EFFECT OF CANOPY MICROCLIMATE ON MERLOT (VITIS VINIFERA L.) GRAPE COMPOSITION

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Abstract. The objective of this work was to evaluate the effect of different canopy management practices on canopy microclimate and consequently berry quality components of the Merlot (Vitis vinifera L.) grape variety. Different microclimate effects were created by the limitations of 1 m, 1.25 m and 1.5 m main shoot lengths and full lateral shoots (FLS), half lateral shoots (HLS) and no lateral shoots (NLS). Microclimatic data was gathered by the sensors placed in the canopies of FLS, HLS and NLS vines located under the 1.25 m main shoot length parcel. In the study, total soluble solids content, titratable acidity, pH, total phenolic content, total anthocyanin content, total tannin content, tartaric and malic acid content and potassium content in the juice were evaluated as the biochemical quality properties. The results of two years indicated that canopy microclimate arrangements may provide some manipulation on grape berry quality according to the vegetation period’s climate characteristics and the desired target quality within limits of macro-meso climate effects.

Keywords: canopy management, summer pruning, phenolic content, anthocyanins, must quality

Introduction

Canopy management applications may have some adverse affects on the physiological properties of the vine as a result of the isolation of vine-canopy microclimate from environmental factors, such as temperature, light exposure, atmospheric humidity and air flow when they are not considered as serious cultivation practices. As the green pruning is not performed according to a methodology, appropriate to the characteristics of the vegetation period, the production/consumption balance may deteriorate in the physiological sense. Exposure of clusters to direct sunlight can also cause physical damage and deterioration of the chemical structure of the berries under high temperatures.

There is an important amount of knowledge about the relationship between microclimate parameters and quality components. Temperature is the main factor controlling growth and quality. Improvements in criteria such as total phenolic, anthocyanin content, main components of sensory characteristics of wines, aroma, color and taste can be seen at certain stress levels (Matthews et al., 1990). Similarly, the positive effects of polyphenol components and antioxidant activity on human health can be increased (German and Walzem, 2000; Dixon et al., 2005). However, high evaporative demand during high temperature periods and growing period may play a role in limiting yield, berry wine quality (Escalona et al., 1999; Chaves et al., 2007). This can lead to wine acidity problems by reducing the coloration and sugar accumulation of the berry (Medrano et al., 2003; Romero et al., 2010). In addition, under the total intertwined impact of environmental stress factors, instant
photosynthesis reduction and risky losses in total carbon assimilation and even total canopy area may occur (Flexas et al., 1998, 2002; Maroco et al., 2002; Santos et al., 2007). The effect of light exposure on the vine (often not easily separated from temperature) is observed in physiological activities, shoot development and wooding, berry formation, fall, ripening processes and quality (Reynolds et al., 1986; Crippen and Morrison, 1986; Rojas-Lara and Morrison, 1989; Schubert et al., 1996; Haselgrove et al., 2000; Bertamini and Nedunchezhian, 2003; Spayd et al., 2011; Profoio et al., 2011).

The effects of the climate crisis that are going on beyond the traditional interaction between viticulture and climate are also discussed by researchers in a multi-dimensional context (Schultz, 2000; Nemani et al., 2001; Jones, 2007; Webb et al., 2008; Fraga et al., 2012; Vrsic and Vodovnik, 2012; Donat et al., 2013). As climate change is inevitable (Carbonneau and Bahar, 2009), different canopy management practices are an important tool for managing and adapting this process (This et al., 2006; Olsen et al., 2011). Canopy microclimate arrangements may provide some manipulation on grape berry and wine quality within limits of macro-meso climate affects and climate crisis.

There is a close relationship between the quality of grapes and wine and the composition of the berries. Therefore, quality depends on many components such as grape varieties, total soluble solids (TSS), organic acids, pH, phenolic substances, the thickness of the berry skin, the berry skin area, the ratio of the skin area/berry volume, the effect of ecological conditions, maturity time, the effect of diseases, rootstock and canopy management (Ribéreau-Gayon et al., 2000; Blouin and Guimberteau, 2000; Keller, 2010; Treutter, 2010).

