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Impact of summer green pruning on the phenolic content of grapes from Cabernet Franc cultivar

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Abstract

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A study was carried out on the phenolic content of Cabernet Franc grape cultivar depending on the applied summer green pruning operations. The research was conducted in a fruiting plantation and covered two consecutive harvests (2021–2022). The effects of bunch thinning and a combination of thinning and defoliation in the bunch area on total, flavonoid, non-flavonoid phenolic compounds and anthocyanin content in rachis, seeds, skins and berries were investigated. The change of the climate factors, air temperature, amount of precipitation and relative air humidity during the vegetation period of 2021 and 2022 was monitored. A positive impact of the applied pruning practices on the phenolic content of grapes compared to the control was found. The amount of the investigated phenolic components in the set variants increased in the order: without green pruning (control) < bunch thinning and defoliation < bunch thinning, and in the structural elements of the grape berries < skins < rachis < seeds. Grapes from the 2022 harvest had a better phenolic content, because of more favorable weather conditions during the ripening period, affecting the accumulation of phenolic compounds.

Keywords: Cabernet Franc; grapes; summer green pruning; climate factors; phenol content

Introduction

Green pruning in viticulture is applied to improve the quantity and quality of the grape harvest. These include thinning (norming) of bunches and defoliation in the bunch zone. These agrotechnical practices affect differently the content of the chemical composition components of grapes, such as sugars, acids, phenolic and aromatic substances (Baiano et al., 2015; King et al., 2015; Uriarte et al., 2016; Bekar et al., 2018; Dimitrov et al., 2021).

Phenols, including anthocyanins, are an important group of compounds in grapes, especially of red cultivars. These are plant secondary metabolites with strong antioxidant potential. Different cultivars have various abundance of total, flavonoid and non-flavonoid phenolic compounds in grapes (Ruberto et al., 2007; Obreque-Slier et al., 2010; Harby et al., 2013; Costa et al., 2015; Dimitrov et al., 2021; Yoncheva et al., 2023). They are contained in the seeds, skins and in the pulp of the grape (Shahab et al., 2023). According to Bonilla et. al. (2003), most phenolic compounds were concentrated in seeds and skins. Other studies show that their amount increases in the following order: berries < skins < rachis < seeds, and the content of anthocyanins in skins is several times higher than in berries (Dimitrov et al., 2021; Yoncheva et al., 2023).

The type and concentration of phenolic substances in different parts of the bunch depend on a number of factors. The availability of structural elements is influenced by the weather conditions of the year, cultivar characteristics, specifics, potential and the agricultural technique used (Franco et al., 2017; Yoncheva et al., 2023). The climate conditions in the area of cultivation have a great significance, such as temperature, humidity, precipitation amount and sunshine (Kelebek et al., 2007; Teixeira et al., 2013; Franco et al., 2017; Ozdemir et al., 2017).

The reserves of phenolic compounds in cultivars depends significantly on the type of applied summer green pruning operations and the period of their application. Bunch thinning balance the load on the vines and can be conducted at a different stage of the vegetation. It leads to a decrease in yield, a decrease in titratable acidity, but it can be successfully used to improve the phenolic content of grapes. It improves ripening, the content of phenolic and aromatic components in grapes and, accordingly, in the wine that is produced (Condurso et al., 2016; Uriarte et al., 2016). This type of pruning significantly increases the amount of total phenols and anthocyanins, especially if it is applied at the beginning of the "mottling" phase (King et al, 2015; Bekar et al., 2018). The removal of leaves (defoliation) around the bunches is usually applied in cooler regions that are characterized by fewer sunny days during the grape ripening period (Kurtev et al., 1969; English et al., 1998).

When different intensities of defoliation are applied, grapes from defoliated vines showed higher content of sugars, lower titratable acidity, total flavonoids, individual anthocyanins and total phenolic content, compared to grapes from non-defoliated vines. Total anthocyanin concentration was not significantly affected by defoliation (Baiano et al., 2015).

Purpose of the study

The aim of the present study is to investigate the impact of summer green prunings on the phenolic content of Cabernet Franc grape cultivar, in terms of anthocyanins, total, flavonoid and non-flavonoid phenolic compounds.

Material and methods

1. Experimental plantation and pruning operations.

The research was conducted in the period 2021-2022 in a fruit-bearing vineyard of Cabernet Franc cultivar, grown in the area of the village of Rakitnitsa, Stara Zagora Municipality. The vineyard is located on a southern slope, the rows are facing north-south. The soil type is leached cinnamon forest soils.

