233	241
Madera	1	D		121	127	231	235	241	241	**176**	184	188	206	238	**266**												
Mörchel	3/2	C																									
Trollinger	1	A	**Syn-new**	133	154	233	235	245	245	180	184	192	194	238	258	167	167	206	208	162	162	201	205	137	153	228	239
Räuschling rot/weiss	6/3	AB		141	150	231	235	241	247	180	188	188	204	242	244	167	167	206	208	137	141	205	205	124	137	239	241
Rèze	2/2	AB	Old CH, VS	131	131	223	225	245	247	184	188	194	200	246	250	168	174	206	208	137	137	190	201	124	151	239	261
Thuner blau, syn.	3/2	BC		131	150	223	229	249	255	178	188	194	200	246	250	166	174	199	208	135	137	199	201	124	124	228	228
Peloursin																											
Uccellina nera	2/2	CD		131	144	231	237	237	**263**	180	205	196	200	242	254	168	186	189	204	181	181	205	209	124	162	233	242

[1] Acc/sites: number of plant accessions and number of sites where samples were collected

[2] Categories of true-to-typeness:
A: true-to-type, based on literature / confirmed origin/ compared to international database (J. Vouillamoz, pers. comm.)
B: true-to-type, based on repeats of several accessions/sites
C: supposed true-to-type, only few accessions are available
D: supposed true-to-type, but more repeats are necessary

Syn: known Synonyms; **Syn-new**: new proposed Synonyms; Creation ACW: cultivars bred by Agroscope ACW Changins
Old CH, VS: old Swiss cultivar from the canton of Valais; E: Eastern Switzerland; W: Western Switzerland
Numbers in bold: rarely found allele lenghts.

New synonyms

Several new synonyms were found among the analyzed cultivars. All cultivars named 'Hitzkircher' (four types) showed the same profiles as 'Erlenbacher Schwarz' collected in Eastern Switzerland (four types). Later, two 'Erlenbacher Schwarz' with a different profile were collected in Western Switzerland.

Four of six markers were identical, and one of them hetero- and homozygous, respectively. There are two possible explanations for this: 1) 'Hitzkircher' and 'Erlenbacher Schwarz' are synonyms for the same cultivar, and the type from Western Switzer-

land is incorrectly named; or 2) The profile of the type from Western Switzerland belongs to the true-to-type cultivar of 'Erlenbacher Schwarz', while in Eastern Switzerland, an error was made and 'Hitzkircher' plants are falsely named 'Erlenbacher Schwarz'. Hitzkirch and Erlenbach are two villages in German speaking Switzerland, one at the lake of Baldegg, Luzern, the other at the lake of Zürich. Little is known about their grapes and whether these two cultivars could have anything to do with each other historically. The grape cultivar might simply have been given a different name at two different growing sites. According to AEBERHARD (2005), only very few plantings of 'Hitzkircher' still exist. In his own private collection, he grows a plant originally purchased from H. Zulauf sen., Schinznach. This plant is also called 'Grosser blauer Mörsch'. The cultivar 'Hitzkircher' had been described by H. ZULAUF sen. as very resistant to downy mildew (*Plasmopara viticola*) (AEBERHARD, 2005) and might be of interest as a genetic resource for disease resistance breeding.

Another synonym is proposed for 'Briegler' and 'Bondola nera'. All ten 'Briegler' and five 'Bondola nera' types analyzed showed the same profile. According to the identification plate in the historical garden in Au, it was supposed that 'Briegler' and 'Hitzkircher' were synonyms, which can be clearly denied based on our results. 'Briegler' may be the German name of 'Bondola nera', a red grape cultivar from Tessin in the southern part of Switzerland, which was grown widely in ancient times (HILLEBRAND et al., 1998). 'Briegler' is neither identical to 'Balsamina nera' nor to 'Ancellotta', as suggested by ampelographic similarities and found in old literature (AEBERHARD, 2005). A unique genetic profile was determined for 'Thuner blau', different from the profiles of 'Heunisch Blau', and 'Hitzkircher' as was already mentioned by AEBERHARD (2005). 'Thuner blau' is not mentioned in any ampelography nor in the global grapevine cultivar register from Geilweilerhof. The comparison with an international database suggested a synonymy with 'Peloursin' (VOUILLAMOZ, pers. comm.). Unfortunately, only one type site is known at the historical garden in Au.

