

The prolific grape variety (*Vitis vinifera* L.) ‘Heunisch Weiss’ (= ‘Gouais blanc’): bud mutants, “colored” homonyms and further offspring

E. MAUL, R. EIBACH, E. ZYPRIAN and R. TÖPFER

JKI - Institute for Grapevine Breeding Geilweilerhof, Siebeldingen

Summary

‘Heunisch Weiss’ (syn. ‘Gouais blanc’) contributed to a considerable increase of our varietal assortment, including renowned varieties like ‘Chardonnay’ and ‘Riesling Weiss’. Three phenotypic variants of ‘Heunisch Weiss’ were discovered in the grapevine collection at the JKI Institute for Grapevine Breeding Geilweilerhof: (a) ‘Heunisch Dreifarbig’ (three coloured ‘Heunisch’; *VIVC* prime name ‘Heunisch Dreifarbig’) expressing intense anthocyanin coloration on shoots, inflorescences and leaf petioles before fruit set and even red berry skin at fruit set stage; (b) ‘Pekasore’ (*VIVC* prime name ‘Heunisch Rotgestreift’; red striped ‘Heunisch’;) with rose to red stripes on white berries and (c) the stenospermocarpic ‘Aspirant’ (*VIVC* prime name ‘Heunisch Weiss Seedless’).

Four cultivars proving to be homonymous in relation to ‘Heunisch’ were investigated at 24 loci to determine their identity or relatedness to ‘Heunisch Weiss’, respectively. ‘Heunisch Schwarz’ turned out to be a ‘Heunisch Weiss’ offspring. No parent offspring relationship was detected for ‘Heunisch Rot’, ‘Haenisch Rot’ = ‘Pamid’, and ‘Heunisch Blau’. Ampelographic description was carried out for some of the accessions to trace back historical evidences. In addition five new ‘Heunisch Weiss’ offsprings were identified and confirmed by analysing 35 nuclear microsatellite loci. The accession ‘Furmint Apiren’ turned out to be a seedless bud mutant of the ‘Heunisch Weiss’ offspring ‘Jordan’.

Key words: somatic mutation; cultivar identification; nuclear microsatellites; parentage analysis; Heunisch Weiss; *Vitis vinifera*.

Introduction

Franconian cultivars like ‘Pinots’ and also ‘Traminer’ prevailed when ‘Heunisch Weiss’ arrived in Germany and northern France (THIS *et al.* 2006, MAUL *et al.* 2010). Such cultivars showing small bunches and berries came into competition with the new cultivar characterized by large bunches, big and juicy berries, resulting in a much higher crop. The geographic and genetic origin of ‘Heunisch Weiss’ is still uncertain. According to citations of ampelographers from earlier centuries it occurred in Czech Re-

public, Slovakia, Hungary, Austria, Croatia, Slovenia, Italy, Germany, Switzerland and France (GOK 1836, TRUMMER 1841, BABO 1844, VIALA and VERMOREL 1905-1910, AEBERHARD 2005). Four significant synonyms mentioned in German ampelographies corroborate the fact that ‘Heunisch Weiss’ B, at least just when it arrived, was extraordinarily appreciated and most likely the very first cultivar with big white berries. The four most disparaging synonyms are ‘Bettschisser’ (shit in bed) (METZGER 1827), ‘Laxiertraube’ (laxative grape) (BABO 1844), ‘Scheißtraube’ (shit grape) (BOCK 1595), and *Vitis cathartica* (SCHÜBLER 1834). For no other cultivar such depreciatory synonyms are documented. Presumably the welcomed additional food source led to an excessive consumption of the newcomer’s grapes. This might explain that hyper-digestive effect rather than ‘Heunisch Weiss’ specific laxative properties.

Several hypotheses concerning the appearance of ‘Heunisch Weiss’ in Western Europe came up (AEBERHARD 2005, KRÄMER 2006), e. g. an introduction by the Huns in the 5th century, by the Magyars after the 9th century or importation by order of Charlemagne around 800. A clear proof for either of these theories does not exist. First citation of “Huniscedruben” (‘Heunisch’ grapes) was discovered in *Summarium Heinrici* from Lorsch-monastery (Hessen/Germany), a scholar compendium of the 11th century (STAAB 1997).

It’s watery and acidulous wine got poor reputation and early citations, e.g. in 1255 and 1399, proscribed its cultivation (SCHUMANN 1997). From the Middle Ages (BOCK 1595) to the 19th century ‘Heunisch Weiss’ covered large areas in nearly all above mentioned wine growing countries (VIALA and VERMOREL 1905-1910). This may explain the almost 120 offspring mentioned by LACOMBE *et al.* (2013). Gradually the mass producer ‘Heunisch Weiss’ was replaced by some of its descendants producing wine of better quality and at the beginning of the 20th century it disappeared almost completely from vineyards. However, some vineyards still exist in Wallis/Switzerland (AEBERHARD 2005). Recently single wines were found, e. g. in the South-Western Alps in Piedmont (SCHNEIDER *et al.* 2001), around Heidelberg (JUNG and MAUL 2004), in France (Jura and Gascony, LACOMBE 2014, pers. comm.) and Western Slovenia / Eastern Italy (Vipava valley, Goriška Brda, Italian Collio, RUSJAN *et al.* 2010). In Portugal the cultivar is officially authorized for wine production under the designation ‘Branco Valente’ (VELOSO *et al.* 2010, EIRAS-DIAS *et al.* 2013). The Portuguese synonym ‘Branco Gigante’ most likely points to its high yielding properties. Recently

some 'Heunisch Weiss' vineyards were newly established in the German grape growing regions Rheingau (Hessen), Pfalz and Nahe (both Rheinland-Pfalz).

For various reasons like time consuming morphological studies, missing reference material, false denomination or poor growth the recognition of cultivars by ampelography only is laborious and somewhat difficult. About twenty years ago nuclear microsatellite markers (SSR-markers) showed up and turned out to be exceptionally useful in grapevine for variety identification and pedigree analysis (BOWERS 1993, THOMAS and SCOTT 1993). Meanwhile SSR-markers have contributed on a large-scale in combination with ampelography to grapevine collection management and genetic resources preservation. This has been shown by more than 300 publications (<http://www.vivc.de/search-Bibliography/dbBibliography.php?retval=3600>).

First parentages discovered by SSR-markers already involved 'Heunisch Weiss' as progenitor of numerous well-known cultivars (REGNER *et al.* 1998, BOURSICQUOT *et al.* 2004), including 'Chardonnay Blanc' and 'Riesling Weiss'. In the meantime the number of 'Heunisch Weiss'-offsprings rose to 119, from which 63 full parentages are known (REGNER *et al.* 1998, MENEGHETTI *et al.* 2009, LACOMBE *et al.* 2013). The present study aimed at (1) discovering further 'Heunisch Weiss'-offspring, (2) depicting morphological variation of 'Heunisch' mutants and viewing them in the historical context and (3) determining the identity of coloured 'Heunisch' accessions.