The plantation is 50 decares, as 30 vines were selected for the experiment. The vines are formed as double-armed Guyot, at a planting distance of 2.20/0.80 m, with a support structure/bearing wire at a height of 60 cm and 2 auxiliary pairs of wires every 40 cm. The mature vines, during pruning, were loaded with 4 bunches with 2 buds each + 2 fruit sticks with 10 buds each – a total of 28 winter buds per vine.

After the completion of blossoming and the formation of the grapes ("pea grain" phase), bunch thinning was conducted on 2/3 of the vines, as 15 well-formed bunches were left on each vine. When reaching the "mottling" phase, 1/3 of the vines, in the bunch zone were defoliated.

According to the type and period of pruning operations, 3 experimental variants were formed:

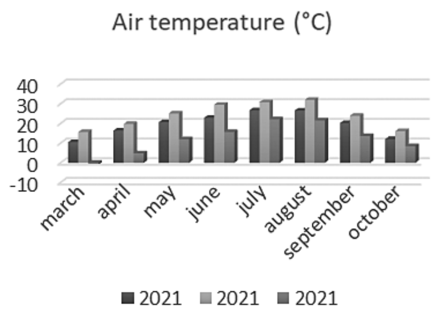
V_1 (control) – without green pruning (thinning and defoliation)

V_2 –with thinning 15 bunches per vine without defoliation, conducted respectively on: 15.07.2021 and 15.07.2022.

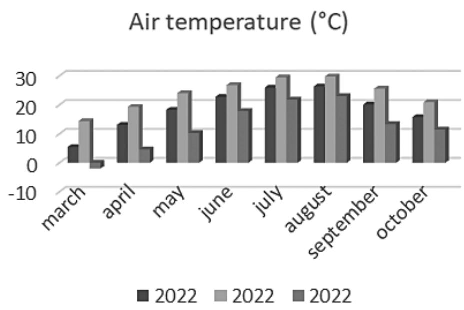
V_3 – with thinning 15 bunches per vine and defoliation in the bunch zone, conducted respectively on: 25.08.2021 and 22.08.2022.

2. Climate indicators

During the research period, the dynamics of the climate indicators were monitored daily: minimum, maximum and average air temperature (°C), air humidity (%), precipitation amount (l/m²). The readings were made with a weather station (Meteobot) located in the vineyard. The values of the studied indicators, for the vegetation (April – October) of 2021 and 2022, are presented in Figure 1, 2 and 3.



a)



b)

Fig. 1. Air temperature (°C) during the vegetation period of the study period
***a)* 2021 *b)* 2022**

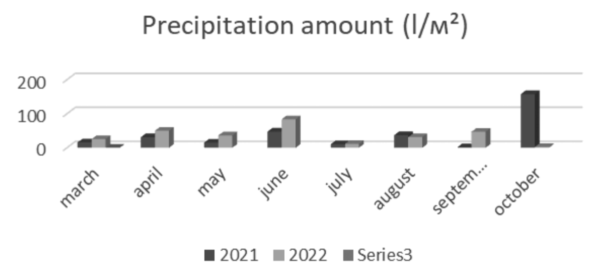


Fig. 2. Precipitation amount (l/m²) during the vegetation period of the study period

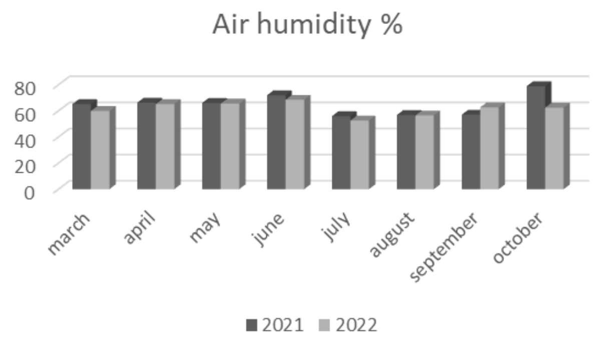


Fig. 3. Air humidity (%) during the vegetation of the study period

3. Phenolic content of grapes

The technological reserve of phenolic compounds of Cabernet Franc grapes and their content in the structural elements of the bunch was determined at technological maturity and after harvesting. An average sample of 2 kg of grapes was taken from each variant, and after destemming, 5 g of rachis (dried and cut into segments), 5 g of seeds (crushed in a mortar), 5 g of skins (dried) and 10 g berries (broken in a mortar and with crushed seeds) were weighed on an electronic scale. Prepared and weighed amounts were transferred to Erlenmeyer flasks. 150 ml of C_2H_5OH/HCl (1% v/v) extractant was used for the extraction of the weighed amounts (Stoyanov et al., 2004; Stoyanov, 2007).