A rare cultivar named 'Mörchel' was located by the founder of the cultivar collection Au, W. EGGENBERGER. Comparison of the genetic profile in this study showed that it has the same profile as true-to-type 'Trollinger' (VOUILLAMOZ, pers. comm.). This result was verified based on ampelographical comparison by Spring from Agroscope ACW Changins (pers. comm.). 'Trollinger' is also a synonym of 'Schiava Grossa', 'Gross-Vernatsch', and 'Frankenthal noir' (HILLEBRAND et al., 1998). The only original Swiss planting of 'Mörchel' is the one at Au (AEBERHARD, 2005).

According to AEBERHARD (2005), the 'Räuschling rot' is an ampelographic rarity, not included in any ampelography nor in any foreign cultivar collection. In the ampelographic descriptions, the plants are identical with the 'Räuschling weiss', except for the pink grapes. As expected, the genetic profile of 'Räuschling rot' is identical to the one of 'Räuschling weiss'. These plants are berry color mutants, identical cultivars except for the berry color. The same situation applies to 'Elbling rot' and 'Elbling weiss', as well as for 'Heunisch weiss' and 'Heunisch dreifarbig'. But, in several other cases, cultivars with the same name and different berry colors turned out to be different cultivars. This applies to 'Bondola bianca', 'Elbling blau' and 'Heunisch blau'. A rare plant from a vineyard in Tessin called 'Bondola bianca' showed a different profile to 'Bondola nera'. 'Elbling blau' and 'Heunisch blau' both showed a unique profile, not identical to 'Elbling rot/weiss' or 'Heunisch weiss', respectively. This result confirms the known fact that these cultivars are not berry color mutants to the 'Elbling' and 'Heunisch'. The profile for 'Heunisch blau' established in our study showed the same profile as 'Heunisch noir' in the database of VOUILLAMOZ (pers. comm.) and also 'Heunisch schwarz' from Germany (JUNG, pers. comm.).

Based on these data we propose 'Bondola nera' - 'Briegler' to be synonyms. The few plants of 'Mörchel' of one type site studied here might be either misnamed, or 'Mörchel' and 'Trollinger' are synonyms. The same situation applies to 'Weisser Äugstler' - 'Madeleine Angevine'. In the case of 'Hitzkircher' - 'Erlenbacher Schwarz' there might have been a confusion of cultivars in the Eastern part of Switzerland ('Hitzkircher' cultivars falsely named 'Erlenbacher'). Further studies are necessary to decide synonymy or true-to-typeness of 'Erlenbacher Schwarz'. 'Hitzkircher' and 'Grosser blauer Mörsch' seem to be local names of the cultivar 'Grossblau' (AEBERHARD, 2005); other synonyms such as 'Urbanitraube', 'Volovina', 'Kriecher' are proposed by the same author. According to these results, the synonym 'Gänsfüsser' - 'Erlenbacher' (proposed by AMBROSI et al., 1994) must be rejected. The synonym 'Gänsfüsser' - 'Argant' was confirmed.

Tab. 5: Profiles of Chasselas and the Muscat groups at 6 microsatellite marker sites, comparison to literature profiles and synonymous names.

Cultivar name (Synonyms)	Identical profiles[1]	VVS2		VVMD5		VVMD7		VVMD27		VrZAG62		VrZAG79	
Chasselas/Gutedel (1)		131	141	225	233	237	245	184	188	194	204	250	258
Muscat blanc a.p.g. (2)	Moscato bianco	131	131	225	233	231	247	178	192	186	196	250	254
Moscato giallo (3)	Moscato giallo	131	141	225	237	237	247	178	178	186	188	248	254
Muscat Ottonel	Muscat Ottonel	131	141	225	225	237	241	178	188	188	194	254	258
Muscat bleu	None	141	148	223	235	235	247	188	188	180	186	254	260
Muscat précoce de Gordola	None	133	150	225	233	237	247	178	184	186	194	238	254
Muscat Olivier	None	133	154	223	233	245	247	178	180	204	204	250	254
Muskateller weissgelber	None	131	133	223	235	231	241	180	184	188	196	238	258
Muskat New York	None	121	133	235	235	233	247	184	184	186	202	238	264

[1] Compared to profiles in CRESPAN and MILANI (2001)

Synynoms (or cultivars with identical profiles) are:

(1) **Chasselas/Gutedel**: Gutedel roter, Kracher Gutedel, Gutedel Malaga, Diamant Gutedel, Chasselas aus Siebenbürgen, Gutedel Schweiz, Weisser Gutedel (100j Stock Meissen), Roter Gutedel (100j Stock Meissen) (collection Gutedelgarten Badenweiler, Germany). Chasselas rouge, Chasselas violet, Chasselas graurot, Chasselas noir, Chasselas rosé royal (cultivar collection Pully, Agroscope ACW). Gutedel violet, Chasselas de Fontainebleau, Musqué Richter, Muskatgutedel (cultivar collection Frümsen). Königsgutedel, Chasselas Musqué (cultivar collection Au).

