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Vitis International Variety Catalogue (*V*IVC): A cultivar database referenced by genetic profiles and morphology

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Abstract. The establishment of the *Vitis* International Variety Catalogue (*V*IVC) dates back to 1984. The idea was to virtually assemble all accessions maintained in the worldwide existing collections to face genetic erosion. In many cases synonymy, homonymy and misnaming hampered the clear assignment of cultivars/accessions to prime names. In the past 15 years nuclear microsatellites, in particular the nine SSR-markers VVS2, VVMD5, VVMD7, VVMD25, VVMD27, VVMD28, VVMD32, VrZAG62 and VrZAG79 were extensively applied for cultivar recognition in combination with ampelography. Genetic fingerprints of more than 15,000 cultivars/accessions were collected. They were taken from more than 300 articles and from microsatellite databases on the web. Allele sizes were adapted according to own internal reference varieties. Comparison of profiles revealed new identities like: “Corbeau” = “Sevilhao”, “Gragnelut” = “Fer”, “Beretinjak” = “Bianco d’Alessano”. The activities aim to equip the prime names of *V*IVC with reliable genetic profiles combined with the validation of their identity by ampelography. Fingerprints from 1,500 cultivars were already uploaded in *V*IVC. Two distinct search modules were implemented: “Microsatellites by varieties” and “Microsatellites by profiles”. The implementation assists the management of grapevine genetic resources, e.g. trueness to type assessment in grapevine collections and serves research and breeding.

1. Introduction

Archaeological remains highly support domestication of grapevine in the Near East about 7000 years ago [1]. In the following millenaries the vegetatively propagated grape cultivars reached new areas mainly due to migration, the development of trade routes and the colonization of Western Europe by Phoenicians, Greeks and Romans. Cultivars known from antiquity were named for example after locations (e.g. “Graecula” and "Pompejana”), tribes (e.g. “Allobrogica”, “Biturica” and “Raetica”) or according to special aptitudes (e.g. “Bumasti”, “Dactylides”, “Duracina”, “Oleaginea”) [2–4], [Pline H.N. XIV]. Many of the numerous denominations remained unexplained. Often on their way to the new destinations the cultivars changed their names [Columella, 3,2,30]. Already in ancient times homonymy existed. For example five different “Apiana” and two distinct “Aminea” and “Nomentana” cultivars were described. Synonyms were documented as well, e.g. “Balisca” = “Coccolubis” and “Vennuncula” = “Surcula” = “Scapula” = “Numisiana” [3], [Pline H.N. XIV]. In the following centuries many new grape cultivars were created [Pline H.N. XIV]. This occurred either via secondary domestication by introgression of local *Vitis sylvestris* into the introduced varieties [5,6] to obtain genotypes with better adaptation to local growing conditions or by crossings within the cultivated grapevines. A huge number of synonyms, homonyms and misnomers arose due to the long period of cultivation and intense exchange, e.g. by trade and pilgrims, between monasteries and growing areas or by order of authorities. Oral dissimination of names and probably lack of appropriate labeling possibilities increased that phenomenon. Due to the large anthropogenic spread of grapevines it is difficult and usually impossible to retrace the true derivation of their names [7,8].

When the *Vitis* International Variety Catalogue (*V*IVC) was setup in 1984 synonymy, homonymy and misnaming turned out to be a major challenge. The objective of implementing the database was to document *Vitis* species, cultivars and clones maintained in the worldwide existing grapevine collections, as recommended by OIV resolution N° 2/82: “Collection and conservation of the genetic resources of *Vitis* ssp.“ [9]. On the basis of this inventory safeguarding of endangered germplasm was thought to become feasible via international cooperation between gene banks. Passport data (e.g. berry color, origin of the cultivar, *Vitis* species and utilization) were gathered from bibliography and from collection catalogues. To each cultivar/breeding line a variety number was attributed and a prime name was chosen according to predefined principles [9]. Assignment of cultivar names to prime names in *V*IVC was carried out (1) with the help of all the synonyms mentioned in ampelographic literature respectively collection catalogues and (2) by consulting ampelographic descriptions, drawings and photos illustrating the cultivars morphology. But confusing synonymy and homonymy sometimes hampered the clear assignment of a cultivar or an accession to a prime name [8]. For example because of homonymy and false synonyms it happened that two different cultivars were registered under only one prime name. This could at the worst induce genetic erosion as in many collections identical genotypes are sorted out. On the other hand sometimes non referenced accession names which were not found elsewhere later turned out to be synonyms and not unique cultivars. Misnaming in grapevine

repositories which is estimated at 5–10% [10] was another reason for erroneous assignment to prime names.