Material and Methods

Plant material: In total 14 accessions were examined listed in Tab. 1 which are assumed to have a genetic relation to 'Heunisch Weiss'. The plants are maintained in the grapevine collection of the JKI Institute for Grapevine Breeding Geilweilerhof (DEU098).

Morphological studies: Eight accessions which are indicated in Tab. 1 were characterized by 44 OIV descriptors (OIV 2009), from which the most discriminating were retained (Tab. 2, supplemental material 1). Refer-

ences in historical bibliography (e.g. METZGER 1827, TRUMMER 1841, BABO 1844, ROY-CHEVRIER 1900 and PREMZL 2001) were studied to confirm their identity.

DNA extraction and PCR amplification: Grapevine DNA was extracted from fresh leaves collected in the field using peqGOLD Plant DNA Mini kit (Peqlab, Erlangen). Extracted DNA was quantified by spectrophotometry and diluted to a concentration of 1 ng·µL⁻¹. To allow profile comparison with internet-SSR-marker-databases and published SSR-allele sizes, 24 most commonly applied microsatellite markers fully characterized by LAUCOU (2011) and SEFC (1999) were analyzed. With respect to 'Heunisch Weiss' phenotypic variants and the likely 'Heunisch Weiss'-offspring additional eight and 11 markers were applied, respectively (see Tab. 1). Seven different multiplex PCR were performed. 1 ng of DNA was mixed with 2,5 µL 2X KAPA2G Fast Multiplex Mix (KAPA Biosystems) and adjusted to 5 µL final volume. Amplification took place using standard conditions at 60 °C annealing temperature. Analysis of PCR amplifications was carried out using an ABI 3130xl genetic analyzer (Applied Biosystems, Weiterstadt). Sizes of fluorescently labeled DNA-fragments were determined with GeneMapper™ v.4.0 software (Applied Biosystems, Weiterstadt) based on a fluorescently labeled size marker covering the range of 75 to 500 bp.

Data analysis: The four homonymous 'Heunisch' accessions with rose, red and black berry colour and 'Heunisch Weiss'-offsprings, whose relatedness was confirmed by comparison of at least 35 loci, were compared with SSR profiles publicly available using IDENTITY4 software (ver. 4.0; Centre for Applied Genetics, University of Agricultural Sciences, Vienna) aiming to confirm true-ness to type and, with respect to the progenies, to determine the second parent.

Results

Bud mutants of 'Heunisch Weiss' B: 'Heunisch Weiss' and its three phenotypic variants showed

Table 1

Listing of accessions examined in this study. All 14 accessions were genotyped (e.g. 24 + 8 SSR loci). Some of the accessions were morphologically described (x). „non identified“ means that no matching profile was found yet

Accession name	Accession number	VIVC prime name	Berry color	VIVC variety number	No of SSR loci analyzed	Morphology description
Aspirant	DEU098-1992-087	Heunisch Weiss Seedless	B	699	24+11+8	x
Balsamina	DEU098-1980-138	Balsamina (non identified)	N	42059	24+11	
Corthumtraube	DEU098-2001-111	Tauberschwarz	N	16156	24+11	
Feteasca alba	DEU098-1984-001	Feteasca alba (non identified)	B	41011	24+11	
Furmint apiren	DEU098-1990-071	Iordan Seedless	B	24152	24+11	
Haenisch Rot	DEU098-2010-128	Pamid	RG	8899	24	x
Heunisch Blau	DEU098-1990-082	Heunisch Blau	N	5370	24	x
Heunisch Dreifarbig	DEU098-2007-018	Heunisch Dreifarbig	RS	24544	24+11+8	x
Heunisch Rot	DEU098-1997-014	Heunisch Rot No 1	RG	5372	24	x
Heunisch Weiss	DEU098-1993-303	Heunisch Weiss	B	5374	24+11+8	x
Hohmann 21/23/24/96	DEU098-2001-109	Heunisch Schwarz	N	12555	24	x
Krkochia Pargava	DEU098-1991-114	Krkochia Pargava	B	6512	24+11	
Pekasore	DEU098-1990-142	Heunisch Rotgestreift	B-RS	5373	24+11+8	x
Servin chernyj	DEU098-1990-030	Kosinjot*	N	23803	24+11	

* In the meanwhile 'Servin chernyi' was identified as 'Kosinjot' from Albania.

the same allelic pattern at 42 analyzed loci - allele sizes from 35 markers are displayed in Tab. 3 (supplemental material 2) - thus confirming that they resulted from bud mutation. Hereupon and for clarity the *Vitis* International Variety Catalogue (IVVC) prime names were adapted to that finding. The IVVC prime name ‘Aspirant’ had been registered in IVVC long before it turned out to be a stenospemcarpic ‘Heunisch Weiss’. The name was traced back to accessions ‘Asprian’, ‘Aspirant sans pepin’ and ‘Asprian Weisser’ still existing in three German grapevine collections. The IVVC prime name ‘Aspirant’ was modified into ‘Heunisch Weiss Seedless’ because of its seedlessness and to avoid confusion with the distinct French cultivar ‘Aspiran blanc’. The accession ‘Pekasore’ had been introduced in the Geilweilerhof collection from the Institute of Horticulture, University of Beograd at the end of the 1980ies. As ‘Pekasore’ and ‘Heunisch Rotgestreift’ turned out to be identical cultivars the IVVC prime name ‘Pekasore’ was assigned to IVVC prime name ‘Heunisch Rotgestreift’, which is the appropriate historical name.

Morphology of ‘Heunisch Weiss’ and its three phenotypic variants matched with respect to shoot tips and leaves. Differences were mainly based on bunch and berry characteristics, except for ‘Heunisch Dreifarbig’. The most distinctive morphologic characteristics of ‘Heunisch Weiss’ variants are specified below. Some are given as OIV descriptor notations specified in Tab. 2 (supplemental material 1).

‘Heunisch Weiss Seedless’: As most seedless varieties ‘Heunisch Weiss Seedless’ formed thin pedicels, which was in contrast to the other three ‘Heunisch cultivars’.

‘Heunisch Rotgestreift’: ‘Heunisch Rotgestreift’ produced on its green berries red and somewhat blurred stripes in direction from the apex to the basis (sectorial). Unseeded segments resulted in most irregular berry shapes.

