Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1409746

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 7 - Issue 2: 144-156 / March 2024

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

Elman BAHAR[1], İlknur KORKUTAL[1]*, Cannur TOK ABAY[1]

[1]*Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Horticulture, 59030, Tekirdağ, Türkiye*

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), bery volume (cm^3), berry skin area (cm^2/grain), berry skin area/berry flesh volume ratio (cm^2/cm^3), berry fresh-dry weight (g), 100 berry fresh weight (g), berry density (g/cm^3), 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.

***Corresponding author:** Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Horticulture, 59030, Tekirdağ, Türkiye
E mail: ikorkutal@nku.edu.tr (İ. KORKUTAL)
Elman BAHAR https://orcid.org/0000-0002-8842-7695
İlknur KORKUTAL https://orcid.org/0000-0002-8016-9804
Cannur TOK ABAY https://orcid.org/0000-0002-1769-9669
Received: December 25, 2023
Accepted: January 24, 2024
Published: March 15, 2024
Cite as: Bahar E, Korkutal İ, Tok Abay C. 2024. Grape berry morphology in semi-arid climate of Tekirdağ: evaluating the effects of environmental factors and stress applications. BSJ Agri, 7(2): 144-156.

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 CO_2 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 CO_2, 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 *Bortytis 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).

Sabır 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 2.5x10^5 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 (cm^3). To calculate berry skin area (cm^2/berry), the radius was found from the berry volume formula (equation 1), and the calculation was performed as follows (Barbagallo et al., 2011).

$$Berry\ surface\ area\ (\frac{cm2}{berry}) = 4\pi r2 \qquad (1)$$

The berry skin area was then ratioed to the berry volume (BSA/BV) (cm^2/cm^3). 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/cm^3) was calculated by dividing berry fresh weight (g) by berry volume (cm^3). % Dry weight (Bahar et al., 2011) was calculated using the following formula (equation 2).

$$\%\ \text{Dry weight} = \text{Berry dry weight (g)x100/ Berry fresh weight (g)} \qquad (2)$$

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 forTekirdağ

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				
	Sa	11.26	11.22	11.24	10.96	10.96	10.96			
	UV-C	11.40	11.43	11.42		Sa			Ca	
	Vib	11.11	11.06	11.08	11.24	11.24	11.24	11.20	11.18	11.19
	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				
Me	Control	10.80	10.88	10.84	11.15	11.15	11.15			
	Sa	11.32	11.14	11.23		Li				
	UV-C	11.48	11.51	11.50	11.21	11.21	11.21			
	Vib	11.18	11.26	11.22		Lr			Me	
	Li	11.34	11.17	11.26	11.33	11.33	11.33	11.19	11.18	11.18
	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.

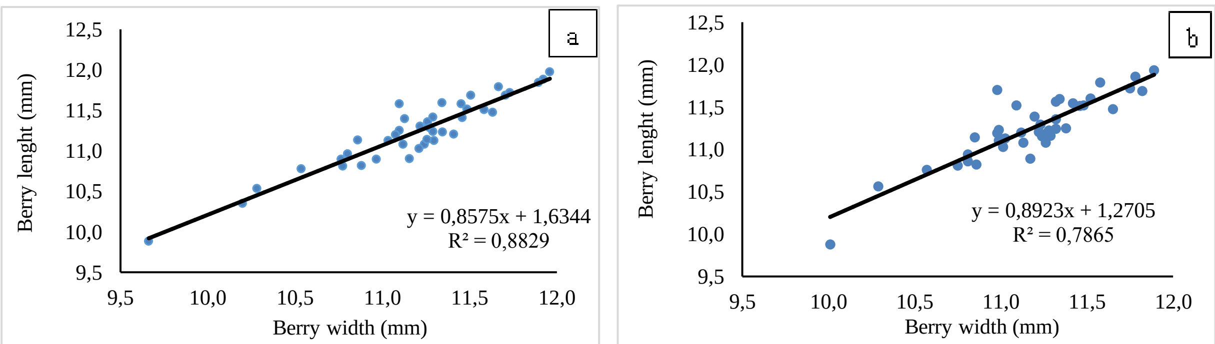

Figure 1. Interaction of berry width and berry length values in 2016 (a) and 2017 (b).

