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ORIGINAL RESEARCH PAPER

INFLUENCE OF DIFFERENT VINE ROOTSTOCKS ON THE VOLATILE COMPOSITION OF RED WINES FROM KAYLASHKI RUBIN GRAPEVINE VARIETY

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Abstract: In order to determine the effect of some rootstocks on the volatile composition of red wines from three harvests (2017, 2018 and 2019) of the grafted interspecific hybrid variety Kaylashki Rubin a gas chromatographic (GC-FID) study was performed. The highest total content of volatile compounds was found in wines from vintage 2017. Acetaldehyde (basic aldehyde) levels were detected in the variants of all three vintages, in concentrations indicating a properly conducted fermentation process and followed sulphitation procedures. In the 2018 and 2019 harvests, it was found that wines obtained from Kaylashki Rubin variety grafted on rootstocks 110 R (2018) and 44-53 M (2019) shown a higher final content of higher alcohols compared to the control. The main representatives of the fraction of higher alcohols identified in wines were 2-methyl-1-butanol, 3-methyl-1-butanol, 1-butanol, 1-hexanol, 4-methyl-2-pentanol, 1-propanol and 2-butanol. The best results for total ester content were found in the wines from the 2019 harvest. In them, the wines of the Kaylashki Rubin variety grafted on the 44-53 M and 110 R rootstocks shown a higher ester content than the control. The basic ester was ethyl acetate. The main representative of the terpene fraction was geraniol. The wines from the 2017 and 2019 harvests at the Fercal rootstock shown a tendency of a higher total terpene concentration compared to the control. In all tested variants, the typical for red wines methyl alcohol concentrations was detected.

Keywords: *aldehydes, esters, grapevine variety, grapes, higher alcohols, red wines, rootstocks, terpenes*

INTRODUCTION

The emergence and rapid spread of phylloxera (*Daktulosphaira vitifoliae*) in Europe (1860) led to the destruction of many vineyards grown on their own roots on the old continent. Later (1880) when American vines were imported to Europe, it was found that they were not attacked by phylloxera. This marked the beginning of a branch of viticulture - the creation of grafting material based on the use of American vines as rootstocks of cultivars in order to solve the problem with phylloxera crisis [1].

The application of different rootstocks in the production of vine seedlings is an important method not only of protection against pests, but also an effective factor on the influence on the growth of the vine, the composition of its grapes and the quality of the resulting wine [2].

Study of Chardonnay and Pinot Noir vines grafted on rootstocks 99 Richter (99 R), 110 Richter (110 R), 140 Rugeri (140 Ru) and Selection Oppenheim (SO4) established the achievement of the highest quality of wine obtained from the fruit of vines grafted on 110 R [3].

The volatile composition of the wine is one of the main parameters for its quality. It is determined by the presence of individual compounds belonging to several main groups - esters, aldehydes, higher alcohols, terpene compounds [4, 5]. The formation of the wine final volatile composition depends on many factors: genetic ability of the grapevine variety to accumulate specific compounds in the grapes [6], climatic and soil characteristics of the growing area [7], the phytosanitary condition of the vine [8, 9], metabolic activity of the yeast microflora during alcoholic fermentation [10], wine aging [11].

A study of the effect of several rootstocks on the volatile composition of Merlot wines found that when 99 R and 140 Ru rootstocks were used, the wines accumulated a higher total ethyl esters content than the control variant (own root vines) [12].

There are few studies in the scientific literature concerning the specific effects of different rootstock combinations on the volatile composition of wines.

The aim of the present study is to determine the effect of the use of certain rootstocks on the volatile composition of red wines from three harvests of the interspecific hybrid Kaylashki Rubin.

MATERIALS AND METHODS

Rootstocks

• Berlandieri x Riparia SO4

The Berlandieri x Riparia SO4 rootstock was obtained in 1896 by Sigmund Teleki and Heinrich Fuhr. It is widespread in almost all wine-growing countries. It was imported to Bulgaria from France (1966), through the Ministry of Agriculture and Food [13]. It was recommended for distribution in 1969 by Mamarov and Dimitrov [14].

The SO4 rootstock withstands up to 17 % active and up to 30 - 40 % total carbonates in the soil. The index of soil chlorinating strength to which it withstands is 30.

The rootstock withstands salinity up to 0.4 ‰ NaCl.

