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Genetics and Breeding

# The influence of the vine rootstock on the agrobiological and technological characteristics of the Kaylashki Rubin variety

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***Abstract.*** *The rootstock had a significant impact on the quantity and quality of grapes of the varieties grafted on it. That had been determined by the different growth strength of the rootstocks, their different absorption capacity and compatibility with the cultivated vine. During the period 2017-2020, a study was carried out on the agrobiological and technological properties of grapes and wine of the Kaylashki Rubin variety, grafted on vine rootstocks SO4, 110 Rihter, 44-53 Malegue and Fercal. Differences in the investigated indicators were found as a result of the influence of the used rootstocks. A mechanical analysis was made to determine the composition and structure of the clusters and berries. For the period, the highest average yield per vine was reported for Fercal rootstock, while the best theoretical yield had the variant on 44-53 Malegue rootstock. The chemical composition of grapes and experimental wines had been determined. On the average for the period the highest sugar accumulation and respectively the lowest titratable acids in grapes were reported in the variant of 44-53 Malegue rootstock. The opposite relationship was observed for 110 Richter. Differences in the chemical composition of the wines depending on the used rootstocks were found. The wines from 44-53 Malegue variant had the highest average alcohol content and sugar-free extract, but the lowest rates of titratable acids. The average amounts of the total phenolic compounds and anthocyanins in the wines from the variants of the different rootstocks were close. Their values were the lowest in the samples 2017 vintage. The rootstock type also affected the organoleptic properties of the Kaylashki Rubin wines; however, there was no common trend for the studied period. In 2018 and 2020, the samples from the 110 Rihter variant showed the best tasting qualities.*

**Keywords:** vine rootstock, Kaylashki Rubin variety, grapes, wine, chemical composition, tasting assessment

## Introduction

The existence and modern viticulture development had been inconceivable without the availability of rootstocks suitable for different soil and climatic conditions and for different cultivars. In most wine-growing regions of the world, grafted vines had been used for planting vineyards. By grafting, grapevine more easily overcame the abiotic and biotic stress of the environment (Radulov et al., 1992; Jogaiah et al., 2015). The roots of the cultivated vine *Vitis vinifera* had been particularly susceptible to the soil pests *Phylloxera* and *Nematodes*. Grafting replaced the own root system of the cultivated vines and was used as a way to regulate the strength of their growth, yield, quality of grapes and wine, to increase their resistance to the changing environmental factors (Gawel, 2009; Dias et al., 2017; Olivera et al., 2019).

A large number of rootstock varieties had been known globally in viticulture. Some were more universal and were found in more countries, while others had rather limited spreading. Rootstocks selected on the basis of the American species Vitis Rupestris, Vitis Riparia, Vitis Berlandieri, Vitis Cordifolia, Vitis Candicans had been mainly used. In Bulgaria the most popular rootstocks had been Rupestris du Lot, Chasselas x Berlandieri 41 B, Berlandieri x Riparia SO4, Berlandieri x Rupestris 110 Rihter, Berlandieri x Rupestris 1103 Paulsen and Fercal (Abrasheva et al., 2008; http://agri.bg/agrosaveti/lozarstvo/izbor-na-podlozhki-za-kultyrnite-sortove-lozi-2).

The rootstock type had determined the economic,

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morphological and agrobiological properties of the grafted varieties. The properly chosen variety-rootstock combination determined greatly the vine development, its growth strength, its susceptibility to the availability of macro- and micronutrients in the soil, resistance to low temperatures, drought, overwetting, damage resistance, the quantity and quality of grape harvest (Abrasheva et al., 2008; Gawel, 2009; Kodur, 2011; Kodur et al., 2013; Tethal et al., 2015; Uzunova et al., 2015; Jogaiah et al., 2015; Dias et al., 2017).

Numerous studies had investigated the influence of the various rootstocks not only on the biological processes in the vine, but also on the biochemical parameters of grapes and wine, determining the ratio of the main components in their composition.

Depending on the soil and climatic conditions in the growing area, the rootstock had a different effect on the grapes composition and for each variety the most suitable rootstock could be selected. The rate of sugar accumulation, shown by the variety grafted on a particular rootstock had been of particular technological importance. Moura et al. (2017) had not observed differences in yield, but found such in terms of sugar content, titratable acids and ripening index of grapes from 5 white wine varieties grafted on IAC 766 Campinas and IAC 572 Jales rootstocks. Moyer et al. (2018) had reported that grapes form Pinot Noir variety 02A clone, grown on its own root had higher titratable acidity than on 420A Millardet et de Grasset, 3309 Couderc, 101-14 Millardet et de Grasset rootstocks. The red wine variety Cerason grafted on K125AA, Amos, Börner, CR2, K5BB, K1SO4 and T5C showed differences in the ratios of sugars, total acids, tartaric and malic acid, absorbable nitrogen and pH in grapes (Tethal et al., 2015). Grapes from Alicante Bouschet variety grafted on IAC 572 in Brazil tropical semi-arid climate contained more tartaric and malic acids than on 1103 P (Olivera et al., 2019). When grafting Cabernet Sauvignon variety on 101-14 Mgt, 1103 P, 110 R, 140 Ru, Fercal, Gravesac, SO4 rootstocks, in semi-arid regions of India, the rootstock significantly affected the content of sugars, organic acids, potassium and pH (Jogaiah et al., 2015). The potassium ratio in grapes might be successfully controlled by choosing a rootstock that accumulated less potassium (Kodur, 2011; Kodur et al., 2013).