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
	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		Sa				
Ca	Vib	11.12	11.11	11.12	11.34	11.35	11.34		Ca	
	Li	11.30	11.24	11.27		UV-C		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		Vib				
	Control	11.05	11.04	11.05	11.19	11.18	11.18			
	Sa	11.28	11.30	11.28		Li				
	UV-C	11.47	11.47	11.47	11.33	11.40	11.37			
Me	Vib	11.26	11.23	11.24		Lr			Me	
	Li	11.36	11.56	11.46	11.27	11.24	11.25	11.22	11.26	11.24
	Lr	11.30	11.32	11.31		Bc				
	Bc	10.85	10.90	10.85	11.01	11.03	11.02			
YE		11.23	11.25							

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.

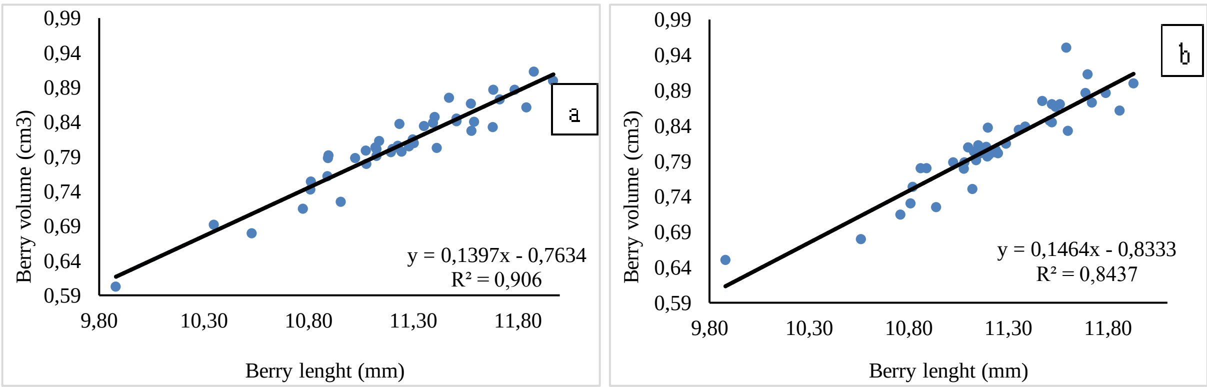

Figure 2. Interaction of berry length and berry volume values in 2016 (a) and 2017 (b).

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 cm^2/berry to 4.17 cm^2/berry. The research findings are consistent with the researcher's results. Candar (2023) reported a berry skin area value ranging from 4.83 cm^2/berry to 6.61 cm^2/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		Control				
	Sa	4.27	4.02	4.15	4.09	3.82	3.95			
	UV-C	4.32	4.11	4.22		Sa				
	Vib	4.16	3.89	4.03	4.24	3.99	4.11		Ca	
	Li	4.14	3.91	4.03		UV-C		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		Vib				
Me	Control	4.03	3.78	3.90	4.18	3.92	4.22			
	Sa	4.21	3.95	4.08		Li				
	UV-C	4.27	4.15	4.21	4.18	4.00	4.05			
	Vib	4.20	3.94	4.07		Lr			Me	
	Li	4.24	4.09	4.16	4.23	3.99	4.10	4.16	3.95	4.06
	Lr	4.26	4.07	4.16		Bc				
	Bc	3.95	3.70	3.83	4.07	3.81	3.94			
YE		4.18A	3.95B							
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		Control				
	Sa	0.82	0.83	0.83	0.77	0.80	0.78			
	UV-C	0.86	0.85	0.86		Sa				
	Vib	0.79	0.80	0.80	0.81	0.83	0.82		Ca	
	Li	0.80	0.79	0.80		UV-C		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		Vib				
Me	Control	0.76	0.77	0.77	0.80	0.82	0.81			
	Sa	0.81	0.82	0.82		Li				
	UV-C	0.83	0.83	0.83	0.81	0.81	0.81			
	Vib	0.81	0.83	0.82		Lr			Me	
	Li	0.82	0.83	0.83	0.82	0.82	0.82	0.80	0.83	0.82
	Lr	0.83	0.83	0.83		Bc				
	Bc	0.74	0.83	0.79	0.77	0.82	0.80			
YE		0.81	0.82							

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.

