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OENO-CARPOLOGICAL AND ENOCHEMICAL CHARACTERIZATION OF WILDLY GROWING GRAPEVINE (VITIS VINIFERA L.) ACCESSIONS FOUND IN GEORGIA

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Abstract
The flora of Georgia is distinguished by the biodiversity of the wild Eurasian grapevine (V. vinifera L.), which includes the wild (forest) vine V. vinifera ssp. sylvestris Gmel., wild cultivated grapevine accessions V. vinifera ssp. sativa DC., and transitional forms between accessions and the wild grapevine V. vinifera ssp. silvestris Ram. Since the second half of the 19th century, as a result of the spread of pests (phylloxera) and fungal diseases introduced from America, wild and transitional grapevines have become rare in the environment. Therefore, the study of the carpological and enological characteristics of six wild grapevine forms preserved in the grapevine collection of the Agricultural Scientific Center, in relation to control varieties, is of particular interest to our research. Experimental wines were made from three forms, and their chemical and organoleptic characteristics were determined. The study showed that the studied individuals are not inferior to the control varieties in terms of eno-carpological data. The experimental wines, like those of the control varieties, are distinguished by good enochemical and organoleptic properties
Keywords: Wild grapevine, carpology, wine, organoleptic

1. INTRODUCTION

Regarding the issues of grapevine domestication, it is interesting to study the gene pool of an indigenous viticulture country like Georgia. Here, we have a large number of wild ancestors of the grapevine [1]. In addition, alongside wild and cultivated grapevines, transitional forms between them have also been recorded in Georgia [2], arising from the rewilding of grapevine varieties [3] and/or gene exchange with wild grapevines [3]-[5]. All in all, this indicates a long and continuous process of wild grapevine domestication in this territory and increases interest in an in-depth study of the biodiversity of Georgian grapevines. These genotypes are found in the wild, but their ampelographic characteristics are close to those of cultivated varieties. Therefore, their study and attempts to return them to cultivation are of great interest.
The discovery of wild-growing forms in Georgia has been recorded since the 19th century, for example, with the case of Asuretuli Shavi [6]. In the 20th century, Forest Vine was discovered in Kakheti, Povnili and Tiskskrudzena were found in Adjara [6], [7]. A significant gene pool was identified and preserved in a collection by Maxim and Revaz Ramishvili, among which more than forty genotypes were studied: Part 40, Vanuri 2, Pirgebuli 40, Kakhi Varazi, Khirsuli Shavi, etc. [8], [9]. Such an unusual discovery of wild vines in the 21st century is currently being held at the Jighaura Head Office of the Agricultural Research Center [10].
When reviewing the state of the study of wild-growing forms in the 21st century, the following picture emerges: eight forms have been discovered through expeditionary means [11], which are preserved in the Jighaura collection.
The eco-geographical environment of their distribution has been discussed [12], and these forms have been fully described ampelographically, with ampelographic maps created [13].

The aim of the experiment was to conduct an oeno-carpological study of the wild-growing grapevine forms preserved in the Jighaura collection, to produce experimental wines, and to assess their enological potential.

2. MATERIALS AND METHODS

Research material: Six grapevine samples from the Jighaura grapevine collection of the Agricultural Research Center (FAO code GEO038) were used for the study. These samples, which previously grew wild in different regions of Georgia, have been preserved in this collection since 2014 (Table 1). The samples were selected based on ampelographic characteristics, as they are compatible with cultivated grapevine varieties. The leading Georgian grapevine varieties, Rkatsiteli (w) and Saperavi (w), as well as the French - Chardonnay (w) and Cabernet Sauvignon (w) - were used as controls.

Table 1. Wild grapevine forms included in the study

#	Name	Region	GPS coordinates	ASL
1	Delisi 01	Tbilisi	N 41°43'23.3" | E 44°04'18.9"	606
2	Dighomi 01	Tbilisi	N 41°46.026" | E 44°45.816"	486
3	Tedotsminda 01	Gori	N 42°01.532" | E 44°03.514"	653
4	Tedottsminda 22(2)	Gori	N 42°02'18.5" | E 44°03'24.4"	662
5	Naghomari 01	Letekhi	N 42°40'34.2" | E 42°45'67.5"	698
6	Nakhiduri 14	Bolnisi	N 42°29'16.5" | E 44°41'18.9"	438

Research methods: For the eno-carpological evaluation of the forms, the phenotyping method developed within the framework of the COST action FA1003 project was used [14]. The sugar content of grape juice was determined in triplicate using a HI96801 digital refractometer.