The phenolic reserves of red wines had been influenced by various factors, such as grape variety, degree of ripeness (Stoyanov et al., 2005), vinification regime (Stoyanov et al., 2004) but the type of the rootstock was also essential. Dias et al. (2017) found that IAC 766 and Rup rootstocks had a positive effect on the phenolic content and alcohol-acid balance of Syrah wines. Grapes from Alicante Bouschet variety grafted on 1103 P had higher ratios of total phenols, non-flavonoids and anthocyanins than on IAC 572 (Olivera et al., 2019). In the Regent variety, which was grown on its own roots and grafted on Couderc 161-49, Sori, Kober 125AA, Börner, Kober 5BB rootstocks, the most polyphenols were reported in the variants of Sori and Kober 125AA (Mijowska et al., 2017). Nedelkovski et al., (2017) had also reported that the phenolic composition of Vranec grapes variety strongly depended on the rootstock. Higher levels of total phenols were observed on Teleki rootstock, of anthocyanins on Chasselas 41B rootstock, of total flavonoids on Rupestris Du Lot and total flavan-3-ols on Fercal.

The objective of this study was to find out the influence of the rootstock by identifying the differences in the agrobiological and technological features of vines, grapes and wine of the Kaylashki Rubin variety grafted on Berlandieri x Riparia SO4, Berlandieri x Rupestris 110 Rihter, Riparia x Rupestris x Cordifolia 44-53 Malegue and Fercal rootstocks.

## Material and methods

The study was carried out at the Institute of Viticulture and Enology (IVE) – Pleven, in the period 2017-2020. Its objects were vines, grapes and wine of the Kaylashki Rubin variety.

*Climate and soils in the growing area*

The region of Pleven is part of the Northern wine-growing region (the Danube plain) and is characterized by a distinctly continental climate, with great heat and frequent, sometimes prolonged droughts in the summer, with minimal precipitation and severe cold in the winter. A typical climatic feature is the relatively cooler spring, which is distinguished by the dynamism of the temperature regime. Autumn occurs in early September with a gradual decrease in average daily temperatures, which is mainly due to the lower values in the morning and in the evening, despite the high daytime temperature. The experimental vineyard was planted on slightly leached black soils formed on clay loess. This type of soil was weakly strong, moderately eroded, heavy sandy-clay by mechanical composition. The soil-climatic conditions of the Experimental Base of the IVE-Pleven were favorable for vine cultivation and research conducting (Pandeliev, 2005; Ivanov, 2016).

*Description of the studied variety*

Kaylashki Rubin is a red medium-ripening variety, selected by intraspecific hybridization in IVE – Pleven and approved in 2010. It was obtained by crossing (Pamid x Hybrid VI 2/15) x (Gamay noir x *Vitis amurensis*). The vines were distinguished for enhanced actual resistance to downy mildew, powdery mildew and low winter temperatures. The grapes had good sugar accumulation. The wines were ruby red in color, having high rates of anthocyanins, pleasant fruity aroma, dense, harmonious, suitable for aging (Ivanov et al., 2011).

*Description of the used rootstocks*

For the study, the vines were grafted on four different vine rootstocks:

- Berlandieri x Riparia, sel. Oppenhein 4 (SO4) – America-American hybrid. It had a good affinity with most table and wine grape varieties; it increased their resistance to low winter temperatures. The vines grafted on it had high fruiting capacity and grapes quality (Radulov et al., 1992; Uzunova et al., 2015; http://agri.bg/agrosaveti/lozarstvo/izbor-na-podlozhki-za-kultyrnite-sortove-lozi-2). The rootstock had been the most widely used in Bulgaria, therefore in the present study it was assumed as control.
- Berlandieri x Rupestris 110 Rihter (110 R) – America-American hybrid. It had a good affinity with most cultivars that when grafted on it showed good vitality and longevity (Radulov et al., 1992; http://agri.bg/agrosaveti/lozarstvo/izbor-na-podlozhki-za-kultyrnite-sortove-lozi-2).
- Riparia x Rupestris x Cordifolia 44-53 Malegue (44-53 M) – complex America-American hybrid, obtained from the crossing of Riparia grand glabre x 144 M (Cordifolia x Rupestris). The vines grafted on it had good fertility and high yields (Radulov et al., 1992).
- Fercal – European-American complex hybrid between BC 1 /Berlandieri x Colombar/ x 333 EM / Cabernet Sauvignon x Berlandieri/. It showed good affinity with most cultivars, that when grafted on it had medium growth strength, good fertility and earlier fruiting onset (Radulov et al., 1992; http://agri.bg/agrosaveti/lozarstvo/izbor-na-podlozhki-za-kultyrnite-sortove-lozi-2).

*Experimental vineyard and grapes*

The experimental vineyard was planted in the spring of 2009 on leached black soils and included 75 vines of each variant. The vines training system was middle-stem, double improved Guyot. The planting distance was 2.00/1.30 m. The pruning and loading of the vines were the same in all variants – 28 winter eyes, obtained with 2 arrows per vine (one on each cordon) with 8 winter eyes and 6 spurs (3 per cordon) with 2 winter eyes. During the grape ripening phase the dynamics of sugar accumulation was monitored by means of refractometer to determine the moment of the grapes technological maturity. Upon technological maturity the productivity indicators were reported and mechanical analysis of the grapes was made. The cluster and berry structure, the average yield per vine and the theoretical yield were determined (Katerov et al., 1990).

*Grapes processing and vinification*

The grapes were harvested per variants, each one consisting of 30 kg and processed in the Experimental Cellar of the IVE – Pleven. Each variant was crushed separately. The classic technology for red dry wine making in the conditions of micro-vinification was applied (Yankov, 1992) – destemming, crushing, sulfiting (50 mg/kg $SO_2$), adding pure culture of dry wine yeast *Saccharomyces cerevisiae Vitilevure CSM* in the amount of 20 g/hl, fermentation temperature 28°C, separation of the young wines from the solids, additional sulfiting, storage.

