JOURNAL of Horticulture, Forestry and Biotechnology
Volume 28(1), 2024, 59-65
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

Relationship between grape berry size and oenological characteristics

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Manuscript received: 15 May 2024; revised: 03 June 2024; accepted: 05 June 2024

Abstract
The composition and oenological characteristics of grape berries can be influenced by various factors, including their size. Therefore, several studies were conducted in the Mișca vineyards between 2019 and 2022, focusing on Merlot, Cabernet Sauvignon and Feteasca Neagră varieties. The studies were carried out considering the varieties, with Simple Guyot training system, and by cluster thinning (at a rate of 40%) or without thinning, during the veraison stage. Random selection of 25 vines from each variety, in each experimental plot was performed. Samples were collected on the harvest day, with maturity determined based on sugar content, titratable acidity and pH of the berry juice. Laboratory analyses included measurements of berry weight, sugar content, total acidity, pH and anthocyanins potential. Statistical analysis was employed to assess differences between means, while the Pearson correlation coefficient was used for further analysis. The results revealed differences between varieties regarding berry weight, sugar content and anthocyanin potential. Furthermore, the berry quality was influenced by the temperature and precipitation of each year. Although thinning of clusters did not significantly influence berry weight, it did affect anthocyanins and sugar content depending on the favourability of the growing season. The study highlighted the complex interaction among vineyard management practices, climatic conditions and grape variety in shaping the characteristics of grape berries.

Key words: anthocyanins, acidity, correlation, pH, sugar

Introduction

The size of berries plays a significant role in determining the quality of wine. This influence is multifaceted, impacting various aspects of the wine-making process and the final product, including flavour concentration, tannin structure, and overall balance [16]. Smaller berries generally have a higher skin-to-pulp ratio compared to larger berries. This higher ratio is crucial because the skin of the grape contains most of the phenolic compounds, including tannins and anthocyanins, which contribute to the colour, flavour, and mouth feel of the wine [10]. Thus, wines made from smaller berries tend to have more concentrated flavours and deeper colour, which are often associated with higher quality in many wine styles [3]. The tannins in grape skins and seeds significantly affect the wine's structure and aging potential. Smaller berries, with their higher skin-to-pulp ratio, usually produce wines with more robust tannin profiles [7]. These tannins contribute to the wine's astringency and complexity, which can enhance the wine's ability to age gracefully [19]. Larger berries, conversely, might produce wines with softer tannins, which can be more approachable in their youth but might lack the complexity and aging potential of wines made from smaller berries [15]. Berry size can also influence the balance and acidity of the wine. Smaller berries tend to have a more concentrated juice, which can lead to higher acidity levels. This acidity is crucial for the wine's freshness and longevity. It helps to balance the wine's flavour profile, making it more vibrant, and lively [4]. Larger berries, with more diluted juice, may produce wines with lower acidity, which can result in a flatter taste profile if not managed properly [13]. There's often a trade-off between yield and quality in vineyards. Vines that produce smaller berries typically yield less fruit [15]. However, this lower yield is associated with higher quality wine, as the vine's

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Volume 28(1), 2024, 59-65
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

