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Research Article/Araştırma Makalesi

Morphological characteristics of cluster of cv. Cabernet-Sauvignon (*Vitis vinifera* L.) grape variety classified according to berry heterogeneity

Tane heterojenitesine göre sınıflanan Cabernet-Sauvignon (Vitis vinifera L.) üzüm çeşidi salkımlarının bazı morfolojik özellikleri

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ABSTRACT

Two experiments were conducted in two vineyards consisting of vines from the organic-certified Cabernet-Sauvignon/1103P graft combination and the conventional cultivation Cabernet Sauvignon/5BB graft combination. Vines were identified based on pre-dawn leaf water potential values according to stress levels in a Split-Plot Experimental Design. Grapevines were classified as <-0.8 MPa and >-0.8 MPa. These vines were further grouped into dryland-shallow soil and bottomland-deep soil areas, and for each area-soil type, Control, Stress 1, and Stress 2 levels were created. At harvest, the berries were divided into four groups based on their diameter: 10mm-12mm, 12mm-14mm, 14mm-16mm, and 16mm-18mm (In some measurements, no berries belonging to the 16-18mm category could be found). The grapes were grouped as Control, Stress 1 (S1 > -0.8 MPa), and Stress 2 (S2 < -0.8 MPa) based on size groups and stress levels, and certain morphological characteristics of the clusters were examined. The width and length of the clusters were not significantly affected by the area-soil type. Cluster weight, cluster volume, and number of berries per cluster criteria were influenced by stress levels. It was determined that organic vineyards with higher stress levels had fewer clusters compared to conventional vineyards. The number of berries in the clusters showed significant differences based on vineyard area and soil type, water stress levels, and berry size. In conclusion, in the Tekirdağ province, to obtain high-quality grapes from the cv. Cabernet-Sauvignon, it is considered suitable to utilize berries ranging from 10mm to 12mm in size, in conjunction with dryland-shallow soil conditions where the water potential (Ψ_{pd}) can decrease to as low as -0.8 MPa during the ripening period.

Key Words: cv. Cabernet Sauvignon, Organic vineyard, Heterogeneity, Cluster characteristics

ÖZ

Organik sertifikalı Cabernet-Sauvignon/1103P aşı kombinasyonu ve Konvansiyonel yetiştiriciliğe sahip Cabernet Sauvignon/5BB aşı kombinasyonundaki omcalardan oluşan iki bağda deneme yürütülmüştür. Stres düzeylerine göre Bölünmüş Parseller Deneme Deseninde Ψşö-şafak öncesi yaprak su potansiyeli değerlerine göre <-0.8 MPa ve >-0.8 MPa olan omcalar belirlenmiştir. Bu omcalar ayrıca kıraç arazi-yüzlek toprak ve taban arazi-derin toprak olarak gruplandırılmış ve her arazi-toprak tipinde Kontrol, Stres 1, Stres 2 düzeyi oluşturulmuştur. Hasatta salkımlardaki taneler çaplarına göre 4 gruba ayrılmıştır. Bu gruplar; 10mm-12mm, 12mm-14mm, 14mm-16mm ve 16-18mm çapa sahiptir. Üzümler boyut gruplarına ve stres düzeylerine göre Kontrol (K), Stres 1 (S1> -0.8 MPa) ve Stres 2 (S2 < -0.8 MPa) olarak gruplandırılmış; bu gruplara göre salkımın bazı morfolojik özellikleri incelenmiştir. Salkım eni ve boyu arazi-toprak tipinden fazla etkilenmemiş; salkım ağırlığı, salkım hacmi ve salkımdaki tane sayısı kriterleri stresten etkilenmiştir. Stresin yoğun olduğu

Organik Bağ omcalarında Konvansiyonel Bağ omcalarına oranla daha az sayıda salkım olduğu belirlenmiştir. Omcaların salkımlardaki tane sayıları; arazi konumu, su stresi seviyeleri ve tane boyutlarına göre önemli ölçüde farklılıklar göstermiştir. Sonuç olarak, Tekirdağ ilinde Cabernet-Sauvignon üzüm çeşidinden yüksek kalitede üzüm elde etmek için; olgunluk döneminde Ψşö -0,8MPa'a kadar düşebildiği kıraç arazi-yüzlek toprak koşullarında ve 10mm-12mm boyuta sahip tanelerin kullanılmasının uygun olacağı düşünülmüştür.