*Chemical composition of grapes and wines*

The chemical composition of the grape must was determined by the following methods (Ivanov et al., 1979): sugars, g/l - hydrometer of Dujardin; glucose and fructose, g/l – iodometric method; titratable acids (TA), g/l – titration with NaOH; tartaric and malic acid, g/l – method of Pochinok; pH - pH-meter; glucoacidimetric index (GAI) – calculation method as the ratio of sugars (%) and TA (g/l).

The main indicators of the chemical composition of red wines were analyzed according to the generally accepted methods in wine practice (Ivanov et al., 1979): sugars, g/l – Schoorl's method; alcohol, vol. % - distillation method, Gibertini apparatus with densitometry of the distillate density; total extract (TE) g/l - Gibertini apparatus with densitometry of the alcohol-free sample density; sugar-free extract (SFE), g/l – calculation method (the difference between TE and sugars); titratable acids (TA), g/l – titration with NaOH; tartaric and malic acid, g/l – method of Pochinok; volatile acids (VA), g/l – distillation method with subsequent titration with NaOH; total phenolic compounds (TPC), g/l – method of Singleton et Rossi; monomeric anthocyanins, mg/l – spectrophotometrically by method of Ribereau-Gayon et Stonestreet via pH changing. The spectral characteristics of the color were also determined: intensity I [abs. units] – Somers method and tint T [abs. units] – Glories method (Chobanova, 2007).

*Organoleptic analysis of wines*

The organoleptic characteristics of the experimental samples were specified on a 100-point scale, for the indicators color, aroma, taste and general impressions (Tsvetanov, 2001) by a 9-member tasting commission.

*Statistical processing of the results*

The presented experimental results for the composition of grapes and wines from each vintage were the arithmetic mean value from two parallel samples. In cases where a significant difference in the value of the analyzed indicator was found, a third sample was worked out and the two closest rates were taken into account.

The data obtained for the study period were statistically processed, represented by mean and standard deviation (± SD). Excel 2007 (Microsoft Office) was used of determination.

## Results and discussion

*Mechanical composition of the grapes of the Kaylashki Rubin variety*

The rootstock had a significant influence on the quantity and quality of the grape harvest of grafted varieties, determined by the different growth strength of the rootstocks, their different absorption capacity and compatibility with the cultivated vine (Hale and Brien, 1978; Uzunova et al., 2015; Tsvetkov et al., 2016; Moura et al., 2017; Mijowska et al., 2017; Dias et al., 2017).

During the period 2017-2020 the grapes of the studied variants of the Kaylashki Rubin variety were harvested after the onset of the technological maturity. Mechanical analysis was made to determine the clusters and berries texture and structure (Table 1).

Regarding the indicator average mass per cluster, the variant of the Fercal rootstock had the highest mass on average for the study period (240.75 ± 54.08 g). The variant grafted on 110 R rootstock had the lowest average mass (204.75 ± 40.46 g).

Apart from its sugar and acid content, the grapes quality had been defined by a whole set of agrobiological indicators such as the rachis to berry ratio, the percentage of skins, mesocarp (fleshy part) and seeds in berries and the theoretically determined yield (Radulov et al., 1992; Abrasheva et al., 2008).

The berry to rachis ratio had been a hereditary trait, differentiated during the long phylogenetic development of vine, as a result it did not change significantly within the same variety. The percentages for the parts of the rachis and berries were per weight and the study results showed that the different rootstocks used had caused small differences both in the berry and rachis ratio in the clusters but also in the rates of skins, seeds and mesocarp in the berries. Minimal differences in the clusters and berries structure and texture were reported each year of the study period (Table 1).

The theoretical yield of wine grapes indicated the individual varietal specifics in relation to the theoretically determined quantity of wine that could be obtained from a certain quantity of grapes. This indicator was mainly influenced by the variety with its specific ampelographic characteristics and the climatic conditions of the particular year (Radulov et al., 1992; Abrasheva et al., 2008). It revealed that varieties the grapes of which had higher theoretical yield would give more wine. From the obtained results it was found that on average for the period the highest theoretical yield was determined for the variant grafted on 44–53 M rootstock – 85.29 ± 2.90%.

The experimental data showed that the highest yield was obtained in the variants grafted on the rootstocks Fercal – 7.65 ± 0.45 kg per vine and 44-53 M – 7.25 ± 0.34 kg per vine. With the lowest yield was the control grafted on SO4 rootstock – 6.18 ± 0.21 kg/vine.

**Table 1.** Mechanical analysis of the grapes of the Kaylashki Rubin variety, grafted on different rootstocks, for the period 2017-2020

