



GRAPE BERRY MORPHOLOGY IN SEMI-ARID CLIMATE OF TEKİRDAĞ: EVALUATING THE EFFECTS OF ENVIRONMENTAL FACTORS AND STRESS APPLICATIONS

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Abstract: The growth and development of grapes are influenced by various biotic and abiotic stresses. The presence of *Vitis vinifera* L. on Earth is threatened by the increase in abiotic stresses and biotic stresses due to global warming. On the other hand, grape quality and, consequently, berry characteristics can also be negatively affected by these stress factors. The hypothesis of this experiment is to determine the effects of biotic and abiotic stresses applied five days before harvest on the berries of live grapevines under field conditions. For this purpose, for two years (2016 and 2017), Cabernet-Sauvignon and Merlot grape varieties grafted onto the SO4 rootstock at Te-Ha Corp. vineyard were used. In the late pre-harvest period (five days before harvest), seven stress applications, including control, were implemented. The stress application methods included control, shock action (1 minute with a plastic hammer at 08:00 and 19:00), leaf removal (removing all leaves), leaf injury (injuring all leaves by hitting with a stick), UV-C (1 minute at 08:00 and 19:00), vibration (1 minute of vibration at 08:00 and 19:00), and *Botrytis cinerea* Pers ex. Fr (once). The measurements of the features performed are as follows, in order: berry width-length (mm), berry volume (cm³), berry skin area (cm²/grain), berry skin area/berry flesh volume ratio (cm²/cm³), berry fresh-dry weight (g), 100 berry fresh weight (g), berry density (g/cm³), and % dry weight. As a result, it was observed that the applied abiotic and biotic stress treatments did not negatively affect berry characteristics in two years, especially in the second year. Therefore, the application of Shock action, UV-C, Vibration, Leaf injury, Leaf removal, and *Botrytis cinerea* for improving grape quality was found not to be objectionable.

Keywords: Abiotic stress, Biotic stress, UV-C, Cabernet-Sauvignon cv., Merlot. cv.

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1. Introduction

Due to the increase in greenhouse gases in the atmosphere, changes are occurring at the biogeochemical levels, leading to an increase in temperature, drought, and an associated rise in CO₂ concentration. In short, the viability of *Vitis vinifera* L. on Earth will be jeopardized in the future due to the increase in abiotic stresses and biotic stresses associated with climate change (Aguilera et al., 2022).

Grapes are subject to various biotic and abiotic stresses that affect their growth and development. Among abiotic stresses, drought (Bianchi et al., 2023; Hewitt et al., 2023), salinity (Aazami et al., 2023), extreme temperatures (Biniari et al., 2023; Hewitt et al., 2023), toxic chemicals, heavy metals, high UV radiation, atmospheric CO₂, and oxidative stresses can be listed (Ma et al., 2012; Lopez-Fernandez et al., 2016). As is known, living organisms such as pathogens, insects, viruses, viroids, bacteria (Ma et al., 2011), and fungi (Cosseboom and Hu, 2022) constitute biotic factors in the ecosystem (Candar, 2023; Darriaut et al., 2023). To practice resilient viticulture against biotic and abiotic stress factors,

healthy soil (Biasi et al., 2023), and appropriate clone-rootstock selection to reduce environmental stress effects are important (Ferrandino et al., 2023). The use of mycorrhiza as a biostimulant is effective in reducing abiotic stresses caused by climate change since it enhances the uptake of water and plant nutrients from the soil (Kara and Erdogan, 2010; Aguilera et al., 2022). Debastiani et al. (2023) found that the use of the S26 isolate obtained from *Bacillus sp.*, as a bioinoculant in Cu-contaminated soils, led to an increase in plant growth to reduce biotic and abiotic stresses in grapevines. Additionally, it was determined that controlled application of UV-C radiation improved grape quality. However, the impact of UV radiation on berry size is not known (Del-Castillo-Alonso et al., 2021). In winemaking, the application of thermovinification + UV-C has been found to enhance the composition of wine compared to traditional winemaking (Tahmaz and Soylemezoglu, 2017). Klarner et al. (2015), using UV-C radiation to eliminate *Botrytis cinerea* in vineyards, reported an 82% reduction in fungicide usage. Lorenzini et al. (2010) expressed that microorganism formation in grape juice



and wine can be sterilized with UV-C. Jung et al. (2018) indicated that exposure to mechanical vibration (vibration) stress through simulation could result in weight loss, rapid ripening, and spoilage in grapes. On the other hand, the timing and intensity of leaf removal should be adjusted considering the local climate (Mucalo et al., 2021).

Sabir et al. (2015) observed that in the Italia grape variety, berry weights were higher under full irrigation. On the other hand, Tardaguila et al. (2010) determined that late-season leaf removal did not alter the number of berries in the cluster. However, Palliotti et al. (2011) stated that early-season leaf removal increased the ratio of pulp to skin in the berries. Additionally, Poni et al. (2009) found that leaf removal before flowering and Korkutal et al. (2017) leaving all basal leaves increased the berry skin area. Romero et al. (2022) expressed that water stress leads to smaller berry size and increased berry skin ratio. Similarly, it was noted that berries from vines subjected to water stress and leaf removal were lighter and had a higher skin ratio compared to the control (Alatzas et al., 2023). These practices are considered by researchers to enhance grape quality (Roby and Matthews, 2004). It should be noted that excessive leaf removal can negatively affect berry color formation (Price et al., 1995).

