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Effect of different viticultural techniques on the qualitative and quantitative characters of cv. Xinomavro under vineyard conditions in Naoussa

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Abstract. In order to counteract the various effects of climate change on the physiology of the grapevine and on the quality of the grapes leading to the wine produced, many different approaches have been proposed. The aim of this study was to assess the effect of different cultivation techniques on the quantitative and qualitative characters of the grapes of cv Xinomavro, during the cultivation season 2019-2020. The experimental vineyard is located in Giannakochori, Naoussa (Greece), where the vines are trained in bilaterally cordon-trained (bilateral Royat) and plant density of 4000 vines/ha. The following viticultural techniques were evaluated on two different sub-plots of the vineyard: (i) the effect of two training systems (Lyre-shaped training system – bilateral Royat) on the southern side of the rows (vineyard orientation W-E), (ii) the effect of two planting densities (4000 and 10000 vines/ha). In all samples, the sugar content of the must was calculated using a refractometer, the active acidity (pH) using a pH meter and the total acidity using a sodium hydroxide solution (NaOH). Mechanical analysis of the grapes of all the samples under study was performed. The weight of thirty (30) berries, the weight of the grape and the length and width of the berries and the grapes of each sample were measured. The use of a spectrophotometer quantified the content of grape's skin in total anthocyanins, total phenolics, condensed tannins, total ortho-diphenols, total flavonoids, total flavanols, total flavonols and flavones and their antioxidant capacity with the use of FRAP and DPPH methods. The use of high-performance liquid chromatography (HPLC) identified the most important anthocyanins and acids found in grapes. The measurements in the grape seeds were made on the same compounds as the skins, except for total and individual anthocyanins. Differences in sugars and active acidity of the must as well as in phenolic compounds were observed during the various treatments. The training systems also exhibited differences: the grapes originating from the Lyre-shaped training system showed higher concentration of total soluble solids and tannins, while those originating from the bilateral Royat recorded higher pH. The right side of the vines, which was more exposed to higher temperatures (due to southern wind), recorded higher concentrations in most phenolic compounds. Planting density recorded differences in almost all measurements and especially in total and individual anthocyanins. Moreover, the results showed increased concentration in skin tannins, in total soluble solids, pH, and higher concentration of total phenolics and flavonoids, thus making the wine coming from these grapes ideal for maturing and ageing.

1 Introduction

The quality characteristics of the grapes and berries, and therefore of the wines are directly related to the environment in which the vines are being cultivated. The so-called terroir is perhaps the most important factor as it links the organoleptic characteristics of the wines to the environmental conditions in which the grapes are grown [1]. According to the OIV, terroir is the concept that refers to an area in which there is collective knowledge of the interactions between the natural, biological environment combined with the influence exerted by the human factor through the viticultural techniques applied to the crop.

Terroir includes parameters such as the soil in which the vines are grown, the topography, the climate, etc. [2]. Among the factors that create the concept of terroir, perhaps one of the most important is climate. Because of this, the suitability of an area for the cultivation of a grape cultivar, the style of the wine produced, the growth and productivity of the vines is determined [3]. In a wine-growing zone, great diversity can be observed in terms of soil-climatic conditions and other factors that affect the products produced. The newly shaped climatic conditions brought about by climate change, directly affect the physiology of the vines, and subsequently the qualitative and quantitative characteristics of the grapes and berries.

The yield, the vine growth and the development and composition of the berries depend on the climatic conditions prevailing in any given area [3]. Solar radiation, the length of day, the percentage of cloud coverage, the average temperature during the day, as well as the difference in temperature between day and night, the type and structure of the soil, humidity, and the heat accumulation in the vineyard, are some of the factors that can significantly vary the microclimate of the vineyard by influencing the growth of the vines and determining, either individually or in combination, the evolution of the viticultural products.

The exposure of grapes to solar radiation is particularly important as the increase in the internal temperature of the vines favors enzyme activity [4]. As a result of his experiment, the berries exposed to the sun, compared to the grapes found in the shade, contained a lower concentration of malic acid and methoxypyrazines, a higher percentage of anthocyanins and phenols, and a higher concentration of monoterpenes. In addition, it was found that when the temperature difference between day and night exceeds 10°C, it has an inhibitory effect on the percentage of berry coloration.