The aim of the present study was to provide a better understanding of the effect of different canopy management practices on canopy microclimate and consequently berry quality components.

Materials and methods

Location, plant material and trial design

The two-year study (2014 and 2015) was conducted at the Tekirdağ Viticulture Research Institute, located in Northwest of Turkey (in Thrace), within the coordinates 40.969184°N-40.973562°N latitudes and 27.461911°E-27.477504°E. longitudes. The climate of Tekirdağ, is defined as a transitional climate among the Continental climate, the Black Sea climate and the Mediterranean climate with an average annual temperature of 14 °C, annual precipitation of 581.80 mm and 1887.00 growing day-degree Winkler Index for the years of 1939-2017 period. The altitude of vineyard was approximately 36 m and was approximately 4 km away from the sea. Merlot/5BB grafting combination 12–13 years old vines were oriented North-South on a high groundwater and clay-loam soil. Vines were arranged in a between-row and within-row spacing of 2.5 × 1.5 m respectively. Double Guyot training vines pruned 16-18 bud per vine.

Different microclimate effects were created by the limitatons of 1 m, 1.25 m and 1.5 m main shoot lengths while they reached 170-180 cm (EL 31-33) shoot lengths for main parcels. Lateral shoot applications were sub-parcels which created by full lateral shoots (6-7 leaves), half lateral shoots (3-4 leaves) and no lateral shoots (no leaf) performed in veraison (EL 35) according to Lorenz et al. (1995). Both applications were kept at the same length until the harvest period.
Data was gathered from meteorological stations located in Tekirdag Viticulture Research Institute in order to determine mesoclimatic and microclimatic conditions. A climate station which located 2 m high from ground was used to collect mesoclimatic data reflecting the general climatic characteristics of the vineyard. Mesoclimatic measurements; temperature, relative humidity, light intensity, wind speed, total precipitation and microclimatic measurements from the insides of the vine canopies which were the descriptive features such as temperature, relative humidity, light intensity, wind speed and leaf wetness were monitored during the years 2014 and 2015.

Microclimatic data sensors were placed in the canopies of full lateral shoot (FLS, 6-7 leaves), half lateral shoot (HLS, 3-4 leaves) and no lateral shoot (NLS) sub-parcel vines that located under 1.25 m main shoot length main parcel, from the beginning of the vegetation period and measurements were continued until the end of harvest by SHT11 Temperature, humidity and leaf wetness sensor module (Sensirion AG, Switzerland) for temperature, humidity and leaf wetness. TEMT 6000 light sensor (Vishay Intertechnology, Inc., Germany) and WGR800 wind sensor (Oregon scientific, USA) readings were gathered by a cloud based datalogger (Mrme AR-GE Bilişim, Turkey). The 5 min averages of two-second readings from each sensor derived as the station’s hourly value.

The inside of the three canopies were equipped with one temperature, humidity, leaf wetness, wind and four light intensity sensors (Fig. 1). Also light intensity sensors positioned two each around cluster zone and center canopy. The wind sensor in the canopy is enclosed in a suitably sized wireframe that does not stop the wind flow to prevent contact with leaves and shoots. Maintenance and control of the sensors placed inside vines were done regularly to avoid any data loses after cultivation practices such as spraying, green pruning etc.

![Figure 1. Placing of different sensors and loggers in vineyard (a) main electric and GSM unity, (b) cloud based datalogger, (c) wind sensor, (d) temperature, humidity, leaf wetness, (e) light sensor](image)

Although the data received from all of the above sensors for all growing process, only outputs of temperature and light intensity effects between veraison-harvest period are evaluated in this publication due to the important effects on must composition.
Despite the equal number of (16) buds left in the winter pruning, the plants that disrupt homogeneity in the number of shoots and bunches were balanced when the shoots reached an average length of 30-40 cm (EL 15-17) or excluded from the trial. Standard cultural practices in the region were applied to all treatments during research. The vines data taken were selected from the same development period and with the approximate charge and those without spaces.