In the last two decades cultivar recognition was revolutionized by nuclear microsatellite (SSR) analysis [11], which was used in combination with ampelography. The breakthrough came along with the recommendation of a consortium of the EU-project GrapeGen06 defining a set of SSR markers for variety identification and the widely use by the grapevine community of at least the nine proposed SSR-markers VVS2, VVMD5, VVMD7, VVMD25, VVMD27, VVMD28, VVMD32, VrZAG62 and VrZAG79 to make genetic profiles comparable [12,13]. These markers proved to be efficient to sort out grapevine collections [14], to identify identical cultivars grown under different names in neighboring countries, indicating cultivar migration over long distances [15–17] and to revise official national variety lists [18,19].

The two tools SSR analysis and ampelography crystallized to be most appropriate to revise *V*IVC records. Therefore the published SSR-marker data were collected, standardized by reference varieties and compared with fingerprints of the European *Vitis* Database and fingerprints generated at the JKI Institute for Grapevine Breeding Geilweilerhof. Besides already published identities, further cultivar matches were found like: “Corbeau" = “Turca” = “Serbina” = “Douce noire" [20] = “Sevilhao”, “Gragnelut” = “Fer”, “Beretinjak” = “Bianco d’Alessano”, Mostosa = Trbjan = Kuk = Biancame and many others.

Two search modules were implemented in *V*IVC, “Microsatellites by varieties” and “Microsatellites by profiles” to retrieve the genetic profiles of prime names and to search the identity of accessions/cultivars via allele sizes, respectively. Currently fingerprints of more than 1,500 cultivars are available. The long-term objective is to link the prime names in *V*IVC with genetic profiles combined with the validation of the prime names by descriptions and pictures.

The recognition of cultivars by the tools described is highly valuable for the management of grapevine genetic resources, e.g. trueness to type assessment in grapevine collections, identification of synonyms, homonyms and misnomers and useful for the preservation of rare and unique genotypes. In addition reliable cultivar names are essential for research, breeding and the exchange of plant material.

2. Material and methods

The nine GrapeGen06-markers VVS2, VVMD5, VVMD7, VVMD25, VVMD27, VVMD28, VVMD32, VrZAG62 and VrZAG79 [14,21] were used in this study. SSR-marker data were taken from more than 300 articles (`http://www.vivc.de/searchBibliography/dbBibliography.php?retval=3600`), which were published since the beginning of the 21st century, including about 8,500 genetic profiles of mainly *Vitis vinifera* L. subsp. *vinifera* cultivars/accessions. National microsatellite databases on the web (`http://www.vivc.de/default.php?value=400`) provided 2,500 molecular fingerprints. The European *Vitis* Database (www.eu-vitis.de) [22] accounted for 4,300 profiles and the JKI Institute for Grapevine Breeding Geilweilerhof (`http://www.vivc.de/searchMicrosatellitesVar/dbMicrosatVar.php?retval=4400`) contributed SSR-marker data from 2,200 cultivars/accessions. Allele sizes of the nine markers from each individual data source were adapted according to own internal reference varieties and compiled in one excel table. Comparison of genetic profiles was carried out by sorting either according to prime names, accession names or allele sizes of the markers.

The use of identification software turned out to be not suited because (1) of missing data since in many publications not the complete set of the nine markers was used and (2) data sources provided different accuracy. Acceptance of one or two mismatches in the software often yielded abundant fingerprints and resulted in time consuming comparison of allele sizes and (3) of the high number of profiles in one data file. Thus the sorting, e.g. by markers and allele sizes and a repeated reordering of markers yielded more matches.

Ampelographies, cultivar specific publications containing cultivar descriptions and images in the various web databases (`http://www.vivc.de/default.php?value=400`) were used to check the results of genetic profile comparison. All the investigated bibliography is retrievable via (http://`www.vivc.de/searchBibliography/dbBibliography.php?retval=3600`).