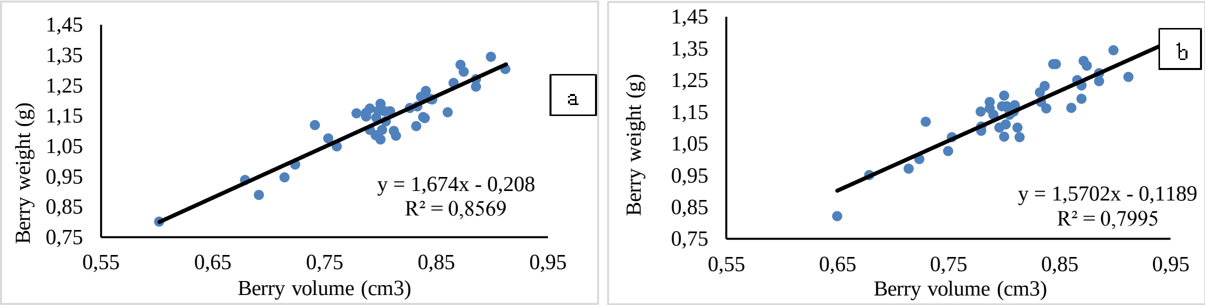

Figure 3. Interaction of berry volume and berry weight values in 2016 (a) and 2017 (b).

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 (cm^2/cm^3) 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 $3.03cm^2/cm^3$ to $3.09cm^2/cm^3$, as reported by Bahar and Öner (2016). For the Merlot grape variety, Ünlüsoy (2019) reported values ranging from $3.91cm^2/cm^3$ to $6.97cm^2/cm^3$. 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
	Control	5.22	4.85	5.04		Control				
	Sa	5.15	4.84	4.99	5.26	4.88	5.07			
	UV-C	5.12	4.86	4.99		Sa			Ca	
Ca	Vib	5.21	4.84	5.02	5.16	4.82	4.99	5.19	4.86	5.02
	Li	5.24	4.94	5.09		UV-C				
	Lr	5.19	4.84	5.01	5.13	4.93	5.03			
	Bc	5.19	4.86	5.03		Vib				
	Control	5.30	4.91	5.10	5.20	4.86	5.03			
	Sa	5.18	4.81	5.00		Li				
	UV-C	5.15	4.99	5.07	5.21	4.91	5.06		Me	
Me	Vib	5.20	4.88	5.04		Lr		5.22	4.87	5.04
	Li	5.18	4.88	5.03	5.17	4.88	5.03			
	Lr	5.15	4.93	5.04		Bc				
	Bc	5.37	4.70	5.03	5.28	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
	Control	1.15	1.17	1.16		Control				
	Sa	1.17	1.15	1.16	1.12	1.13	1.12			
	UV-C	1.21	1.25	1.23		Sa			Ca	
Ca	Vib	1.10	1.11	1.11	1.17	1.18	1.17	1.15	1.15	1.15
	Li	1.12	1.13	1.13		UV-C				
	Lr	1.14	1.14	1.14	1.21	1.24	1.22			
	Bc	1.11	1.12	1.12		Vib				
	Control	1.08	1.09	1.09	1.13	1.14	1.13			
	Sa	1.17	1.20	1.19		Li				
	UV-C	1.20	1.23	1.22	1.12	1.14	1.13		Me	
Me	Vib	1.15	1.16	1.16		Lr		1.14	1.16	1.15
	Li	1.12	1.15	1.13	1.17	1.17	1.17			
	Lr	1.20	1.21	1.21		Bc				
	Bc	1.03	1.09	1.06	1.07	1.11	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.

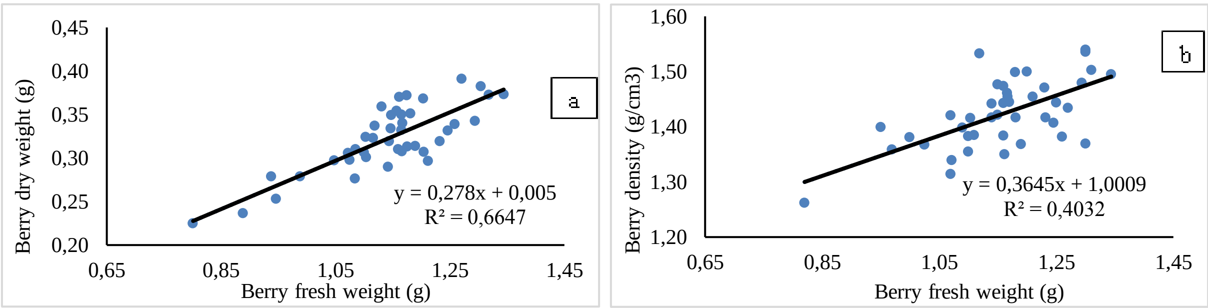

Figure 4. Interaction between berry weight and berry dry weight in 2016 (a) and berry weight and berry density in 2017 (b).