energy is concentrated on fewer berries, enhancing their flavour and structural components. In contrast, higher-yielding vines with larger berries might produce more wine, but this wine may not reach the same quality level due to the dilution of flavours and phenolic compounds [6]. The size of the berries is influenced by various factors, including the grape variety, terroir, and vineyard management practices. For example, certain grape varieties naturally produce smaller berries, while others tend to have larger berries [5;21]. Terroir elements such as soil type, climate, and water availability also play a significant role. Vineyard practices like canopy management, irrigation, and crop thinning can be adjusted to control berry size, ultimately influencing the quality of the wine produced [14; 22]. The sugar content in grapes, which converts to alcohol during fermentation, is a key determinant of grape quality. Smaller berries often exhibit higher sugar concentration due to the higher skin-to-pulp ratio and potentially lower water content. This concentration can lead to better-balanced berries with ideal sugar levels, crucial for achieving desired alcohol levels in wine [24;15]. Aromatic compounds are primarily located in the grape skins. Smaller berries, with more skin relative to pulp, often have a richer aromatic profile. These compounds contribute to the complexity and depth of the berry's aroma, which translates into more fragrant and aromatic wines. Larger berries, with relatively less skin, might lack this aromatic intensity [20]. Berry size and quality can be influenced by cluster thinning directly by managing the vine's yield and ensuring better ripening conditions [8]. By reducing the number of grape clusters, cluster thinning decreases the overall yield of the vine. This allows the vine to concentrate its resources (water, nutrients, and energy) on fewer clusters, leading to the production of smaller, higher-quality berries. The remaining berries benefit from improved exposure to sunlight and air circulation, which promotes even ripening and enhances quality [9]. Cluster thinning helps in achieving uniform ripening within the vineyard. With fewer clusters to support, the vine can allocate more resources to each berry, ensuring that they ripen evenly. This uniformity is crucial for producing high-quality wine, as it ensures a consistent flavour profile and optimal levels of sugar, acidity, and phenolics [23]. With fewer berries to nourish, the vine can enhance the concentration of flavours and phenolic compounds in the remaining fruit. This results in more intense and complex flavours, higher phenolic content and better colour in the berries, which are all desirable traits for premium wine production [1]. Thinning the clusters also improves air circulation around the remaining berries, reducing the risk of fungal diseases and pests. This healthier environment supports the production of higher-quality berries by minimizing the need for chemical treatments and allowing the natural ripening process to precede unhindered [17].

The aim of this paper was to investigate the impact of berry size on the composition and oenological characteristics of grape berries, particularly focusing on Merlot, Cabernet Sauvignon, and Feteasca Neagră varieties grown in the Mișca vineyards between 2019 and 2022. By examining these factors comprehensively, the research aims to provide valuable insights into optimizing vineyard practices to enhance wine quality through the manipulation of berry size and cluster thinning techniques.

Material and Method

The studies were carried out in the Mișca vineyard (46°36'0.00"N 21°36'0.00"E) Arad County, on the Merlot, Cabernet Sauvignon, and Feteasca Neagră varieties, over four years (2019 to 2022) on neighbouring plots. The influence of berry size on wine quality was studied according to the variety in Simple Guyot training system, and according to the thinning of the clusters at veraison with an intensity of 40%. The experimental setup consisted of 25 vines randomly arranged in the plot. For each variety and experimental plot, the number of buds left during winter pruning was the same. Grapes were collected on the same harvest day in each plot at berry maturity, defined by the sugar content, total acidity, and pH. The grapes were collected in self-sealing bags and labelled. The berry weight was determined by weighing with a Kern EHA 3000-1 precision balance, 3000 g (EHA 3000-1) Amex-Lab.

Sample Preparation: Grape juice from berries was extracted using a juicer and then filtered to remove any solid particles or debris. A small amount of potassium metabisulphite solution was added to preserve the samples. The refractometer was calibrated using distilled water. Classical analyses of the grape juice (sugars, acidity, and pH) were carried out according to the protocols proposed by O.I.V. Juice sugar content (°Brix) was determined by refractometry (Atago model N1 Atago, Japan), total acidity by titrimetry, and pH by potentiometry (Hanna model HI8521 Hanna Instruments, Italy). The concentration of their total anthocyanin potential was expressed in mg per litre. Two replicate analyses were performed using a DLAB SP-UV1000 UV/Vis spectrophotometer, 200 - 1000 nm, provided with LCD display and USB interface (Amex-Lab, RO). Climatic data (Figure 1) were recorded throughout the study period from a meteorological station subject to the technical standards established by the National Institute of Meteorology.