**Must composition**

The total soluble solids (%), pH, total acidity (g/L of tartaric acid), and the concentration of tartaric acid (g/L), malic acid (g/L) and potassium (mg/L) in must from grapes collected from each experimental replication at the harvest date was determined using the official methods of the Organisation Internationale de la Vigne et du Vin (OIV) (OIV, 2012). Also, total phenolic content (mg/kg), total anthocyanin content (mg/kg) and total tannin content (g/kg) were found out as biochemical analysis (AOAC, 1998; Waterhouse, 2002).

**Statistical analysis**

The experiment consisted with combination of 3 different main shoot length and 3 different lateral shoot length applications. A randomized block design was used with 3 replications of a total of 108 vines under 27 parcels. JMP 13.2.0 statistical program was used for determining differences in applications and years. In order to determine differences in findings, LSD test was used at 5% significance level.

**Results and discussion**

**Phenological development stages**

As a result of the phenological observations made throughout the trial, the day green shoot tips seen clearly in the buds was 02.04.2014 (91st calendar day) for the year 2014, for 2015 it was observed as 12.04.2015 (101st calendar day) (Table 1).

| Budburst (EL 04-07) | Flowering (EL 23-25) | Verasion (EL 35) | Harvest (EL 38) |
|--------------------|----------------------|-----------------|-----------------|
| 02.04.2014         | 29.05.2014           | 30.07.2014      | 16.09.2014      |
| 12.04.2015         | 28.05.2015           | 01.08.2015      | 05.10.2015      |

**Climatic conditions**

**General climatic conditions of 2014-2015 years’**

While the average temperature was recorded as 16.08 °C in 2014 and 16.00 °C in 2015, the average temperature in Tekirdağ province for long years (1939-2017) was 14 °C. 2014 was an extraordinary year in terms of precipitation. The annual total precipitation was 770.50 mm, which is significantly higher than the average of 589.10 mm for long years. Vegetation period precipitation was also remarkable with 475.20 mm which is also above 139.00 mm average of long years. In 2015, the total annual precipitation was 507.90 mm and 187.40 mm precipitation in the vegetation
The period is around the average for long years. Due to the general characteristics of 2014, light exposure (PFD) and wind speed were lower than 2015 in 2014 both during the year and vegetation period. Average proportional humidity was also higher for year and vegetation period in 2014.

In 2014, the maximum temperature was measured as 33.50 °C, while the lowest temperature was recorded as 16.10 °C. Also verasion-harvest period average temperature ranged from 22.00 to 27.60 °C. The light intensity (PFD) ranged between 62.53 μmol m²/s and 1976.27 μmol m²/sec, with an average of 1134.53 μmol m²/s in 2014.

In 2015, the highest temperature was recorded as 39.70 °C and the lowest temperature was 12.30 °C and the average temperature was between 14.30 and 29.00 °C. In the same period, while PFD measurements ranged from 44.37 μmol m²/s to 1894.88 μmol m²/sec, the average period was recorded as 1042.43 μmol m²/s (Fig. 2).

![Figure 2. General temperature and light intensity data of verasion-harvest period in year 2014 and 2015](image)

Microclimatic conditions inside canopies between verasion and harvest period

Temperature related microclimatic assessments were made for 5 critical intervals per hours/day in terms of the duration of exposure for lateral shoot applications. In addition, the average, lowest and highest temperatures in the related phenological periods were determined.

All lateral shoot leaf removal applications were completed in the first week of August in both years and targeted canopy architectures were created. The most remarkable issue in terms of temperatures for 2014, while the highest temperature in the whole of the vineyard was recorded as 30.10 °C in August and 27.70 °C in August-September mean, the temperature of the canopy was exposed to temperatures in the
range of 30-35 °C and over 35 °C in all lateral shoot applications. It is noteworthy that temperatures below 20 °C in 2015 are 3-4 times more than in 2014. In both years, temperatures above 35 °C were observed in the NLS application for the longest period, while the temperature above 30 °C was measured at the maximum HLS application. It was observed that in the period between verasion and harvest; most seen temperature range was between 20 and 25 °C in 2014 and 2015. Another remarkable point is that the FLS application remains the longest at temperatures below 20 °C. Temperatures above 35 °C were observed for longer periods with the removal of the lateral leaves (Table 2). The positive and negative aspects of this phenomenon will be mentioned in the headings on must analytical analysis.