After the extraction in the liquid phase, the content of the following compounds was determined:

- total phenolic compounds (TPC), g/l gallic acid – Singleton et Rossi method with Folin – Chiocalteu reagent (Ivanov et al., 1979)
- flavonoid phenolic compounds (FPC), mg/l catechin equivalent – Sommers method (Chobanova, 2007)
- non-flavonoid phenolic compounds (NPC), mg/l coffee equivalent – Sommers method (Chobanova, 2007)
- monomeric anthocyanins, mg/l – spectrophotometrically according to the method of Ribereau-Gayon and Stonestreet by changing the pH (Ivanov et al., 1979).

The values of the investigated indicators were recalculated for 100 g of product, respectively, rachis, seeds, skins and berries.

4. Statistical processing of the results

The data obtained from the analyzes performed for the study period were subjected to statistical processing, represented by the mean value of triplicate measurement and standard deviation (±SD). The program Excel 2007 (Microsoft Office) was used for the determination.

Results and discussion

1. Climate characteristics of the study period.

Dry and hot vegetation was observed in 2021. In August, the temperatures reached their maximum, and the air humidity was at the lowest measured values for the period June – August. The least precipitation amount was measured in September, which coincides with the ripening and reaching of technological maturity of the grapes. The highest precipitation amount for 2021 was recorded in October (Figure 1a, 2, 3). The following year 2022 was characterized by a greater precipitation, and for the period March – June it was almost double, compared to the previous year. The temperatures in the two reporting years are comparable, and again in August the maximum for the vegetation period was recorded, followed by those in the months of July and June. Air humidity is similar to 2021, but lower in the period March – August, while in September it becomes higher, due to the greater precipitation amount, compared to the previous year, (Figure 1b, 2, 3).

In 2021, the grapes reached technological maturity during the first ten days of October. Low atmospheric humidity, little precipitation for the 2021 vegetation period and high air temperatures are a prerequisite for the abnormal functioning of the vine, causing difficulty in the course of physiological processes. In 2021, the applied defoliation of the vines did not contribute to higher phenolic values compared to the variant with thinning of bunches. In 2022, technological maturity occurred earlier than the previous year – in the second ten days of September. This is due to the more favorable weather conditions during the ripening period in terms of relative humidity, precipitation and temperature. The defoliation conducted at the end of August gave a positive result on the phenol content of the cultivar.

2. Phenolic content of Cabernet Franc grapes during the study period.

The structural elements of the bunch have different abundances of total, flavonoid and non-flavonoid phenolic compounds, as well as anthocyanins. These components are unevenly distributed in the different parts and their concentration strongly depends on the cultivar. Their content is highest in the rachis and seeds, followed by the skins and the berries (Yoncheva et al., 2023). The content of phenols and anthocyanins is particularly important for red cultivars, which pass into the wine during vinification and determine the colour and taste of the future wine. Their amount is specific for each cultivar. When studying the phenolic content of three red cultivars, Dimitrov et al. (2021) found that Rubin cultivar had the highest concentration of anthocyanins in the skins, followed by Cabernet Sauvignon, whereas Gamza cultivar had the lowest.

The results of the phenolic content of Cabernet Franc grapes during the study period are presented in Table 1.

The presented data do not show a general trend in the anthocyanin content by variants during the studied period. In 2021, more anthocyanins were contained in the skins and berries of the bunch thinning variant (607.22±23.75 and 186.33±9.02 mg/100 g, respectively), whereas in 2022 it was the thinning and defoliation variant (674.83±9.14 and 207.05±7.90 mg/100 g, respectively). In the 2022 harvest, the control and the variant with thinning and defoliation showed a better anthocyanin content, compared to 2021, which will positively affect the colour characteristics of the obtained wine.

The amount of total, flavonoid and non-flavonoid phenolic compounds in the rachis, seeds, skins and berries of Cabernet Franc cultivar was also determined. Their content in the structural elements of the bunch decreased in the order: seeds > rachis > skins > berries.

The amount of TPC in the elements of the bunch, according to harvests and variants, is similar and varies within the limits – from 3.03±0.01 to 3.62±0.03 g/100 g rachis, from 6.02±0 to 7.28±0.01 g/100 g seeds, from 1.00±0 to 1.62±0 g/100 g skins and from 0.37±0 to 0.92±0 g/100 g berries. The control had the lowest content of TPC in all structural elements of the bunch. The thinning variant contained the most TPC in the rachis (2022) and in the seeds (2021), whereas the thinning and defoliation variant had the best reserves in the skins (2022) and in the berries (2021).