Anahtar Kelimeler: Cabernet-Sauvignon, Organik bağcılık, Heterojenite, Salkım özellikleri

Introduction

The presence of water and its efficient use are influential in vineyard management. Additionally, irrigation is a factor that not only stabilizes yield but also affects wine quality (Chaves et al., 2010). Signs of abiotic stress due to water deficiency in grapevines start to appear depending on drought conditions (Hirayama and Shinoza, 2010). The water status of the vine is an important factor that determines yield, grape composition, and wine quality (Roux et al., 2019). Excessive water deficit leads to yield loss and negatively affects wine quality (Zsofi et al., 2014). The differences in the land where the vineyard is established and the soil characteristics limit the efficient use of water throughout the vegetation season. In this way, if an irrigation schedule is established without considering the variations in area and soil type, there is a risk of excessive water stress in certain areas, resulting in a decrease in yield and quality (Bellvert et al., 2021). Among the measurements of plant water status, pre-dawn and midday leaf water potential and stem water potential can be mentioned (Suter et al., 2019). The effects of water stress vary depending on the vine's phenological stage, the level of water stress, and the duration of stress (Deloire and Pellegrino, 2021). Furthermore, it has been found that climate and soil conditions can modify the impact of water stress (Wenter et al., 2018; Zufferey et al., 2018). Limited irrigation strategies applied at different phenological stages have varying effects on vine growth and yield. Early-stage (pre-veraison) water restriction has been reported to negatively affect vine growth (Munitz et al., 2016; Korkutal et al., 2022). However, Intrigliolo et al. (2012) determined that early or late water restriction did not have a significant impact on vine development. Nevertheless, the climatic conditions and genotype at the experimental site also play a role in determining the vine's response to water stress (Bota et al., 2016; Cogato et al., 2022).

Cheng et al. (2014) have shown that water deficiency and low organic matter in the soil reduce cluster density in Cabernet Sauvignon cv. Echeverria et al. (2017) have mentioned that shallow soil has limited access to water, resulting in reduced yield due to slow vegetative growth, but it improves grape quality. Munitz et al. (2016) achieved the best vegetative growth and high yield in a parcel with regular and continuous water deficit regime, ranging from easy access to water from flowering to cluster formation and low limited irrigation from berry set to harvest. Calderon-Orellana et al. (2019) reported that post-veraison water restriction did not affect cluster density, moderate stress prevented uniform color development at harvest, and high stress led to green remaining berries.

In wine grape varieties, characteristics such as berry size, color, taste, and aromas are important (Poni et al., 2018). Additionally, Kontoudakis et al. (2011) stated that the heterogeneity of grape berries has a significant impact on wine composition and quality. Especially in red grape varieties, moderate stress is desired for high quality (Ferrandino et al., 2014; Levin et al., 2020). On the other hand, Ojeda et al. (2001) reported that water stress observed at the beginning of vegetation leads to a lower number of berries per cluster, severe water stress occurring between berry set and veraison reduces berry weight and increases heterogeneity in berry size. Chen et al. (2018) divided Cabernet Sauvignon grape berries into three groups: small (≤ 0.75g), medium (0.76-1.25g), and large (> 1.25g), and found that medium-sized berries accounted for over 50% numerically. Melo et al. (2015) grouped Syrah grape berries based on their diameter as small (<13mm), medium (13mm< to <14mm), and large (>14mm) using a sieve, and they found that small berries were more abundant and their size distribution did not change over two years. Decreased berry volume (bunch closure stage to post-veraison/ripening) reduces yield but generally supports quality (reduced cluster density, increased concentration of primary and secondary metabolites), and it is important to avoid inhibiting ripening (Deloire and Pellegrino, 2021).

Soil characteristics also influence grape quality. However, Van Leeuwen et al. (2004) determined that three different soil types (gravelly, heavy clay, sandy-loam) had less influence on grape quality compared to climate. Seguin (1986) stated that grape quality originates from the physical properties of the soil. Additionally, it should be noted that in some vineyards, the capacity of a wide and deep, well-developed root system enables vines to withstand water deficiency (Zufferey et al., 2018).

In this study, grapes from vines exposed to high water stress for many years in two vineyards, one organic and one conventional, were grouped based on leaf water potentials at harvest time, and berry sizing was performed to determine the effects of berry heterogeneity on cluster characteristics. Furthermore, the effect of berry heterogeneity on clusters characteristics and how this will be reflected in quality has been investigated.