• Berlandieri x Rupestris 110 Richter

The Berlandieri Resseguier 2 x Rupestris Martin rootstock was created in 1889 by Franz Richter in France. It is distributed in Algeria, Spain, Italy, Portugal, Switzerland, Turkey, Greece and some other countries. It is not widespread in Bulgaria, although it was imported in 1927. In North Africa and partly in Morocco, where the climate is very dry, its resistance to active carbonates increases to 22 %. Berlandieri x Rupestris 110 Richter gives growth strength and accelerates the ripening of grapes of its grafted varieties. It withstands up to 17 % (even 22 % in very dry climate) active and 30 - 40 % total carbonates in the soil. The soil chlorinating strength index to which it withstands is 30. The rootstock is sensitive to excess moisture in the soil. Its resistance to salts in the soil is zero.

• 44-53 Malègue [Riparia grand glabre x 144 M (Cordifolia x Rupestris)]

The 44-53 M rootstock is a complex hybrid obtained by Malégue in 1890 by crossing the Riparia grand glabre and 144 M rootstocks (Cordifolia x Rupestris). For a long time after its creation, it was not used in practice. It was described by Gervais and was recognized as spreading in France in 1944. Between 1945 and 1960, it was distributed widely in France after being found its resistance to the short-knot virus and to drought.

In Bulgaria this rootstock was imported from France in 1966, through the Ministry of Agriculture and Food, but it is not widely propagated. It was tested at the Institute of Viticulture and Enology in Pleven in 1967-1969, together with the rootstocks imported at the same time and those widely used in the country. It is recommended as suitable for the Bolgar grapevine variety.

The rootstock 44-53 M is a moderately mature with moderate growth. When it is used for transplantation of European varieties, it catches well and gives high quality grapes.

It is resistant to phylloxera. The resistance of carbonates in the soil is relatively weak – 10 % active, 20 - 25 % total carbonates. The rootstock shows sensitivity in the absence of magnesium.

• Fercal

The Fercal rootstock was created in 1959 by Roger Pouget at the National Institute for Agronomic Research in Bordeaux (France) by crossing the BC1 (Berlandieri x Colombard №1) x Z33 EM (Berlandieri x Cabernet Sauvignon) rootstocks. It was recognized as a variety in 1978 for soils with high chlorinating power.

Drought resistance is superior to rootstock 41 B and close to that of rootstock 110 R. It is characterized by high resistance to carbonates and in this quality, it is superior to rootstock 41 B. For now, this rootstock is the most resistant to carbonates in the soil and can safely grow on highly carbonated soils with high chlorinating power. It withstands up to 45 % active and up to 60 - 70 % total carbonates in the soil. The index of chlorinating strength of the soil to which it withstands is 120. Fercal tolerates well the conditions of temporary water deficit in the spring.

It gives an average force of growth to the graft, slightly higher than that given by the rootstock 41 B.

Climate, soils, vinification

The study was conducted at the Institute of Viticulture and Enology (IVE) - Pleven, in the period 2017 - 2019. The object of the current study was red wines obtained from three harvests (2017, 2018 and 2019) of the variety Kaylashki Rubin - interspecific hybrid with parental forms - (Pamid x Hybrid VI 2/15) x (Game noir x *Vitis amurensis*) [15]. The grapevine variety was cultivated in the region of Central Northern Bulgaria at the Experimental Base of IVE, Pleven. It was distributed on an area of 0.3 ha.

The region of Pleven is a part of the Northern Wine Region (Danube Plain), which is characterized by a typical continental climate, early spring with frequent late frosts, hot and relatively dry summers, long and warm autumns with early frosts, cold and frosty winter. The soils include all types of chernozems - typical, carbonate, leached, heavily leached and podzolic, formed on loess. The region is characterized by the following indicators: temperature sum during the vegetation period: 3130 - 4003 °C; duration of the vegetation period: 190 - 210 days; duration of the frost-free period: 178 - 223 days; beginning of vegetation: 02.04. to 14.04.; frequency of spring frosts: up to 20 %; average temperature of the warmest month: 20.03 - 24.02 °C; annual amount of precipitation: 532 - 753 $mm\cdot dm^{-3}$; hydrothermal coefficient for June, July and August: 0.7 - 1.5 [16, 17].