‘Heunisch Dreifarbig’: ‘Heunisch Dreifarbig’ was expressing complete anthocyanin coloration of shoots, inflorescences and leaf petioles at flowering time. Coloration was persisting on bunch rachises until harvest. After fruit set stage berry skin became red to red spotted with occasional few green ones interspersed. With respect to descriptor uniformity of berry size (OIV 222) all four ‘Heunisch’ cultivars produced a few small berries, in some years more than in others. To distinguish genetically the phenotypic variants, further 24 ‘Heunisch Weiss’ accessions most of them discovered in old German vineyards (JUNG and MAUL 2004), ‘Heunisch Weiss Seedless’, ‘Heunisch Dreifarbig’ and ‘Heunisch Rotgestreift’ were investigated at seven additional loci which previously turned out to reveal diversity within clones and were thus recommended for clonal differentiation (RIAZ 2002, PELSLEY *et al.* 2010). These seven microsatellite loci are VMC3a9, VMC5g7, VMC6c10, VMC6f11, VMC7f2, VMC8f10 and VVMD31. All 24 accessions displayed the same standard alleles and no allelic shift and no triple-allelic genotypes were caused by periclinal chimeras. Thus other markers or SNPs would be needed to distinguish ‘Heunisch Weiss’ clones to identify regional types and to trace back their migration route from the East to Western Europe.

Homonymous accessions of ‘Heunisch’ with rose, red and black berry colour: In addition to ‘Heunisch Weiss’ and its phenotypic variants four distinct ‘Heunisch’ accessions with rose, red and blue berries were analyzed: ‘Heunisch Rot’ (IVVC prime name ‘Heunisch Rot No 1’), ‘Haenisch Rot = Pamid’, ‘Heunisch Blau’ and ‘Hohmann 21/23/24/96’ (IVVC prime name ‘Heunisch Schwarz’). Microsatellite profiles of the four genotypes (Tab. 3, supplemental material 2) were compared with published SSR-marker data (<http://www.vivc.de/searchBibliography/dbBibliography.php?retval=3600>) and with fingerprints uploaded in the European *Vitis* Database (www.eu-vitis.de), (BACILIERI and THIS 2010). Identities, parent-offspring relationships and the most important morphologic features of the four cultivars are described below and in Tab. 2 (supplemental material 1).

‘Heunisch Rot No 1’: The genetic fingerprint matched ‘Rossara 1’ (ITA362#1173) maintained at FEM, S. Michele all’ Adige. No parent-offspring relationship was detected.

‘Haenisch Rot’ = ‘Pamid’: The accession ‘Haenisch Rot’ turned out to be ‘Pamid’ (DZHAMBANOVA *et al.* 2009, HVARLEVA *et al.* 2004).

‘Heunisch Blau’: The same cultivar is registered in INRA Vassal collection as ‘Heunisch Schwarz’ (LACOMBE 2014, pers. comm.). In this French collection, it is represented by four accessions called ‘Blauer Heunisch’, ‘Heunisch bleu’, ‘Prachttraube’ and ‘Debela crbina’. No parent-offspring relationship was discovered.

‘Heunisch Schwarz’: The genotypic profile of the accession ‘Hohmann 21/23/24/96’ matches ‘Hängling blau’ (Collection Ravaz) from INRA Vassal collection (LACOMBE 2014, pers. comm.). In this French collection, this cultivar is represented by two accessions called ‘Blauer Hängling’ and ‘Hängling bleu’. This cultivar is a further ‘Heunisch Weiss’-offspring. The congenial parent was not found.

‘Heunisch Weiss’-offspring: In the Geilweilerhof-collection five further ‘Heunisch Weiss’-offspring were found, which were not described so far. Parent-offspring relationship to ‘Heunisch Weiss’ was proven by allele sizes at 35 loci. Allele sizes are given in Tab. 3 (supplemental material 2). Profiles of the respective genotypes were compared with published SSR-marker data (<http://www.vivc.de/searchBibliography/dbBibliography.php?retval=3600>) and the European *Vitis* Database (www.eu-vitis.de), (BACILIERI and THIS 2010). The IDENTITY4 program was applied to determine the second parent.

‘Balsamina’ turned out to have a unique profile. Allelic data of the accession did not match ‘Balsamina nera’ (FREI *et al.* 2005) and ‘Balsamina Emiliana’ = ‘Balsamina Romagnola’ (LABRA *et al.* 2003). Identity with ‘Blaue Balsamina’ as described by BABO (1844) and TRUMMER (1855) was doubtful. According to that finding and to prevent confusion before the true identity is discovered a new IVVC prime name was created: ‘Balsamina’ (non identified). The accession ‘Corthumtraube’ (IVVC prime name ‘Tauber-schwarz’) turned out to be the same as ‘Haengling Blau’ - a true synonym - maintained at FEM, S. Michele all’ Adige (European *Vitis* Database (www.eu-vitis.de) 2007-2011;

BACILIERI and THIS 2010; GRANDO 2014). Morphology matched the drawing given by BABO and METZGER (1836) and descriptions from the 19th century (METZGER 1827, BABO 1844, TRUMMER 1855). Concerning ‘Servin Cherny’ and ‘Krkochia Pargava’ neither literature citations nor matching genetic fingerprints were found. The accession ‘Servin Cherny’ was obtained from Weinbaustation Senkvice / Slovakia and ‘Krkochia Pargava’ from Faculty of Agriculture, Belgrade-Zemun, Serbia. For ‘Krkochia Pargava’ full parentage was determined revealing ‘Alba imputato’ as the second parent. No coincident SSR profile was found for the accession ‘Feteasca alba’ (VIVC prime name ‘Feteasca alba’ (non identified)). Thus it remained unnamed. The accession ‘Furmint Apiren’ maintained in the collection of Geilweilerhof was received from the Research and Development Station for Viticulture and Oenology, Minis, Romania at the end of the 1980ies. Interestingly it turned out to be the seedless bud mutation of ‘Iordan’. Parent offspring relationship of ‘Iordan’ with ‘Heunisch Weiss’ was already stated by LACOMBE (2013). The seedless ‘Iordan’ was described by CONSTANTINESCU (1958-1961) and mentioned as ‘Gordan mic’ by GALET (2000). Again in this case for clarity and to illustrate the relationship with ‘Iordan’ the VIVC prime name ‘Furmint Apiren’ was changed in VIVC prime name ‘Iordan Seedless’. With three seedless mutants, ‘Heunisch Weiss Seedless’, ‘Chardonnay Seedless’ and ‘Iordan Seedless’, a certain genetic disposition in ‘White Heunisch’ for seedlessness seems to exist.