Therefore, anthocyanins are directly related to the percentage of berries exposed to solar radiation. More generally, the biosynthesis of phenolic compounds

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depends on the same factor. However, temperature and solar radiation are two factors that cannot be separated in order to make a separate study of their effects on the quality characteristics of the vines [4]. The light and temperature conditions that are formed around each stump depend on factors that affect the arrangement of the foliage, such as the formation system, the winter pruning for fruiting and green pruning, etc. [5].

The training system of the vines determines to a large extent the phenolic composition of the berries. The management of the annual vegetation, in combination with the various training systems, affects, through the exposure of the vine to solar radiation, the microclimate of the grape growing zone [6].

Temperature is a factor with an important role in the development of the berry and the synthesis of total flavonols and anthocyanins is enhanced by the exposure of grapes to solar radiation [7, 8].

Also, taking into account that the training system affects the relationship between leaf surface of the canopy and the grapes and therefore the distribution of solar radiation, it is concluded that the degree of ripening of the grapes and the accumulation of phenolic compounds can differ between the training systems [9]. At the same time, the temperature of the shoots seems to affect the degree of synthesis of aromatic compounds [10].

The leaf surface, the exposure of the grapes to solar radiation in combination with the exposure of the dormant buds, as well as the water condition of the vines are factors directly dependent on the training system of the vine Training systems have been modified since the ultimate goal is to achieve the balance between vegetation and fruiting [9].

Another viticultural technique in order to adjust the microclimate of the vineyard is the density of planting. Planting density determines the characteristics of the vines. Vigor and productivity of a cultivated variety are some of the characteristics to be considered in relation to planting density. In general, it is difficult to separate the direct effect exerted by different planting densities, such as vine competition for water, from the indirect effect of microclimate or soil structure on the whole vineyard [11]. The determination becomes more difficult in vineyards which are characterized by the same planting density but differ in the spacing of the vines between and on the planting rows.

Planting density has changed for viticulture in Europe since 1850. Before the phylloxera infestation, planting densities reached 30,000-50,000 vines/ha. In Europe, planting densities range from around 4,000-5,000 bushels/ha with the potential to increase to 10,000. Planting densities of 1,100-1,600 plants/ha are quite common in the California region of the USA as well as in Australia

Vineyards that are planted in high densities often carry desirable characteristics, such as better grape quality and wine with enhanced color. In a study that was conducted, the same vineyards show a reduced productivity which is due to the reduced vegetation due to the root competition created inside the soil. Finally, high planting densities come with the disadvantage of high costs for setting up a vineyard [11].

The aim of the present study was to investigate the effects of different viticultural techniques on berry composition of grape cultivar Xinomavro under vineyard conditions in Naoussa.

2 Material and methods

2.1 Experimental design

The experiment was conducted in Giannakochori, Naoussa (Greece), where vines from grape cultivar Xinomavro (*Vitis vinifera* L.) are bilaterally cordon-trained (bilateral Royat), with a plant density of 4000 vines/ha (control vines). Xinomavro is a multi-dynamic cultivar of the Greek vineyard, a fact that constantly motivates the interest in the search for ways to improve its cultivation. It is worth mentioning that the study of wine grape cultivars aims at improving the wines produced, thus concluding that the complexity of wines, beyond the winemaking method, is largely due to the complexity of the terroir and the cultivation techniques of vineyard management.

On two different sub-plots of the vineyard (40°39'47"N, 22°04'50"E; 40°39'45"N, 22°04'09"E) and at an altitude of 180 m (Fig. 1), the following viticultural techniques were evaluated on the quantitative and qualitative characters of the grapes and berries: (i) the effect of two training systems (Lyre-shaped training system–bilateral Royat) on the southern side of the rows (vineyard orientation W-E), (ii) the effect of two plant densities (4,000 and 10,000 vines/ha), at the top (density-top), the middle (density-middle) and the bottom (density-bottom) of the slope. It should be noted that the same soil and climatic conditions prevail throughout the entire vineyard and its sub-plots.

Figure 1. Location of the vineyard and its sub-plots, Giannakochori, Naoussa.

2.2 Grape sampling

At harvest, grapes were randomly selected from each sub-plot of the two treatments (two different training systems; two different plant densities. The sampling process, described in a previous study [12] involved the random selection of three (3) grapes from different vines of each treatment and three (3) sampling processes, whereas each sampling was considered as one (1) replication.