Material and Methods

Experimental area, vineyards and experimental design

Two separate vineyards were used in the study, one organic and one conventional. The organic vineyard is located at 41° 02' 20.74" N and 27° 48' 41.90" E, with an elevation of 130m. It consists of 12-year-old vines of Cabernet-Sauvignon/1103P graft combination, planted with a spacing of 2 x 2.5 m in a N-S direction on a slope of 18%. The vertical shoot positioning (VSP) trellis system was used. Cultural practices in this vineyard included fertilization (with compressed granular animal manure), soil cultivation (once with a hoe and hoeing), and weed trimming. Summer pruning involved two topping and two shoot thinning operations. In terms of pest control, Bordeaux mixture (max. 4 kg ha^{-1}), sulfur, and copper-based preparations were used. No irrigation was applied in the organic vineyard.

The conventional vineyard is located at 40° 55' 50.23" N and 27° 25' 19.16" E, with an elevation of 200m. It is situated 5km away from the sea. The vines in this vineyard were of the Cabernet-Sauvignon/5BB graft combination. They were planted with a spacing of 1.5 x 2.5 m in a N-S direction and trained using the Double Cordon Royat trellis system. Soil cultivation involved four times of hoeing and mechanical weeding. Summer pruning included one topping and one shoot thinning. Regular applications of Bordeaux mixture and systemic preparations containing copper and sulfur were carried out every 15 days. No irrigation was applied. Additionally, it should be noted that cluster and shoot numbers were not equalized in both the organic and conventional vineyards.

The study was conducted using a Split-Plot Design, with two soil types (Dryland-Shallow soil and Bottomland-Deep soil) and three different stress levels (Control, Stress 1, and Stress 2). The experiment was replicated three times, with two vines per replication.

Sample collection

A total of 144 clusters were selected, with four clusters per vine. The berries were then grouped based on their size: berries with a diameter smaller than 12mm, berries with a diameter between 12mm-14mm, berries with a diameter between 14mm-16mm, and berries with a diameter between 16mm-18mm. Due to the characteristics of the variety, berries with a diameter larger than 18mm could not be identified. There were also some parcels where berries with a diameter between 16-18mm were not found.

Area and soil types

In both vineyards, the northern and southern sides had different soil characteristics due to the slope. The northern slopes consisted of gravel, sand, and limestone structure, with lower organic matter content. Due to the low presence of clay, the cultivation and surface soil treatments resulted in the formation of an impermeable limestone layer. This soil structure, with a very low water holding capacity, was defined as barren. Similarly, the southern slopes in both vineyards had a soil structure with abundant clay and sand, resulting in a soil with a high water holding capacity. These slopes, rich in water and organic matter from rainfall, were defined as base. This soil was more resistant to water stress compared to the barren soil.

The trial field is divided into two different land-soil types as seen below (Table 1):

Dryland - Shallow soil (DS): Parcel with high water permeability and abundant gravel

Bottomland - Deep soil (BD): Parcel with high clay content and deep base soil

It is also divided into three groups according to stress levels as given below:

Conventional vineyard (Control): Vineyard using conventional methods

Organic vineyard (Stress 1): Low predawn leaf water potential (Ψ_{pd})

Organic vineyard (Stress 2): High predawn leaf water potential (Ψ_{pd})

Table 1. Trial design according to the area-soil type and stress levels

Area and Soil type	Stress Levels	Repetition						Total
		I		II		III		
		1.vine	2. vine	1. vine	2. vine	1. vine	2. vine	
Dryland-Shallow soil (DS)	Control	1	1	1	1	1	1	6
	S1 < -0.8 MPa	1	1	1	1	1	1	6
	S2 > -0.8 MPa	1	1	1	1	1	1	6
Baseland-Deep soil (BD)	Control	1	1	1	1	1	1	6
	S1 < -0.8 MPa	1	1	1	1	1	1	6
	S2 > -0.8 MPa	1	1	1	1	1	1	6
Total Grapevine Number								36

Data Collection

Climate data and phenological development stages

In order to determine the effects of different soil types and vineyard management techniques (organic-conventional) on the vegetative growth and yield of the Cabernet Sauvignon variety, the dates of phenological development stages were determined according to Coombe (1995) and Lorenz et al. (1995).