| Vintage | Average mass of a cluster | Average yield of vine | Cluster texture | | Average mass per 100 berries | Berry structure | | | Theoretical yield |
|---|---|---|---|---|---|---|---|---|---|
| | | | rachis | berry | | skins | seeds | mesocarp | |
| | g | kg | % | % | g | % | % | % | % |
| | | | | | SO4 (control) | | | | |
| 2017 | 239.50 | 6.45 | 4.18 | 95.82 | 194.00 | 10.15 | 3.76 | 86.09 | 82.49 |
| 2018 | 183.50 | 6.10 | 3.54 | 96.46 | 168.30 | 10.10 | 3.68 | 86.22 | 83.17 |
| 2019 | 184.00 | 5.94 | 3.53 | 96.47 | 170.00 | 9.64 | 3.58 | 86.78 | 83.32 |
| 2020 | 328.50 | 6.22 | 3.19 | 96.81 | 195.00 | 10.25 | 3.84 | 85.91 | 83.17 |
| *mean* | *233.88* | *6.18* | *3.61* | *96.39* | *181.83* | *10.04* | *3.72* | *86.25* | 83.04 |
| *±SD* | *±68.34* | *±0.21* | *±0.41* | *±0.41* | *±14.66* | *±0.27* | *±0.11* | *±0.37* | ±0.37 |
| | | | | | 110 Rihter | | | | |
| 2017 | 232.50 | 7.37 | 3.44 | 96.56 | 197.30 | 7.24 | 3.95 | 88.81 | 85.75 |
| 2018 | 181.00 | 6.76 | 3.31 | 96.69 | 168.30 | 9.80 | 3.74 | 86.46 | 83.60 |
| 2019 | 160.50 | 6.13 | 3.73 | 96.27 | 170.00 | 9.41 | 3.52 | 87.07 | 83.82 |
| 2020 | 245.00 | 6.30 | 4.08 | 95.92 | 210.00 | 9.33 | 3.33 | 87.34 | 83.78 |
| *mean* | *204.75* | *6.64* | *3.64* | *96.36* | *186.40* | *8.95* | *3.64* | *87.42* | 84.24 |
| *±SD* | *±40.46* | *±0.55* | *±0.34* | *±0.34* | *±20.59* | *±1.15* | *±0.27* | *±1.00* | ±1.01 |
| | | | | | 44-53 Malegue | | | | |
| 2017 | 254.50 | 7.72 | 3.93 | 96.07 | 218.30 | 8.88 | 3.20 | 87.92 | 84.46 |
| 2018 | 160.50 | 7.28 | 4.67 | 95.33 | 165.00 | 10.42 | 3.93 | 85.65 | 81.65 |
| 2019 | 172.50 | 6.97 | 3.59 | 96.41 | 175.00 | 9.48 | 3.54 | 89.98 | 86.70 |
| 2020 | 250.00 | 7.04 | 3.92 | 96.08 | 210.00 | 9.67 | 3.42 | 91.91 | 88.31 |
| *mean* | *209.38* | *7.25* | *4.03* | *95.97* | *192.08* | *9.61* | *3.52* | *88.87* | *85.29* |
| *±SD* | *±49.78* | *±0.34* | *±0.46* | *±0.46* | *±26.04* | *±0.63* | *±0.30* | *±2.69* | *±2.90* |
| | | | | | Fercal | | | | |
| 2017 | 279.00 | 8.17 | 3.76 | 96.24 | 223.30 | 10.79 | 3.62 | 85.59 | 82.37 |
| 2018 | 185.00 | 7.88 | 3.78 | 96.22 | 163.30 | 10.34 | 3.67 | 85.99 | 82.74 |
| 2019 | 204.50 | 7.34 | 3.91 | 96.09 | 170.00 | 10.00 | 3.82 | 86.18 | 82.81 |
| 2020 | 294.50 | 7.21 | 3.73 | 96.27 | 223.30 | 9.04 | 3.58 | 87.38 | 84.12 |
| *mean* | *240.75* | *7.65* | *3.80* | *96.21* | *194.98* | *10.04* | *3.67* | *86.29* | *83.01* |
| *±SD* | *±54.08* | *±0.45* | *±0.08* | *±0.08* | *±32.82* | *±0.74* | *±0.10* | *±0.77* | *±0.76* |

*Chemical composition of the grapes of the Kaylashki Rubin variety*

The chemical composition of the grapes had been determined by a number of factors – soil and climatic conditions in the growing area, the meteorological conditions of the year, the applied agronomic practices, the used rootstock (Cheng et al., 2015; Jogaiah et al., 2015; Dias et al., 2017; Moura et al., 2017; Moyer et al. 2018; Olivera et al., 2019), etc.

After harvesting the grapes from the experimental variants, the chemical composition of the grape juice was determined. The differences in the values of the studied indicators were found, both per variants and per vintages (Table 2).

**Table 2.** Chemical composition of the grapes of the Kaylashki Rubin variety, grafted on different rootstocks, for the period 2017-2020