2.3 Phenolic analysis

The polyphenolic content and antioxidant properties of the samples studied were evaluated, in terms of the qualitative and quantitative characters, by performing the following measurements: (i) mechanical analyses of grapes and berries, (ii) analyses on the must (pH, soluble solids content, total titratable acidity), (iii) determination of total phenols (in skins and seeds), (iv) determination of total and individual anthocyanins (in skins), (v) determination of total flavonoid content (in skins and seeds), (vi) determination of total flavanols (in skins and seeds), (vii) determination of flavone and flavonol content (in skins and seeds), (viii) antioxidant activity with FRAP and DPPH methods (in skins and seeds), (ix) determination of individual organic acids and individual sugars (in must).

All reagents and chemicals as well as all procedures regarding the determination of mechanical analyses of grapes and berries, the analyses on the must, and the preparation of samples for spectrophotometric and HPLC analyses have been performed by following protocols described in a previous study [13].

2.4 Statistical analysis

All statistical analysis and correlations were obtained using the JMP v.10 statistical software (SAS Institute Inc., Cary, NC, USA). The significance of the results was tested by Analysis of Variance (ANOVA) and the means of the values were compared by Tukey's range test at $P \leq 0.05$. Letters in columns denote statistically differences (Tukey-HSD, $P \leq 0.05$).

3 Results and Discussion

As mentioned above, during the technological maturity of the grapes, measurements related to the qualitative and quantitative characters of the grapes, berries and must were performed, in order to assess whether there were differences recorded between the two training systems and the two plant densities.

The results (mean value and standard error) of each parameter measured and for each treatment are shown in Tables 1-12. The statistically significant differences found between the treatments and for each parameter measured, have been highlighted and flagged with discrete letter.

3.1 Mechanical properties of grapes and berries, and characters of the must

Regarding the grape weight, the highest value was recorded in the Royat training system, with no statistically significant differences compared to the other treatments (Table 1). Between the different rows in the density treatment (top-middle-bottom), the middle and bottom parts of the slope recorded higher values in all mechanical analyses of the grape.

Regarding the mechanical properties of the berries, there were statistically significant differences recorded between the two training systems and between the plant densities in all measurements (Table 2).

The density-bottom treatment recorded the higher values in berry length and width, followed by density-top and density-middle treatments.

Table 1. Mechanical properties of the grapes**.**

Treatments	Grape length (cm)	Grape width (cm)	Grape weight (g)
Density-top	15.70 ± 0.20 b	10.00 ± 0.32 b	242.00 ± 6.79 b
Density-middle	16.50 ± 0.50 b	11.00 ± 0.42 ab	310.80 ± 1.71 a
Density-bottom	17.17 ± 0.62 ab	10.33 ± 0.60 ab	319.67 ± 3.71 a
Royat	15.25 ± 0.48 b	11.75 ± 0.48 a	321.00 ± 1.58 a
Lyre	18.63 ± 0.62 a	11.50 ± 0.29 ab	304.75 ± 1.93 a

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–b) are significantly different at significance level $p \leq 0.05$.

There were statistically significant differences recorded in the weight of 50 berries in all treatments with density-bottom exhibiting the higher values.

Table 2. Mechanical properties of the berries**.**

Treatments	Berry length (mm)	Berry width (mm)	Weight of 30 berries (g)
Density-top	14.46 ± 0.16 c	14.82 ± 0.18 b	54.67 ± 1.20 c
Density-middle	14.90 ± 0.19 bc	15.03 ± 0.20 b	60.33 ± 0.73 b
Density-bottom	15.79 ± 0.14 a	15.93 ± 0.14 a	68.67 ± 0.88 a
Royat	15.29 ± 0.15 ab	15.33 ± 0.16 ab	57.66 ± 0.88 bc
Lyre	14.73 ± 0.20 bc	15.09 ± 0.19 b	55.00 ± 1.73 c

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

The higher pH values were recorded in the density-top treatment, while the higher total titratable acidity values were recorded in density-top and the Lyre training systems (Table 3), with statistically significant differences compared to the other treatments.

The total soluble solids concentration was higher in the density-top treatment, and with a statistically significant difference compared the other treatments. These results are not in agreement compared to results from a previous study [14], in which the study of the plant density of grape cultivar Tempranillo showed that the pH and total soluble solids exhibited no difference between the different plant densities. The result of the present study could be due to that fact that the vines collected from the density-top treatment are located at the top of the slope.