3. Results and discussion

Effective germplasm management in grapevine repositories relies on trueness to type assessment and aims at safeguarding of unique genotypes. That perspective in mind and projects funded by the European Commission and Bioversity paved the way even for a large and comprehensive transnational cooperation [13,23] In the same context the idea of “A European Genebank Integrated System” (AEGIS – `www.ecpgr.cgiar.org/aegis`) developed by the “European Cooperative Program for Plant Genetic Resources” (ECPGR) was launched to share responsibilities between repositories and to coordinate joint germplasm maintenance. For that ambitious purpose it is essential to determine the identity of accessions conserved in the European grapevine collections.

Nuclear microsatellite analysis complemented by ampelography is a powerful tool to reach that goal. In the scope of two European projects it was demonstrated via a broad investigation that the SSR-fragment sizes are comparable independent of the laboratories protocols and conditions. Prerequisite is the adaptation of allele sizes according to reference cultivars [12]. In the past 15 years about 17,500 genetic profiles including the nine GrapeGen06 markers were gathered and standardized. Sorting of the data by prime names, accession names, markers and allele sizes provided corresponding profiles. Until now for about 2,200 cultivars matching fragment sizes were found from which 1,500 were uploaded in *V*IVC. Data viewing and comparison is still ongoing. The number of unique fingerprints existing in the data set will be determined in a second step. The latter is important to initiate duplicate preservation of original and rare genotypes.

Allelic data comparison revealed three different cases, according to the findings in COST Action FA1003 [23]:

- identical fingerprints and corresponding accession/prime names. In this ideal case the cultivars identity was confirmed, provided the genotyped material

derived from distinct sources. In consequence the fingerprint was registered in *V*IVC and assigned to the corresponding prime name.

- identical fingerprints and different accession/prime names. Here the true designation needed to be figured out. Synonyms respectively misnomers had to be determined. Helpful indications on synonymy were found in the European *Vitis* Database. If available, ampelographic descriptions and images were consulted to validate the findings. In the last years fingerprint comparison studies were intensified. Since then more than 400 prime names in *V*IVC revealed to match with other prime names and were thus merged. The decision on the name to be kept as a prime name in *V*IVC was done according to historical references. The denomination used in the presumed country of origin of the cultivar was given priority. In unclear cases curators of grapevine collections were asked to assist. Mutants carrying a distinct name were taken into consideration.
- distinct fingerprints and corresponding accession/prime names. In these cases it had to be determined (a) which of the two or more fingerprints belonged to the true to type genotype, (b) which of the names were true homonyms and (c) which were misnomers. This was possible in cases for which fingerprints from further sources and ampelographic information were available. Occasionally new prime names had to be generated. For example two distinct cultivars were registered in *V*IVC under the prime name "Plavay": the more diffused Romanian "Plavay" and the minor cultivar "Plavec Zuti". Because they shared many synonyms they were considered as one and the same cultivar. Differences in the genetic fingerprints [24,25] pointed to their distinctness and entailed their separation.

In the last two examples sampling errors were further possible reasons for confusion.

3.1. Synonyms

Since the creation of *V*IVC synonyms were registered. They were collected from ampelographies, articles about cultivar identification by SSR-analysis (`http://www.vivc.de/searchBibliography/dbBibliography.php?retval=3600`) and transmitted by curators of grapevine collections. It turned out that in particular ancient and widely grown grape cultivars displayed the highest number of synonyms. This was partly due to the multitude of alternative spellings. This fact is explained here for "Pinot Noir" the cultivar with 315 synonyms registered in *V*IVC. Pinot itself is also spelled Pino or Pineau and these denominations were found in bibliography with all kind of combinations like blauer, cernii, chernyi, corni, crni, negru, nero, noir and schwarzer for the black berry color. Interestingly "Pinot Noir" was named in several languages the "black" ("Blauer", "Cherna", "Noirien", "Roter", "Schwarzer", "Tinto"), most likely pointing to the fact that Pinot noir was in some regions for a long time the only existing cultivar with black berries [26]. All these slightly differing spellings were recorded to allow retrieval of prime names, also independent of languages and transliterations. For some prime names the number of synonyms is shown in Table 1. Due to merging of prime names the number of synonyms increased enormously. This was stated in particular for cultivars that migrated over long distances like for Muscat à "Petits Grains Blancs", "Heunisch Weiss", "Sultanina", "Dodrelyabi" and "Malvasia di Sardegna". Examples for synonymies detected via the comparison of the 17,500 genetic profiles are given in Table 2. In most of the cases neighboring countries shared the same cultivars like Moldavia and Romania, the Balkan and Italy, Spain and Portugal. Several French cultivars had moved to Portugal. Interestingly the denominations turned out to be rather distinct. They were not simple translations, thus indicating that migration or just relocation produced completely new names. For example "Rayada Melonera" from Spain (translation = striped melon) [27,28] revealed to be the same as "Corropio" [29,30] from Portugal. A painting of "Melonera" from the beginning of the 19th century [31] (Fig. 1) and a photograph of "Corropio" (Fig. 2) [32] illustrate the extraordinary striped phenomenon of the berry, which served as an ampelographic proof for the identity of the two variants of the same cultivar. In this case the name of the cultivar can be traced back and is self-explanatory. It refers to its striking berry characteristic.