The grape harvest was carried out in the second half of September when the grapes reached technological maturity. The grapes (30 kg) were processed under the conditions of micro-vinification in the Experimental Wine Cellar of IVE. A classic scheme for the production of dry red wines was applied [18]: crushing and destemming, sulphitation (50 $mg\cdot kg^{-1}$ SO_2), inoculating with pure culture dry yeasts *Saccharomyces cerevisiae* Siha Rubio Cru (EATON Begerow) – 20 $g\cdot hL^{-1}$, temperature of fermentation – 28 °C, separation from solids, further sulphitation, storage.

Volatile content determination (GC-FID)

Gas chromatographic determination of the volatile components in wines was done. The content of major volatile compounds was determined on the basis of stock standard solution prepared in accordance with the IS method 3752:2005 [19]. The method describes the preparation of standard solution with one congener. Hereby a solution containing 32 compounds was prepared. The compounds in the standard solution (with their retention times) had > 99% purity (Merck, Darmstadt, Germany) and were: acetaldehyde (3.141), ethyl acetate (3.758), methanol (3.871), 2-propanol (5.170), isopropyl acetate (5.975), 1-propanol (6.568), 2-butanol (7.731), propyl acetate (9.403), 2-methyl-propanol (10.970), 1-butanol (11.509), isobutyl acetate (11.662), ethyl butyrate (12.710), butyl acetate (12.752), 2-methyl-1-butanol (13.054), 4-methyl-2-pentanol (13.629), 3-methyl-1-butanol (13.840), 1-pentanol (15.180), isopentyl acetate (15.965), pentyl acetate (16.033), 1-hexanol (16.276), ethyl hexanoate (16.376), hexyl acetate (16.510), 1-heptanol (16.596), linalool oxide (16.684), phenyl acetate (18.055), ethyl caprylate (18.625), *α*-terpineol (19.066), 2-phenyl ethanol (19.369), nerol (19.694), *β*-citronellol (19.743), geraniol (19.831), ethyl decanoate (19.904). Octanol (16.345) was used as an internal standard.

The 2 μL of prepared standard solution was injected in gas chromatograph Varian 3900 (Varian Analytical Instruments, Walnut Creek, California, USA) with a capillary column VF max MS (30 m, 0.25 mm ID, DF = 0.25 μm), equipped with a flame ionization detector (FID). The used carrier gas was He. Hydrogen to support combustion was supplied to the chromatograph via a hydrogen bottle. The injections were performed manually using microsyringes (with maximum volume capacity of 10 μL) at the injection volume of 2 μL.

The parameters of the gas chromatographic determination were: injector temperature – 220 °C; detector temperature – 250 °C, initial oven temperature – 35 °C/retention 1 min, rise to 55 °C with step of 2 $°C \cdot min^{-1}$ for 11 min, rise to 230 °C with step of 15 $°C \cdot min^{-1}$ for 3 min. Total time of chromatography analysis – 25.67 min. After determination of the retention times of the compounds in the standard solution the identification and quantification of the volatile substances in the wine distillates was done. Prepared samples were injected in an amount of 2 μL in a gas chromatograph and was carried out an identification (by corresponding retention times of pure compounds in the standard solution) and quantification (by the internal standard concentration) of the substances in each of them.