(2) **Muscat blanc a petits grains**: Muskateller roter, Muscat du Valais, Moscato bianco (cultivar collection Au). Moscato di Canelli (private collection). Muscat rosé, Muskateller violett, Muscat rouge a petits grains (cultivar collection Frümsen).

(3) **Moscato giallo**: Muscat vert, Muscat du pays (cultivar collection Pully, Agroscope ACW).

Interesting alleles

In two of the analyzed cultivars, we found special alleles. One was 'Madera', which shows a 176 bp long allele at VVMD27. This allele was not found in any other cultivar profile so far, yet is not included in the standard reference alleles proposed by THIS et al. (2004). According to the coding proposed in that study, this allele would be n+2 for VVMD27. The other cultivar with a special allele, 'Uccellina nera', showed a rare allele at the marker VVMD7, with a length of 263 bp. This allele is the largest found in the standard set of alleles for this marker (VVMD7, n+34) and was found in the two rootstock cultivars 'Kober 5BB' and 'Teleki 5C' (THIS et al., 2004). The rootstock cultivars 'Kober 5BB' and 'Teleki 5C' are crosses between *Vitis berlandieri* and *Vitis riparia*. Morphologically it is obvious that 'Madera' and 'Uccellina nera' do not belong to the *Vitis vinifera* species, but are interspecific crosses of unknown origin. Our results indicate that 'Uccellina nera' from Tessin is not the same cultivar as the one from Italy, which belongs to *Vitis vinifera*.

Chasselas and Muscat group

In the Chasselas and the Muscat group, we found nine different profiles (Table 5). The Muscat profiles were compared to the profiles in CRESPAN and MILANI (2001), and three matches with literature were found. Most of the cultivars named 'Chasselas', 'Gutedel' or a combined name, belong to the Chasselas profile. These include (local names): 'Roter Gutedel Freiburg', 'Kracher Gutedel', 'Gutedel Malaga', 'Diamant Gutedel', 'Chasselas' aus Siebenbürgen, 'Chasselas noir', 'Chasselas Musqué', 'Gutedel Schweiz', 'Weisser Gutedel' (100jähriger Stock, Meissen), 'Roter Gutedel' (100jähriger Stock, Meissen), 'Chasselas rouge', 'Chasselas violet', 'Chasselas graurot', 'Chasselas rosé royal', 'Chasselas de Fontainebleau'. Another group profile was that of 'Muscat Ottonel', also found in the Chasselas collection. Interestingly, two of the 'Muskat Gutedel' showed the same profile as 'Muscat Ottonel' ('Muskat Gutedel Eg' and 'Muskat Gutedel FR'), while 'Musqué Richter' and 'Muskat Gutedel' from cultivar collection Frümsen showed the same profile as 'Chasselas'. Morphologically, 'Muskat Gutedel' is very similar to 'Muscat Ottonel' and therefore can easily be confused. So, the two 'Muskat Gutedel' must be correctly named 'Muscat Ottonel'. Within the Muscats, another profile was the one of 'Muscat blanc à petits grains'. Synonyms in Switzerland were found: 'Moscato bianco', 'Moscato di Canelli', 'Muscat du Valais', 'Muscat rosé', 'Muskateller roter' and 'Muskateller violetter'. Another Muscat found in Valais, called 'Muscat du pays' or 'Muscat vert', was found to be a 'Moscato giallo', identical to the profile of CRESPAN and MILANI (2001). Five more cultivars, 'Muscat bleu', 'Muscat précoce de Gordola', 'Muscat Olivier', 'Muskateller weissgelber' and 'Muskat New York', each had an individual profile not found elsewhere in our database.

Together with the University of Neuchatel, our research institute is working on a microsatellite characterization of all Swiss cultivars. The complete database comprising genetic profiles of Swiss cultivars is availa-

ble on the internet (http://www.unine.ch/nccr/svmd). Identification of Swiss grapevine cultivars, especially all the autochthonous and typical cultivars, is far from being completed. Of all errors in naming grapevines, the most severe are the ones in cultivar collections, since they represent standard plants for ampelographers as well as for establishing genetic profiles. Continuing efforts for correct cultivar identification and quality control are therefore imperative.

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