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 cm^3 (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/cm^3 and 1.44 g/cm^3 (Candar, 2023). The values obtained in this study fall within a similar range as the measured berry density values in this research.

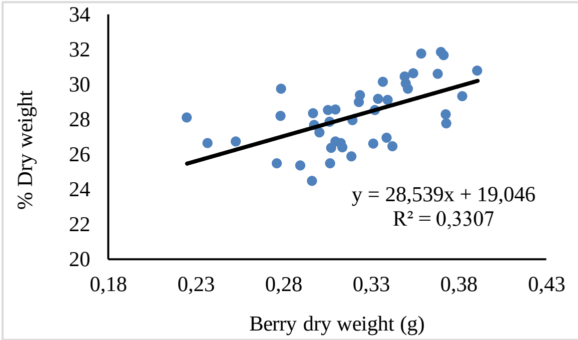

Figure 5. Interaction between berry dry weight and dry weight % values in 2016.

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

C	A	C x A int. 2016	2017	Mean	AE 2016	2017	Mean	CE 2016	2017	Mean
	Control	0.33	0.32	0.32		Control				
	Sa	0.33	0.33	0.33	0.31	0.31	0.31 AB			
	UV-C	0.37	0.34	0.35		Sa				
Ca	Vib	0.32	0.32	0.32	0.32	0.32	0.32 AB		Ca	
	Li	0.33	0.32	0.32		UV-C		0.33	0.33	0.33
	Lr	0.33	0.34	0.34	0.35	0.34	0.34 A			
	Bc	0.31	0.31	0.31		Vib				
	Control	0.30	0.30	0.30	0.31	0.31	0.31 AB			
	Sa	0.31	0.31	0.31		Li				
	UV-C	0.34	0.33	0.33	0.33	0.33	0.33 AB			
Me	Vib	0.30	0.31	0.31		Lr			Me	
	Li	0.33	0.33	0.33	0.33	0.34	0.34 AB	0.32.	0.32	0.32
	Lr	0.34	0.34	0.34		Bc				
	Bc	0.28	0.30	0.29	0.30	0.30	0.30 B			
YE		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. 2016	2017	Mean	AE 2016	2017	Mean	CE 2016	2017	Mean
	Control	28.24	27.75	28.00		Control				
	Sa	27.91	28.77	28.34	28.03	27.74	27.89			
	UV-C	30.15	27.33	28.74		Sa				
Ca	Vib	28.86	28.50	28.68	27.13	27.26	27.19		Ca	
	Li	28.96	28.83	28.89		UV-C		28.75	28.46	28.61a
	Lr	28.80	29.99	29.40	29.07	27.07	28.07			
	Bc	28.31	28.07	28.19		Vib				
	Control	27.82	27.74	27.78	27.69	27.62	27.65			
	Sa	26.34	25.76	26.05		Li				
	UV-C	27.99	26.81	27.40	29.11	28.89	29.00			
Me	Vib	26.52	26.74	26.63		Lr			Me	
	Li	29.27	28.94	29.11	28.50	29.01	28.75	27.74	27.21	27.47b
	Lr	28.19	28.03	28.11		Bc				
	Bc	28.02	26.44	27.23	28.17	27.25	27.71			
YE		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.

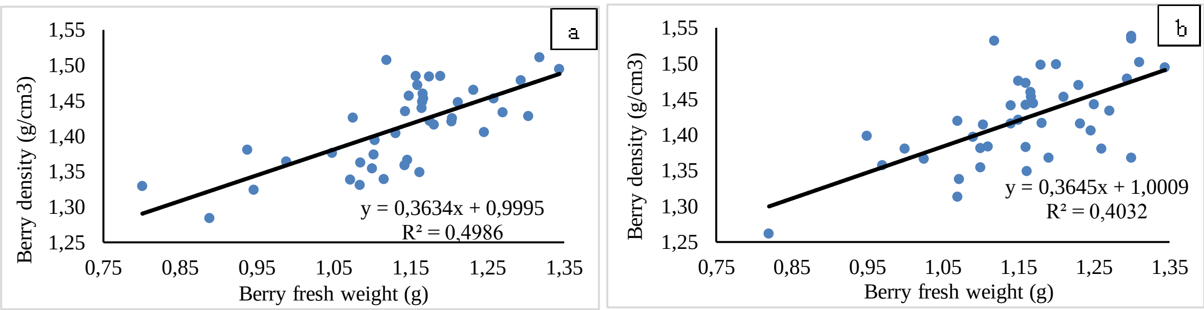

Figure 6. Interaction of berry density and berry weight values in 2016 (a) and 2017 (b).