Dai et al. (1995) reported that berry weight is influenced by environmental and viticultural practices, while Barbagallo et al. (2011) mentioned that quality decreases when berries are large. This is because in red wine grape varieties, a small berry size is desired, and it has been emphasized by Matthews and Anderson (1988) that wines from small berries are of higher quality. In contrast, Kasimatis et al. (1985) and Johnstone et al. (1995) reported that there is no such relationship between berry size and wine quality.

Berry size is emphasized to be influenced by the position of the berry in the cluster, the number of berries in the cluster, and the balance between the production center and the consumption center of the vine (Ollat et al., 2002; Dai et al., 2009). In addition, the effect of temperature on berry shape has been known for many years, with lower temperatures leading to longer berries (Harris et al., 1968). Furthermore, it has been noted that berry size can also vary with different pruning practices (mechanical, 2-buds, and 4-8 buds+2 buds) (Holt et al., 2008). As is known, there is a close relationship between quality and the composition of grape berries in grapes and wine. Therefore, quality is primarily dependent on the distribution of substances in its composition, such as grape variety, total soluble solids, organic acids, pH, and phenolic compounds. Quality is also influenced by factors such as berry skin thickness, berry skin area, the ratio of skin area to berry volume (Roby and Matthews, 2004), ecological conditions, maturity time, the impact of diseases, and practices such as rootstock and canopy management (Ribéreau-Gayon et al., 2000; Blouin and Guimberteau, 2000; Karanis and Çelik, 2002; Keller,

2010).

In the scope of this study, two types of stress applications, abiotic and biotic, were applied to live grapevines. Shock action, UV-C, vibration, leaf injury, leaf removal, and *Botrytis cinerea* stress applications were performed in the field conditions five days before harvest. The study aimed to determine whether these late-season stress applications had a negative impact on berry characteristics. Because the abiotic stress factors tested in this research are actually factors that could endanger the vitality of grapevines. Among these factors, especially, the application of UV-C can result in the loss of plant life. Or the winter buds for the following year may not emerge due to UV-C radiation. Practices such as impact, vibration, removal of all leaves, and leaf injury, while not as impactful as UV-C radiation, can still have negative effects on the next year's bud yield. As a result of this study, it will be revealed whether the applications performed five days before harvest affect berry characteristics (quality) in the year of stress occurrence and the subsequent year. Similarly, it will be observed whether the biotic stress of *Botrytis cinerea*, conducted in a similar manner, contributes to this effect.

2. Materials and Methods

2.1. Trial Site

The Merlot (VIVC number 7657) and Cabernet-Sauvignon (VIVC number 1929) grape varieties of *Vitis vinifera* L. were used as plant material. These varieties are grafted onto SO4 rootstock in a vineyard established in 2007. The vineyard is located in Tekirdag province at an altitude of 235 m above sea level. Rows are planted in a north-south direction with a spacing of 2,6 m between rows and 0,9 m between vines on the row. The vineyard is trained in a double cordon Royat system. In a Randomized Complete Block Design, the experiment consists of 2 grape varieties, 7 treatments [Control, *Botrytis cinerea* (biotic), UV-C, shock action, leaf injury, leaf removal, and vibration (abiotic)], 3 replicates, and a total of 126 vines with 3 vines in each replicate.

When the soil characteristics of the trial area (0-30 cm) were examined, it was determined that the soil structure of cv. Cabernet-Sauvignon and cv. Merlot vineyards is clay-loamy. In the cv. Cabernet-Sauvignon vineyard, it was found that potassium, calcium, iron, copper, and manganese elements are sufficient; organic matter, total nitrogen, and zinc are low. In the cv. Merlot vineyard, it was observed that phosphorus, potassium, calcium, iron, copper, and manganese elements are sufficient; organic matter, total nitrogen, and zinc are also low. The soil analysis results revealed that magnesium is very high in both vineyards.

2.2. Stress Applications

The grape harvest was conducted on Sept 18, 2016, and Sept 27, 2017. Trial clusters were selected as homogeneously as possible. Biotic and abiotic (such as UV-C) stresses that negatively affect and can even be lethal to the plant were planned, and these applications

were carried out five days before harvest. Special attention was given to the short time remaining until harvest when determining the durations of these stress applications. The aim of these applications conducted five days before harvest was to preserve the vitality of the plant in the trial year and the following year, and to enhance the grape quality in the trial year. The stress applications conducted are outlined below:

- Control: No stress was applied.
- Shock action: The trunk and arms of the vines were subjected to shock action twice a day (08:00 and 19:00) for 1 minute each, for 5 days, using a plastic hammer.
- UV-C irradiation: A cabin covering an entire vine was created, and UV-C radiation (Langcake and Pryce, 1977) was applied twice a day (08:00-19:00) for 1 minute each, over 5 days.
- Vibration: Mechanical vibration was applied to trunk, arm junction, and arm of the vine using a drill with an isolated tip.
- Leaf injury: Leaves were wounded by striking the vines in two directions with a flexible rod. This application was performed for 5 days at 1-minute intervals (08:00 and 19:00).
- Leaf removal: All leaves on a cluster were manually defoliated.

-*Botrytis cinerea* Pers ex. Fr. inoculation: The *Botrytis cinerea* isolate's 14-day conidia were placed in sterile distilled water. A sterile 2.5×10^5 conidia/ml spore suspension was sprayed onto the clusters using a hand sprayer, and the clusters were covered with a PE bag.