Table 1. Number of synonyms of old and widespread grapevine cultivars (source: *V*IVC April 2015).

***V*IVC variety number**	**Prime name**	**Number of synonyms per prime name**
9279	Pinot noir N	317
2473	Chasselas Blanc B	314
8193	Muscat a Petits Grains Blancs B	304
122	Afus Ali B	219
5374	Heunisch Weiss B	213
8241	Muscat of Alexandria B	200
12609	Gewuerztraminer RG	184
12051	Sultanina B	143
12628	Trebbiano Toscano B	129
4461	Garnacha Tinta N	127
2455	Chardonnay Blanc B	125
3616	Dodrelyabi N	123
9553	Plavay B	115
13186	Vulpea N	108
5648	Cayetana Blanca B	94
8075	Mostosa B	88
2742	Siria B	86
259	Aleatico N	72
7266	Malvasia di Sardegna B	58

Table 2. Examples for synonymous prime names detected in *V*IVC via comparison of 17,500 fingerprints.

Maintained prime name, berry color (country of origin), *V*IVC variety number	**Matching prime name, considered as synonym**
Asswad Karech N (LBN) 12125	Mijajusa (HRV)
Aubun N (FRA) 761	Castelino (PRT)
Bombino Bianco San Severo B (ITA) 24748	Trebbiano Abruzzese (ITA)
Bouboulenc B (FRA) 1612	Pe Comprido (PRT)
Brun Fourca N (FRA) 1707	Tinto Gallego (ESP)
Camaraou Noir N (FRA) 2017	Couxo (ESP) = Caino Redondo (ESP)
Catawba RG (USA) 2340	Catalan Roxo (ESP)
Cayetana Blanca B (ESP) 5648	Sarigo (PRT)
Corbeau Noir N (FRA) 2826	Sevilhao (PRT)
Docal Tinto N (PRT) 3612	Cascon/Courbillon (ESP)
Durif N (FRA) 3738	Mondet (PRT)
Famoso B (ITA) 23019	Rambella (ITA)
Fer N (FRA) 4085	Gragnelut (ITA)
Flot Rouge N (FRA) 4164	Folla Redonda (ESP)
Folgasao B (PRT) 4178	Cagarrizo (ESP)
Folha de Figueira B (PRT) 14142	Prieto Picudo Blanco (ESP)
Grec rouge RG (FRA) 4962	Rabigato Franco (PRT)
Ives N (USA) 5592	Bordo (BRA)
Kosinjot N (ALB) 23808	Servin Cernyi (?)
Manseng Noir N (FRA) 7340	Espadeiro Mole (PRT)
Molar N (PRT) 15678	Verdejo Negro (ESP)
Mondeuse Noire N (FRA) 7921	Rodo (PRT)
Mostosa B (ITA) 8075	Marastina omis (HRV) = Trbjan (SRB)
Naparo RS (ESP) 8345	Alicante Rose (PRT)
Nehelescol B (ISR) 8467	Promissao (PRT)
Pecsi Szagos B (HUN) 9075	Misket Vratchanskii (BGR)
Peloursin N (FRA) 9107	Tinta Penajoia (PRT)
Perdea B (FRA) 9142	Blanc de Saillon (CHE)
Piccola Nera N (ITA) 9235	Malocrn/Gnjet (SVN)
Plavay B (MDA) 9553	Sghigarda (ROM)
Rayada Melonera N (ESP) 7617	Corropio (PRT)
Schuyler N (USA) 10835	Glorie Boskoop (NDL)
Taylor B (USA) 12889	Melonentraube (?)
Tamjanika crna N (BAL) 15936	Moscato rosa (ITA)
Trincadeira das Pratas B (PRT) 15688	Allaren (ESP)
Tsitsa Caprei B (MDA) 16449	Cilibarca (SRB)
Uva Crova N (ITA) 24563	Carraresa rada (ITA)