RESULTS AND DISCUSSION

The data for the identified and quantified volatile compounds in the wines of the Kaylashki Rubin variety (harvests 2017, 2018 and 2019) are presented in Tables 1 - 3.
The variation in the established ethanol content of the wines in the individual variants by harvests was: harvest 2017 (12.91 vol.% - 13.90 vol.%) < Harvest 2019 (13.52 vol.% - 14.28 vol.%) < Harvest 2018 (14.40 vol.% - 14.71 vol.%). It was evident that the highest content of ethyl alcohol in the studied red wines was found in the variants of the 2018 harvest. The concentration of this component depends on the climatic conditions of the year, forming the degree of sugar accumulation in the grapes [18].
The total amount of volatile compounds identified in the highest concentrations at the 2017 harvest variants was found. In this harvest, the highest total volatile compound content was found in the SO4 rootstock variant (470.58 $mg \cdot dm^{-3}$), which has a control role in the study. It was followed by the wine of the variant on a 44-53 M rootstock (422.57 $mg \cdot dm^{-3}$). The lowest value on this indicator shown the variant grafted on the Fercal rootstock (233.76 $mg \cdot dm^{-3}$).
The total volatile content of the wines from the 2018 harvest was lower than that of the previous harvest. In these variants, again with the highest concentration of volatile compounds was the control - red wine obtained from grapes of vines grafted on the SO4 rootstock (332.06 $mg \cdot dm^{-3}$). Second, in terms of the total concentration of volatile compounds, was the wine obtained from the variant grafted on the Fercal rootstock (309.93 $mg \cdot dm^{-3}$).
The results from the third harvest (2019) shown the highest content of volatile compounds in the wines of the Kaylashki Rubin variety grafted on a 44-53 M rootstock (392.04 $mg \cdot dm^{-3}$) and the lowest at 110 R (196.77 $mg \cdot dm^{-3}$).
The acetaldehyde content in wines is highly dependent on the fermentation regime and the composition of the must, and in dry wines it should be in an acceptable amount up to 100.00 $mg \cdot dm^{-3}$ [20]. Characteristic of this aldehyde is the manifestation of an oxidation flavour in the wine taste and aroma when it excesses its permissible concentrations [21].
For wines from the 2017 harvest, the acetaldehyde content ranged from 0.05 $mg \cdot dm^{-3}$ (44-53 M) to 29.86 $mg \cdot dm^{-3}$ (SO4). It was highest in the control variant.
The next harvest (2018) has shown very low acetaldehyde levels. In all tested variants it was found at a concentration of 0.05 $mg \cdot dm^{-3}$.

Table 1. *Volatile composition of red wines of the Kaylashki Rubin variety (harvest 2017) grafted on different rootstocks*

Identified compounds [mg·dm^{-3}]	Wines (harvest 2017)			
	Kailashky Rubin			
	SO4	***44-53 M***	***110 R***	***Fercal***
Ethyl alcohol, vol.%	12.91	13.90	13.20	13.18
Acetaldehyde	29.86	0.05	12.97	0.05
Methanol	49.84	10.03	21.72	21.76
2-Methyl-1-propanol	ND*	ND*	ND*	ND*
2-Methyl-1-butanol	ND*	12.94	35.60	31.86
3-Methyl-1-butanol	49.19	126.59	126.18	133.70
4-Methyl-2-pentanol	ND*	36.85	ND*	ND*
2-Phenylethanol	ND*	ND*	ND*	ND*
1-Propanol	ND*	ND*	ND*	ND*
1-Butanol	46.23	35.79	27.62	19.29
1-Pentanol	194.80	ND*	ND*	ND*
1-Hexanol	24.98	0.05	5.34	3.82
1-Heptanol	ND*	ND*	0.05	0.05
Total higher alcohols	***315.20***	***212.17***	***194.79***	***188.72***
Ethyl acetate	52.33	178.88	13.65	3.41
Propyl acetate	22.88	21.27	18.93	18.99
Pentyl acetate	ND*	ND*	ND*	ND*
Ethyl decanoate	ND*	ND*	ND*	ND*
Hexyl acetate	ND*	ND*	ND*	ND*
Total esters	***75.21***	***200.15***	***32.58***	***22.40***
α-Terpineol	ND*	ND*	ND*	ND*
Linalool oxide	0.26	ND*	ND*	ND*
Nerol	ND*	ND*	ND*	ND*
β-Citronellol	ND*	ND*	ND*	ND*
Geraniol	0.21	0.17	0.16	0.83
Total terpenes	***0.47***	***0.17***	***0.16***	***0.83***
TOTAL CONTENT	***470.58***	***422.57***	***262.22***	***233.76***

*ND - Not Detected

The last harvest (2019) has shown relatively higher levels of acetaldehyde than the previous one. Its concentration in the red wines from this harvest varied from 4.01 mg·dm^{-3} (Fercal) to 47.61 mg·dm^{-3} (110 R).

All detected concentrations of acetaldehyde (in all three harvests) were up to 2 times lower than the limit value. This is an indicator for properly performed fermentation and followed sulphitation procedures, eliminating the negative effect (oxidation in taste) of higher levels of this aldehyde [21]. The data correlate with the concentrations stated by Velkov [20].

The total content of higher alcohols in the wines from the 2017 harvest varied between the experimental variants in the range of 188.72 mg·dm^{-3} (Fercal) - 315.20 mg·dm^{-3} (SO4). The highest concentration of higher alcohols in the control variant was found. In the wines of the 2018 harvest, lower final levels of higher alcohols were established (169.97 mg·dm^{-3} - 110 R - 191.02 mg·dm^{-3} - SO4), compared to the previous harvest. Here, too, the highest concentration of higher alcohols in the control variant was found.