In February 2019, mild temperatures (3.61°C) were generally unfavourable for grapevines, but warming up to 9.85°C in March was more favourable, with 25.5 mm of rain aiding early vine development. In April, the weather continued warming (10.84°C) and significant rainfall (55.1 mm) created good conditions for

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https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

vine growth. Warm temperatures (17.37°C) with steady precipitation (53.6 mm) in May were excellent for growth and flowering. Peak warmth (21.92°C) in June with drier conditions (20.6 mm) was ideal for grapevine flowering and fruit set. Hot temperatures (23.55°C) in July, with low rainfall (18.9 mm), were stressful for vines but generally favourable. Similar hot conditions (23.87°C) in August with increased rain (38.1 mm) were good for ripening. Cooling down (17.87°C) with higher precipitation (54 mm) in September was favourable for grape maturation, and cooler temperatures (11.87°C) in October with very little rain (5.9 mm) were good for late harvests.

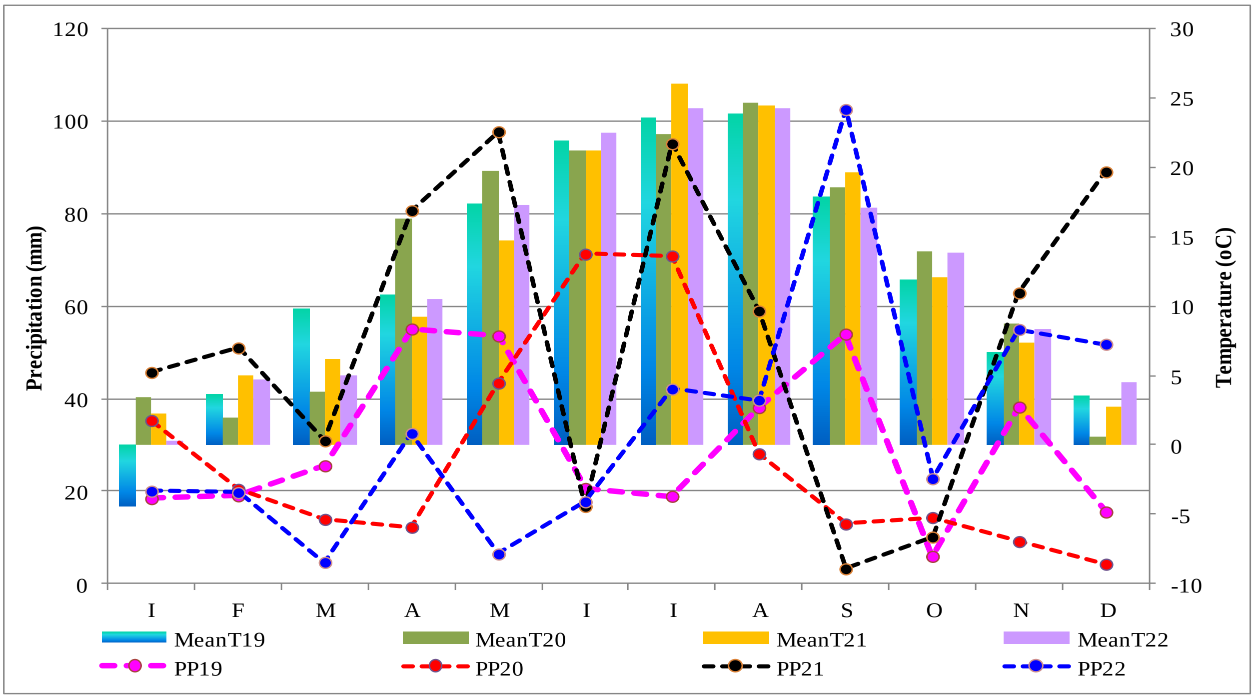

Figure 1. Temperature and precipitation during research (2019-2022) in Mişca, Arad County (MeanT – average annual temperature, PP – annual precipitation)