| Table 2. Verasion-harvest period temperature intervals in canopy (hours/day) |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Verasion-harvest period | ≤20 °C | 20-25 °C | 25-30 °C | 30-35 °C | ≥35 °C | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| NLS | 2.45 | 6.18 | 9.34 | 8.14 | 3.44 | 3.19 | 4.34 | 3.43 | 3.23 | 2.25 |
| HLS | 2.36 | 5.49 | 8.55 | 6.49 | 3.53 | 4.20 | 8.1 | 5.51 | 0.27 | 1.11 |
| FLS | 2.53 | 8.29 | 7.41 | 6.15 | 4.47 | 5.11 | 6.39 | 3.20 | 0.16 | 0.43 |

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves)

While the mean temperature in the canopy ranged between 26.16 and 26.92 °C in of 2014 verasion-harvest period, the average outside canopy temperature at 2 m was recorded as 23.02 °C. In 2015 verasion-harvest period in canopy mean temperature was changed between 23.36 and 25.26 °C and average temperature at 2 m outside canopy was recorded as 24.40 °C.

During the same period in 2014, the highest average temperature was 27.70 °C at 2 m, while the maximum high temperature was 46.06 °C (NLS) and the lowest high temperature was 37.80 °C (HLS). The highest average temperature was 35.90 °C at 2 m and in canopy measurement was found 49.77 °C for NLS application and 42.77 °C for HLS application in 2015.

In canopy low temperature averages range between 14.46 °C and 15.70 °C and 2 m was recorded as 18.70 °C in year of 2014. Two meters low temperature averages were also recorded as 15.40 °C in 2015, and ranged between 5.12 °C (NLS) and 11.18 °C (FLS) in canopy (Table 3).

In both years, outside canopy low temperatures are higher than in canopy low temperatures. Cold weather is trapped inside the canopy at night. In summary, there are no significant differences between the inside and outside of the canopy in terms of average temperatures, but dramatic differences can be observed at low and high temperatures. In the case of high temperatures, it is observed that in canopy temperatures have increased by 18.36 °C for 2014 and 13.87 °C in 2015 for the NLS application due to loss of shade effect created by lateral shoot leaves.

Light intensity averages based on phenological periods

The light intensity measurements were evaluated by calculating the mean data from the canopy microclimates and the data mean obtained from the overall vineyard according to phenological periods.
In 2014 Verasion-harvest period NLS, HLS and FLS applications were measured as 51.29 μmol m²/sec, 45.75 μmol m²/s and 30.30 μmol m²/sec, respectively and the outside canopy light at 2 m level was recorded as 1155.14 μmol m²/s (Table 4). In this period, it was seen that the total light intensity that reached to the whole of the vineyard could only reach the canopy center and clusters in 4.44% NLS application, 3.96% in HLS application and 2.62% in FLS application (Fig. 3).

Table 3. In and outside canopy temperature averages according to the applications between the periods of verasion-harvest in 2014 and 2015 (°C)

| Verasion-harvest period | Max. temperature (°C) | Mean temperature (°C) | Min. temperature (°C) |
|-------------------------|-----------------------|-----------------------|-----------------------|
|                         | 2014                  | 2015                  | 2014                  | 2015                  | 2014                  | 2015                  |
| NLS                     | 46.06                 | 49.77                 | 26.92                 | 24.83                 | 15.70                 | 5.12                  |
| HLS                     | 37.80                 | 42.77                 | 26.42                 | 25.26                 | 15.58                 | 10.36                 |
| FLS                     | 41.91                 | 43.33                 | 26.16                 | 23.36                 | 14.46                 | 11.18                 |
| Outside canopy 2 m.     | 27.70                 | 35.90                 | 23.02                 | 24.40                 | 18.70                 | 15.40                 |

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves)