2.3. Berry Measurements

Berry characteristics are listed as qualitative (color, shape, etc.) and quantitative (size, weight, etc.) determinants in the OIV descriptor (Bodor-Pesti et al., 2022 and 2023; Szűgyi-Reiczigel et al., 2022).

For all berry measurements, sampling for each repetition in each application combination was conducted with two clusters from each vine, and 12 berries were selected from each cluster. According to OIV (2009), berry width (mm) and length (mm) were measured using a digital caliper (Leo brand, 150 mm, Zhejiang Leo Co. Ltd., China).

The sampled berries were used to record the volume of water displaced by the berries in a ranked cylinder using the water displacement method (cm³). To calculate berry skin area (cm²/berry), the radius was found from the berry volume formula (equation 1), and the calculation was performed as follows (Barbagallo et al., 2011).

$$\text{Berry surface area } \left(\frac{\text{cm}^2}{\text{berry}}\right) = 4\pi r^2 \tag{1}$$

The berry skin area was then ratioed to the berry volume (BSA/BV) (cm²/cm³). In this way, BSA/BV was determined (Palma et al., 2007). Berry fresh weight (g) was measured on a precision scale sensitive to 0.01 g (Knmaster, MT 200 model, Karun Teknoloji, Türkiye). The fresh weight of 100 berries (g) was also measured in the same manner. The berries used to determine berry dry weight (g) were dried in an oven (Nüve, EN300 model, Nüve Sanayi Malz. İmalat ve Tic. A.Ş., Türkiye) at 65-70°C for 72 hours and weighed on the same scale. Berry density (g/cm³) was calculated by dividing berry fresh weight (g) by berry volume (cm³). % Dry weight (Bahar et al., 2011) was calculated using the following formula (equation 2).

$$\% \text{ Dry weight} = \text{Berry dry weight (g)} \times 100 / \text{Berry fresh weight (g)} \tag{2}$$

2.4. Statistical Analysis

The data obtained from the experiment were evaluated using the MSTAT-C program, and the LSD test was employed to reveal the differences that emerged. The two-year impact of these stress applications has been assessed.

3. Results and Discussion

3.1. Climate data for Tekirdağ

Tekirdağ is located in a semi-arid climate zone. According to long-term climate data (1939-2017), the average temperature during the vegetation period is 18.99°C. The hottest months are July and August (Table 1). The total precipitation during the vegetation period has been recorded as 247.60 mm over the years.

Table 1. Long term and 2016 and 2017 vegetation period weather conditions in Tekirdag

Month/Year	Mean daily temperature, °C			Rainfall, mm		
	2016	2017	1937-2017	2016	2017	1937-2017
April	15.61	11.10	11.80	25.50	51.80	40.90
May	17.94	16.80	16.80	28.10	16.70	36.70
June	23.57	21.90	21.30	35.70	36.80	37.90
July	25.58	24.10	23.80	0.10	52.20	22.80
August	24.65	25.10	23.80	0.10	14.60	13.30
September	21.64	21.60	20.00	3.90	11.20	33.60
October	15.95	15.00	15.40	35.40	111.20	62.40
Mean temperature, °C	20.71	19.37	18.99			
Cumulative rainfall, mm				128.80	294.50	247.60

In the long-term average, rainfall in the months of April, May, June, September, and October has been determined to be above 30 mm. In the first year of the experiment,

2016, the average temperature was 1.72°C higher than the long-term average. Additionally, the total precipitation was 118.8 mm below the long-term

average. In 2016, with these values, the year was hotter and drier than the long-term averages. The temperature in 2017 was 0.38°C higher than the long-term average, with the total precipitation being 46.9 mm above the long-term average. When comparing the averages of the two experimental years, it is observed that 2016 was 1.34°C warmer and had 165.7 mm less precipitation than 2017 (MGM, 2016; MGM, 2017a; MGM, 2017b).

3.2. Berry Width

The berry width values for the years 2016 and 2017 are presented in Table 2. All main effects and interactions on berry width values were found to be statistically insignificant. When the interaction between berry width values and berry length was examined, it was determined

that in both 2016 and 2017, berry width and berry length increased together, indicating a linear interaction between the two values (Figure 1).

Melo et al. (2015) stated that with an increase in berry size, berry weight, volume, and berry surface area also increased. Bahar and Öner (2016) reported berry width values for the Cabernet-Sauvignon variety ranging from 11.06 mm to 12.07 mm, while Candar (2023) indicated that these values varied between 11.20 mm and 14.7 mm for the Merlot grape variety. The measured berry width values in the study fall within a similar range. Thus, it can be observed that berry width was not affected by the late-season stress factors.