In January 2020, warmer temperatures (3.45°C) and increased rainfall (35.3 mm) were somewhat better for dormancy. Significant warming (16.32°C) and drier conditions (12.2 mm) in April were good for early vine development. The warm May (19.81°C) with substantial rainfall (43.4 mm) was ideal for growth and flowering. In June, the continued warmth (21.23°C) and significant rain (71.3 mm) supported fruit set. Hot temperatures (22.45°C) in July, with heavy rainfall (70.9 mm), were both beneficial and challenging due to the risk of disease. Warm weather (24.63°C) in August with reduced rainfall (28.1 mm) was good for ripening, and cooling (18.6°C) in September with low precipitation (12.9 mm) was favourable for harvest, which continued into the mild (13.94°C) October with light rain (14.3 mm) that supported late harvests.

The cold weather (2.29°C) in January 2021, associated with high rainfall (45.7 mm), was quite stressful for vines, but the milder March (6.24°C) with increased rainfall (30.9 mm) supported early growth. In April, the weather was also mild (9.25°C) with heavy rainfall (80.7 mm), which aided vine development but increased disease risk. Warm (14.76°C) and very wet (97.8 mm) conditions in May promoted growth but required disease management. The hot June (21.23°C) with drier conditions (16.7 mm) was ideal for fruit set, followed by a very hot July (26.03°C) with significant rain (95.2 mm), which was challenging due to heat and disease risk. Hot (24.47°C) and high rainfall (59 mm) in August supported ripening but required careful management. Cooler (19.68°C) but very dry (3.2 mm) conditions in September were good for harvest, while mild (12.08°C) weather with light rain (10.07 mm) in October supported late harvests.

Cold weather (0.26°C) with moderate rainfall (20 mm) in January 2022 affected dormancy, but the warming in April (10.47°C) with moderate rainfall (32.5 mm) aided vine development. Hot (22.5°C) with moderate rainfall (17.7 mm) conditions in June were favourable for fruit set. Very hot weather (24.33°C) with higher rainfall (42.1 mm) in August supported ripening. September 2022 was cool (17.13°C) but very wet (102.6 mm), posing a risk of disease during harvest, but milder weather (13.87°C) in October with 22.7 mm of rain supported late harvests.

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https://jhfb.ro/index.php/jhfb
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Statistical Analyses: Analyses of variance were performed on the chosen variables, followed by the differentiation of means using the Tukey test (p=5%). Correlation calculations between variables were performed using the Pearson 'r' method. The statistical packages XLStat (2016) and Prism for Windows (ver. 7.05 GraphPad Software, Boston) were used for data statistical analysis.

Results and Discussion

The influence of variety: the berry weight of showed significant differences depending on the variety, Feteasca Neagră having the largest berries in three of the four years analyzed (Table 1). This variation can be explained by the genetic differences related to berry growth, (cell expansion) observed by Tello et al. (2015) [18]. Sugar content and anthocyanin potential are also significantly higher in Fetească Neagră variety and these characteristics are independent of berry size (Table 1). The climate conditions from 2019 to 2022 in Mișca, Arad County show variability that influences grapevine growing: warm temperatures in spring and summer with moderate to high rainfall generally supported grapevine growth, flowering, and fruit set. Warm and dry conditions in late summer and early autumn were ideal for ripening and harvesting. However, cold winters were stressful for dormant vines. High rainfall, particularly in spring and summer, increased the risk of fungal diseases, requiring effective management. Drier periods, especially in May 2022, were inadequate for vines without irrigation. The decrease in the quality component levels in 2022 may be due to the combined effect of very cool nights, with minimum temperatures on some nights in May reaching 2ºC and in July reaching 7ºC, which contributed to high stress.