Titratable acidity was determined using the OIV method [15] OIV-MA-AS313-01. The pH of the grape juice was measured in triplicates using a DpH-2 digital pH meter. In order to determine the total anthocyanins and phenolic compounds in the berries (seed and skin), the skin and seeds were separately revealed for each replicate in an acidified ethanol solution (70% ethanol, 29% distilled water, 1% HCl (38%)). The experiment was performed in triplicates. The total anthocyanins and total polyphenols in the extracts were determined using a UV-1100 spectrophotometer. Additionally, total anthocyanins were determined in mg/kg of grapes and converted to malvidin-3-5-glucoside equivalents. Total polyphenols were determined separately in the skin and seed extracts in mg/kg of grapes as (+) catechin equivalents [14]. Experimental wines were made from wild-growing accessions Delisi 01 (white), Naghomari 01 (red), Tedotsminda 01 (red), and control varieties. The winemaking process took place from October to March. The harvest date was determined based on the visual characteristics of the grapes and the sugar-acidity index. Grapes were harvested by hand. The classic technology for white and red wine production was used, which includes fining, crushing, sulfitation, fermentation using pure culture, removal of wine from lees, pressing, cleaning, racking, and bottling [16]. Sparkling wine was made using the traditional champagne method. A pure yeast culture (IOC 18-2007) was introduced to conduct fermentation. Fermentation lasted 12-13 days, with the average temperature of the fermented liquid being 20-22°C. Enological analyses were performed according to the methods of the International Organization of Vine and Wine (OIV) (OIV-MA-AS313-01, OIV-MA-AS312-01A) [17]. Sensory evaluation of the wine was carried out by a specially selected tasting commission in a tasting room, in accordance with OIV standards. Mean values of all indicators were used for the overall assessment of the wine. The obtained numerical data were processed using descriptive variational statistics methods with the SPSS v.26 software package. The study was conducted in 2020-2023.

3. RESULTS

For grapevine domestication, fruit size and grape juice sugar content were among the key characteristics. Therefore, it is important to study bunch, berry carpological, and Skin biochemical data in the study samples [18]. As expected, the bunch weight, berry weight, skin weight, seed weight, number of seeds per berry, berry length and width of the studied wild forms showed considerable diversity from the control varieties (Table 2)

Table 2. Carpological parameters of wild forms and control varieties (2020-2022 average)

Name	Bunch weight (g)	Berry weight (g)	Skin weight (g)	Number of seeds	Seed weight (g)	Berry length (mm)	Width of the berry (mm)
Delisi 01	191,8±25,9	1,9±0,2	0,5,0±0,2	1,5	0,07±0,01	4,3±1,2	13,1±0,5
Digomi 01	145,7±22,9	2,9±0,4	0,7±0,2	1,7	0,08±0,02	15,9±1,4	14,8±1,1
Tedotsminda 01	47,5±13,2	0,8±0,01	0,3±0,1	2,4	0,1±0,08	9,7±0,7	10,2±0,6
Tedotsminda 22(2)	82,0±19,5	2,2±0,2	0,5±0,1	1,2	0,07±0,01	14,3±0,3	14,2±0,3
Naghomari 01	94,0±18,9	1,2±0,1	0,3±0,1	2,1	0,09±0,01	11,5±0,3	11,4±0,6
Nakhiduri 14	208,5±128,0	2,8±0,3	0,6±0,1	1,8	0,08±0,01	14,7±3,7	13,7±2,7
Cabernet sauvignon	144,9±64,3	1,2±0,1	0,3±0,05	1,9	0,1±0,06	11.9±1,6	11,2±1,2
Rkatsiteli	199,3±41,8	1,6±0,2	0,5±0,1	1,8	0,1±0,08	13,0±1,0	12,3±0,7
Saperavi	171,0±64,5	1,3±0,3	0,4±0,1	1,6	0,09±0,06	12,2±0,5	12,5±0,8
Chardonnay	83,5+53.1	1,5±0,1	0,4±0,08	1,6	0,06±0,01	12,6+±0,1	12,0±0,2