Table 3. Characters of the must.

Treatments	TSS (Brix°)	pH	Total titratable acidity (g L^{-1})
Density-top	20.73 ± 0.18 a	3.64 ± 0.00 a	7.38 ± 0.13 a
Density-middle	18.40 ± 0.00 e	3.60 ± 0.00 b	6.75 ± 0.00 bc
Density-bottom	20.00 ± 0.00 b	3.56 ± 0.00 c	6.88 ± 0.13 bc
Royat	19.40 ± 0.00 c	3.56 ± 0.00 c	6.50 ± 0.13 c
Lyre	18.93 ± 0.07 d	3.38 ± 0.00 d	7.13 ± 0.00 ab

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–e) are significantly different at significance level $p \leq 0.05$.

3.2 Polyphenolic compounds

3.2.1 Total phenolics in seeds and skins

The results showed that the higher concentrations of total phenolics were recorded in the planting density treatments both in the seeds and skins (Table 4),

Statistically significant differences were recorded in the skin total phenolics and the density-top and density-middle treatments followed by the other treatments. These results are generally in agreement with the hypothesis that higher plant densities have a positive effect on the phenolic potential of grape cultivars [11]. On the contrary, the two training systems exhibited lower values.

Table 4. Total phenolics in seeds and skins.

Treatments	Total phenolics seeds (mg gallic acid/g FW)	Total phenolics skins (mg gallic acid/g FW)
Density-top	20.69 ± 0.75 a	7.21 ± 0.43 a
Density-middle	17.92 ± 1.29 ab	7.47 ± 0.88 a
Density-bottom	19.32 ± 0.50 a	4.80 ± 0.55 c
Royat	14.98 ± 0.08 b	5.31 ± 0.34 b
Lyre	15.86 ± 0.38 b	6.14 ± 1.03 b

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

3.2.2 Total flavanols in seeds and skins

Regarding the seed total flavanols, the lowest value was recorded in the Lyre training system, with this treatment being the only one to be statistically significant different from the other treatments (Table 5). In the case of skin total flavanols, the highest concentration was recorded in the density-bottom treatment, with no statistically significant difference from the other density treatments, but with a statistically significant difference compared to the two training systems.

Table 5. Total flavanols in seeds and skins.

Treatments	Total flavanols seeds (mg catechin/g FW)	Total flavanols skins (mg catechin/g FW)
Density-top	20.26 ± 0.65 a	2.17 ± 0.12 ab
Density-middle	20.17 ± 0.37 a	2.14 ± 0.16 abc
Density-bottom	22.33 ± 0.53 a	2.45 ± 0.04 a
Royat	20.48 ± 0.59 a	1.70 ± 0.06 c
Lyre	12.51 ± 0.34 b	1.86 ± 0.03 bc

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

3.2.3 Total flavonoids in seeds and skins

Regarding the total flavonoids concentration both in seeds and skins, the density-top treatment exhibited the highest values, and with a statistically significant difference when compared to the other treatments (Table 6).

Table 6. Total flavonoids in seeds and skins.

Treatments	Total flavonoids seeds (mg catechin/g FW)	Total flavonoids skins (mg catechin/g FW)
Density-top	169.12 ± 6.12 a	28.55 ± 0.27 a
Density-middle	141.96 ± 3.41 bc	28.04 ± 0.39 a
Density-bottom	158.48 ± 0.86 ab	27.41 ±1.48 a
Royat	153.25 ± 1.30 abc	22.82 ± 0.13 b
Lyre	139.30 ± 0.40 c	23.31 ±1.15 b

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

3.2.4 Total flavone and flavonol content in seeds and skins

Regarding the total flavone and flavonol content, the values of the concentrations of the skins were mostly at the same level, with statistically significant differences being recorded between the density treatments (Table 7). In the analyses that took place in the seeds, it was the density-middle treatment that recorded the highest value, but with no statistically significant difference among the other treatments.

Table 7. Total flavones and flavonols in seeds and skins.

Treatments	Total flavones and flavonols seeds (mg rutin/g FW)	Total flavones and flavonols skins (mg rutin/g FW)
Density-top	0.26 ± 0.02 a	0.70 ± 0.04 a
Density-middle	0.31 ± 0.04 a	0.65 ± 0.02 ab
Density-bottom	0.29 ± 0.02 a	0.48 ± 0.02 b
Royat	0.23 ± 0.02 a	0.49 ± 0.04 b
Lyre	0.29 ± 0.04 a	0.55 ± 0.04 ab

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–b) are significantly different at significance level $p \leq 0.05$.