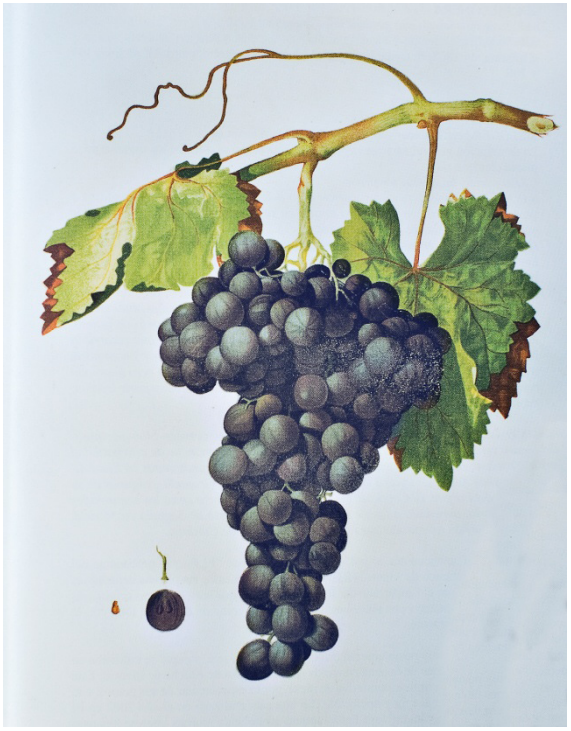

Figure 1. Melonera (prime name "Rayada Melonera") described for Andalucia/Spain by Simón de Rojas Clemente y Rubio in 1807 [31]. The painting displays the characteristic stripes on the berries.

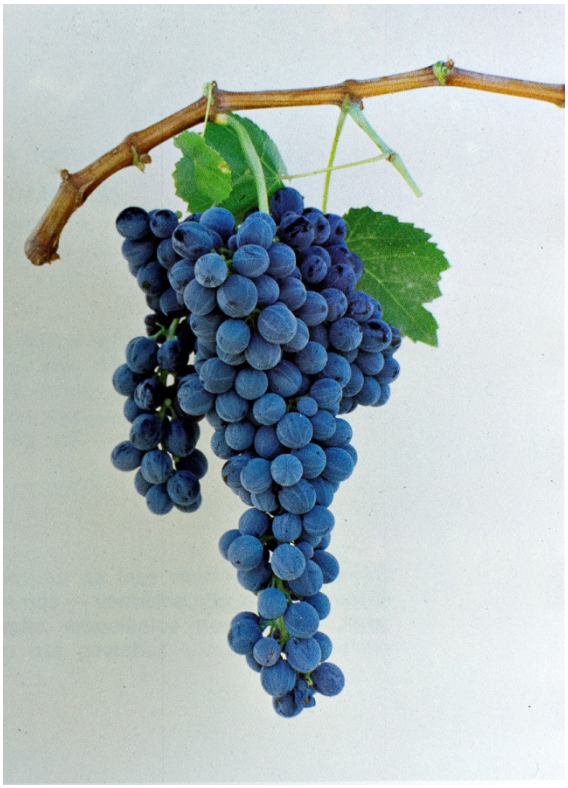

Figure 2. Corropio (prime name "Rayada Melonera") cultivated in Alentejo/Portugal [32]. The photo shows grey stripes on blue berries.

3.2. Homonyms

If the same name is used for different varieties they are called homonyms. An extreme example represents "Boal". In the *V*IVC "Boal" is recorded for seven prime names. In combination with further designations like "Boal Bonifacio", "Boal Branco", "Boal Cachudo", etc. this name is registered for further twenty-six prime names. For the *V*IVC that confusing situation was clarified by the use of genetic fingerprints insofar as the *V*IVC prime names could be distinguished and synonyms reorganized.