Among the studied samples, Tedotsminda 01, Tedotsminda 22(2), Naghomari 01, and the control variety Chardonnay have very small bunches (up to 100 g); Delisi 01, Digomi 01, Rkatsiteli, Saperavi, and Cabernet Sauvignon have small bunches (up to 200 g); and Nakhiduri 14 has medium-sized bunches (over 200 g) according to the OIV (2009) descriptors (Table 2).
The weight of the berries in the studied forms varies from 0.3 g to 2.9 g (Table 2). In the control varieties, it ranges from 1.2 g to 1.6 g. Digomi 01 has the largest berries, while Tedotsminda 01 has the smallest.
The remaining forms and control varieties have approximately similar berry weights.
In terms of berry length, according to the OIV classification, short berry length (up to 13 mm) was observed in Naghomari 01 and Tedotsminda 01, similar to Saperavi, Chardonnay, and Cabernet Sauvignon.
An average result (up to 18 mm) was observed in the berries of Digomi 01, Nakhiduri 14, Delisi 01, and Tedotsminda 22(2), similar to Rkatsiteli (Table 2).
In terms of berry width, short berries (up to 13 mm) were observed in all control forms and in Tedotsminda 01 and Naghomari 01 among the wild forms. The average width (up to 18 mm) was found in Digomi 01, Delisi 01, Nakhiduri 14, and Tedotsminda 22(2).
According to berry size, Digomi 01 has the largest berries, measuring 15.9 x 14.1 mm.
The number of seeds per berry in Tedotsminda 01 is 2-3. All other forms, including the control varieties, have 1-2 seeds per berry. The seeds of all studied forms are similar to those of full-fledged cultivated varieties. High sugar levels are accumulated by Naghomari 01, with a sugar content of 24.7%. Delisi 01 and Tedotsminda 01 have sugar contents ranging from 21% to 23%, which is similar to the control varieties. Tedotsminda 22(2) is characterized by a low total sugar content in grape juice (16.3%).

The sugar content in Nakhiduri 14 and Digomi 01 (18.1% and 18.5%, respectively) is considered average according to the OIV methodology.

Table 3. Biochemical data of wild forms and control varieties (2020-2022 average)

Name	Sugars (%)	Titratable acidity, g/l	pH
Delisi 01	21,3 ± 1,0	7,7 ±1,2	3,1 ± 0,2
Digomi 01	18,5 ± 0,2	3,7 ± 0,2	3,1 ± 0,2
Tedotsminda 01	21,8 ± 0,7	10,5 ± 0,8	3,1 ± 0,2
Tedotsminda 22(2)	16,0 ± 2,1	4,4 ± 0,5	3,3 ± 0,2
Naghomari 01	24,7 ± 0,1	8,6 ± 0,3	3,1± 0,3
Nakhiduri 14	18,1 ± 0,8	6,5 ± 1,4	3,5 ± 0,2
Cabernet sauvignon	22,3 ± 0,8	7,3 ± 2,8	3,1 ± 0,1
Rkatsiteli	22,2 ± 0,8	5,5 ± 2,4	3,4 ± 0,3
Saperavi	21,0 ± 1,0	7,8 ± 2,1	3,4 ± 0,1
Chardonnay	23,2 ± 0,6	7,6 ± 1.5	3,5 ± 0,2

Similar to sugar content, variation was also observed in the acidity of grape juice. Tedotsminda 01 and Naghomari 01 are distinguished by high acidity.

The titratable acidity of grape juice (converted to g/l tartaric acid) is very low in Digomi 01 and Tedotsminda 22(2) (3.7 g/l and 4.4 g/l, respectively), low in Nakhiduri 14 and Rkatsiteli, and average in Delisi 01, Chardonnay, Cabernet Sauvignon, and Saperavi.

In all studied forms and control varieties, the pH of grape juice varies between 3.1 and 3.5, which is considered an average indicator according to the OIV methodology (OIV, 2009).

Table 4. Polyphenols and anthocyanins of wild forms and control varieties (2020-2022 average)

Name	Color	Skin phenols (mg|kg)	Seed phenols (mg|kg)	Total polyphenols (mg/kg in	Total anthocyanins (mg|kg per grape)
Delisi 01	Black	431	20	451±125	0
Digomi 01	Black	248	27	275±147	0
Tedotsminda 01	Red	1287	115	1402±490	783±52
Tedotsminda 22(2)	Black	336	38	374±160	0
Naghomari 01	Red	1469	92	1561±964	922±508
Nakhiduri 14	Black	276	25	301±288	0
Cabernet sauvignon	Black	924	80	1004±314	610±243
Rkatsiteli	Red	291	60	351±146	0
Saperavi	Black	926	35	961±89	668±256
Chardonnay	Red	302	19	321±32	0

Experimental Wines

Experimental wines were made from three wild-growing forms of the Jighaura collection: Delisi 01, Tedotsminda 01, and Naghomari 01, along with four control varieties.

According to enological parameters, the wines made from wild-growing vines are comparable to those of the control varieties in all chemical indicators. They are distinguished by higher alcohol content; however, their titratable acidity exceeds that of the control wines. The pH in all of them ranges from 3.5 to 3.8. In terms of total phenolic content, the wine from Naghomari 01 exceeds that of Saperavi and slightly lags behind the phenolic content of Cabernet Sauvignon. In the white wines, the phenolic content is similar in all forms.