Table 2. *Volatile composition of red wines of the Kaylashki Rubin variety (harvest 2018) grafted on different rootstocks*

Identified compounds [mg·dm^{-3}]	**Wines (harvest 2018)**			
	Kailashky Rubin			
	SO4	***44-53 M***	***110 R***	***Fercal***
Ethyl alcohol, vol.%	14.41	14.40	14.06	14.71
Acetaldehyde	0.05	0.05	0.05	0.05
Methanol	79.34	77.82	78.22	70.38
2-Methyl-1-butanol	30.46	26.12	25.64	30.91
3-Methyl-1-butanol	104.19	104.22	97.56	102.10
4-Methyl-2-pentanol	0.05	0.05	0.05	0.05
2-Phenylethanol	ND*	ND*	ND*	ND*
1-Propanol	6.69	0.05	7.49	7.75
2-Butanol	38.14	39.48	36.25	37.32
1-Pentanol	11.49	ND*	9.81	9.38
1-Hexanol	ND*	0.05	ND*	ND*
Total higher alcohols	***191.02***	***169.97***	***176.80***	***187.51***
Ethyl acetate	27.64	30.03	32.01	30.58
Propyl acetate	ND*	ND*	ND*	ND*
Pentyl acetate	0.05	ND*	0.05	0.05
Ethyl decanoate	33.66	0.05	ND*	21.31
Ethyl caprylate	0.05	ND*	0.05	ND*
Ethyl hexanoate	0.05	ND*	ND*	ND*
Total esters	***61.45***	***30.08***	***32.11***	***51.94***
α-Terpineol	0.05	ND*	0.05	ND*
Linalool oxide	0.05	ND*	ND*	ND*
Nerol	0.05	ND*	0.05	0.05
β-Citronellol	0.05	ND*	ND*	ND*
Geraniol	ND*	0.05	0.05	ND*
Total terpenes	***0.20***	***0.05***	***0.15***	***0.05***
TOTAL CONTENT	***332.06***	***277.97***	***287.33***	***309.93***

*ND - Not Detected

For red wines from the 2019 harvest, the highest levels of the fraction of higher alcohols were found in the variant of red wine produced from grapes of the Kaylashki Rubin variety grafted on the 44-53 M rootstock (256.34 mg·dm^{-3}). Very low levels were found in the variant grafted on 110 R (60.11 mg·dm^{-3}).

Higher alcohols are components of the volatile composition with high threshold of aromatic perception, but they have significant influence on the ester formation. Their total concentration in red wines varies up to 300.00 - 600.00 mg·dm^{-3} [21]. The data obtained in this study correlates with it.

In the wines from the 2017 harvest, 2-methyl-1-butanol, 3-methyl-1-butanol, 1-butanol and 1-hexanol dominated from the representatives of the higher alcohols fraction. In the next harvest (2018), 2-methyl-1-butanol, 3-methyl-1-butanol, 4-methyl-2-pentanol, 1-propanol and 2-butanol were dominant from this group. The wine from the 2019 harvest was characterized by the main representatives - 2-methyl-1-butanol, 3-methyl-1-butanol, 2-phenylethanol and 1-propanol.

The highest concentration component from the higher alcohols fraction was 3-methyl-1-butanol. For the wines of the 2017 harvest, it ranged from 49.19 mg·dm^{-3} (SO4) to 133.70 mg·dm^{-3} (Fercal). In the next harvest (2018) it was observed in the wines in the presence of 97.56 mg·dm^{-3} (110 R) - 104.22 mg·dm^{-3} (44-53 M). In the last harvest (2019) its concentrations were lower (19.60 mg·dm^{-3} in Fercal, 64.57 mg·dm^{-3} in 44-53 M) compared to the previous two.