3.2.5 Condensed tannins in seeds and skins

Regarding condensed tannins in seeds, the Lyre training system and the density-bottom treatment exhibited the higher values with a statistically significant difference compared to the other treatments (Table 8). When it comes to condensed tannins in skins, the density-top treatment recorded the highest value with a statistically significant difference compared to all other treatments.

Table 8. Condensed tannins in seeds and skins.

Treatments	Tannins seeds (mg catechin/g FW)	Tannins skins (mg catechin/g FW)
Density-top	79.72 ± 1.40 c	31.23 ± 0.86 a
Density-middle	96.22 ± 0.20 b	11.74 ± 0.48 b
Density-bottom	105.38 ± 1.98 a	11.21 ± 0.45 b
Royat	57.02 ± 2.12 d	16.11 ± 2.16 b
Lyre	109.84 ± 1.98 a	5.07 ± 0.05 c

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–d) are significantly different at significance level $p \leq 0.05$.

3.2.6 Antioxidant activity in seeds and skins

Regarding the antioxidant activity, which was determined both with the FRAP method, the results showed that the Royat training system exhibited the highest values both in seeds and skins, and with a statistically significant difference compared to the other treatments (Table 9).

When determined with the DPPH method, the highest antioxidant activity concentration was recorded in the density-top treatment both in seeds and skins, and with a statistically significant difference compared to the other treatments.

Table 9. Antioxidant activity in seeds and skins.

Treatments	FRAP (mg Trolox/g FW)		DPPH (mg Trolox/g FW)	
	Seeds	Skins	Seeds	Skins
Density-top	150.74 ± 0.34 ab	35.18 ± 1.35 a	63.91 ± 0.60 a	17.40 ± 0.40 a
Density-middle	143.43 ± 0.77 c	30.58 ± 0.75 b	58.18 ± 0.65 bc	14.73 ± 0.31 bc
Density-bottom	148.97 ± 0.70 b	31.32 ± 0.20 b	59.60 ± 0.85 b	15.28 ± 0.13 b
Royat	155.81 ± 2.03 a	36.56 ± 0.54 a	56.09 ± 0.28 c	14.23 ± 0.16 bc
Lyre	124.56 ± 1.30 d	28.86 ± 0.64 b	57.76 ± 0.39 bc	13.73 ± 0.18 c

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–d) are significantly different at significance level $p \leq 0.05$.

3.3 Total and individual anthocyanins

The density-top treatment recorded the highest concentrations in total anthocyanins, but with no statistically significant differences compared to the majority of the other treatments (Table 10a).

The same treatment also exhibited the highest concentrations of malvidin, petunidin, and both esters of malvidin (acetic and coumaric) (Table 10b).

There were no statistically significant differences observed between the two training systems regarding total anthocyanins, but in the case of individual anthocyanins, the Royat training system exhibited better results compared to Lyre training system (Tables 10a, 10b).

Table 10a. Total and individual anthocyanins.

Treatments	Total anthocyanins (mg malvidin/g FW)	Individual anthocyanins		
		Delphinidin (μg/g FW)	Cyanidin (μg/g FW)	Petunidin (μg/g FW)
Density-top	2.78 ± 0.21 a	30.05 ± 0.98 a	5.43 ± 0.26 b	60.45 ± 1.52 a
Density-middle	2.53 ± 0.07 a	31.87 ± 4.16 a	10.30 ± 0.19 a	51.98 ± 1.51 abc
Density-bottom	1.71 ± 0.05 b	21.22 ± 0.67 a	9.25 ± 0.29 a	39.26 ± 1.41 bc
Royat	2.20 ± 0.13 ab	24.88 ± 3.50 a	2.89 ± 0.19 c	54.05 ± 4.73 ab
Lyre	2.32 ± 0.18 ab	16.34 ± 0.59 b	3.92 ± 0.53 c	37.57 ± 0.95 c

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

Table 10b. Individual anthocyanins.