Table 2. Change in berry width for the years 2016 and 2017

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	11.10	11.07	11.09	Control			11.20	11.18	11.19
	Sa	11.26	11.22	11.24	10.96	10.96	10.96			
	UV-C	11.40	11.43	11.42	Sa					
	Vib	11.11	11.06	11.08	11.24	11.24	11.24			
	Li	11.18	11.14	11.16	UV-C					
	Lr	11.25	11.17	11.21	11.46	11.46	11.46			
	Bc	11.12	11.16	11.14	Vib					
	Control	10.80	10.88	10.84	11.15	11.15	11.15			
Me	Sa	11.32	11.14	11.23	Li			11.19	11.18	11.18
	UV-C	11.48	11.51	11.50	11.21	11.21	11.21			
	Vib	11.18	11.26	11.22	Lr					
	Li	11.34	11.17	11.26	11.33	11.33	11.33			
	Lr	11.46	11.45	11.46	Bc					
Bc	10.71	10.83	10.77	10.95	10.95	10.95				
YE		11.19	11.18							

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

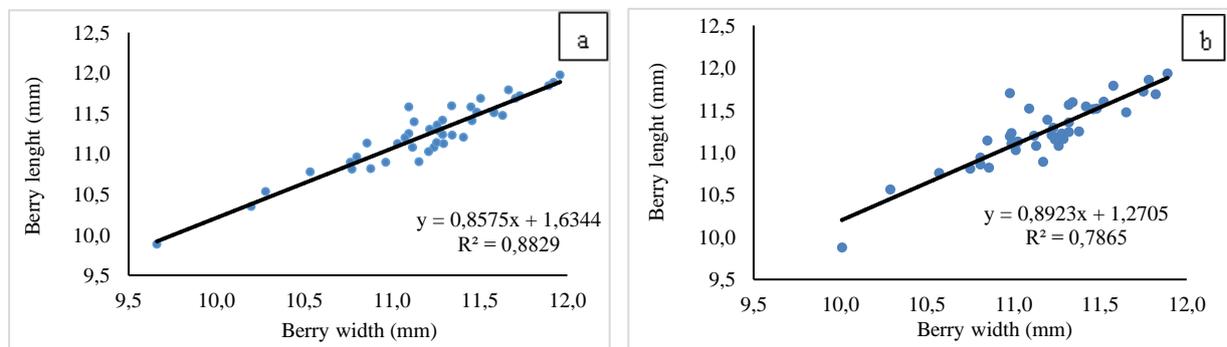


Figure 1. Interaction of berry width and berry length values in 2016 (a) and 2017 (b).

3.3. Berry Length

According to the statistical analysis, no significant difference was observed between the berry length values for the years 2016 and 2017. The conducted stress applications did not alter the berry length values for both grape varieties. When examining the data for the year 2017, it is particularly noteworthy that practices with the potential to cause damage to the vine, such as UV-C, Vib,

Sa, Li, Lr, and Bc, did not affect the berry length. This finding is considered important in demonstrating that potentially harmful practices did not impact berry length (Table 3). The main effects of Cultivar Main Effect (CE) and Year Main Effect (YE) are not statistically significant. According to OIV (2009), the berry size of the Cabernet-Sauvignon cv. is approximately in the "short" category, with a size around 13 mm. However, the obtained results

indicate values smaller than this reference. The findings of the research align with the results of previous studies, where Bahar and Öner (2016) reported Cabernet-Sauvignon berry length ranging from 11.60 mm to 12.28 mm, and Candar (2023) found that the berry length of the Merlot cv. varied between 11.90 mm and 14.60 mm,

demonstrating a similar range to the research values. Similar to the findings stated by Melo et al. (2015), an increase in berry size is associated with an increase in berry volume. In line with this, a linear interaction between berry length and berry volume was observed in 2016 and 2017 (Figure 2).

Table 3. Change in berry length for the years 2016 and 2017

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	11.07	11.14	11.11	Control					
	Sa	11.40	11.41	11.41	11.06	11.09	11.08			
	UV-C	11.40	11.44	11.42						
	Vib	11.12	11.11	11.12	11.34	11.35	11.34			
	Li	11.30	11.24	11.27				11.24	11.24	11.24
	Lr	11.24	11.16	11.20	11.44	11.46	11.45			
	Bc	11.16	11.16	11.16						
	Control	11.05	11.04	11.05	11.19	11.18	11.18			
Me	Sa	11.28	11.30	11.28						
	UV-C	11.47	11.47	11.47	11.33	11.40	11.37			
	Vib	11.26	11.23	11.24						
	Li	11.36	11.56	11.46	11.27	11.24	11.25			
	Lr	11.30	11.32	11.31				11.22	11.26	11.24
	Bc	10.85	10.90	10.85	11.01	11.03	11.02			
YE		11.23	11.25							

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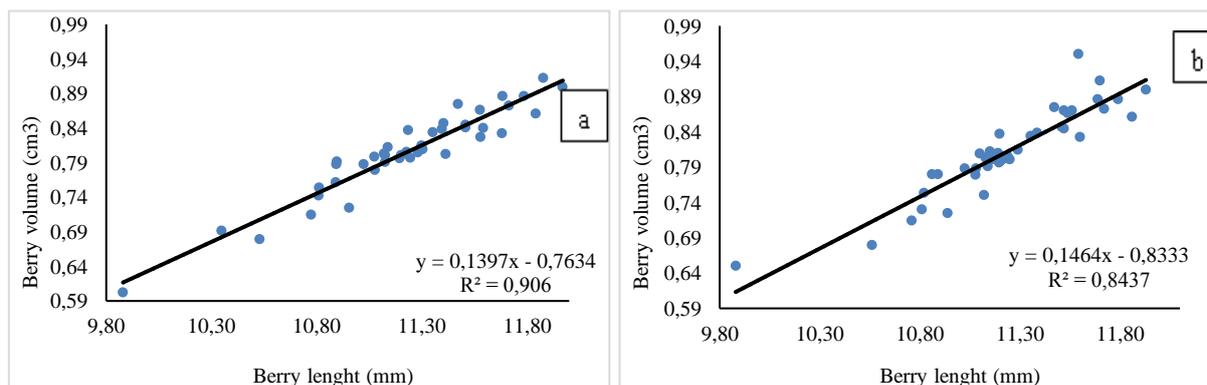


Figure 2. Interaction of berry length and berry volume values in 2016 (a) and 2017 (b).