Table 1. Berry fresh weight, sugar, titratable acidity, pH and anthocyanins concentration in Cabernet Sauvignon, Merlot and Fetească Neagră different sized berries influenced by variety, Simple Guyot training

Variety	Berry weight (g)	Sugar (ºBrix)	Titratable acidity (g/l)	pH	Anthocyanins (mg/l)
2019					
Cabernet Sauvignon	1.64[b]	21.71[a]	4.61[a]	3.41[a]	184.94[b]
Merlot	1.78[a]	20.96[b]	4.47[a]	3.47[a]	166.92[c]
Fetească Neagră	1.69[a]	23.83[a]	4.52[a]	3.43[a]	218.93[a]
2020					
Cabernet Sauvignon	1.46[c]	21.80[b]	4.33[b]	3.56[a]	190.21[b]
Merlot	1.53[b]	22.13[b]	4.56[a]	3.32[b]	152.23[c]
Fetească Neagră	1.71[a]	24.52[a]	4.48[a]	3.51[a]	201.18[a]
2021					
Cabernet Sauvignon	1.64[c]	22.34[b]	4.72[a]	3.68[a]	194.73[b]
Merlot	1.79[b]	21.71[c]	4.57[a]	3.45[b]	180.97[c]
Fetească Neagră	1.85[a]	24.54[a]	4.63[a]	3.61[a]	214.32[a]
2022					
Cabernet Sauvignon	1.69[b]	21.82[b]	4.46[a]	3.39[b]	209.52[b]
Merlot	1.58[c]	20.55[c]	4.32[b]	3.36[b]	190.83[c]
Fetească Neagră	1.76[a]	24.10[a]	4.51[a]	3.52[a]	221.56[a]

Different lowercase letters in a row indicate significant differences ($p < 0.05$) between berry size classes. Different uppercase letters in a column indicate significant differences ($p < 0.05$) between varieties

Table 2. Pearson correlation (r) among the variables (berry weight, sugar, titratable acidity, pH and anthocyanins) in the Cabernet sauvignon, Merlot and Fetească Neagră varieties (2019-2022), influenced by variety

Variables	Berry Weight	Sugar	Titratable acidity	pH	Anthocyanin
Berry Weight	**1**	0.429	0.417	0.254	0.376
Sugar	0.429	**1**	0.346	0.426	0.644
Titratable acidity	0.417	0.346	**1**	0.394	0.017
pH	0.254	0.426	0.394	**1**	0.391
Anthocyanins	0.376	0.644	0.017	0.391	**1**

No values in bold different from 0 with a significance level alpha=0.05

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Volume 28(1), 2024, 59-65
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

The analysis reveals that sugar content has the strongest positive correlations with both anthocyanin concentration (0.644) and berry weight (0.429), indicating that berries with higher sugar levels tend to be larger and have higher anthocyanin concentrations (Table 2). Titratable acidity and pH also show moderate positive correlations with several variables, suggesting complex interactions affecting grape berry quality. These findings highlight the importance of managing these parameters to optimise grape and wine quality.

Cluster thinning did not produce significant differences in berry weight (Table 3), confirming the results of Mesić et al. [11] for Cabernet Sauvignon and Merlot grown in Slavonia, Croatia. Several authors report an increase in berry size after thinning, but this effect is interpreted as the result of compensation from the reduction of clusters [9;12]. Generally, this effect occurs when thinning is carried out at berry set, during a period of strong berry growth [2]. In the Fetească Neagră variety, cluster thinning resulted in a significantly higher berry weight. Additionally, cluster thinning led to an increase in anthocyanin accumulation, a finding also noted by Wang et al. [23], for Cabernet Sauvignon.

Table 3. Berry fresh weight, sugar, titratable acidity, pH and anthocyanins concentration in Cabernet Sauvignon, Merlot and Fetească Neagră influenced by cluster thinning (40%), Simple Guyot training