Leaf water potential (Ψ_{pd}, MPa)

The predawn leaf water potential (Ψ_{pd}) has been measured once at harvest time using a Scholander Pressure Chamber (Deloire et al., 2020). These measurements were taken pre-dawn between 03:00-05:00 A.M. (Cole and Pagay, 2015). The measurements were evaluated according to Table 2.

Table 2. Predawn leaf water potential and grapevine water status (Carbonneau 1998, Deloire and Rogiers 2015)

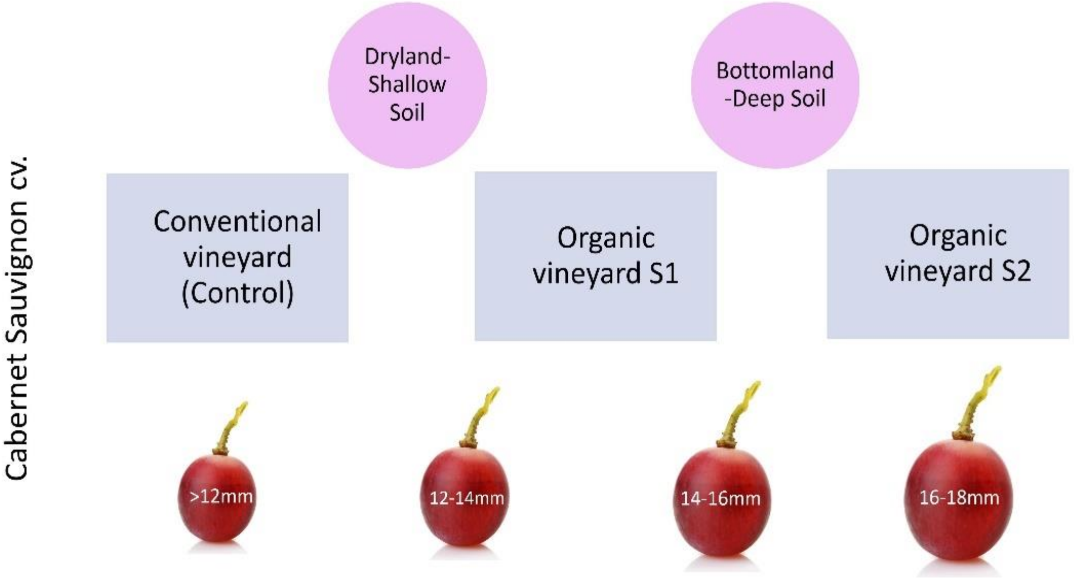
Classes	Predawn leaf water potential	Level of water stress
0	0 MPa ≥ Ψ_{pd} ≥ -0.2 MPa	No water deficit
1	-0.2 MPa ≥ Ψ_{pd} ≥ -0.4 MPa	Mild to moderate water deficit
2	-0.4 MPa ≥ Ψ_{pd} ≥ -0.6 MPa	Moderate to severe water deficit
3	-0.6 MPa > Ψ_{pd} > -0.8 MPa	Severe to high water deficit (= stress)
4	< -0.8 MPa	High water deficit (=stress)

Cluster size groups (%)

The grape berries on the clusters were classified according to diameter groups and examined based on soil type characteristics (Table 3). The proportion of berries in each diameter group is provided as a percentage. The evaluation of all examined criteria was conducted based on these groups. In both area and soil types, clusters with a berry size of 12mm-14mm constituted around 60% of the total. Following this group, there were clusters with a diameter between 10mm-12mm (23.68%) and the 14mm-16mm group (13.55%). The diameter group with the lowest proportion was the 16mm-18mm range (1.84%).

Table 3. Berry diameter group percentages acording to the area and soil type

Area and Soil type	Berry diameter groups (%)			
	10-12 mm	12-14 mm	14-16 mm	16-18 mm
DS	25.89	65.85	7.,29	0.97
BD	21.46	56.01	19.81	2.72
DME (Diameter Main Effect)	23.68	60.93	13.55	1.84



Figurel 1. Area-soil type and berry size groups

Some morphological characteristics of the clusters

For determining the cluster characteristics, 144 clusters were selected and grouped according to their sizes, with 4 clusters per vine at harvest (Figure 1).

The width and length of the cluster were measured using a ruler (cm). The cluster weight (g) was calculated by dividing the yield per vine by the number of clusters. The cluster volume (cm^3) was determined using the water dipping method.