3.4. Berry Skin Area

The effects of applications and interactions of these applications on berry skin area values in Cabernet-Sauvignon and Merlot grape varieties in 2016 and 2017 were examined. Only the main effect of the YE was found to be statistically significant at the P<0.01 level (Table 4). Melo et al. (2015) stated that with the increase in berry size, the berry skin area also increases. In their research, Bahar and Öner (2016) determined that the berry skin

area of the Cabernet-Sauvignon variety ranged from 3.86 cm²/berry to 4.17 cm²/berry. The research findings are consistent with the researcher's results. Candar (2023) reported a berry skin area value ranging from 4.83 cm²/berry to 6.61 cm²/berry in the Merlot grape variety. The research findings are lower than the researcher's findings, and this is thought to be due to differences in the year and soil structure of the vineyard.

Table 4. Change in berry skin area for the years 2016 and 2017

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	4.15	3.87	4.01						
	Sa	4.27	4.02	4.15	4.09	3.82	3.95			
	UV-C	4.32	4.11	4.22						
	Vib	4.16	3.89	4.03	4.24	3.99	4.11		Ca	
	Li	4.14	3.91	4.03				4.20	3.95	4.08
	Lr	4.20	3.91	4.05	4.30	4.13	4.00			
	Bc	4.20	3.91	4.05						
	Control	4.03	3.78	3.90	4.18	3.92	4.22			
Me	Sa	4.21	3.95	4.08						
	UV-C	4.27	4.15	4.21	4.18	4.00	4.05			
	Vib	4.20	3.94	4.07					Me	
	Li	4.24	4.09	4.16	4.23	3.99	4.10			
	Lr	4.26	4.07	4.16				4.16	3.95	4.06
	Bc	3.95	3.70	3.83	4.07	3.81	3.94			
	Control	4.18A	3.95B							
	YE									
P< 0.01		0.148								
YE P< 0.01= 0.148										

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

3.5. Berry Volume

It has been observed that the stress applications on berry volume values for the years 2016 and 2017 did not have statistically significant effects in terms of main effects and interactions of years and varieties (Table 5).

Melo et al. (2015) stated that there is a proportional relationship between berry size increase and berry volume. It should be noted that the increase in accumulated sugar and water content also plays a role in the increase in berry volume (Ağaoğlu, 2002). The berry volume for Cabernet-Sauvignon is reported to range from

0.88cm³ to 1.37cm³ by Bahar and Öner (2016). Ünlüsoy (2019) also mentioned that this value varies between 1.08cm³ and 1.25cm³ for the Merlot grape variety. In this study, it is observed that these values are in a similar range.

In the years 2016 and 2017, as the berry volume increased, the berry weight also increased, and a linear interaction between these two values was observed (Figure 3). It is a scientific fact that these two characteristics are highly correlated with each other (Roby and Matthews, 2004; Houel et al., 2013).

Table 5. Changes in berry volume for the years 2016 and 2017

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	0.79	0.80	0.80						
	Sa	0.82	0.83	0.83	0.77	0.80	0.78			
	UV-C	0.86	0.85	0.86						
	Vib	0.79	0.80	0.80	0.81	0.83	0.82		Ca	
	Li	0.80	0.79	0.80				0.81	0.81	0.81
	Lr	0.80	0.81	0.81	0.84	0.84	0.84			
	Bc	0.81	0.80	0.81						
	Control	0.76	0.77	0.77	0.80	0.82	0.81			
Me	Sa	0.81	0.82	0.82						
	UV-C	0.83	0.83	0.83	0.81	0.81	0.81			
	Vib	0.81	0.83	0.82					Me	
	Li	0.82	0.83	0.83	0.82	0.82	0.82			
	Lr	0.83	0.83	0.83				0.80	0.83	0.82
	Bc	0.74	0.83	0.79	0.77	0.82	0.80			
	Control	0.81	0.82							
	YE									

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

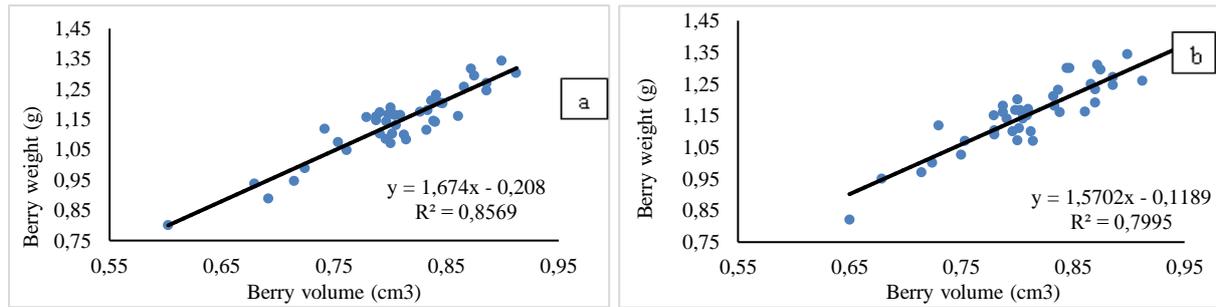


Figure 3. Interaction of berry volume and berry weight values in 2016 (a) and 2017 (b).