Discussion

The ancestry of ‘Heunisch Weiss’ is witnessed by far more than hundred traditional cultivars it generated from Eastern to Western Europe (LACOMBE *et al.* 2013) and the ancestry of the cultivars it produced. Among them are ‘Riesling Weiss’, ‘Elbling Weiss’ and ‘Räuschling Weiss’ (BOURSIQUOT *et al.* 2004), first mentioned in the 15th and 16th century, respectively (SCHUMANN 1997, AEBERHARD 2005). Specifically the finding that ‘Heunisch Weiss’ and the ‘archaic’ ‘Pinot’ (LEVADOUX 1956, MAUL *et al.* 2010) were predecessors and progenitors of ‘Aligoté’, ‘Chardonnay Blanc’, ‘Gamay Noir’ (BOWERS *et al.* 1999) and many other nowadays widespread varieties in northern European wine growing areas, points to a bottle neck existing before their arrival (THIS *et al.* 2006, MAUL *et al.* 2010) and particularly to the ‘Heunisch Weiss’ age. ‘Heunisch Weiss’ synonyms are extraordinary numerous (BOURSIQUOT *et al.* 2004), mounting up to 213 registered designations in the *Vitis* International Variety Catalogue (www.vivc.de) (VIVC). Distinct spellings of the same name allude to the time of oral tradition. Considerable morphologic variability of ‘Heunisch Weiss’ clones were described with respect to anthocyanin coloration, hairiness, leaf profile and shape of petiole sinus (BOURSIQUOT *et al.* 2004), a further proof of the cultivars ancestry which was vegetatively propagated for centuries or even millenaries (PELSY *et al.* 2010). Furthermore, besides a cultivar specific disposition to mutation, its “omnipresence in nearly all wine growing coun-

tries” (BOCK 1595) which can be supposed for the Middle Ages, presumably intensified extensive intravarietal diversity.

Bud mutants of ‘Heunisch Weiss’: The three phenotypic variants described in this study were striking for their uniqueness and originality. The most obvious differences were found in regard to berry traits. Compared to the original phenotype these are the rose coloured berries of ‘Heunisch Dreifarbig’, the red-green striped berries of ‘Heunisch Rotgestreift’ and stenospermocarp of ‘Heunisch Weiss Seedless’. Stenospermocarpic clones of traditional varieties were reported earlier, with examples like ‘Chasselas Blanc Sans Pépins’ (GALET 1964) and ‘Chardonnay Seedless’ (TREZISE 2005). Seedlessness of the parthenocarpic type ‘Corinto Bianco’ (prime name: ‘Pedro Ximenez Seedless’ in VIVC) (VARGAS *et al.* 2007) and ‘Cape Currant’, bud mutant of ‘Muscat à Petits Grains Rouges’ (ADAM-BLONDON *et al.* 2001), probably is due to distinct genetic factors. Recently ‘Corinto Nero’ (prime name: ‘Sangiovese Seedless’ in VIVC) turned out be a non-seeded ‘Sangiovese’ mutation (SCHNEIDER 2009). In contrast to seedlessness, variants of traditional cultivars with extraordinarily intense anthocyanin coloration were not depicted so far. ‘Heunisch Dreifarbig’ displayed deeply red colored shoots, tendrils, rachises of inflorescences, leaf veins and from the early beginning of berry formation red berry skin. Likewise no mutants with red striation on green berries as for ‘Heunisch Rotgestreift’ are known. The existence of the three phenotypic variants was documented in the 19th century and with respect to ‘Heunisch Weiss Seedless’ even earlier.

‘Heunisch Dreifarbig’ was first described by TRUMMER (1841). Based on his detailed description the accession maintained at the Institute for Grapevine Breeding Geilweilerhof could be clearly identified. The plant was introduced in 2007 from a private Swiss collection (Marcel Aeberhard), which obtained the material (FRA139-0Mtp477) from the French Vassal collection, where the ‘Heunisch Dreifarbig’ was described before (BOURSIQUOT *et al.* 2004). The INRA Vassal collection itself received the accession from Mutenice in Czech Republic in 1958 (LACOMBE 2014, pers. comm.). Corresponding to the Geilweilerhof accession features, TRUMMER (1841) already stated intense coloration of increasing berries immediately after flowering. According to his and BRONNERS (1856) description berries changed color at ripening time to “pale red” (= rose) or totally green or yellow, pointing to its name “three colors”. BABO (1844) himself maintained a ‘Heunisch Siebenfarbig’ (seven colored) in his collection with green and blue berries and all shades in between. A colored drawing of leaves and bunches with photographic quality was painted by Conradin and Vinzenz Kreuzer (PREMZL 2001) in the 19th century. It displays exactly the ‘Heunisch Dreifarbig’ morphology, except anthocyanin coloration of leaf veins and petioles, which was more expressed in the Geilweilerhof accession. According to TRUMMER (1841) and BRONNER (1856) this mutant was rare and of low value.

Again it was the Styrian TRUMMER (1841) who described first ‘Heunisch Rotgestreift’ precisely. He mentioned red

stripes on green ground color of berries, observed that berries in the shade remain green and reported blossom sensitivity resulting in poor fruit set. The red striation of the Geilweilerhof accession turned to somewhat marmorate at ripening time. Incomplete pollination produced unequal berry shapes, where the compartments with not developed seeds were reduced, see Fig. 1.

The painting of Conradin and Vinzenz Kreuzer (PREM-ZL 2001) (Fig. 2) illustrated exactly the red stripes phenomenon in placing bright red lines of distinct length like zebra striations on the green ground of the berry.

In most of the years ‘Heunisch Weiss’, like his offspring ‘Riesling Weiss’, suffers from grape bud mite (*Eriophyes vitis*) infection. Interestingly on the two ‘Heunisch Rotgestreift’ leaves, Conradin and Vinzenz Kreuzer reproduced the susceptibility to that acarian by painting more than 30 protuberances (PREM-ZL 2001). For its curious appearance TRUMMER (1841) suggested to maintain it as a table grape but finally attested no good table grape qualities.

The particularity of ‘Heunisch Weiss Seedless’ is its seedlessness. This mutation is related to smaller berries of irregular size as compared to ‘Heunisch Weiss’. In Fig. 3 entire and bisected berries of both cultivars illustrate the variability in berry size, occurring in the original ‘Heunisch Weiss’ phenotype as well. Seed traces of ‘Heunisch Weiss Seedless’ are shown on the right.

The translucent small berries pretend sweet grape juice and badly disappoint the consumer. High acidity prevails. ‘Heunisch Weiss Seedless’ wine is sourly and lacking any bouquet. AEBERHARDT (2005) discovered the description of a plant with similar characteristics by BAUHIN (1540-1613)



Fig. 1: Berries of ‘Heunisch Rotgestreift’ on the left and of ‘Heunisch Weiss’ on the right.



Fig. 2: Painting of Conradin and Vinzenz Kreuzer illustrating the “rotgestreift” = red stripes phenomenon. PREM-ZL (2001): Zbirka Ampelografskih Upodobitev Vinzenza in Conrad Kreuzerja - The Collection of Ampelographic Drawings of Vinzenz and Conrad Kreuzer, Umetniski Kabinet Primoz. With the kind authorization of the Agriculture Institute of Maribor, Slovenia as the source of the drawing.