Cluster density was calculated using the formula:

$$Cluster\ Density\ =\ Number\ of\ Berries\ in\ the\ Cluster \times Berry\ Volume\ (cm^3) / Cluster\ Volume\ (cm^3)$$

(OIV, 2009). The obtained value was evaluated as dense if it was less than 1 and sparse if it was greater than 1.

Number of berries in the cluster (number): In order to determine the number of berry per cluster, 3 replicates were conducted for each stress group. In each replicate, 2 vines were sampled, and 4 clusters were taken from each vine. Harvested clusters were brought to the laboratory as soon as possible, and the berries were separated from the clusters without mixing. They were then classified using sieves with diameters of 10mm, 12mm, 14mm, 16mm, and 18mm. The clusters were counted and weighed according to the berry groups. Subsequently, every 4 clusters per vine were combined into 4 different size groups: 10mm-12mm, 12mm-14mm, 14mm-16mm, and 16mm-18mm. In some measurements, no berries belonging to the 16-18mm category could be found.

Additionally, the yield (kg da^{-1}) was calculated by weighing the clusters after individual harvests from each vine and multiplying it by the number of vines per decare.

Statistical analysis

The data were analyzed using the MSTAT-C statistical program, and the LSD test was used to determine significant differences at the 1% and 5% levels. In some statistical analyses, the 16mm-18mm berry size group was not used due to an insufficient number of berries.

Results and Discussion

Climate data

Throughout the entire vegetation period, there was a total of 173mm of rainfall, with 16mm of rainfall occurring from budbreak (EL 35) to harvest (EL 38). During this period, the average temperature was 25.2℃, and the average relative humidity was 71.5%. According to the Winkler Index, the accumulated heat units were 2235 degree-days (TMM, 2018) (Figure 2).

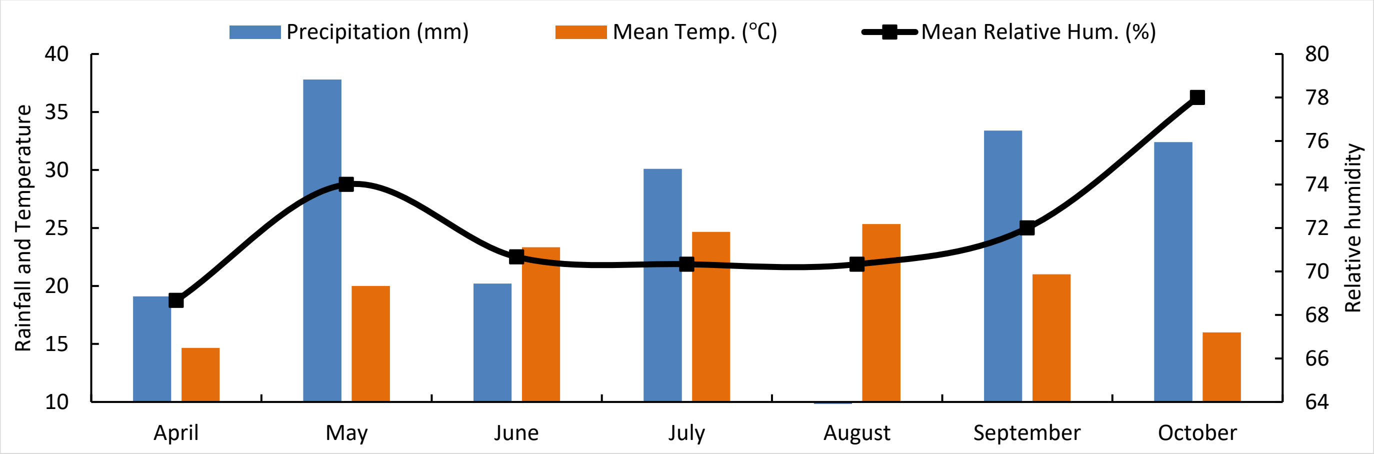


Figure 2. Precipitation, temperature, and relative humidity values in Tekirdağ province (TMM, 2018)

Phenological development stages

The phenological development dates for the organic vineyard were recorded as budbreak (EL 14) on April 15, flowering (EL 23) on May 25, veraison (EL 35) on July 24, and harvest (EL 38) on August 31. In the conventional vineyard, budbreak (EL 14) occurred on April 15, flowering (EL 23) on May 28, veraison (EL 35) on July 26, and harvest (EL 38) on September 17, 2018, based on maturity analysis conducted after veraison (Figure 3).