Variety	Berry weight (g)	Sugar (ºBrix)	Titratable acidity (g/l)	pH	Anthocyanins (mg/l)
2019					
Cabernet Sauvignon	1.85^{b}	22.51^{a}	4.22^{b}	3.37^{a}	203.47^{b}
Merlot	1.81^{b}	20.90^{b}	4.37^{a}	3.40^{a}	196.28^{c}
Fetească Neagră	1.99^{a}	23.66^{a}	4.31^{a}	3.39^{a}	221.34^{a}
2020					
Cabernet Sauvignon	1.90^{a}	23.19^{a}	4.29^{b}	3.51^{a}	219.16^{b}
Merlot	1.76^{b}	21.98^{b}	4.37^{a}	3.29^{b}	209.34^{c}
Fetească Neagră	1.98^{a}	24.62^{a}	4.41^{a}	3.48^{a}	231.09^{a}
2021					
Cabernet Sauvignon	1.96^{b}	23.87^{a}	4.64^{a}	3.62^{a}	199.96^{c}
Merlot	1.83^{c}	22.99^{b}	4.49^{b}	3.41^{b}	201.33^{b}
Fetească Neagră	2.02^{a}	24.63^{a}	4.58^{a}	3.57^{a}	224.12^{a}
2022					
Cabernet Sauvignon	1.89^{b}	23.18^{b}	4.38^{a}	3.37^{b}	214.08^{b}
Merlot	1.78^{c}	21.93^{c}	4.28^{b}	3.30^{c}	200.96^{c}
Fetească Neagră	2.09^{a}	25.11^{a}	4.47^{a}	3.47^{a}	243.69^{a}

Different lowercase letters in a row indicate significant differences ($p < 0.05$) between berry size classes. Different uppercase letters in a column indicate significant differences ($p < 0.05$) between varieties

Table 4. Pearson correlation among the variables (berry weight, sugar, titratable acidity, pH and anthocyanins) in the Cabernet sauvignon, Merlot and Fetească Neagră varieties (2019-2022) influenced by cluster thinning

Variables	Berry Weight	Sugar	Titratable acidity	pH	Anthocyanins
Berry Weight	**1**	**0.917**	0.464	**0.685**	**0.801**
Sugar	**0.917**	**1**	0.515	**0.650**	**0.809**
Titratable acidity	0.464	0.515	**1**	**0.716**	0.123
pH	**0.685**	**0.650**	**0.716**	**1**	0.288
Anthocyanins	**0.801**	**0.809**	0.123	0.288	**1**

Values in bold are different from 0 with a significance level alpha=0.05

The analysis of data from Table 4 influenced by the cluster thinning, show significant positive correlations between berry weight and other quality parameters, particularly sugar content (0.917) and anthocyanin concentration (0.801). Sugar content also shows strong positive correlations with anthocyanin concentration (0.809) and pH (0.650). Titratable acidity has strong positive correlations with pH (0.716), indicating a complex interaction affecting grape berry quality. These findings suggest that larger berries tend to have higher sugar levels and anthocyanin concentrations, which are important factors in grape and wine quality. Effective management of these parameters can optimise grape production and quality.

Conclusions

The data from 2019 to 2022 reveal that Fetească Neagră generally exhibited the highest sugar content and anthocyanin levels, suggesting it may be the most suitable variety for high-quality wine production in this region. Cabernet Sauvignon showed stable performance with a slight improvement in anthocyanin concentration in 2022. Merlot had a notable decrease in sugar content in 2022, which may affect the wine quality. The overall trends indicate that while the climate conditions were variable, the grape varieties managed to maintain quality components with some year-to-year variations. High anthocyanin levels in 2022, particularly for Fetească Neagră, suggest favourable conditions for colour development in that year. The cluster thinning (40%) had a positive impact on berry quality components, particularly for Fetească Neagră. Cabernet Sauvignon also showed improvements in sugar content and anthocyanin concentration, particularly in 2020. Merlot displayed stable quality components, with some small variations. Overall, the practice of cluster thinning enhanced berry weight, sugar content, and anthocyanin levels across all varieties, demonstrating its effectiveness in improving grape quality. The analysis from both correlations datasets underscores the critical role of sugar content in grape berry quality These findings reinforce the importance of managing sugar content and other related parameters to enhance grape and wine quality.

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JOURNAL of Horticulture, Forestry and Biotechnology
Volume 28(1), 2024, 59-65
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Print ISSN: 2066-1797
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