Fig. 3: Berries of seeded ‘Heunisch Weiss’ on the left and seedless ‘Heunisch Weiss Seedless’ on the right. The normal size of the two varieties berries are in the 3rd row.

(ROY-CHEVRIER 1900). Bauhin entitled “white bunches with small berries” and indicated that they were called ‘Bo(e)se Hintschen’ (boese = bad) in Württemberg and ‘Chenois’ around Montbéliard and in Burgundy. MERLET (around 1630) in ROY-CHEVRIER (1900) wrote: “Raisin sans pépin is a species of Bar-sur-Aube”, hence enlarging the geographic occurrence given by Bauhin to Champagne, Ardennes. BIDET (1709-1782) called the grape directly ‘Bar-sur-Aube’ (ROY-CHEVRIER 1900). The name ‘Aspirant’ appeared first

in METZGER's Rheinischer Weinbau (1827). He mentioned even two 'Aspirant'. 'Aspirant Sans Pepin' suggesting French origin was attributed by him to 'Große Corinthe' and 'Aspirant' was assigned to 'Kleine Corinthe', both seedless cultivars. Leaf and bunch description of both types were mixed up by METZGER (1827) and adjusted by BABO (1844), providing the first detailed description of 'Aspirant' = 'Heunisch Weiss Seedless'. Beyond that TRUMMER (1855) was the first realizing 'Heunisch Weiss'-like leaves. METZGER's (1827) synonymous designation 'Große Corinthe', meaning big 'Corinthe', probably was not related to any morphologic characteristic. Possibly 'gros' was used in the sense of crude, referring to 'Heunisch Weiss Seedless' sour taste (MERLET around 1630) in ROY-CHEVRIER (1900).

Furthermore a 'Heunisch Grob' (grob = crude) with tiny grains was described by TRUMMER (1841). According to his observation at flowering time shedding of caps did not take place, preventing pollination and resulting in berries that never developed. Single fertilized berries reached normal size. This phenomenon might be comparable to 'Pedro Ximénez Seedless' where, besides small-sized berries, a few normally developed berries are visible (VARGAS 2007). BRONNER (1856) and TRUMMER (1841) reported about ineffective cultural practices to revitalize the plants fertility. In consequence both assumed degeneration of the "probably oldest variety in Styria and Germany". Virus infection can be largely excluded as the precise observer did not note any virus symptoms. Despite their non economic value outstanding 'Heunisch Weiss' clones survived for their rareness (TRUMMER 1841) and curiosity (BABO 1844) in grapevine collections. Further mutants most likely existed but disappeared owing to less spectacular characteristics.

Homonyms of 'Heunisch' with rose, red and black berry colour: In the Middle Ages the designation 'Heunisch' was conferred to different high crop yielding cultivars. The identity or relatedness of four cultivars sharing 'Heunisch' in their name was analyzed morphologically and genetically by investigation at 24 nuclear microsatellite loci. SSR-profiles clearly showed that these four cultivars are not mutants of 'Heunisch Weiss'.

'Heunisch Rot No 1': Three distinct accessions were introduced at Geilweilerhof under the names 'Heunisch Blau', 'Heunisch Grau' and 'Heunisch Rot'. They turned out to be the same cultivar. Morphology corresponded to the description of METZGER (1827), who mentioned the dark green leaves, and TRUMMER (1841) who noted the typical recognition features. These were in particular the partial red autumn coloration of leaves, cobwebby hairs on the lower side of leaf blade, erect hairs on ribs and the ramified, big and compact bunch. TRUMMER (1841) clearly distinguished 'Heunisch Rot No 1' from 'Heunisch Weiss', both having only wood characteristics and hairiness of leaves in common, thus suggesting their separation in his classification system. Even if 'Heunisch Rot No 1' was not dominant in Styria, it was fairly abundant (TRUMMER 1841) and hence painted by Conradin and Vinzenz Kreuzer (PREMZL 2001). On their drawing they even reproduced erect hairs, which were densely arranged

on the ribs on the lower side of the leaves. Enigmatical is the presence of another distinct 'Heunisch Rot' (IIVC prime name 'Heunisch Rot No 2') in INRA Vassal collection, which was introduced from Geilweilerhof collection in 1952 (LACOMBE 2014, pers. comm.). At Geilweilerhof this accession is extinct since at least 30 years. According to LACOMBE *et al.* (2013) 'Heunisch Rot No 2' of INRA Vassal collection is a 'Heunisch Weiss'-offspring, the 2nd parent was not found, and it revealed unique in terms that a genotype with a matching profile was not yet discovered elsewhere. Likewise 'Heunisch Rot No 1' from Geilweilerhof seems to be unique. With the exception of the non identified 'Rossara 1' from FEM, S. Michele all' Adige [European *Vitis* Database (www.eu-vitis.de) 2007-2011]; no matching profile was detected in the huge INRA Vassal SSR-marker database, encompassing profiles from their own and their partners collections (LACOMBE 2014, pers. comm.). To distinguish the two homonymous cultivars, IIVC prime names were given as follows 'Heunisch Rot No1' for the accession from Geilweilerhof and 'Heunisch Rot No2' for the accession of INRA Vassal collection.

'Haenisch Rot' = 'Pamid': In the scope of a prospection initiative, financed by the German Bundesanstalt für Landwirtschaft und Ernährung (BLE) the cultivar was detected by Andreas Jung in an old vineyard in the proximity of Rohrbach/Heidelberg, who named it 'Haenisch Rot'. It turned out to match with 'Pamid' from which several accessions are maintained at Geilweilerhof under the accession names 'Beerheller' (misnomer), 'Steinschiller Rot' and 'Slankamenka Rot', the two latter being true synonyms. In the ampelographies of TRUMMER (1841) and BABO (1844) the description of this cultivar seems not to exist. Instead, entitled 'Le Haenisch rouge', it was painted by KERNER (1803). The medium lobed roundish leaves and the olive shaped rose berries illustrate 'Pamid' and documents its occurrence in Germany around 1800.

'Heunisch Blau' and 'Heunisch Schwarz': The accession 'Hohmann 21/23/24/96' (IIVC prime name 'Heunisch Schwarz') revealed to be an additional 'Heunisch Weiss'-offspring. The descriptions of 'Heunisch Blau' and 'Heunisch Schwarz' found in ampelographies did not allow a clear statement about their true identity. In particular confusing homonymy raised further disturbance. For example the painting provided by Conradin and Vinzenz Kreuzer (PREMZL 2001) under the name 'Heunisch Schwarz'/'Debela črnina' did not correspond to the two Geilweilerhof accessions. In Tab. 4 (supplemental material 3) a comprehensive compilation of distinct bibliographic sources is given.