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
	Control	1.45	1.46	1.46		Control				
	Sa	1.41	1.39	1.40	1.43	1.44	1.43 AB			
	UV-C	1.44	1.47	1.46		Sa				
Ca	Vib	1.41	1.38	1.40	1.42	1.42	1.42 AB		Ca	
	Li	1.42	1.43	1.42		UV-C		28.75	28.46	28.61a
	Lr	1.38	1.41	1.40	1.44	1.48	1.46 A			
	Bc	1.37	1.39	1.38		Vib				
	Control	1.42	1.42	1.42	1.43	1.41	1.42 AB			
	Sa	1.44	1.46	1.45		Li				
	UV-C	1.44	1.48	1.46	1.39	1.40	1.39 B			
Me	Vib	1.45	1.43	1.44		Lr			Me	
	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				
	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.

Acknowledgments

This research was a part of third authors MSc. Thesis (YOK Thesis No: 686735 / Date: 08.06.2021).

References

Aazami MA, Maleki M, Rasouli F, Gohari G. 2023. Protective effects of chitosan based salicylic acid nanocomposite (CS-SA NCs) in grape (*Vitis vinifera* cv. Sultana) under salinity stress. Sci Rep, 13: 883.

Aguilera P, Ortiz N, Becerra N, Turrini A, Gaínza-Cortés F, Silva-Flores P, Aguilar-Paredes A, Romero JK, Jorquera-Fontena E, Mora M de LL, Borie F. 2022. Application of Arbuscular Mycorrhizal Fungi in vineyards: water and biotic stress under a climate change scenario: new challenge for Chilean grapevine crop. Front Microbiol, 13: 12.

Ağaoğlu YS. 2002. Bilimsel ve uygulamalı bağcılık. Kavaklıdere Eğitim Yayınları, Asma fizyolojisi-1, Cilt: 2, No: 5, Ankara, Türkiye, pp: 445.

Alatzas A, Theocharis S, Miliordos DE, Kotseridis Y, Koundouras S, Hatzopoulos P. 2023. Leaf removal and deficit irrigation have diverse outcomes on composition and gene expression during berry development of *Vitis vinifera* L. cultivar Xinomavro. OENO One, 57(1): 289-305.

Bahar E, Carbonneau A, Korkutal I. 2011. The effect of extreme water stress on leaf drying limits and possibilities of recovering in three grapevine (*Vitis vinifera* L.) cultivars. Afr J Agric Res, 6(5): 1151-1160.

Bahar E, Öner H. 2016. Cabernet-Sauvignon üzüm çeşidinde farklı kültürel işlemlerin verim özellikleri üzerine etkileri. Bahçe, 45(Özel Sayı): 591-598.

Barbagallo MG, Guidoni S, Hunter JJ. 2011. Berry size and qualitative characteristics of *Vitis vinifera* L. cv. Syrah. S Afr J Enol Vitic, 32(1): 129-136.

Bianchi D, Ricciardi V, Pozzoli C, Grossi D, Caramanico L, Pindo M, Stefani E, Cestaro A, Brancadoro L, De Lorenzis G. 2023. Physiological and transcriptomic evaluation of drought effect on own-rooted and grafted grapevine rootstock (1103P and 101-14Mgt). Plants, 12: 1080.

Biasi R, Brunori E, Vanino S, Bernardini A, Catalani A, Farina R, Bruno A, Chilosi G. 2023. Soil-plant interaction mediated by indigenous AMF in grafted and own-rooted grapevines under field conditions. Agric, 13: 1051.

Biniari K, Athanasopoulou E, Daskalakis I, Xyrafis EG, Bouza D, Stavrakaki M. 2023. Effect of foliar applications on the qualitative and quantitative characters of cv. Assyrtiko and cv. Mavrotragano in the island of Santorini, under vineyard conditions. BIO Web Conf, 56: 01008.

Blouin J, Guimberteau G. 2000. Maturation et maturite des raisins. Editions Féret, Bordeaux, France, pp: 167.