| Vintage | Date of harvest | Sugars g/l | Glucose g/l | Fructose g/l | Titratable acidity g/l | Tartaric acid g/l | Malic acid g/l | pH | GAI |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Chemical indicators | | | | |
| | | | | | SO4 (control) | | | | |
| 2017 | 26/09/ | 228.00 | 101.70 | 126.30 | 5.75 | 2.35 | 3.56 | 3.41 | 3.96 |
| 2018 | 26/09/ | 237.00 | 86.60 | 150.40 | 5.60 | 2.49 | 3.33 | 3.39 | 4.23 |
| 2019 | 13/09/ | 264.00 | 99.00 | 165.00 | 5.55 | 2.42 | 3.29 | 3.41 | 4.75 |
| 2020 | 15/09/ | 244.00 | 105.30 | 138.70 | 5.33 | 2.61 | 3.92 | 3.45 | 5.58 |
| *mean* | | *243.25* | *98.15* | *145.10* | *5.56* | *2.47* | *3.53* | *3.42* | *4.63* |
| *±SD* | | *±15.30* | *±8.12* | *±16.52* | *±0.17* | *±0.11* | *±0.29* | *±0.03* | *±0.71* |
| | | | | | 110 Rihter | | | | |
| 2017 | 26/09/ | 227.00 | 105.30 | 121.70 | 5.85 | 1.94 | 3.29 | 3.43 | 3.88 |
| 2018 | 26/09/ | 232.00 | 90.70 | 141.30 | 5.80 | 1.94 | 3.29 | 3.43 | 4.00 |
| 2019 | 13/09/ | 259.00 | 99.00 | 160.00 | 5.70 | 2.77 | 3.80 | 3.43 | 4.54 |
| 2020 | 15/09/ | 228.00 | 108.00 | 120.00 | 5.80 | 3.78 | 3.12 | 3.44 | 3.93 |
| *mean* | | *236.50* | *100.75* | *135.75* | *5.76* | *2.61* | *3.38* | *3.43* | *4.09* |
| *±SD* | | *±15.15* | *±7.69* | *±18.88* | *±0.05* | *±0.87* | *±0.29* | *±0.01* | *±0.30* |
| | | | | | 44-53 Malegue | | | | |
| 2017 | 26/09/ | 233.00 | 104.40 | 128.60 | 5.55 | 2.01 | 3.67 | 3.45 | 4.20 |
| 2018 | 26/09/ | 244.00 | 98.80 | 145.20 | 5.00 | 2.15 | 3.36 | 3.48 | 4.88 |
| 2019 | 13/09/ | 262.00 | 97.20 | 164.80 | 5.25 | 2.73 | 3.93 | 3.48 | 4.90 |
| 2020 | 15/09/ | 252.00 | 109.80 | 142.20 | 5.30 | 2.40 | 3.46 | 3.46 | 4.75 |
| *mean* | | *247.75* | *102.55* | *145.20* | *5.28* | *2.32* | *3.61* | *3.47* | *4.68* |
| *±SD* | | *±12.28* | *±5.73* | *±14.93* | *±0.22* | *±0.31* | *±0.25* | *±0.02* | *±0.33* |
| | | | | | Fercal | | | | |
| 2017 | 26/09/ | 225.00 | 105.30 | 119.70 | 5.85 | 2.69 | 3.13 | 3.47 | 3.84 |
| 2018 | 26/09/ | 237.00 | 90.70 | 146.30 | 5.68 | 2.95 | 3.23 | 3.41 | 4.17 |
| 2019 | 13/09/ | 262.00 | 97.20 | 164.80 | 5.55 | 2.73 | 3.93 | 3.48 | 4.72 |
| 2020 | 15/09/ | 238.00 | 108.90 | 129.10 | 5.60 | 2.35 | 3.82 | 3.40 | 4.25 |
| *mean* | | *240.50* | *100.53* | *139.98* | *5.67* | *2.68* | *3.53* | *3.44* | *4.25* |
| *±SD* | | *±15.50* | *±8.17* | *±19.88* | *±0.13* | *±0.25* | *±0.40* | *±0.04* | *±0.36* |

The rootstock used, on which the cultivar was grafted, had determined its growth strength, the berry size, the intensity of ripening and sugar accumulation (Jogaiah et al., 2015; Tethal et al., 2015; Moura et al., 2017; Moyer et al., 2018). There were also studies that had not found a significant effect of the rootstock on the chemical composition of grapes, within one vintage, in terms of sugars, acids and phenols (Dias et al., 2017).

The experimental results demonstrated that the Kaylashki Rubin variety, grafted on the four rootstocks, manifested high sugar accumulation. The average rates for the period were within the range from 236.50 ± 15.15 to 247.75 ± 12.28 g/l and increased in the order of 110 R < Fercal < SO4 < 44-53 M. The control (SO4) was exceeded only by the average values of 44-53 M rootstock. The content of the monosaccharides glucose and fructose was identified, with an established predominance of fructose, characteristic of high sugar content and grapes overripeness. In all experimental variants there was a common trend in sugar accumulation per vintage. The grapes from the 2017 harvest had the lowest sugars, varying in the range from 225.00 (Fercal) to 233.00 (44-53 M) g/l. The highest sugar content was reported in the 2019 harvest, with close rates of the variants – from 259.00 (110 R) to 264.00 (SO4) g/l.

When the grape ripening process occurred properly, the increase in sugars was accompanied by a proportional drop down of the titratable acids. In some studies, depending on the type of the rootstock used and the soil and climatic conditions in the growing area, there were proven (Jogaiah et al., 2015; Tethal et al., 2015; Olivera et al., 2019) or not proven (Dias et al., 2017) significant differences in the titratable acidity of grapes. In the present study, the average values of the titratable acidity in the experimental variants were close, varied in the range from 5.28 ± 0.22 to 5.76 ± 0.05 g/l and increased in the order of 44-53 M < SO4 < Fercal < 110 R. Of the available organic acids in grapes, the main ones were determined – tartaric and malic. Their concentration strongly depended on the rootstock type, the potassium content in the soil and accordingly determined the pH value of the must (Kodur et al., 2011; Jogaiah et al., 2015; Tethal et al., 2015). In this study, the quantitative predominance of malic over tartaric acid was reported in the grape juice of all experimental variants. The differences in the titratable acidity of the variants from each rootstock, but from the different vintages was insignificant. The grapes from the 2017 harvest, from all rootstocks, had the highest titratable acidity. For the variants of 110 R and Fercal rootstocks the lowest acidity was found in 2019, and for SO4 and 44-53 M, respectively, in 2020 and 2018.

In the case of red wine varieties, the type of the rootstock used had been of particular importance, as it also affected the grapes phenolic composition. The effect was manifested in relation to the total phenols, flavonoid and non-flavonoid compounds and monomeric anthocyanins in grapes, as well as the condensed tannins in the skins, the pulpy part and the seeds (Olivera et al., 2019). Of the flavonoid components in Cabernet Sauvignon grapes, Jogaiah et al. (2015) found the predominance of quercetin, with the highest amount reported for Fercal rootstock and the lowest for 110 R.