3.6. Berry Skin Area/Berry Volume

The difference between the two years in terms of the ratio of berry skin area to berry volume (cm²/cm³) was found to be statistically significant at P<0.01 level (Table 6). The size of grape berries is known to be an important quality characteristic in wine grape varieties due to its association with the ratio of berry skin area to berry pulp volume (Roby et al., 2004; Barbagallo et al., 2011). On the other hand, as the berry size increases, the ratio of berry skin area to berry volume decreases (Melo et al., 2015), and therefore, it is known that smaller berries have a

higher ratio of berry skin area to berry volume (Roby and Matthews, 2004). The research results revealed that both varieties had a similar ratio of berry skin area to berry pulp volume. The values for the ratio of berry skin area to berry volume for the Cabernet-Sauvignon grape variety ranged from 3.03cm²/cm³ to 3.09cm²/cm³, as reported by Bahar and Öner (2016). For the Merlot grape variety, Ünlüsoy (2019) reported values ranging from 3.91cm²/cm³ to 6.97cm²/cm³. The measured values in this study fell within a similar range as the findings of the researchers.

Table 6. Changes in the ratio of berry skin area to berry volume in 2016 and 2017.

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	5.22	4.85	5.04	5.26	Control		5.19	Ca	5.02
	Sa	5.15	4.84	4.99		4.88	5.07			
	UV-C	5.12	4.86	4.99		4.82	4.99			
	Vib	5.21	4.84	5.02		4.82	4.99			
	Li	5.24	4.94	5.09		4.93	5.03			
	Lr	5.19	4.84	5.01		4.93	5.03			
	Bc	5.19	4.86	5.03		4.86	5.03			
Me	Control	5.30	4.91	5.10	5.21	Li		5.22	Me	5.04
	Sa	5.18	4.81	5.00		4.91	5.06			
	UV-C	5.15	4.99	5.07		4.91	5.06			
	Vib	5.20	4.88	5.04		4.91	5.06			
	Li	5.18	4.88	5.03		4.88	5.03			
	Lr	5.15	4.93	5.04		4.88	5.03			
	Bc	5.37	4.70	5.03		4.78	5.03			
YE		5.20A	4.87B							
P<0.01		0.094								
Yıl X Çeşit X Uygulama		P<0.01= 0.094								

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

3.7. Berry Fresh Weight

The applications on berry weight of the varieties, year, and their interactions did not have a significant effect (Table 7). However, it should be noted that berry weight is a variety-specific genetic trait (Houel et al., 2013). The values for berry weight in the Cabernet-Sauvignon variety, ranging from 0.94g to 1.30g (Bahar and Öner, 2016) and 0.95g to 1.08g (Roby and Matthews, 2004), are in line with the trial findings. Similarly, in the Merlot grape variety, the values for berry weight ranged from

1.12g to 1.35g (Ünlüsoy, 2019), which aligns with the research. In addition, berry weight was observed to have a positive relationship with berry volume (Gray and Coombe, 2009; Houel et al., 2013), berry skin area (Melo et al., 2015), and berry size (Chen et al., 2018), similar to the findings of other researchers.

In the year 2016, as the berry fresh weight increased, the berry dry weight also increased, and in the year 2017, an increase in berry weight was associated with an increase in berry density (Figure 4). There is a linear relationship

between these values.

Table 7. Berry weight changes in 2016 and 2017.

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	1.15	1.17	1.16						
	Sa	1.17	1.15	1.16	1.12	1.13	1.12			
	UV-C	1.21	1.25	1.23						
	Vib	1.10	1.11	1.11	1.17	1.18	1.17			
	Li	1.12	1.13	1.13				1.15	1.15	1.15
	Lr	1.14	1.14	1.14	1.21	1.24	1.22			
	Bc	1.11	1.12	1.12						
	Control	1.08	1.09	1.09	1.13	1.14	1.13			
Me	Sa	1.17	1.20	1.19						
	UV-C	1.20	1.23	1.22	1.12	1.14	1.13			
	Vib	1.15	1.16	1.16						
	Li	1.12	1.15	1.13	1.17	1.17	1.17			
	Lr	1.20	1.21	1.21				1.14	1.16	1.15
	Bc	1.03	1.09	1.06	1.07	1.11	1.09			
	Control	1.08	1.09	1.09						
	YE		1.14	1.16						

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

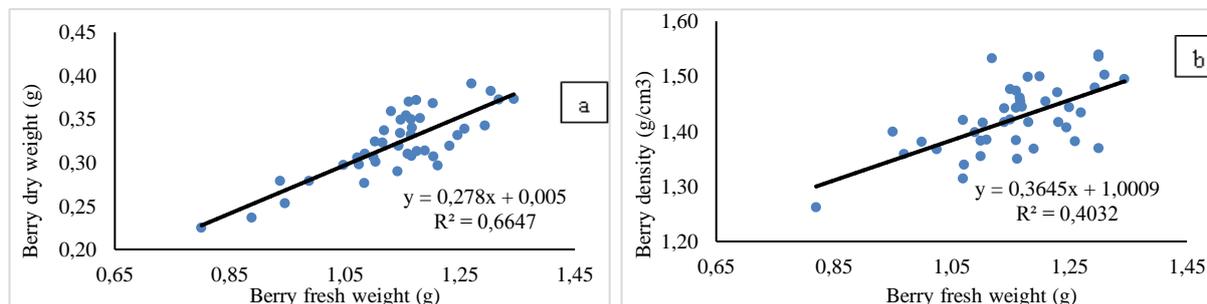


Figure 4. Interaction between berry weight and berry dry weight in 2016 (a) and berry weight and berry density in 2017 (b).