Table 3. *Volatile composition of red wines of the Kaylashki Rubin variety (harvest 2019) grafted on different rootstocks*

Identified compounds [mg·dm^{-3}]	**Wines (harvest 2019)**			
	Kailashky Rubin			
	SO4	***44-53 M***	***110 R***	***Fercal***
Ethyl alcohol, vol.%	14.28	14.27	14.25	13.52
Acetaldehyde	9.50	11.40	47.61	4.01
Methanol	34.96	46.21	12.62	11.81
2-Methyl-1-butanol	16.68	48.78	23.13	20.32
3-Methyl-1-butanol	49.10	64.57	24.59	19.60
2-Phenylethanol	103.96	108.91	ND*	125.65
1-Propanol	4.12	2.75	12.39	1.45
2-Propanol	ND*	11.57	ND*	ND*
1-Butanol	ND*	ND*	ND*	ND*
2-Butanol	ND*	ND*	ND*	ND*
1-Pentanol	ND*	19.76	ND*	ND*
Total higher alcohols	***173.86***	***256.34***	***60.11***	***167.02***
Ethyl acetate	13.48	28.90	50.12	16.26
Propyl acetate	30.42	35.96	12.46	8.75
Isopropyl acetate	2.76	5.53	13.85	ND*
Isopentyl acetate	10.68	7.47	ND*	ND*
Pentyl acetate	ND*	ND*	ND*	ND*
Phenyl acetate	ND*	ND*	ND*	ND*
Ethyl caprylate	ND*	ND*	ND*	ND*
Total esters	***57.34***	***77.86***	***76.43***	***25.01***
α-Terpineol	ND*	ND*	ND*	0.58
Nerol	0.44	0.23	ND*	0.24
β-Citronellol	ND*	ND*	ND*	ND*
Total terpenes	***0.44***	***0.23***	***ND****	***0.82***
TOTAL CONTENT	***276.10***	***392.04***	***196.77***	***208.67***

*ND - Not Detected

The second higher alcohol (by quantitative presence) was 2-methyl-1-butanol. In the wines of the 2017 harvest, its concentrations were: 12.94 mg·dm^{-3} (44-53 M) and 35.60 mg·dm^{-3} (110 R). The next harvest (2018) has shown close to these concentrations (26.12 mg·dm^{-3} for the 44-53 M variant and 30.91 mg·dm^{-3} for the Fercal variant). In the last harvest (2019) it was available in wines in the range of 16.68 mg·dm^{-3} (SO4) - 48.78 mg·dm^{-3} (44-53 M).

The data obtained by the species presence of basic higher alcohols in the present study correlated with the findings of Šehović *et al.* [22], according to which the main higher alcohols in wines were 1-propanol, 2-methyl-1-propanol, 2-methyl-1-butanol and 3-methyl-1-butanol.

The total ester content of the wines from the 2017 harvest between the different variants varied from 22.40 mg·dm^{-3} (Fercal) to 200.15 mg·dm^{-3} (44-53 M). In the 2018 harvest, a total ester content in the wines of 30.08 mg·dm^{-3} (44-53 M) - 61.45 mg·dm^{-3} (SO4) was found between the different variants grafted on different rootstocks. For the 2019 harvest, this variation was - 25.01 mg·dm^{-3} (Fercal) - 77.86 mg·dm^{-3} (44-53 M). It was noteworthy that the variants grafted on 44-53 M and 110 R rootstocks shown a higher final ester content in the wines compared to the control variant (SO4).

The esters are components of the volatile composition that most significantly determine the wine aroma. This is due to their diversity and low thresholds of aromatic perception. In young wines, their total amount is about 50.00 mg·dm^{-3}, when the wines aged, they increase significantly due to process of chemical esterification [20]. The data obtained in the present study correlates with this amount.

The ethyl acetate was the main representative of the ester fraction, quantitatively dominant. In the wines from the 2017 harvest, it was found in concentrations of 22.40 mg·dm^{-3} (Fercal) - 178.88 mg·dm^{-3} (44-53 M). Its concentration variation in the wines from the 2018 harvest was 27.64 mg·dm^{-3} (SO4) - 32.01 mg·dm^{-3} (110 R). It is noteworthy here that in wines produced from grapes of the Kaylashki Rubin variety, grafted on 44-53 M, 110 R and Fercal rootstocks, a slight increase in the amount of this ester was found, compared to the control grafted on SO4. For the wines from the 2019 harvest, the variation of ethyl acetate was 13.48 mg·dm^{-3} (SO4) - 50.12 mg·dm^{-3} (110 R). 110 R and Fercal has shown a higher amount of the ester than the control.