The glucoacidimetric index was defined for the grapes from all samples. It represented the quantitative ratio between the sugars and the acids and was indicative of the raw material quality and its use for wine making (Yankov, 1992). The average GAI values for the period varied in the narrow range from 4.09 ± 0.30 (110 R) to 4.68 ± 0.33 (44-53 M). The GAI for the control (SO4) was 4.63 ± 0.71 and was exceeded only by the variant 44-53 M. For all rootstocks, the grapes from the 2017 harvest had the lowest rates for this indicator, and from the 2019 vintage – the highest (except for SO4).

*Chemical composition and tasting assessment of the experimental wines of the Kaylashki Rubin variety*

The wine chemical composition and its organoleptic properties were determined and strongly depended on the grapes characteristics, which were influenced by the rootstock on which the cultivated variety was grafted (Dias et al., 2015; Jogaiah et al., 2015; Olivera et al., 2019).

The type of the used rootstock had indirectly determined the balance between the alcohol concentration and acidity of wines that was especially important for their taste characteristics (Dias et al., 2015).

After the alcoholic fermentation which was monitored daily, the young red wines of the studied variants were subjected to chemical analysis. The main chemical indicators of their composition had been identified (Table 3).

**Table 3.** Chemical composition of the experimental wines of the Kaylashki Rubin variety, grafted on different rootstocks, for the period 2017-2020

| | Chemical indicators | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vintage | Alcohol vol. % | Sugars g/l | Total extract g/l | Sugar-free extract g/l | Titratable acids g/l | Volatile acids g/l | Tartaric acid g/l | Malic acid g/l | TPC g/l | Anthocyanins mg/l | Colour tint T [abs. un.] | Colour intensity I [abs. un.] | pH |
| SO4 (control) | | | | | | | | | | | | | |
| 2017 | 12.91 | 1.58 | 23.60 | 22.02 | 5.50 | 0.64 | 1.26 | 3.05 | 1.29 | 190.97 | 0.81 | 9.05 | 3.45 |
| 2018 | 13.41 | 2.74 | 26.00 | 23.34 | 5.00 | 0.68 | 1.30 | 2.78 | 1.53 | 257.93 | 0.86 | 9.88 | 3.41 |
| 2019 | 14.28 | 1.88 | 24.70 | 22.82 | 5.25 | 0.62 | 1.34 | 2.82 | 1.50 | 232.88 | 0.83 | 9.48 | 3.44 |
| 2020 | 13.85 | 1.28 | 23.46 | 22.18 | 5.15 | 0.60 | 1.52 | 3.22 | 1.37 | 206.80 | 0.72 | 9.20 | 3.39 |
| *mean* | *13.61* | *1.87* | *24.44* | *22.59* | *5.23* | *0.64* | *1.36* | *2.97* | *1.42* | *222.15* | *0.81* | *9.40* | *3.42* |
| *±SD* | *±0.59* | *±0.63* | *±1.18* | *±0.61* | *±0.21* | *±0.03* | *±0.11* | *±0.21* | *±0.11* | *±29.46* | *±0.06* | *±0.36* | *±0.03* |
| 110 Rihter | | | | | | | | | | | | | |
| 2017 | 13.20 | 0.84 | 23.36 | 22.52 | 5.55 | 0.60 | 1.64 | 2.49 | 1.17 | 187.56 | 0.88 | 9.20 | 3.43 |
| 2018 | 13.56 | 3.48 | 26.93 | 23.45 | 5.40 | 0.62 | 1.26 | 2.09 | 1.41 | 222.50 | 0.88 | 9.38 | 3.44 |
| 2019 | 14.25 | 1.88 | 25.20 | 23.32 | 5.53 | 0.64 | 1.30 | 2.29 | 1.29 | 215.90 | 0.88 | 9.37 | 3.44 |
| 2020 | 13.00 | 1.28 | 23.94 | 22.66 | 5.50 | 0.60 | 1.16 | 2.18 | 1.42 | 224.19 | 0.75 | 9.29 | 3.37 |
| *mean* | *13.50* | *1.87* | *24.86* | *22.99* | *5.50* | *0.62* | *1.34* | *2.26* | *1.32* | *212.54* | *0.85* | *9.31* | *3.42* |
| *±SD* | *±0.55* | *±1.15* | *±1.57* | *±0.46* | *±0.07* | *±0.02* | *±0.21* | *±0.17* | *±0.12* | *±17.03* | *±0.06* | *±0.08* | *±0.03* |
| 44-53 Malegue | | | | | | | | | | | | | |
| 2017 | 13.40 | 1.71 | 24.75 | 23.04 | 5.08 | 0.54 | 1.23 | 2.12 | 1.25 | 207.58 | 0.85 | 9.36 | 3.45 |
| 2018 | 13.91 | 3.46 | 27.06 | 23.60 | 4.55 | 0.66 | 1.30 | 2.89 | 1.44 | 222.50 | 0.83 | 9.46 | 3.40 |
| 2019 | 14.27 | 3.84 | 27.40 | 23.56 | 5.18 | 0.68 | 1.45 | 2.12 | 1.40 | 224.36 | 0.87 | 9.50 | 3.44 |
| 2020 | 14.04 | 3.54 | 27.30 | 23.76 | 5.33 | 0.62 | 1.71 | 2.32 | 1.46 | 226.41 | 0.77 | 9.43 | 3.45 |
| *mean* | 13.91 | *3.14* | *26.63* | *23.49* | *5.04* | *0.63* | *1.42* | *2.36* | *1.39* | *220.21* | *0.83* | *9.44* | *3.44* |
| *±SD* | *±0.37* | *±0.96* | *±1.26* | *±0.31* | *±0.34* | *±0.06* | *±0.21* | *±0.36* | *±1.00* | *±8.57* | *±0.04* | *±0.06* | *±0.02* |
| Fercal | | | | | | | | | | | | | |
| 2017 | 12.83 | 1.71 | 21.90 | 21.19 | 5.10 | 0.60 | 1.19 | 2.66 | 1.24 | 192.80 | 0.88 | 9.28 | 3.34 |
| 2018 | 13.40 | 2.54 | 26.30 | 23.76 | 5.25 | 0.68 | 1.30 | 2.95 | 1.37 | 238.42 | 0.82 | 9.43 | 3.44 |
| 2019 | 14.22 | 1.94 | 24.61 | 22.67 | 5.40 | 0.68 | 1.41 | 3.25 | 1.54 | 259.04 | 0.80 | 9.56 | 3.43 |
| 2020 | 13.42 | 1.34 | 24.20 | 22.86 | 5.15 | 0.66 | 1.41 | 2.87 | 1.28 | 208.79 | 0.78 | 9.38 | 3.35 |
| *mean* | *13.47* | *1.88* | *24.25* | *22.62* | *5.23* | *0.66* | *1.33* | *2.93* | *1.36* | *224.76* | *0.82* | *9.41* | *3.39* |
| *±SD* | *±0.57* | *±0.50* | *±1.81* | *±1.06* | *±0.13* | *±0.04* | *±0.10* | *±0.24* | *±0.13* | *±29.65* | *±0.04* | *±0.12* | *±0.05* |