3.8. 100 Berry Weight

Similarly, there was no statistical difference observed among the values of 100-berry weight, which varied in the same way as berry weight. In the study of Kotseridis et al. (2012) on Merlot grape variety, where they collected all leaves in the cluster region and obtained an average of 100g, 107g by removing the basal leaves, and a control value of 109g, the findings were similar to the values obtained for the same variety in this research (114.96g). Likewise, a similarity was observed with Candar (2023), who reported this value between 145.17-158.47g. For Cabernet-Sauvignon variety, the 100-berry weight was reported as 89g by collecting all leaves in the cluster region, 98g by removing basal leaves, and 105g for control (Kotseridis et al., 2012), which parallel the research findings (114.91g). The study findings align with Drenjančević et al. (2023), who reported that the 100-berry weight slightly decreased compared to the control during flowering and berry drop, but this difference was not statistically significant.

3.9. Berry Dry Weight

In 2016, as the berry dry weight increased, the percentage of dry weight also increased (Figure 5). The

same positive relationship is present with berry fresh weight (Melo et al., 2015). In 2016 and 2017, AE (Application Main Effect) was found to have a significant effect on berry dry weight (P<0.01). It was observed that Ultraviolet-C application had the highest effect on berry dry weight (0.34g), while Bc application (0.30g) had the least impact (Table 8). Other applications took values between these two applications. The measured berry dry weight value for Cabernet-Sauvignon variety (ranging from 0.10g to 0.37g) was found to be similar to the findings of Bahar and Öner (2016) and an average of 0.23g reported by Cooley et al. (2017).

3.10. Dry Weight Percentage

According to the combined year data for the percentage of dry weight in 2016 and 2017, the year 2016 was observed to have the highest value with an average of 28.24%. Statistical differences were detected among varieties at a 5% LSD level. The percentage of dry weight was highest in Cabernet-Sauvignon, reaching 28.61% (Table 9).

In a study involving different leaf removal and soil cultivation practices, the percentage of dry weight values for Cabernet-Sauvignon ranged from 27.35% to 28.14%

(Bahar and Öner, 2016). In another study involving different shoot treatments in Merlot grape variety, the percentage of dry weight values ranged from 23.57% to 24.42% (Candar, 2023). These values from previous studies are within a similar range as the measured percentage of dry weight values in this research.

3.11. Berry Density

In the years 2016 and 2017, as the berry weight increased, the berry density also increased (Figure 6). 2016 and 2017 average berry density data indicate that 2017 had the highest average berry density with 1.42 cm³ (Table 10). LSD at a 1% level of significance was observed among applications in the combined years (Table 10).

In a study where different shoot applications were applied to Merlot grape variety, the berry density values ranged between 0.84 g/cm³ and 1.44 g/cm³ (Candar,

2023). The values obtained in this study fall within a similar range as the measured berry density values in this research.

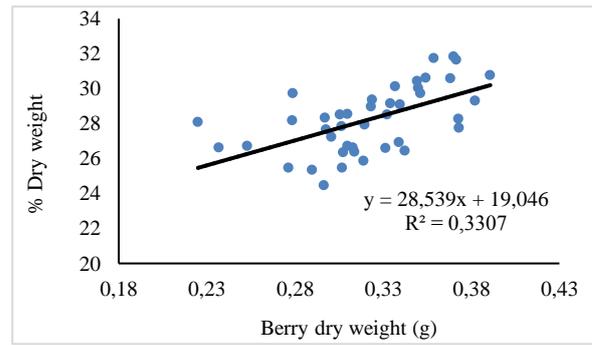


Figure 5. Interaction between berry dry weight and dry weight % values in 2016.

Table 8. Berry dry weight values for the years 2016 and 2017

C	A	C x A int.			AE			CE			
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	
Ca	Control	0.33	0.32	0.32	0.31	Control		0.33	0.33	0.33	
	Sa	0.33	0.33	0.33		0.31 0.31 AB					
	UV-C	0.37	0.34	0.35		Sa					
	Vib	0.32	0.32	0.32		0.32 0.32 AB					
	Li	0.33	0.32	0.32		UV-C					
	Lr	0.33	0.34	0.34		0.34 0.34 A					
	Bc	0.31	0.31	0.31		Vib					
Me	Control	0.30	0.30	0.30	0.31	0.31 0.31 AB		0.32	0.32	0.32	
	Sa	0.31	0.31	0.31		Li					
	UV-C	0.34	0.33	0.33		0.33 0.33 AB					
	Vib	0.30	0.31	0.31		Lr					
	Li	0.33	0.33	0.33		0.34 0.34 AB					
YE	Lr	0.34	0.34	0.34	0.30	Bc		0.30	0.30	0.30	
	Bc	0.28	0.30	0.29		0.30 0.30 B					
	Control	0.31	0.32								
P < 0.01						0.040					
AE P < 0.01=0.040											