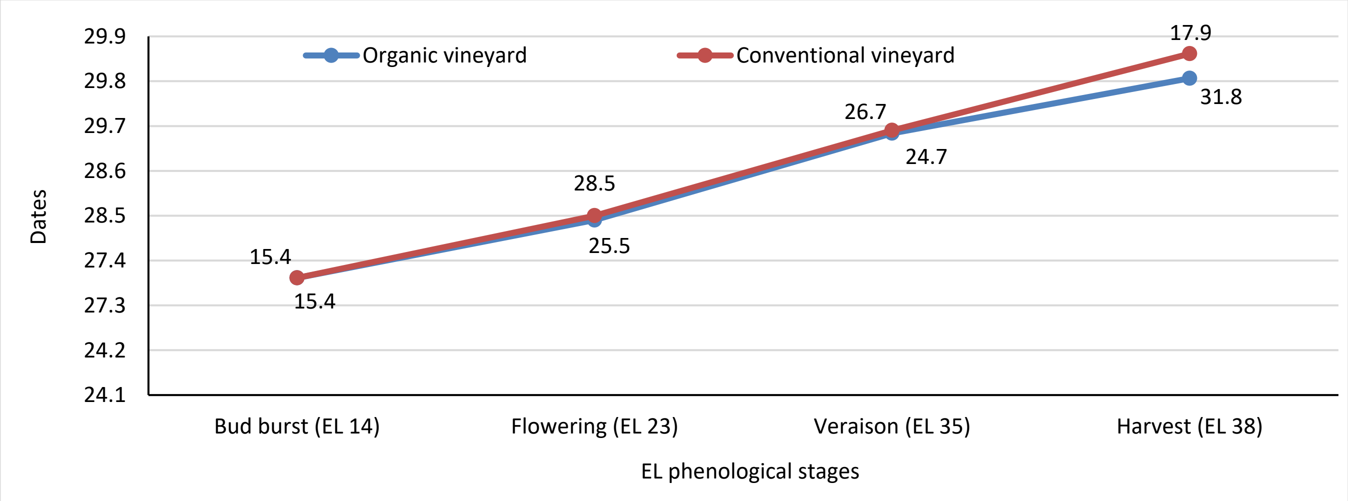


Figure 3. Phenological development stages of organic and conventional vineyards

Predawn leaf later potential (Ψ_{pd}, MPa)

The vine water status, represented by the predawn leaf water potential (Ψ_{pd}), was determined (Table 4). The vines were grouped according to area and soil type x Stress levels, and their predawn leaf water potentials (MPa) were examined. In the Dryland-Shallow soil (DS) vineyard, the average leaf water potential of vines at Stress level 1 was -0.77 MPa, at Stress level 2 it was -1.22 MPa, and for the Control group, it was -0.92 MPa, which falls between the two stress levels. In the Bottomland–Deep soil (BD) vineyard, the average leaf water potential of vines for the Control group was -0.29 MPa, for Stress level 1 it was -0.77 MPa, and for Stress level 2 it was -0.92 MPa.

Table 4. Leaf water potential (Ψ_{pd}; MPa) values in terms of area and soil type, and stress level

Area and Soil type	Stress Levels	Replication			Mean
		I	II	III	
DS (Dryland - Shallow soil)	Conventional (Control)	-1.00	-0.90	-0.85	-0.92
	S1 >-0.8 MPa	-0.75	-0.80	-0.77	-0.77
	S2 <-0.8 MPa	-1.28	-1.15	-1.22	-1.22
BD (Bottomland – Deep soil)	Conventional (Control)	-0.25	-0.30	-0.31	-0.29
	S1 >-0.8 MPa	-0.77	-0.80	-0.72	-0.76
	S2 <-0.8 MPa	-0.95	-0.92	-0.90	-0.92

According to Table 1 (Thresholds of predawn leaf water potential and grapevine water status), the average values of Area and soil type and Stress levels indicate that the DS x Control interaction had a value of -0.92 MPa, indicating high stress. The DS x Stress level 1 interaction had a value of -0.77 MPa, indicating severe-high stress. The DS x Stress level 2 interaction had a value of -1.22 MPa, indicating high stress. In terms of the BD vineyard, the average values of Stress levels interaction were as follows: BD x Control interaction had a value of -0.29 MPa, indicating low-medium stress; BD x Stress level 1 interaction had a value of -0.76 MPa, indicating severe high stress, and BD x Stress level 2 interaction had a value of -0.92 MPa, indicating high stress.