The alcohol ratio found in the experimental samples corresponded to the sugar accumulation in the grapes per variants and vintages. The average alcohol content of wines varied from 13.47 ± 0.57 (Fercal) to 13.91 ± 0.37 (44-53 M) vol. %. In all variants, the samples with the highest alcohol rates were from the 2019 harvest, and the lowest – from the 2017 harvest (except for 110 R).

The average amount of sugars in the experimental wines was from 1.87 ± 0.63 to 3.14 ± 0.96 g/l, defining them as dry (Chobanova, 2012). Due to the higher sugar accumulation in the variants of 44-53 M rootstock, for the studied period, a higher rate of residual sugars was found in the wines.

The amount of total and sugar-free extract in wines also affected their organoleptic taste properties. The extract was formed from all non-volatile components of organic and inorganic origin – carbohydrates, organic acids, phenolic compounds, nitrogen and minerals (Chobanova, 2012). The average rate of total extract in Kaylashki Rubin wines varied from 24.25 ± 1.81 to 26.63 ± 1.26 g/l, and sugar-free – from 22.59 ± 0.61 to 23.49 ± 0.31 g/l. The highest values were reported in the variant of 44-53 M rootstock. The control sample, on SO4 rootstock, had the lowest rates of SFE on average for the period. In the variants of SO4, 110 R and Fercal rootstocks, the highest SFE rates were found in the wines from the 2018 vintage, and in the case of 44-53 M rootstock - in the sample from the 2020 harvest. In all experimental variants, the wines from the 2017 harvest contained the least SFE (Table 3).

The average values of titratable acids of the experimental wines for the study period changed in a narrow range – from 5.04 ± 0.34 (44-53 M) to 5.50 ± 0.07 (110 R) g/l. For SO4 and 110 R rootstocks, the samples from the 2017 harvest had the highest acidity, while for 44-53 M – the sample from the 2020 harvest, and for Fercal – from the 2019. With the exception of Fercal, in the variants of the other rootstocks, the lowest acids were reported in the samples from the 2018 vintage (Table 3). The content of the main organic acids in the wines was also analyzed. The reduction of the tartaric acid was a result of the chemical and physical processes associated with the formation and precipitation of tartrates (Kučerova and Široky, 2011). The malic acid amount affected the taste of wine – when its content was higher it gave a sharp, greenish taste, and when it was very low, the wine was flat and inharmonious (Tethal et al., 2015). The identified concentration in the study showed not complete course of malolactic fermentation in the experimental wines at the time of the analysis. In all samples from the studied vintages, the course of the process was found at a later stage.

All experimental Kaylashki Rubin wines had normal volatile acidity that did not adversely affect their organoleptic qualities. The mean values for the period were from 0.62 ± 0.02 to 0.66 ± 0.04 g/l. The volatile acids ratio per variants and vintages was identical.

The pH rates were related to the wines' acidity. In the study, the pH values of the samples were almost identical between the variants of the different rootstocks. The same was found by Olivera et al. (2019). In other studies, however, differences were observed. Jogaiah et al. (2015) found that Cabernet Sauvignon wines from Fercal rootstock had significantly higher pH compared to those from 110 R.