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

Table 9. Changes in percentage of dry weight values for the years 2016 and 2017

C	A	C x A int.			AE			CE			
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	
Ca	Control	28.24	27.75	28.00	28.03	Control		28.75	28.46	28.61a	
	Sa	27.91	28.77	28.34		27.74 27.89					
	UV-C	30.15	27.33	28.74		Sa					
	Vib	28.86	28.50	28.68		27.13 27.26 27.19					
	Li	28.96	28.83	28.89		UV-C					
	Lr	28.80	29.99	29.40		29.07 27.07 28.07					
	Bc	28.31	28.07	28.19		Vib					
Me	Control	27.82	27.74	27.78	28.50	27.69 27.62 27.65		27.74	27.21	27.47b	
	Sa	26.34	25.76	26.05		Li					
	UV-C	27.99	26.81	27.40		29.11 28.89 29.00					
	Vib	26.52	26.74	26.63		Lr					
	Li	29.27	28.94	29.11		29.01 28.75					
YE	Lr	28.19	28.03	28.11	28.17	Bc		27.25	27.71		
	Bc	28.02	26.44	27.23		27.25 27.71					
	Control	28.24	27.83								
P < 0.01										0.930	
CE P < 0,01=0.930											

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

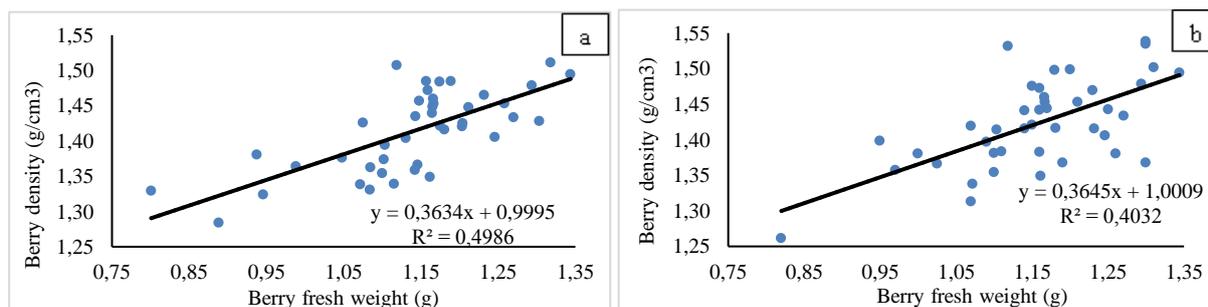


Figure 6. Interaction of berry density and berry weight values in 2016 (a) and 2017 (b).

Table 10. Berry density values for the years 2016 and 2017

C	A	C x A int.			AE			CE		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ca	Control	1.45	1.46	1.46						
	Sa	1.41	1.39	1.40	1.43	1.44	1.43 AB			
	UV-C	1.44	1.47	1.46						
	Vib	1.41	1.38	1.40	1.42	1.42	1.42 AB	28.75	28.46	28.61a
	Li	1.42	1.43	1.42						
	Lr	1.38	1.41	1.40	1.44	1.48	1.46 A			
	Bc	1.37	1.39	1.38						
Me	Control	1.42	1.42	1.42	1.43	1.41	1.42 AB			
	Sa	1.44	1.46	1.45						
	UV-C	1.44	1.48	1.46	1.39	1.40	1.39 B			
	Vib	1.45	1.43	1.44						
	Li	1.37	1.40	1.36	1.41	1.44	1.42 AB	27.74	27.21	27.47b
	Lr	1.42	1.45	1.45						
	Bc	1.39	1.35	1.38	1.38	1.38	1.38 B			
YE		1.41	1.42							
P < 0.01						0.063				
AE P < 0.01=0.063										

C= Cultivar, Ca= Cabernet-Sauvignon, Me= Merlot, CE= Cultivar main effect, AE= Application main effect, YE= Year main effect, A= Applications, Sa= Shock action, Vib= Vibration, Li= Leaf injury, Lr= Leaf removal, Bc= *Botrytis cinerea*, C x A int.= Cultivar x Application interaction.

4. Conclusion

In the years 2016 and 2017, the effects of some biotic and abiotic stresses applied were examined on berry characteristics in this study. Considering that Cabernet-Sauvignon and Merlot varieties, which were the subject of the experiment, have different genetic structures, differences between the two varieties are expected. Therefore, the data of the two varieties have not been compared with each other. However, as is known, the berries of the Merlot grape variety are larger than the berries of Cabernet Sauvignon.

When examined in terms of the year effect, it is observed that the year 2016 was hotter and drier compared to the year 2017. However, in the year 2017, the criteria of berry skin area and berry skin area/berry volume slightly decreased compared to the year 2016. It is believed that this might be attributed to the abundant rainfall experienced in the year 2017. Nevertheless, this decrease is noteworthy as it indicates that the applied stress factors did not have a very negative impact.

In terms of the application effect, the UV-C application,

expected to be destructive in terms of berry weight and berry density values, was slightly elevating compared to other stress applications, and the Bc application was slightly lowering these two values. However, neither of the stresses has caused a significant negative impact on the plant and the berries.

It was observed that abiotic and biotic stress applications applied to clusters in the late period (5 days before harvest in the vineyard) did not have a negative effect on berry characteristics in both the application year and the following year. Therefore, it was not considered problematic to perform Shock action, UV-C, Vibration, Leaf injury, Leaf removal, and *Botrytis cinerea* applications to improve grape quality. When the principles of the stress applications tested in the study were adhered to, it was revealed that the berry characteristics of the next year did not change.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	E.B.	İ.K.	C.T.A.
C	40	30	30
D	100		
S	100		
DCP	20	5	75
DAI	50		50
L	10	50	40
W	10	80	10
CR	40	30	30
SR		100	
PM	100		

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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