Table 1. Phenolic content of Cabernet Franc grapes, for the period 2021-2022

Variant / Indicators	Structural elements of the bunch	Without green prunnings (control)		Thinning of bunches		Thinning and defoliation	
		2021	2022	2021	2022	2021	2022
Anthocyanins mg/l/ 100 g product	skins	498.21 ±26.04	562.35 ±20.81	607.22 ±23.75	573.92 ±20.07	552.58 ±17.47	674.83 ±9.14
	berries	132.31 ±7.36	128.48 ±2.43	186.33 ±9.02	165.00 ±3.87	156.29 ±9.96	207.05 ±7.90
TPC g/l/ 100 g product	bunches	3.03±0.01	3.46±0	3.54 ±0	3.62±0.03	3.27±0	3.53±0.02
	seeds	6.12±0	6.02±0	7.28 ±0.01	6.57±0	6.30 ±0	7.14±0
	skins	1.00 ±0	1.36±0	1.48 ±0	1.50±0	1.34±0	1.62±0
	grapes	0.43 ±0	0.37±0	0.56 ±0.04	0.58±0	0.92±0	0.87 ±0
NPC mg/l/ 100 g product	rachis	1162.84 ±21.26	1582.21 ±3.92	2039.98 ±10.96	1814.78 ±3.34	1166.26 ±25.50	1924.74 ±3.57
	seeds	1274.50 ±39.25	1872.57 ±19.51	2215.85 ±31.74	1997.00 ±7.07	1774.50 ±39.25	2061.55 ±32.51
	skins	1066.25 ±25.50	1357.53 ±1.92	1676.01 ±36.33	1672.06 ±15.56	1350.97 ±44.97	1444.44 ±12.19
	berries	215.85 ±0.95	361.86 ±0.96	280.66 ±2.30	413.03 ±17.52	406.65 ±1.06	442.88 ±0.85
FPC, mg/l/ 100 g product	rachis	6968.71 ±170.70	6264.89 ±16.54	9165.05 ±102.80	7017.52 ±67.03	7759.30 ±65.89	6964.67 ±48.62
	seeds	7807.79 ±158.78	8640.71 ±43.64	10142.21 ±96.71	12923.35 ±76.17	8604.59 ±148.00	10146.91 ±40.61
	skins	3289.35 ±154.77	4262.49 ±75.46	5109.94 ±105.02	5519.16 ±10.91	4175.08 ±23.70	5650.33 ±98.70
	berries	1051.68 ±21.60	1158.60 ±11.71	2175.08 ±23.70	2650.33 ±98.70	1247.98 ±29.66	1329.80 ±16.10

In 2022, the reserve of NPC in rachis, seeds, skins and berries was significantly higher in the control and thinning and defoliation variants. This trend is observed only in the berries in bunch thinning. In this variant, the rachis and seeds from the 2021 harvest show a better reserve, and for the skins it was almost the same in both years.

Significant differences are also observed regarding the content of FPC in the structural elements of the bunch. In the rachis, the reserve varied from 6264.89±16.54 to 9165.05 ±102.80 mg/100 g, and in all three variants of the 2021 harvest, the amount was higher than in 2022. The reserve of the seeds is from 7807.79 ±158.78 to 12923.35±76.17 mg/100 g. In both years of the study, the variant with bunch thinning was distinguished by a significantly higher flavonoid content, followed by the variant with thinning and defoliation. The lowest reserve is in the control. In all experimental variants, the seeds from the 2022 harvest are richer in FPC, compared to 2021. The FPC reserve of the skins varies from 3289.35±154.77 to 5650.33±98.70 mg/100 g. The control has the lowest content. Higher reserve is reported in the fruit skin from the 2022 harvest, in all variants. The lowest concentration of FPC was found in the berries – from 1051.68±21.60 to 2650.33±98.70 mg/100 g. The trend of the highest and lowest concentration is preserved for them, respectively, in thinning and the control, and higher values in the 2022 harvest.

Conclusion

It can be summarized from the results of the present research:

The summer pruning operations, such as thinning of bunches, thinning and defoliation in the bunch zone had a positive impact on the phenolic content of the cultivar compared to the control (without green pruning).

The amount of anthocyanins, TPC, NPC and FPC by variants increased in the order: control < thinning and defoliation < thinning.

The amount of anthocyanins, TPC, NPC and FPC in the structural elements of the bunch increased in the order: berries < skins < rachis < seeds.

Regarding most of the phenolic components studied, the grapes from the 2022 harvest have a better phenolic content, due to the more favorable weather conditions in the ripening period and the earlier onset of technological maturity.

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