Cultivars were named 'Heunisch' due to the big bunch and high crop they produced and also because of similarities of bunch and berry shape. The latter may have contributed to the historical confusion about 'Chasselas Blanc' and 'Heunisch Weiss', the cluster resemblance being emphasized by MERLET (ROY-CHEVRIER 1900) around 1630. Also SPRENGER (1766) wrote that bunch and berries of both are the same. Cels (ROY-CHEVRIER 1900) in fact attributed 'Aspirant' = 'Heunisch Weiss Seedless' to 'Gros Corinthe' but for him it appeared to be a "*Chasselas à grains plus petits et moins doux*". Almost the same re-

spective comment “*une sorte de Chasselas*” was made by Chomel (ROY-CHEVRIER 1900). The Conradin and Vinzenz Kreuzer painting of ‘Heunisch Weiss’ (PREMZL 2001) reproduced perfectly a ‘Chasselas Blanc’ and in the end two accessions introduced as ‘Heunisch Weiss’ and ‘Heunisch Rotgestreift’ in the Geilweilerhof-collection turned out to be ‘Chasselas Blanc’ as well.

‘Heunisch Weiss’-offspring: Five further ‘Heunisch Weiss’-offspring were discovered in the grapevine collection of the Institute for Grapevine Breeding Geilweilerhof. All of them, except the accession ‘Corthumtraube’ (VIVC prime name ‘Tauberschwarz’), are very likely of Eastern European origin. Accessions ‘Servin chernyj’ and ‘Krkochia Pargava’ introduced from Czech Republic and Serbia, respectively, lack bibliographical references, as well as the misnomer ‘Feteasca alba’ (VIVC prime name ‘Feteasca alba’ (non identified)). The historical identity of ‘Heunisch Schwarz’ could not be ascertained. The accession ‘Balsamina’ (VIVC prime name ‘Balsamina’ (not identified)) had nothing in common with the Italian ‘Balsamina’ cultivars. ‘Tauberschwarz’ is a minor cultivar of local importance in the Taubertal/Württemberg. Its wine was appreciated in previous centuries (SPRENGER 1766, KRÄMER 2006). Prospections in old vineyards led to the renaissance of the cultivar, being planted on 11 ha today.

Considering all ‘Heunisch Weiss’-offspring detected so far, almost 60 % (77 cultivars) are presumably of French origin, demonstrating the immense increase of varieties after its appearance in that country. So far Germany and Austria count nine and eight descendants, respectively. Most of the remaining offspring are quite evenly distributed further east and cover Bulgaria, Croatia, Czech Republic, Georgia, Greece, Hungary, Italy, Moldavia, Romania, Serbia, Slovakia, Slovenia and Switzerland. Chloroplast DNA microsatellites analysis unraveled ‘Heunisch Weiss’, exhibiting chlorotype C, preponderance as the mother in the crosses (ARROYO-GARCIA *et al.* 2006, HUNT 2010), in particular what concerned French offspring. This finding was confirmed by own studies (unpubl. results). Interestingly all, except one, of the German ‘Heunisch Weiss’-offspring shared chlorotype A. Presumably this is due to two different selection processes in France and Germany. It can be imagined that “French strategy”, was based on sowing the seeds of the more fertile parent, possibly carried out in monasteries. In Germany however it is most likely that selection occurred in the Rhine floodplains according to that what BRONNER (1857) did in the 19th century (MAUL 2010). In the Rhine floodplains *Vitis sylvestris* (chlorotype A) thrived abundantly. Cultivated grapevine grew in nearby vineyards, as documented by donations given to monasteries since the 8th century (BASSERMANN-JORDAN 1923). This coexistence is probably the reason that BRONNER (1857) was able to collect between Rastatt and Mannheim more than 30 cultivated grape-like individuals, which he described in detail and from which three had white berry color (MAUL 2010).

To date the existence of ‘Heunisch Weiss’ was reported neither for Eastern European countries like Moldavia, Romania, Bulgaria or Greece nor for Caucasus. As migration of cultivars always took place it is possible that ‘Heunisch

Weiss’-offspring immigrated in these countries or ‘Heunisch Weiss’ disappeared relatively early as it could not be retraced for example in the large Romanian ampelography of CONSTANTINESCU (1958-1967). Nevertheless in these countries ‘Heunisch Weiss’-offspring are grown on a commercial scale, like ‘Jordan’ and ‘Francuse’ in Romania and ‘Xynomavro’ in Greece. With respect to the birthplace of ‘Heunisch Weiss’ without scientific proof its true origin remains obscure.

Acknowledgements

The authors thank T. LACOMBE from INRA Vassal-Montpellier (France) for thorough review and invaluable contributions. D. AGRAWAL contributed to the analysis of chlorotypes. C. GLEICH, F. DÖRNER and A. MAHLER-RIES provided expert technical assistance.