Another example is the Italian "Trebbiano Abruzesse", which was registered in *V*IVC as a synonym of "Bombino Bianco". The profile of the accession "Trebbiano Abruzesse" maintained in Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente (SAFE) – Università degli Studi di Foggia (Italian *Vitis* Database `www.vitisdb.it`) turned out to match "Bombino Bianco di San Severo" [33], hence explaining why it was by some authors considered to be "Bombino Bianco".

The accession "Albillo" in the grapevine collection at Geilweilerhof was long considered as either a misnomer or a non identified homonym. Due to the fingerprint published by Diaz-Losada et al. (2013) it showed up to be "Albillo Monte Lentiscal", an almost extinct cultivar maintained in the collection of Instituto Canario de Investigaciones Agrarias at Tenerife , Canary Islands, Spain.

3.3. Microsatellite search options in *V*IVC

Finally *V*IVC is an ideal site to assemble, concentrate and making available the entire prime name specific information extracted from the mentioned sources and thus also the respective genetic fingerprints. Two distinct search modules were implemented: "Microsatellites by varieties", where profiles of three prime names and three accessions/ cultivars can be compared and "Microsatellites by profiles", which can be used for cultivar identification by the editing of allele sizes. Currently (Mai, 2015) fingerprints from more than 1,500 cultivars are searchable. Allelic profiles from further cultivars are in preparation and will be soon uploaded.

In the two *V*IVC microsatellite modules a three color code informs about the validation status of allelic data. The light blue background color is indicating that matching profiles were found in at least two distinct sources. The cultivar/accession was assumed to be true to type and thus the fingerprint was assigned to the respective prime name. Green background color means that the genetic fingerprint is based on only one bibliographical data source. Until now in most cases these profiles could be validated by cross-checking with those available in the European *Vitis* Database. Rosé color stands for mainly non published data generated at Geilweilerhof and funded by the BÖLN-project "Weiterentwicklung von Wissenstransfer- und Informationssystemen zur nachhaltigen Nutzung rebengenetischer Ressourcen" (runtime 2014–2016).

For each prime name the sources of the profiles are given in a table on a separate page. This compilation is including the bibliographical references and the name of the cultivar/accession in the article, web-database or collection. This information is also useful for confirmation of synonyms.

3.4. Relationship between *V*IVC and the European *Vitis* Database

In the European *Vitis* Database 58 institutes from 28 countries are registered maintaining altogether 37,170 accessions. Each accession is unambiguously distinguishable by a unique identifier which is the accession number. The availability of fingerprints now in *V*IVC is a further tool to countercheck the accessions trueness to type. Big efforts are made to equip these clearly tagged accessions with *V*IVC variety numbers. Hence the medium term goal is that in the European *Vitis* Database under each *V*IVC variety number all accessions are assembled, that are sharing the same genetic profile independent of their designation. In addition accessions displaying unique fingerprints can be determined, evaluated and will be possibly proposed for duplicate preservation. Recent studies within COST Action FA1003 [23] demonstrated that via comparison of fingerprints, which are maintained by eminent SSR-marker databases of large grapevine collections, sorting out of accessions identity is possible. It revealed also the importance of morphological references for validation of findings and the fact that many cases still remained unsolved and needed further investigation. Hence further efforts are required to continue trueness to type determination in the European *Vitis* Database and prime name referencing by genetic profiles and morphology in *V*IVC.

4. Conclusion

The activities presented aim at improving *V*IVC by equipment of prime names with reliable genetic profiles combined with the validation of the prime names by ampelography. The completion of this activity is considered as a medium-term to long-term objective. Awareness about all the described obstacles needs to be emphasized. Nevertheless the correct attribution of cultivar/accession names to prime names in *V*IVC is attempted to the best of one's knowledge. Modifications will always be on the agenda.

With this ambitious objective *V*IVC highly assists the management of grapevine genetic resources, e.g. trueness to type assessment in grapevine collections, identification of synonyms, homonyms and misnomers. These endeavors will help to identify rare and unique genotypes and to promote their duplicate preservation in gene banks. Trueness to type is also important for the exchange of grapevine material, for reliable outputs in research and thus the correct assignment of cultivars properties to corresponding prime names and for grape breeding. Furthermore the identity of traded grape plant material can be verified by validated profiles. The constant numbers of users, which are at least 3,700 per month (`www.vivc.de/default.php?value=510`) affirm the importance of *V*IVC and motivate to continuously improve and update the prime name specific information.

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