Table 4. In and outside canopy light intensity averages according to the applications between the periods of verasion-harvest in 2014 and 2015 (μmol m²/s)

| Verasion-harvest period | 2014 | 2015 |
|-------------------------|------|------|
| NLS                     | 51.29| 28.71|
| HLS                     | 45.75| 21.43|
| FLS                     | 30.30| 23.05|
| Outside canopy 2 m.     | 1155.14| 1068.69|

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves)

Figure 3. Penetration percentage of light into the canopy from outside in version-harvest period in years’ 2014 and 2015

Although 2015 was a year with a higher number of cloudless skies compared to the previous year, the late harvest date led to a decrease in the overall average light
intensity across the vineyard. Thus, the average light intensity of the outside canopy at 2 m was measured as 1068.69 μmol m²/s while the application of NLS was 28.71 μmol m²/s, HLS application was 21.43 μmol m²/s and FLS application was 23.05 μmol m²/s. The penetration rates into the canopy were calculated as 2.19% for NLS application, 2.01% for HLS application and 2.16% for FLS application (Fig. 3). In addition, the damage to the leaves and the relative reduction in total leaf area due to the severe Plasmopara viticola outbreak in 2014 may have resulted in higher light penetration into the canopy this year. Although not statistically significant, this phenomenon is supported by the decrease in yield and the increase in anthocyanin amounts this year.

Although these values appear to be very low, Smart et al. (1990) stated that approximately only 6% of the intense light from the sun is absorbed by the leaf, and that when the intense canopy formation is seen in the grapevine, the light penetration into the canopy is very low and only 1% of the upper leaves are able to be illuminated. Escalona et al. (2003) also have obtained similar results in double-cordon trained Monte Negro grapes from measurements of outer and inner surfaces of canopies. On the other hand, in Taiz and Zeiger (2010), indicated that only 5% of the total energy presence was used in carbohydrate production while explaining the process of converting solar energy into leaves by carbohydrates.

**Must analytical analyzes**

*Yield (kg per vine)*

As stated before, in both years, 16 buds per vine were left in winter prunings, and shoots and clusters were equalized when the shoots reached 30–40 cm in length. Thus, the differences between the yield values were not statistically significant. Yield values were seen the lowest for NLS application with 4.60 kg/vine and highest for FLS application with 5.00 kg/vine.

*Total soluble solids (%)*

As known, the amount of sugar in the berry is one of the most important components of industrial maturity. While the effects of lateral shoot applications were found to be statistically significant in both years, differences in main shoot practices were found to be insignificant in terms of TSS values. In the average of two years, 1.25 m main shoot length application reached 21.88% highest TSS quantity while FLS application remained at 21.67%. Differences in years averages were insignificant (Table 5).

It is observed that the application of NLS in water-soluble dry matter gives different results in both years. In 2014, the extreme rainfall and high proportional moisture occurring during the vegetation period affected the physiological activity positively in the application of full-fledged seat shoot and accelerated the availability of photosynthesis and hence the accumulation of dry matter throughout the vine. Under the relatively hot and dry conditions of 2015, the microclimate, in which the NLS application was affected, in particular in terms of high temperatures, slowed down the accumulation of TSS.

Therefore, it can be seen that the manipulations made at the right time and in the right way on the canopies provide options for the struggle against the negativity caused by the general climate characteristics.
**Total acidity (g/L)**

The effects of different main and lateral shoot applications on total acidity were found to be statistically significant in 2014 and for the mean of two years in terms of lateral shoot applications, whereas in 2015 the differences were not significant. At the two-year average, the HLS and FLS applications were in the same statistical class with higher values, while the NLS application created another statistical class with lower total acidity (Table 5).