References

- ADAM-BLONDON, A. F.; LAHOGUE-ESNAULT, F.; BOUQUET, A.; BOURSQUOT, J. M.; THIS, P.; 2001: Usefulness of two SCAR markers for marker-assisted selection of seedless grapevine cultivars. *Vitis* **40**, 147-155.
- AEBERHARD, M.; 2005: Geschichte der alten Traubensorten. Ein historisch – ampelographischer Rückblick. Arcadia-Verlag Solothurn.
- ARROYO-GARCIA, R.; RUIZ-GARCIA, L.; BOLLING, L.; OCETE, R.; LÓPEZ, M. A.; ARNOLD, C.; ERGUL, A.; SÖYLEMEZOGLU, G.; ÜZUN, H. I.; CABELLO, F.; IBANEZ, J.; ARADHYA, M. K.; ATANASSOV, A.; ATANASSOV, I.; BALINT, S.; CENIS, J. L.; CONSTANTINI, L.; GORISLAVETS, S.; GRANDO, M. S.; KLEIN, B. Y.; MCGOVERN, P. E.; MERDINOGLU, D.; PEJIC, I.; PELSY, F.; PRIMIKIRIOS, N.; RISOVANNAYA, V.; ROUBELAKIS-ANGELAKIS, K. A.; SNOUSSI, H.; SOTIRI, P.; TAMHANKAR, S.; THIS, P.; TROSHIN, L.; MALPICA, J. M.; LEFORT, F.; MARTINEZ-ZAPATER, J. M.; 2006: Multiple origins of cultivated grapevine (*Vitis vinifera* L. ssp. *sativa*) based on chloroplast DNA polymorphisms. *Molec Ecol* **15**, 3707-3714.
- BABO, L.; 1844: Der Weinstock und seine Varietäten. Verlag Brönnner, Frankfurt.
- BABO, L.; METZGER, J.; 1836: Die Wein- und Tafeltrauben der deutschen Weinberge und Gärten. Heinrich Hoff, Mannheim.
- BACILIERI, R.; THIS, P.; 2010: GrapeGen06 an European project for the management and conservation of grapevine genetic resources (<http://www1.montpellier.inra.fr/grapegen06/>) accessed 10 December 2013.
- BASSERMANN-JORDAN, F.; 1923: Die Geschichte des Weinbaus. Band 1. Druck von Brügel & Sohn A.G., Ansbach.
- BOCK, H.; 1595: Kretterbuch, Straßburg.
- BOURSQUOT, J. M.; LACOMBE, T.; BOWERS, J.; MEREDITH, C. P.; 2004: Le Gouais, un cépage clé du patrimoine viticole européen. *Bull. O. I. V. (Off. Int. Vigne Vin)* **77**, 875-880.
- BOWERS, J. E.; BANDMANN, E. B.; MEREDITH, C. P.; 1993: DNA fingerprint characterization of some wine grape cultivars. *Am J Enol Vitic* **44**, 266-274.
- BOWERS, J. E.; BOURSQUOT, J. M.; THIS, P.; CHU, K.; JOHANSSON, H.; MEREDITH, C. P.; 1999: Historical genetics: The parentage of Chardonnay, Gamay and other wine grapes of northeastern France. *Science* **285**, 1562-1565.
- BRONNER, J. P.; 1856: Die Bereitung der Rothweine und deren zweckmäßige Behandlung. Frankfurt am Main.
- BRONNER, J. P.; 1857: Die wilden Trauben des Rheinthaales. Buchdruckerei von Georg Mohr Heidelberg.
- CONSTANTINESCU, G.; 1959-1967: Ampelografia Republicii Populare Romîne. Editura Academiei Republicii Populare Romîne.
- DU HAMEL DU MONCEAU, H. L.; 1783: Beschreibung der Weinstöcke, aus dessen Abhandlung von den Obstbäumen besonders herausgegeben. Adam Wolfgang Winterschmidtsche.
- DZHAMBAZOVA, T.; TSVETKOV, I.; ATANASSOV, I.; RUSANOV, K.; MARTINEZ-ZAPATER, J. M.; ATANASSOV, A.; HVARLEVA, T.; 2009: Genetic diversi-