Bodor-Pesti P, Somogyi E, Deák T, Nyitrainé Sárdy DÁ, Ladányi M. 2022. Quantitative image analysis of berry size and berry shape of different grapevine (*Vitis vinifera* L.) accessions. Mitt Klost, 72: 130-136.

Bodor-Pesti P, Taranyi D, Deák T, Nyitrainé Sárdy DÁ, Varga Z. 2023. A Review of ampelometry: Morphometric characterization of the grape (*Vitis* spp.) leaf. Plants, 12, 452.

Candar S. 2023. How abiotic stress induced by artificial wounding changes maturity levels and berry composition of Merlot (*Vitis vinifera* L.). Eur Food Res Tech, 249, 2611-2623.

Chen Wei-Kai, He Fei, Wang Yu-Xi, Liu Xin, Duan Chang-Qing, Wang Jun. 2018. Influences of berry size on fruit composition and wine quality of *Vitis vinifera* L. cv. Cabernet Sauvignon grapes. S Afr J Enol Vitic, 39(1): 67-76.

Cooley NM, Clingeleffer PR, Walker RR. 2017. Effect of water deficits and season on berry development and composition of Cabernet Sauvignon (*Vitis vinifera* L.) grown in a hot climate. Aus J Grape and Wine Res, 23: 260-272.

Cosseboom SD, Hu M. 2022. Ontogenic susceptibility of grapevine clusters to ripe rot, caused by the *Colletotrichum acutatum* and *C. gloeosporioides* species complexes. Phytopathol, 112(9): 1956-1964.

Dai GH, Andary C, Mondolot-Cosson L, Boubals D. 1995. Involvement of phenolic compounds in the resistance of grapevine callus to downy mildew (*Plasmopara viticola*). Eur J Plant Pathol, 101(5): 541-547.

Dai ZW, Vivin P, Robert T, Milin S, Li SH, Genard M. 2009 Model-based analysis of sugar accumulation in response to source-sink ratio and water supply in grape (*Vitis vinifera*) berries. Funct Plant Biol, 36(6): 527-540.

Darriaut R, Tran J, Martins G, Ollat N, Masneuf-Pomarède I, Lauvergeat V. 2023. In grapevine decline, microbiomes are affected differently in symptomatic and asymptomatic soils. Appl Soil Ecol, 183: 104767.

Debastiani GL, Berghahn E, Cavião HC, Vigano L, Montes AL, Giongo A, Schwambach J, Granada CE. 2023. Biotechnological potential of *Bacillus* sp. S26 for alleviation of abiotic and biotic stresses in vine. World J Mic Biotech, 39: 150.

Del-Castillo-Alonso MÁ, Monforte L, Tomás-Las-Heras R, Ranieri A, Castagna A, Martínez-Abaigar J, Núñez-Olivera E. 2021. Secondary metabolites and related genes in *Vitis vinifera* L. cv. Tempranillo grapes as influenced by ultraviolet radiation and berry development. Physiol Plant, 173: 709-

724.

Drenjančević M, Kujundžić T, Jukić V, Karnaš M, Braun U, Schwander F, Teklić T, Rastija V. 2023. Impact of leaf removal as a source of stresses on grapevine yields, chemical characteristics, and anthocyanin content in the grapevine variety Babica. Ann Appl Biol, 183(1): 43-52.

Ferrandino A, Pagliarani C, Pérez-Álvarez EP. 2023. Secondary metabolites in grapevine: crosstalk of transcriptional, metabolic and hormonal signals controlling stress defence responses in berries and vegetative organs. Front Plant Sci, 14: 1124298.

Gray JD, Coombe BG. 2009. Variation in Shiraz berry size originates before fruitset but harvest is a point of resynchronisation for berry development after flowering. Aust J Grape and Wine Res, 15: 156-165.

Harris JM, Kriedemann PE, Possingham JV. 1968. Anatomical aspects of grape berry development. Vitis, 7: 106-119.

Hewitt S, Hernández-Montes E, Dhingra A, Keller M. 2023. Impact of heat stress, water stress, and their combined effects on the metabolism and transcriptome of grape berries. Sci Rep, 13: 9907.

Holt HE, Francis IL, Field J, Herderich MJ, Iland PG. 2008. Relationships between berry size, berry phenolic composition and wine quality scores for Cabernet Sauvignon (*Vitis vinifera* L.) from different pruning treatments and different vintages. Aust J Grape Wine Res, 14: 191-202.