### Table 5. Effects of main shoot and lateral shoot treatments on total soluble solids, total acidity and pH

| Treatments | 2014 | 2015 | Mean of years |
|------------|------|------|---------------|
|            | TSS (%) | Total acidity (g/L) | pH | TSS (%) | Total acidity (g/L) | pH | TSS (%) | Total acidity (g/L) | pH |
| 1 m        | 20.97 | 7.45 | 3.54 | 22.42 | 5.85 | 3.75 | 21.70 | 6.65 | 3.65 |
| 1.25 m     | 20.97 | 7.53 | 3.54 | 22.80 | 5.83 | 3.73 | 21.88 | 6.68 | 3.63 |
| 1.5 m      | 20.86 | 7.56 | 3.53 | 22.75 | 5.90 | 3.77 | 21.81 | 6.73 | 3.65 |
| NLS        | 21.31 | 7.13 | 3.58 | 22.42 | 5.78 | 3.75 | 21.86 | 6.45 | 3.66 |
| HLS        | 20.84 | 7.61 | 3.54 | 22.86 | 5.86 | 3.75 | 21.85 | 6.74 | 3.65 |
| FLS        | 20.66 | 7.80 | 3.50 | 22.68 | 5.93 | 3.75 | 21.67 | 6.86 | 3.62 |
| YME        | 20.94 | 7.51 | 3.54 | 22.65 | 5.86 | 3.75 | n.s.  | n.s.  | n.s. |

MSME LSD0.05 n.s. n.s. n.s. n.s. n.s. n.s. n.s. n.s. n.s.
LSME LSD0.05 0.383 0.273 0.034 0.343 0.180 0.019 0.234 0.180 0.019
YME LSD0.05 0.234 0.180 0.019 0.234 0.180 0.019

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves). MSME means main shoot main effect, LSME means lateral shoot main effect and YME means year main effect. Different lowercase superscript letters in same column and uppercase letters in same line represent statistically significant differences between means at $p < 0.05$ according to least significant difference test. n.s. means not significant.

The most significant relationship between temperature and berry quality appears by reduction of organic acid concentration in berry with high temperatures (Kliewer, 1973).

Tartaric and malic acids are the predominant organic acids which are effective in all stages of berry development and cause significant effects on acidity and pH (Morris et al., 1983). In particular, the malate is stored in berries until the verasion period as a potential source for the carbon demand in the maturation process (Ruffner, 1982). In this period, the decrease in malic acid decreases the total acidity and balances the sugar and acid ratios (Kliewer, 1965). The decrease in titratable acid levels for 2014 and 2015 was directly proportional to the daily exposure time at temperatures between 20-25 °C. At temperatures near 30 °C, seems to reduce the consumption of malic acid by inhibiting photosynthesis. Sweetman et al. (2014) states that enzymes and metabolic pathways that are effective in regulating organic acids during berry growth and development should be further investigated, especially in temperature rise and day/night temperature changes. On the other hand, the increase in the main shoot length caused an increase in titratable acid in years. According to a different study in the same location; Although it is not statistically significant, the main shoot length increase leads to a decrease in total acidity (Yasasin et al., 2018).
pH

Ph values were found to be very close among the applications in 2015. In 2014 and the average of years, the NLS application reached the highest values and created a different statistical class. Thus, it can be said that in the years of unusual precipitation in vegetation period such as 2014, lateral shoot applications made a difference (Table 5).

Total anthocyanin (mg/kg)

When total anthocyanin contents of grape varieties were examined, it was determined that the highest mean of total anthocyanin content was obtained from NLS application in 2014 (Table 6). The amount of high anthocyanin in the lateral shoot applications in both years between veraison harvest period was observed to be proportional to the time spent in 20-25 °C temperature range. But similar relationships were not determined at temperatures above 30 °C as found by Kliewer (1970), Kataoka et al. (1984), Mori et al. (2004), Tomana et al. (1979) or in Yamane et al. (2006) for the night temperatures below 20 °C. Maybe, the lower number of berries in cluster, lower berry fresh weights and lower leaves of pH and factors like higher skin/flesh ratio and acidity in 2014 (data not shown) may have appeared as more important factors than temperature and rainfall.

In our study, it is seen that the increasing stress tendency caused higher anthocyanin levels in mean of years with increasing main shoot lengths, but not statistically. According to Yasasin et al. (2018), although it is not statistically significant, the total amount of anthocyanin in the main shoot length of 1.5 m is higher than the 1 m main shoot length.

Observing the direct effects of canopy management practices on the total amount of anthocyanins is quite difficult, as the mechanisms affecting the synthesis, deposition and degradation of anthocyanin are related to a number of factors. However, it is possible to influence the amount of anthocyanins by specific applications selected according to the prescribed climatic characteristics.