- ty in native Bulgarian grapevine germplasm (*Vitis vinifera* L.) based on nuclear and chloroplast microsatellite polymorphisms. *Vitis* **48**, 115-121.
- DZHAMBZOVA, T.; TSVETKOV, I.; SIMEONOV, I.; IVANOV, M.; NAKOV, Z.; DIMITROVA, V.; ATANASSOV, I.; HVARLEVA, T.; 2012: Genetic diversity and relationships of indigenous and newly bred Bulgarian grape cultivars assessed by nuclear and chloroplast markers. *J Int Sci Vigne Vin* **46**, 113-121.
- EIRAS-DIAS, J. E.; FAUSTINO, R.; CLÍMACO, P.; FERNANDES, P.; CRUZ, A.; CUNHA, J.; VELOSO, M.; DE CASTRO, R.; 2013: Catálogo das Castas para Vinho Cultivadas em Portugal, Vol. II, Instituto da Vinha e do Vinho, Lisboa.
- FREI, A.; PORRET, N. A.; BAUMGARTNER, D.; FREY, J. E.; GAFNER, J.; 2005: Identification of Swiss grapevine cultivars with an optimized method applying multiplex microsatellite markers, 38-41. *Int. Grape Genomics Symp.*, St. Louis, Missouri, USA.
- GALET, P.; 1964 : Cépages et Vignobles de France. Dehan, Montpellier.
- GALET, P.; 2000 : Dictionnaire Encyclopédique des Cépages. Hachette Livre.
- GOK, C. V.; 1836: Die Weinrebe und ihre Früchte oder Beschreibung der für den Weinbau wichtigen Wein-Reben-Arten nach einem naturgemäßen Classifikations-System. Ebner Stuttgart.
- GRANDO, M. S.; 2014: Istituto Agrario di S. Michele all' Adige. European *Vitis* Database (www.eu-vitis.de), accessed 4 December 2013.
- HVARLEVA, T.; RUSANOV, K.; LEFORT, F.; TSVETKOV, I.; TANASSOV, A.; ATANASSOV, I.; 2004: Genotyping of Bulgarian *Vitis vinifera* L. cultivars by microsatellite analysis *Vitis* **43**, 27-34.
- HUNT, H. V.; LAWES, M. C.; BOWER, M. A.; HAEGER, J. W.; HOWE, C. J.; 2009: A banned variety was the mother of several major wine grapes. *Biologia (Bratislava)* **6**, 367-369.
- JUNG, A., MAUL, E.; 2004: Preservation of grapevine genetic resources in Germany based on new findings in old, historical vineyards. *Bull. O. I. V. (Off. Int. Vigne Vin)* **77**, 616-630.
- KERNER, J. S.; 1803 : Le Raisin, ses Espèces et Variétés, Dessinées et Colorées d'après Nature, Stuttgart.
- KRÄMER, C.; 2006: Rebsorten in Württemberg. Herkunft, Einführung, Verbreitung und die Qualität der Weine vom Spätmittelalter bis ins 19. Jahrhundert. Jan Thorbecke Verlag, Ostfildern.
- KREUZER, V.; KREUZER, C.; PREMZL, P.; 2001: Zbirka Ampelografskih Upodobitev Vinzenza in Conrad Kreuzerja - The Collection of Ampelographic Drawings of Vinzenz and Conrad Kreuzer. Umetniški kabinet P. Premzl.
- LABRA, M.; IMAZIO, S.; GRASSE, F.; ROSSONI, M.; CITTERIO, S.; SGORBATI, S.; SCIENZA, A.; FAILLA, O.; 2003: Molecular approach to assess the origin of cv. Marzemino. *Vitis* **42**, 137-140.
- LACOMBE, T.; BOURSQUOT, J. M.; LAUCOU, V.; DI VECCHI-STARAZ, M.; PÉROS, J. P.; THIS, P.; 2013: Large-scale parentage analysis in an extended set of grapevine cultivars (*Vitis vinifera* L.) *Theor Appl. Genet.* **126**, 401-14.
- LAUCOU, V.; LACOMBE, T.; DECHESNE, F.; SIRET, R.; BRUNO, J. B.; DESSUP, M.; DESSUP, T.; ORTIGOSA, P.; PARRA, P.; ROUX, C.; SANTONI, S.; VARÈS, D.; PÉROS, J. P.; BOURSQUOT, J. M.; THIS, P.; 2011: High throughput analysis of grape genetic diversity as a tool for germplasm collection management *Theor. Appl. Genet.* **122**, 1233-1245.
- LEVADOUX, L.; 1956: Les Populations Sauvages et Cultivées de *Vitis vinifera* L. *Ann Amélior Plantes* **6**, 59-117.
- MAUL, E.; 2004: Die sehr alte Rebsorte Weißer Heunisch und ihre zum Teil berühmt gewordenen Kinder, wie z.B. Chardonnay. *Dt. Weinbau-Jahrbuch* 2005, 129-145.
- MAUL, E.; SCHUMANN, F.; TÖPFER, R.; 2010: Vom Spätburgunder zum Riesling - Ein Beitrag zur Entstehung unserer Rebsortenlandschaft. *Dt. Weinbau Jahrbuch* 2011, 106-117.
- MENEGHETTI, S.; COSTACURTA, A.; CRESPIAN, M.; MAUL, E.; HACK, R.; REGNER, F.; 2009: Deepening inside the homonyms of 'Wildbacher' by means of SSR markers. *Vitis* **48**, 123-129.
- METZGER, J.; 1827: Der Rheinische Weinbau, August Obwald, Heidelberg.
- MONCADA, X.; PELS, F.; MERDINOGLU, D.; HINRICHSEN, P.; 2006: Genetic diversity and geographical dispersal in grapevine clones revealed by microsatellite markers. *Genome* **49**, 1459-1472.
- OIV; 2009: OIV Descriptor List for Grape Varieties and *Vitis* Species. (2nd edition). Org. Int. Vigne Vin, Paris, France.
- OLMO, H. P.; 1940: Somatic mutation in the *vinifera* grape. III. The Seedless Emperor. *J. Hered.* **31**, 211-213.
- PELS, F.; 2009: Molecular and cellular mechanisms of diversity within grapevine varieties. *J. Hered.* **104**, 331-340.
- PELS, F.; HOCQUIGNY, S.; MONCADA, X.; BARBEAU, G.; FORGET, D.; HINRICHSEN, P.; MERDINOGLU, D.; 2010: An extensive study of the genetic diversity within seven French wine grape variety collections. *TAG* **120**, 1219-1231.
- REGNER, F.; STADLBAUER, A.; EISENHELD, C.; 1998: Heunisch x Fränkisch, ein wichtiger Genpool europäischer Rebsorten (*Vitis vinifera* L. *sativa*). *Wein-Wissenschaft* **53**, 114-118.
- RIAZ, S.; GARRISON, K. E.; DANGL, G. S.; BOURSQUOT, J. M.; MEREDITH, C. P.; 2002: Genetic divergence and chimerism within ancient asexually propagated winegrape cultivars. *J Amer Soc Hort Sci* **127**, 508-514.
- ROY-CHEVRIER, J.; 1900 : Ampélographie Rétrospective. Coulet et Fils Montpellier – Masson et Cie Éditeurs Paris.
- RUSJAN, D.; JUG, T.; STAJNER, N.; 2010: Evaluation of genetic diversity: Which of the varieties can be named 'Rebula' (*Vitis vinifera* L.)? *Vitis* **49**, 189-192.
- SCHNEIDER, A.; CARRA, A.; AKKAK, A.; THIS, P.; LAUCOU, V.; BOTTA, R.; 2001: Verifying synonymies between grape cultivars from France and Northwestern Italy using molecular markers. *Vitis* **40**, 197-203.
- SCHNEIDER, A.; RAIMONDI, S.; MOREIRA MAIA, F.; DE SANTIS, D.; ZAPPÀ, R.; TORELLO MARINONI, D.; LIBRANDI, N.; GRANDO, M. S.; 2009 : Contributo all'identificazione dei principali vitigni calabresi. *Rivista di frutticoltura e di ortofloricoltura*, **71**, 46-55.
- SCHÜBLER, G.; MARTENS, G.; 1834 : Flora von Württemberg, C.F. Osian-der, Tübingen.
- SCHUMANN, F.; 1997: Rebsorten und Weinarten im mittelalterlichen Deutschland. In: Quellen und Forschungen zur Geschichte der Stadt Heilbronn, 9, *Weinwirtschaft im Mittelalter*. Stadtarchiv Heilbronn, 221-254.
- SEFC, K. M.; REGNER, F.; TURETSCHKE, E.; GLÖSSL, J.; STEINKELLNER, H.; 1999: Identification of microsatellite sequences in *Vitis riparia* and their applicability for genotyping of different *Vitis* species. *Genome* **42**, 367-373.
- SPRENGER, B.; 1766: Praxis des Weinbaus bzw. vollständige Abhandlung des gesamten Weinbaus. Stuttgart.
- STAAB, J.; 1971: 500 Jahre Rheingauer Klebrot = Spätburgunder. *Schriften zur Weingeschichte* Nr. 24.
- STAAB, J.; 1997: Weinwirtschaft im frühen Mittelalter, insbesondere im Frankenreich und unter den Ottonen. In: Quellen und Forschungen zur Geschichte der Stadt Heilbronn, 9, 29-76. *Weinwirtschaft im Mittelalter*. Stadtarchiv Heilbronn.
- THIS, P.; LACOMBE, T.; THOMAS, M. R.; 2006: Historical origins and genetic diversity of wine grapes. *Trends Genet.* **22**, 511-519.
- THOMAS, M. R.; SCOTT, N. S.; 1993: Microsatellite repeats in grapevine reveal DNA polymorphisms when analysed as sequence-tagged sites (STSs). *Theor Appl Genet* **86**, 985-990.
- TREZISE, R. G.; BURNE, P. M.; 2005: Seedless Grape. United States Plant Patent Application Publication.
- TRUMMER, F. X.; 1841: Systematische Classification und Beschreibung der im Herzogthume Steiermark vorkommenden Rebsorten, K.K. Landwirtschafts-Gesellschaft in Steiermark, Grätz.
- TRUMMER, F. X.; 1855: Nachtrag zur systematischen Klassifikation und Beschreibung der im Herzogtum Steiermark vorkommenden Rebsorten, K.K. Landwirtschafts-Gesellschaft in Steiermark, Grätz.
- VARGAS, A. M.; VELEZ, M. D.; DE ANDRÉS, M. T.; LAUVOU, V.; LACOMBE, T.; BOURSQUOT, J. M.; BORREGO, J.; IBANEZ, J.; 2007: Research Note, Corinto blanco: A Seedless Mutant of Pedro Ximenes, *Am. J. Enol. Vitic.* **58**, 540-543.
- VELOSO, M. M.; ALMANDANIM, M. C.; BALEIRAS-COUTO, M.; PEREIRA, H. S.; CARNEIRO, L. C.; FEVEIREIRO, P.; EIRAS-DIAS, J.; 2010 : Microsatellite database of grapevine (*Vitis vinifera* L.) cultivars used for wine production in Portugal. *Ciência e Técnica Vitivinícola* **25**, 53-61.
- VIALA, P.; VERMOREL, V.; 1905-1910 : Traité Général de Viticulture. Masson et Cie., Paris.