Houel C, Martin-Magniette ML, Nicolas SD, Lacombe T, Le Cunff L, Franck D, Torregrosa L, Conéjéro G, Lalet S, This P, Adam-Blondon AF. 2013. Berry size. Aust J Grape Wine Res, 19: 208-220.

Johnstone RS, Clingeleffer PR, Lee TH. 1995 The composition of Shiraz grape berries - implications for wine. In: Proceedings of the IX. Australian Wine Industry Technical Conference, 16-19 July, Adelaide, South Australia, pp: 105-108.

Jung HM, Lee S, Lee WH, Cho BK, Lee SH. 2018. Effect of vibration stress on quality of packaged grapes during transportation. Eng Agr Env Food, 11(2): 79-83.

Kara Z, Erdoğan E. 2010. The effects of mycorrhizae applications on grapevine cv. Kalecik Karası (*Vitis vinifera* L.) grafted onto Kober 5BB rootstock. In: Proceedings 2nd Int Symp on Sustainable Development, Sarajevo, Bosnia-Herzegovina, pp: 8-9.

Karanis C, Çelik H. 2002. Amasya'da yetiştirilen bazı üzüm çeşitlerinin tane içeriklerindeki değişimin incelenmesi ve optimum hasat zamanlarının tespiti üzerine araştırmalar. Türkiye V. Bağcılık ve Şarapçılık Semp Bildiriler Kitabı, 5-9 Ekim, Nevşehir, Türkiye, pp: 441-448.

Kasimatis AN, Bowers KW, Vilas EP. 1985 Conversion of cane-pruned Cabernet Sauvignon vines to bilateral cordon training and a comparison of cane and spur pruning. Amer J Enol Vitic, 36: 240-244.

Keller M. (2010). The science of grapevines, anatomy and physiology. Elsevier Academic Press, Burlington, MA, New Jersey, USA, 1st ed., pp: 400.

Klarner S, Flemming B, Berkelmann-Löhnertz B. 2015. Studies on mould prevention in viticulture by means of UV-C application of vines (*Vitis vinifera* L.). Landtechnik, 70(4): 139-148.

Korkutal İ, Bahar E, Bayram S. 2017. Farklı toprak işleme ve yaprak alma uygulamalarının Syrah üzüm çeşidinde su stresi, salkım ve tane özellikleri üzerine etkileri. Ege Ün Zir Fak Derg, 54(4): 397-407.

Kotseridis Y, Georgiadou A, Tikos P, Kallithraka S, Koundouras S. 2012. Effects of severity of post-flowering leaf removal on berry growth and composition of three red *Vitis vinifera* L. cultivars grown under semiarid conditions. J Agric Food Chem, 60(23): 6000-6010.

Langcake P, Pryce RJ. 1977. The production of resveratrol and the viniferins by grapevines in response to ultraviolet irradiation. Phytochemistry, 16(8), 1193-1196.)

Lopez-Fernandez S, Compant S, Vrhovsek U, Bianchedi PL, Sessitsch A, Pertot I, Campisano A. 2016. Grapevine colonization by endophytic bacteria shifts secondary metabolism and suggests activation of defense pathways. Plant Soil, 405: 155-175.

Lorenzini M, Fracchetti F, Bolla V, Stefanelli E, Rossi F, Torriani S. 2010. Ultraviolet light (UV-C) irradiation as an alternative technology for the control of microorganisms in grape juice and wine. In: Proceedings of 33rd World Congr Vine and Wine, June 20-27, Tblissi, Georgia, p: 8.

Ma Y, Prasad MNV, Rajkumar M, Freitas H. 2011. Plant growth promoting rhizobacteria and endophytes accelerate phytoremediation of metalliferous soils. Biotech Adv, 29(2): 248-258.

Ma Y, Qin F, Tran LS. 2012. Contribution of genomics to gene discovery in plant abiotic stress responses. Mol Plant, 5(6): 1176-1178.

Matthews MA, Anderson MM. 1988. Fruit ripening in *Vitis vinifera* L.: Response to seasonal water deficits. Amer J Enol Vitic, 39(4): 313-320.

Melo MS, Schultz HR, Volschenk C, Hunter JJ. 2015. Berry size variation of *Vitis vinifera* L. cv. Syrah: Morphological dimensions, berry composition and wine quality. S Afr J Enol Vitic, 36: 1-10.

Meteroloji Genel Müdürlüğü (MGM) 2016. 2016 yılı iklim değerlendirmesi. URL: https://mgm.gov.tr/FILES/iklim/yillikiklim/2016-iklim-raporu.pdf (accessed date: November 12, 2016).