Table 5. Enochemical parameters of experimental wines (2021-2022 average)

Analysis	Rkatsiteli	Chardonnay	Delisi 01	Naghomari 01	Tedotsminda 01	Saperavi	Cabernet sauvignon
Alcohol %	13,1	14,5	12,9	14,0	12,6	12,4	13,5
Sugar content. g/l	1,2	1,3	2,3	2,8	2,0	2,6	2,9
Titratable acidity. mg/l (tartaric acid)	4,6	7,2	7,6	8,0	8,0	5,4	5,1
Volatile acidity g/l	0,3	0,4	0,4	0,5	0,3	0,3	0,3
Extract. g/l	18,9	25,7	23,1	30,7	22,5	22,8	23,7
Total phenolic content. mg/l	3,7	3,8	3,5	3,6	-	3,8	3,6
Total anthocyaninssin wine. mg/l	235	221	222	1450	-	1375	1620

Sensory Evaluation of Wine

The wild-growing form of Delisi 01 was produces as both dry white wine (using the classical method) and sparkling wine (using the traditional champagne method). The wines from the study sample were compared to the wines made from Rkatsiteli and Chardonnay. According to the tasters, the still wine from Delisi 01 was inferior to the wines of the control varieties in terms of aroma intensity and taste properties, although it was superior in acidity (Fig. 1)

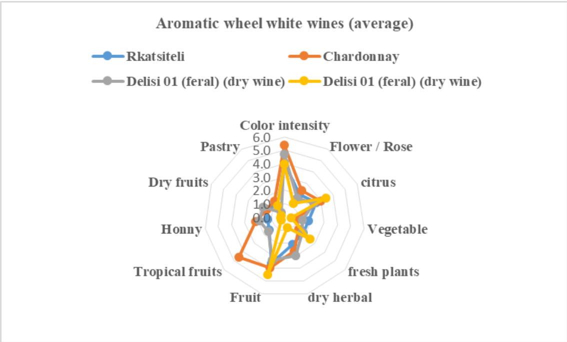

Fig. 1. Aroma Wheel of Dry White Wines

The tasters' evaluation revealed that the Delisi 01 dry wine is inferior to the Delisi 01 sparkling wine in terms of aroma duration, acidity, and balance (Fig. 2). Accordingly, the Delisi 01 wine shows more potential in the sparkling wine category.

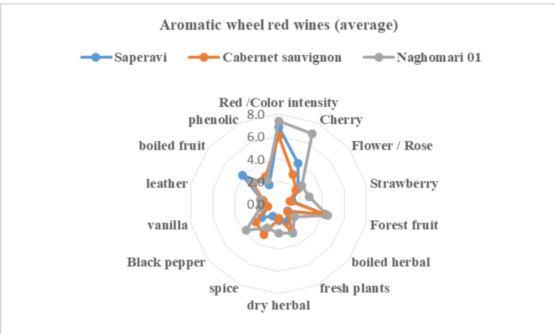

Fig. 2. Flavor Wheel of White Wines

Dry red wine made from the wild form Naghomari 01 using the traditional method, according to experts, is full-bodied, balanced, harmonious, high-acid, medium tannin, with good alcohol content, and cherry-colored. It has a pleasant aroma of cherry, forest fruits, and black pepper, similar to Saperavi and Cabernet Sauvignon wines, which surpass Naghomari 01 wine with aromas of roasted fruit and spices (Fig. 6). The wine made from this form has an interesting, long-lasting aroma, a rich taste, and great potential in the category of dry red wines.

Naghomari 01 wine was compared to Saperavi and Cabernet Sauvignon wines of the same year and location, made using the Classic method. The wines of the control varieties were distinguished by an abundance of aromas characteristic of young wines. Naghomari 01 wine was comparable to the wines of the control varieties in terms of aroma duration, structure, and alcohol content, but it surpassed them in sweetness and acidity.

Wine made from Naghomari 01 raised great interest among tasters as a new, promising form for use in Georgian winemaking.

4. CONCLUSIONS

The eno-carpological study of wild-growing forms revealed that the samples Digomi 01, Tedotsminda 22(2), and Nakhiduri 14, with their large grape and berry sizes, low sugar content, and titratable acidity, belong to table varieties. In contrast, the samples Delisi 01, Tedotsminda 01, and Naghomari 01, with their relatively small berries, high sugar content, and acidity, belong to wine varieties.

Two wild-growing forms, Naghomari 01 and Tedotsminda 01, were identified, which total polyphenol index and anthocyanin content exceed similar data for the control varieties.

The study of enological parameters—enochemical variables and organoleptic (sensory) profiles—showed a high potential for producing high-quality wines. Among these, Delisi 01 can be successfully used for the production of sparkling wines, while Naghomari 01 is considered promising in the category of dry red wines.

The differences in biochemical and organoleptic parameters are attributed to genotypic differences.

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