Percentage of grape berry diameter groups in the cluster

When grape berries in the clusters were classified according to diameter groups and analyzed based on field-soil type characteristics, it was observed that clusters with a diameter of 12mm-14mm accounted for approximately 60%. This group was followed by the group with a diameter of 10mm-12mm (23.68%) and the group with a diameter of 14mm-16mm (13.55%). The lowest percentage was recorded for the 16mm-18mm diameter group (1.84%) (Table 5).

Table 5. Grape berry diameter groups according to area and soil type

Area and Soil Type	Berry diameter groups (%)			
	10mm-12mm	12mm-14mm	14mm-16mm	16mm-18mm
DS (Dryland–Shallow soil)	25.89	65.85	7.29	0.97
BD (Bottomland–Deep soil)	21.46	56.01	19.81	2.72
DME (Diameter Main Effect)	23.68	60.93	13.55	1.84

N.S.

Some morphological characteristics of the cluster

Cluster width (cm)

When examining the cluster width criteria for all berry diameter groups, the Stress Main Effect (SME), Area and Soil Type Main Effect (ASTME), and Area and soil type x Stress Levels interactions were not found to be statistically significant (Table 6).

Table 6. Cluster width values at different stress levels based on area and soil type

Area and soil type	Stress Levels			ASTME (Area and Soil Type Main Effect)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	9.16	8.91	9.02	9.03
Bottomland-Deep soil	8.71	8.01	8.66	8.46
SME (Stress Main Effect)	8.93	8.45	8.84	

N.S.

When examining the criterion of cluster width in terms of Area and soil type Main Effect (ASTME) values of 9.03 cm were obtained from the Dryland-Shallow soil (DS) and 8.46 cm for the Bottomland-

Deep soil (BD). When analyzing the interaction between stress level and area and soil type, it was found that cluster width values ranged from 8.01 cm (BD x Stress 1) to 9.16 cm (DS x Control). From the perspective of SME (Stress Main Effect), cluster width values were ranked from lowest to highest as follows: Stress 1: 8.45 cm, Stress 2: 8.84 cm, and Control: 8.93 cm. The cluster width of the Cabernet Sauvignon grape variety was classified as medium (~120 mm) according to OIV (2009) standards and assigned a code of 5.

Cluster length (cm)

No statistical differences were observed in terms of the main effect and interactions for cluster length (Table 7). In terms of area and soil type, the Dryland-Shallow soil had a length of 12.91 cm, while the Bottomland-Deep soil had a length of 15.71 cm. When examining the length of clusters from a stress perspective, they were ranked as follows: Stress 2 (13.80 cm), Stress 1 (14.15 cm), and Control (14.99 cm). Regarding the interaction between area and soil type and stress level, the values ranged between 12.03 cm (DS x Stress 2) and 15.89 cm (BD x Control). The cluster length of the Cabernet-Sauvignon grape variety was classified as short-medium (120 - 160 mm) according to OIV (2009) standards and given codes 3 and 5.

Table 7. Cluster length values at different stress levels based on area and soil type

Area and soil type	Stress Levels			ASTME (Main Effect of Area and soil type)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	14.08	12.63	12.03	12.91
Bottomland-Deep soil	15.89	15.67	15.57	15.71
SME (Stress Main Effect)	14.99	14.15	13.80	

N.S.

Cluster weight (g)

The ASTME and SME had a statistically significant impact on cluster weight (LSD %1) (Table 8). It was determined that the BD (181.98 g) had a greater effect on cluster weight compared to the DS (133.98 g). When examining cluster weight from a SME perspective, the Control group (192.92 g) formed the first significant group, followed by the Stress 2 group (135.32 g) and the Stress 1 group (145.71 g). In terms of the interaction between area and soil type and stress levels, cluster weight values ranged between 111.93 g (DS x Stress 2) and 221.09 g (BD x Control).