Meteroloji Genel Müdürlüğü (MGM). 2017a. 2017 yılı iklim değerlendirmesi. URL: https://mgm.gov.tr/FILES/iklim/yillikiklim/2017-iklim-raporu.pdf (accessed date: November 12, 2017).

Meteoroloji Genel Müdürlüğü (MGM). 2017b. Tekirdağ ili genel istatistik verileri. URL: https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler (accessed date: November 13, 2017).

Mucalo A, Budić-Leto I, Lukšić K, Maletić E, Zdunić G. 2021. Early defoliation techniques enhance yield components, grape and wine composition of cv. Trnjak (*Vitis vinifera* L.) in Dalmatian hinterland wine region. Plants, 10: 551.

OIV 2009. 2nd Edition of the OIV descriptor list for grape varieties and vitis species. OIV, Paris, France. pp 232.

Ollat N, Diakou-Verdin P, Carde JP, Barrieu F, Gaudillère JP, Moing A. 2002 Grape berry development: A review. OENO One, 36(3): 109-131.

Palliotti A, Gatti M, Poni S. 2011. Early leaf removal to improve vineyard efficiency: gas exchange, source-to-sink balance, and reserve storage responses. Amer J Enol Vitic, 62(2): 219-228.

Palma L, Novello V, Tarricome L, Frabboni L, Lopriore G, Soleti F. 2007. Grape and wine quality as influenced by the agronomical soil protection in a viticultural system of southern Italy. Quaderni di Scienze Viticole ed Enologiche, Univ Torino, 29: 83-111.

Poni S, Bernizzoni F, Civardi S, Libelli N. 2009. Effects of pre-bloom leaf removal on growth of berry tissues and must composition in two red *Vitis vinifera* L. cultivars. Aust J Grape Wine Res, 15(2): 185-193.

Price SF, Breen PJ, Valladao M, Watson BT. 1995. Cluster sun exposure and quercetin in Pinot noir grapes and wine. Amer J

Enol Vitic, 46: 187-194.

Ribéreau-Gayon P, Glories Y, Maujean A, Dubourdieau D. 2000. Handbook of enology, Vol 2: The chemistry of wine and stabilization and treatments 2nd Edition. John Wiley and Sons Ltd., London, England, pp: 441.

Roby G, Harbertson JF, Adams DA, Matthews MA. 2004. Berry size and vine water deficits as factors in winegrape composition: Anthocyanins and tannins. Aust J Grape Wine Res, 10: 100-107.

Roby G, Matthews M. 2004. Relative proportions of seed, skin and flesh, in ripe berries from Cabernet Sauvignon grapevines grown in a vineyard either well irrigated or under water deficit. Aust J Grape Wine Res, 10(1): 74-82.

Romero P, Navarro JM, Ordaz PB. 2022. Towards a sustainable viticulture: The combination of deficit irrigation strategies and agroecological practices in Mediterranean vineyards. A review and update. Agric Water Manag, 259: 107216.

Sabır A, Sabır F, Yazar K, Kara Z. 2015. Italia (*V. vinifera* L.) sofralık üzüm çeşidinde saksı kültüründe kısıntılı sulamanın verim ve kaliteye etkileri. Selçuk Üniv Selçuk Tarım Gıda Bil Derg-A, 27: 1-7.

Szűgyi-Reiczigel Z, Ladányi M, Bisztray GD, Varga Z, Bodor-Pesti P. 2022. Morphological traits evaluated with random forest method explains natural classification of grapevine (*Vitis vinifera* L.) cultivars. Plants, 11: 3428.

Tahmaz H, Söylemezoğlu G. 2017. Effects of vinification techniques combined with UV-C irradiation on phenolic contents of red wines. J Food Sci, 82: 1351-1356.

Tardaguila J, de Toda FM, Poni S, Diago MP. 2010. Impact of early leaf removal on yield and fruit and wine composition of *Vitis vinifera* L. Graciano and Carignan. Amer J Enol Vitic, 61(3): 372-381.

Ünlüsoy S. 2019. Merlot üzüm çeşidinde farklı toprak işleme ve salkım seyreltme uygulamalarının tane heterojenitesi ve bileşimi üzerine etkileri. MSc thesis, Namık Kemal Üniv, Fen Bilimleri Enst, Bahçe Bitkileri ABD, Tekirdağ, pp: 150.