Total tannin (g/kg)

In terms of tannins, there was no significant relationship between lateral and main shoot length applications and total tannin amount except for the different climatic characteristics of the two years (Table 6).

Total phenolic (mg/kg)

The statistical significance differences between the applications for phenolic substances were only seen in 2014. The highest phenolic substance content was found in the application of NLS (Table 6). Roby et al. (2004) and Chacon et al. (2009) reported that increased water stress increases the total phenolic content. In our study, it is seen that the relationship with the increased main shoot length did not significantly affect the total phenolic substance on the basis of years or years. However, it should be kept in mind that water stress did not occur at the levels that can be considered significant in the years when the trial was conducted. The increase in light intensity level and the relative increase in photosynthesis rates due to the removal of all lateral leaves under the effect of the climate conditions of 2014 is thought to have led to this increase.
Table 6. Effects of main shoot and lateral shoot treatments on total anthocyanin, total tannins and total phenolics

| Treatments | 2014 | 2015 | Mean of years |
|------------|------|------|---------------|
|             | Total anthocyanin (mg/kg) | Total tannins (g/kg) | Total phenolics (mg/kg) | Total anthocyanin (mg/kg) | Total tannins (g/kg) | Total phenolics (mg/kg) | Total anthocyanin (mg/kg) | Total tannins (g/kg) | Total phenolics (mg/kg) |
| 1 m         | 624.51 | 2.48  | 1810.27       | 472.64 | 4.22  | 2900.00       | 548.57 | 3.35  | 2355.14 |
| 1.25 m      | 628.62 | 2.68  | 1822.50       | 562.97 | 4.37  | 2985.83       | 595.79 | 3.52  | 2404.17 |
| 1.5 m       | 666.51 | 2.61  | 1966.38       | 572.29 | 4.39  | 3037.91       | 619.40 | 3.50  | 2502.15 |
| HLS         | 719.68 | 2.75  | 2069.44       | 574.57 | 4.35  | 3098.33       | 647.13 | 3.55  | 2583.88 |
| NLS         | 621.28 | 2.53  | 1742.77       | 521.70 | 4.37  | 2909.44       | 571.49 | 3.45  | 2326.45 |
| FLS         | 578.68 | 2.49  | 1786.94       | 511.63 | 4.26  | 2915.97       | 545.16 | 3.38  | 2351.45 |
| YME         | 639.88 | 2.59  | 1866.38       | 535.97 | 4.32  | 2974.58       | 619.40 | 3.50  | 2502.15 |

MSME LSD0.05 n.s. n.s. n.s. n.s. n.s. n.s. n.s. n.s. n.s. n.s.
LSME LSD0.05 101.184 n.s. 230.276 n.s. n.s. n.s. 61.893 N.S. 183.857
YME LSD0.05 50.404 0.115 150.129 50.404 0.115 150.129

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves). MSME means main shoot main effect, LSME means lateral shoot main effect and YME means year main effect. Different lowercase superscript letters in same column and uppercase letters in same line represent statistically significant differences between means at \( p < 0.05 \) according to least significant difference test. n.s. means not significant.

Tartaric acid (g/L)

It was observed that different lateral shoot length and main shoots length applications did not significantly affect the amount of tartaric acid in grape berries in 2014 and 2015. However, in the rainy 2014 year, the year main effect of tartaric acid was found to be 6.28 g/L, whereas in 2015 it was found lower and statistically significant with 4.28 g/L. (Table 7).