Of particular importance for the quality and characteristics of red wines were the ratios of TPC, that influenced the taste, and of the anthocyanins, which determined the color, with its deepness and intensity. The phenolic profile of wines strongly depended on the phenolic content of grapes (Stoyanov et al., 2005; Dias et al., 2015; Jogaiah et al., 2015; Nedelkovski et al., 2017; Olivera et al., 2019). The results presented in Table 3 did not reveal any significant influence of the rootstock on the content of these components. The same was found by Dias et al. (2015) in Syrah wines. The amounts of TPC and anthocyanins in the experimental variants of the studied rootstocks were similar. Their mean values for the study period varied from 1.32 ± 0.12 (110 R) to 1.42 ± 0.11 (SO4) g/l and from 212.54 ± 17.03 (110 R) to 224.76 ± 29.65 (Fercal) mg/l. The data showed that the wines made from the variants of 110 R rootstock contained the least phenolic substances and anthocyanins. According to Blank et al. (2022), however, Pinot Noir wine from 110 R rootstock had more anthocyanins. Jogaiah et al. (2015) also found the highest ratios of total phenols in Cabernet Sauvignon wine from 110 R rootstock, and the lowest – from Fercal. The amount of phenols and anthocyanins in the experimental samples affected their color and the wines of variant 110 R had the highest average value of the tint (0.85 ± 0.08 abs. units) and the lowest of the intensity (9.31 ± 0.08 abs. units), respectively. The lowest ratio of TPC, anthocyanins and color intensity were reported in all samples from the 2017 harvest, respectively. However, no trend was found regarding the highest ratio of phenolic components and anthocyanins in the wines. For 110 R and 44-53 M rootstocks these were the variants from the 2020 harvest, for SO4 – from the 2018, and for Fercal – from the 2019. The values of the color intensity of the experimental samples per variants and vintages were close. The mean values for the period varied in the narrow range from 9.31 ± 0.08 (110 R) to 9.44 ± 0.06 (44-53 M) [abs. units].

In determining the phenolic profile of wines obtained using different rootstocks in vine cultivation, it was found that in Cabernet Sauvignon and Alicante Bouscher wines catechin, epicatechin, and quercetin had the highest ratios from the flavonoid components and malvidin, peonyidin, delphinidine petunidin and cyanidin from the anthocyanins. The gallic and vanillic acid predominated from the non- flavonoids (Jogaiah et al., 2015; Mijowska et al., 2017; Olivera et al., 2019).

The influence of the type of rootstock on the tasting qualities of wines was also found (Olivera et al., 2019). Organoleptic analysis of the experimental wines of Kaylashki Rubin was performed per variants and vintages. The characteristics of the samples in terms of color, aroma, taste, aftertaste and general impressions were established. The differences in the total tasting assessment of the wines, per variants and vintages, were presented in Figure 1. In the variants of SO4 and 110 R rootstocks, the samples from the 2020 vintage had the highest scores, and from the 44-53 M and Fercal rootstocks – from the 2017 harvest. Although the wines from the 2018 harvest were characterized by good chemical indicators in terms of extractivity, acidity, phenolic and anthocyanin content, during the tasting they received the least points for the study period.

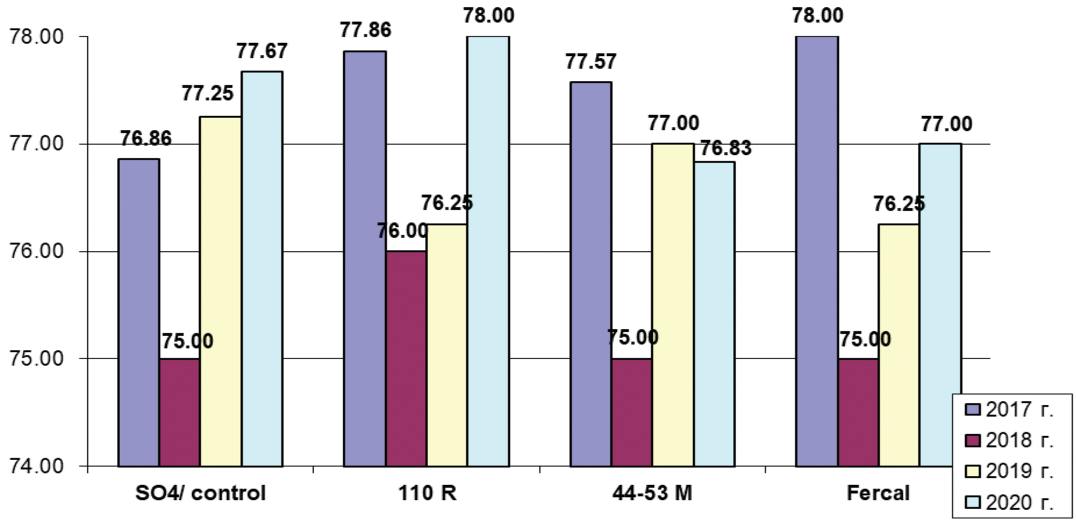


**Figure 1.** Tasting assessment of the experimental wines of the Kaylashki Rubin variety, grafted on different rootstocks, for the period 2017-2020

## Conclusion

The study had shown that the different rootstocks had a positive effect on the different agrobiological and technological indicators of the grapes and wine composition. The highest average mass per cluster and yield per vine was reported in the variety-rootstock combination Kaylashki Rubin/Fercal, 240.75 ± 54.08 g and 7.65 ± 0.45 kg, respectively. The theoretical yield was the highest in the variant grafted on the 44–53 M rootstock (85.26 ± 2.89%). The studied variety, grafted on the four rootstocks, revealed high sugar accumulation. The average rates for the period were in the range from 236.50 ± 15.15 to 247.75 ± 12.28 g/l and increased in the order of 110 R < Fercal < SO4 < 44-53 M. The values of titratable acidity of grapes and wines from the experimental variants were close. The highest were reported for 110 R rootstock. The wine of 44-53 M rootstock variant contained the highest amount of total and sugar-free extract. With the lowest SFE, on the average for the period was the control, on SO4 rootstock. The contents of TPC and anthocyanins in the experimental wines from the studied variants were similar. The sample, from the variant of 110 R rootstock, contained the least phenols, anthocyanins and the lowest average value of the color intensity. The experimental wines had different organoleptic characteristics per variant and vintage. The control, on SO4 rootstock, was assessed the lowest in the 2017 harvest and the highest in the 2019 harvest. In the 2018 and 2020 harvests it was exceeded only by the 110 R rootstock variant.

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