Treatments	Peonidin (mg/g FW)	Malvidin (μg/g FW)	Acetic ester of malvidin (μg/g FW)	Coumaric ester of malvidin (μg/g FW)
Density-top	24.49 ± 0.39 c	664.51 ± 5.73 a	152.37 ± 4.82 a	872.41 ± 23.01 a
Density-middle	39.79 ± 0.77 a	640.56 ± 20.50 a	120.21 ± 7.85 b	618.75 ± 4.40 b
Density-bottom	30.45 ± 1.50 b	377.43 ± 10.34 b	73.92 ± 4.00 c	395.13 ± 10.44 c
Royat	20.77 ± 1.11 c	645.76 ± 15.58 a	120.37 ± 4.71 b	595.49 ± 25.19 b
Lyre	20.93 ± 0.58 c	480.05 ± 10.86 b	86.38± 3.63 c	416.41 ± 5.51 c

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

3.4 Individual sugars and organic acids in must

The results regarding the individual sugars showed that the concentration of fructose was higher than the one of glucose in all treatments (Table 11). The concentration of sugars exhibits no statistically significant differences between the treatments, with density-bottom treatment recording the highest values both in glucose as well as fructose.

Table 11. Individual sugars in must.

Treatments	Glucose (g/L must)	Fructose (g/L must)
Density-top	94.50 ± 1.54 b	110.56 ± 1.67 a
Density-middle	96.25 ± 2.20 ab	106.11 ± 2.71 a
Density-bottom	102.42 ± 0.90 a	113.90 ± 0.97 a
Royat	95.46 ± 0.57 ab	109.65 ± 0.47 a
Lyre	93.76 ± 2.40 b	107.95 ± 2.09 a

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–b) are significantly different at significance level $p \leq 0.05$.

The individual organic acid with the higher concentration was tartaric acid. followed by malic acid (Table 12). In the case of tartaric acid, the Lyre training system exhibited the higher concentration, with statistically significant differences compared to the other treatments. Regarding malic acid, the density-middle treatment recorded the higher concentration with statistically significant differences when compared to the other treatments.

Consequently, it seems that the most important organic acid was affected to a different extent by the different viticultural techniques, with the two training systems exhibiting better results.

The high concentration of tartaric acid, especially in the case of cultivars such as Xinomavro, which can be aged for a long time, are significant and results in a lower pH which acts as a natural antioxidant for the wine.

Table 12. Individual organic acids in must.

Treatments	Tartaric acid (mg/mg must)	Malic acid (mg/mg must)	Ascorbic acid (μg/mg must)
Density-top	51.38 ± 1.59 bc	12.62 ± 0.77 bc	177.58 ± 5.15 ab
Density-middle	48.67 ± 0.10 c	17.50 ± 1.37 a	221.05 ± 9.16 ab
Density-bottom	49.09 ± 0.18 c	14.83 ± 1.04 ab	242.95 ± 9.64 a
Royat	54.68 ± 0.07 bc	12.57 ± 0.58 bc	233.58 ± 15.30 a
Lyre	61.97 ± 0.83 a	9.52 ± 0.40 c	158.67 ± 3.11 b

Values are the means of triplicates (±SE). Values on the same column carrying a different letter (a–c) are significantly different at significance level $p \leq 0.05$.

4 Conclusions

The purpose of this research was to study the potential of grape cultivar Xinomavro quantitatively and qualitatively, under different training systems and dense planting. Based on the results, it appears that the various viticultural techniques affected the phenolic composition of the berries, to a different degree.

The results related to planting density showed that in the bottom part of the slope, a small percentage of individual and total anthocyanins was recorded, something that could be explained by the fact that this particular row, being on the inner side of the vineyard and due to the density of the vines, received less percentage of sunshine in the grapes, resulting in the inability to synthesize anthocyanins to a greater extent.

At the same time, the row at the top part of the slope, exhibited an increased concentration of skin tannins, higher concentration of total soluble solids, the highest pH and the highest concentration of total phenolics and flavonoids, which makes the produced wine coming from the grapes of this particular row more suitable for ripening and ageing.

The Lyre training system exhibited higher concentration of total soluble solids, a fact that is probably due to the larger surface area of the canopy, the better distribution and exposure to the sun. At the same time, the Royat training system exhibited less total soluble solids, but recorded higher concentrations of antioxidant compounds in the skins.

Different viticultural techniques either on their own or in combination, can significantly affect the final composition of the grapes and berries, at a given terroir and for a specific cultivar, and the ideal approach is of great importance to counteract the effects of climate change and its implications on the vines.

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