Table 7. Effects of main shoot and lateral shoot treatments on tartaric acid, malic acid and potassium

| Treatments | 2014 | 2015 | Mean of years |
|------------|------|------|---------------|
|             | Tartaric acid (g/L) | Malic acid (g/L) | Potassium (mg/L) | Tartaric acid (g/L) | Malic acid (g/L) | Potassium (mg/L) | Tartaric acid (g/L) | Malic acid (g/L) | Potassium (mg/L) |
| 1 m         | 6.10  | 1.68  | 2496.28       | 3.56  | 1.20  | 1084.77       | 4.83  | 1.44  | 1790.53 |
| 1.25 m      | 6.23  | 1.65  | 2332.11       | 5.34  | 1.05  | 1065.66       | 5.79  | 1.35  | 1698.89 |
| 1.5 m       | 6.53  | 1.89  | 2485.08       | 3.92  | 0.88  | 935.99        | 5.22  | 1.39  | 1710.34 |
| HLS         | 6.27  | 1.53  | 2475.53       | 4.53  | 1.01  | 963.26        | 5.40  | 1.27  | 1719.40 |
| NLS         | 6.25  | 1.93  | 2478.49       | 4.45  | 1.30  | 1091.68       | 5.35  | 1.62  | 1785.09 |
| FLS         | 6.33  | 1.76  | 2359345       | 3.86  | 0.82  | 1031.09       | 5.09  | 1.29  | 1695.27 |
| YME         | 6.28  | 1.74  | 2437.82       | 4.28  | 1.05  | 1028.67       | 5.40  | 1.35  | 1698.89 |

MSME LSD0.05 n.s. n.s. n.s. n.s. n.s. n.s. 0.482 n.s. n.s.
LSME LSD0.05 n.s. n.s. n.s. n.s. n.s. 0.238 n.s. 0.179 n.s.
YME LSD0.05 0.453 0.138 123.45 0.453 0.138 123.45

NLS, HLS, and FLS represent no lateral shoots (no leaf), half lateral shoots (3-4 leaves) full lateral shoots (6-7 leaves). MSME means main shoot main effect, LSME means lateral shoot main effect and YME means year main effect. Different lowercase superscript letters in same column and uppercase letters in same line represent statistically significant differences between means at \( p < 0.05 \) according to least significant difference test. n.s. means not significant.

Malic acid (g/L)

Significant differences were found in malic acid amount in lateral shoot practices in 2015. While HLS application reached the highest amount of malic acid with 1.30 g/L,
NLS application was measured as 1.01 g/L and FLS application was measured as 0.82 g/L and they produced different statistic classes. In 2014, no significant differences were found between the practices. As the main effect of the year, in 2015, as in tartaric acid, lower amounts of malic acid were detected (Table 7).

Potassium (mg/L)

One of the prominent features in the determination of maturity is the accumulation of potassium in the skin in parallel with the accumulation of sugar in berry flesh. Although it is one of the most important mineral substances in berry composition, very high potassium levels may decrease quality and may have a negative effect on wine quality especially in red wines (Davies et al., 2006).

It also plays an important role in the rapid phase of the cell division during the first stage of berry development due to the potent role in osmotic regulation. Potassium levels during berry development can be affected by many external factors such as soil, grape variety and cultivation practices (Mpelasoka et al., 2003).

However, although potassium levels were not significantly affected by different main shoot and lateral shoot applications, it was observed that higher potassium accumulation occurred in berries in 2014, when precipitation occurred above normal conditions. However, potassium levels were within the expected values in both years (Table 7).

Conclusion

As a result, Merlot/5BB combination vines are affected positively in terms of physiological activities and quality criteria when the lateral shoots are kept with 3–4 leaves from the verasion to the harvest in hot years like 2015 (187.40 mm precipitation, 73.43% relative humidity, 1243.56 μmol m²/s light intensity) when rainfall and proportional humidity are relatively low in vegetation period. It is recommended that the lateral shoots should be completely removed during verasion to harvest period, in cool years like 2014 (475.20 mm precipitation, 77.53% relative humidity, 790.31 μmol m²/s light intensity) when vegetation period has high rainfall and proportional humidity and low light intensity.

In terms of main shoot lengths, as the shoot length increases, stress and some quality criteria tend to increase, but these effects are generally not statistically significant. Even when the main shoot length is kept at 1 m, leaf area can reach a sufficient level in terms of yield and quality.

It is considered that future studies should be carried out with modeling studies related to clustermicroclimate, especially with regard to lighting and wind movements within the canopy. In addition, it is considered necessary to transfer green pruning applications to mechanization in practical terms.

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