The ethyl acetate has a positive effect on the wine aroma at concentrations of 50.00 - 60.00 mg·dm^{-3}, above 120.00 mg·dm^{-3} it begins to give aromatic defects [1]. Of the studies performed, only the variant grafted on the 44-53 M rootstock (harvest 2017) shown a significantly higher level of ethyl acetate (178.88 mg·dm^{-3}), with a negative effect. All other variants of the all three harvests demonstrated the optimal presence of this ester, generating its positive aromatic expression.

The highest total terpene composition in the wines of the 2017 harvest was established in the variant grafted on the Fercal rootstock (0.83 mg·dm^{-3}) and the lowest in the variant grafted on 110 R (0.16 mg·dm^{-3}). The next harvest (2018) shown significantly lower levels of terpene compounds compared to the previous one. Here, the highest terpene concentration was found in the control SO4 (0.20 mg·dm^{-3}). The 2019 harvest shown good terpenes levels, and again, as in the 2017 harvest, their concentration was the highest in the red wine of the Kaylashki Rubin variety grafted on the Fercal rootstock (0.82 mg·dm^{-3}). Dominant and concentration-determining presence of geraniol was observed in the wines form all three harvests. It was the main terpene alcohol identified. The data correlated with Heroiu [23], according to which geraniol is the main terpene alcohol, occupying 24.2 % of the representatives of this group. Terpenes are compounds with biological activity, synthesized in the grapes, from where they pass into the wine. They are mainly responsible for the aroma of wines from muscat grapevine varieties [24].

Methanol is a product of the breakdown of fruit pectin by its own pectolytic enzymes [25]. Methanol concentrations in red wines should not exceed 350.00 mg·dm^{-3} [21]. In the wines of the 2017 harvest, the content of this component between the individual variants was in the range of 10.03 mg·dm^{-3} (44-53 M) - 49.84 mg·dm^{-3} (SO4), the highest amount was reported in the control variant. In the next harvest (2018) slightly higher levels of methyl alcohol (70.38 mg·dm^{-3} – Fercal, 79.34 mg·dm^{-3} – SO4) were found, compared to the previous one. The established levels between the different variants of this harvest were very close one to another. The third harvest (2019) shown levels of methanol in wines (11.81 mg·dm^{-3} – Fercal, 46.21 mg·dm^{-3} – 44-53 M), close to those of the first harvest (2017).

The methanol levels found in all the wines analyzed in the present study were much lower than the permissible threshold. This made the wines safe for consumption.

CONCLUSION

The following conclusions can be drawn from the study conducted for determination of the effect of grafting of the interspecific hybrid Kaylashki Rubin on some rootstocks on the volatile composition of red wines from three harvests:

• The highest total concentrations of volatile compounds were found in wines from the 2017 harvest. In them, the control grafted on the SO4 rootstock shown the highest concentration level of total volatile compounds (470.58 mg·dm^{-3}).

• The levels of basic aldehyde (acetaldehyde) in all three harvests were in concentrations that indicated a properly conducted fermentation process and followed sulphitation procedures.

• The total content of higher alcohols in the studied red wines corresponded to the normal range of its presence. In the 2017 harvest, they were the highest in the control grafted on the SO4 rootstock. In the 2018 and 2019 harvests, however, wines obtained from the Kaylashki Rubin variety grafted on 110 R and 44-53 M rootstocks shown higher final levels of higher alcohols compared to the control variant.

• The main identified representatives of the higher alcohols in the studied variants were: 2-methyl-1-butanol, 3-methyl-1-butanol, 1-butanol, 1-hexanol, 4-methyl-2-pentanol, 1-propanol and 2- butanol.

• In terms of the total content of esters, the best results were shown by the wines from the 2019 harvest. The variants grafted on the 44-53 M and 110 R rootstocks were distinguished by their high ester content (higher than the control content). The main representative of the ester fraction was ethyl acetate. In almost all studied variants (except for the variant grafted to the 44-53 M rootstock, vintage 2017) its levels were optimal and generate a positive effect on the wine aroma.

• The total terpene content in almost all variants was mainly determined by the terpene alcohol geraniol. The use of the Fercal rootstock for the Kaylashki Rubin variety in the 2017 and 2019 harvests shown a tendency of higher total terpene concentration in the wines, compared to the control.

• Methyl alcohol levels typical for red wines were found lower than the permissible threshold in the studied variants. This made the wines safe for consumption.

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