Table 8. Cluster weight values at different stress levels based on area and soil type

Area and soil type	Stress Levels			ASTME (Main Effect of Area and soil type)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	164.76	125.27	111.93	133.98 b
Bottomland-Deep soil	221.09	166.15	158.71	181.98 a
SME (Stress Main Effect)	192.92 A	145.71 B	135.32 B	

SME LSD %1 = 17.90629; ASTME LSD %5=15.98

According to Ojeda et al. (2001) and Zombardo et al. (2020), no significant differences were found in cluster weight between control and stressed grapevines, indicating a lack of similarity. It is believed that this difference could be attributed to the grape variety. However, a parallel result was observed between the research findings of Shellie and King (2020), which showed that stress reduced cluster weight by approximately 27%. Similarly, Bahar et al. (2017) obtained results in line with the finding that the highest cluster weight occurred between -0.3 MPa and -0.7 MPa, while the lowest cluster weight was observed at stress levels of -0.7 MPa and above.

Cluster volume (cm3)

The SME (LSD %1) and Area and soil type x Stress (LSD %5) interactions were found to have a significant effect on cluster volume (Table 9). When examining cluster volume from a SME perspective, the Control group (163.92 cm^3) had the highest cluster volume, placing it in the first significant group, while Stress 1 (111.04 cm^3) and Stress 2 (106.00 cm^3) levels were classified in the second significant group.

Table 9. Cluster volume values at different stress levels based on area and soil type

Area and soil type	Stress Levels			ASTME (Main Effect of Area and soil type)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	146.00 *b*	82.42 *d*	88.04 *d*	105.49 b
Bottomland-Deep soil	181.83 *a*	139.67 *b*	123.96 *c*	148.49 a
SME (Stress Main Effect)	163.92 A	111.04 B	106.00 B	

SME LSD %1 = 12.5976; Area and soil type x Stress interaction LSD %5 = 12.5214; ASTME LSD %5=11.34

Bottomland-Deep soil (148.49 cm^3) increased cluster volume compared to Dryland-Shallow soil (105.49 cm^3). In terms of the Area and soil type x Stress levels interaction, the BD x Control interaction (181.83 cm^3) is in the first significant group. The DS x Stress 2 (88.04 cm^3) and DS x Stress 1 interactions (82.42 cm^3) form the last significant group.

It is found that the decrease in berry volume is due to an increase in water deficit, obtaining similar results. It should be noted that the decrease in berry volume (from the bunch closure to the post-veraison/ripening stage) reduces yield while supporting quality (Deloire and Pellegrino, 2021).

Number of berries in the cluster (number)

When examining the number of berries in the cluster based on size groups, both DME (LSD %5) and SME (LSD %5) were found to be significant (Table 10). From a DME perspective, the 12mm-14mm berry size group was in the first significant group with a value of 63.65 number. The 10mm-12mm (27.44 number) and 14mm-16mm (15.88 number) size groups formed the second significant group. In this measurement, no berries belonging to the 16-18mm category could be found. From SME perspective, it was determined that the number of berries in the cluster was lower in the Stress 1 and Stress 2 compared to the Control. The finding that the number of clusters per vine or berries per cluster decreases as the stress level increases (Deloire and Pellegrino, 2021) aligns with similar results.

Table 10. Changes in the number of berries in the cluster based on area and soil type, different stress levels, and berry sizes

Area and soil type and Stress		Berry diameter			
		10mm-12mm	12mm-14mm	14mm-16mm	ASTME
Dryland-Shallow soil		30.28	61.24	4.99	32.17 b
Bottomland-Deep soil		24.6	66.06	26.77	39.14 a
					SME
Control		39.57	67.02	29.39	45.32 a
Stress 1		17.82	63.8	10.67	30.88 b
Stress 2		24.94	60.13	7.59	30.76 b
					Area-soil type x Stress Int
Dryland-Shallow soil	Control	51.42	73.04	1.82	42.09
	Stress 1	18.17	59.38	7.79	28.45
	Stress 2	21.25	51.29	5.38	25.97
Bottomland-Deep soil	Control	27.71	61.01	56.96	48.56
	Stress 1	17.46	68.21	13.54	33.07
	Stress 2	28.63	68.96	9.80	35.80
DME (Diameter Main Effect)		27.44 B	63.65 A	15.88 B	

DME LSD %5 = 14.19287; SME LSD %5=12.03

Furthermore, when examining Table 11, it can be seen that all main effects and interactions are significant. In terms of SME, the highest number of berries in the cluster was obtained from the Control treatment (135.98 number). The lowest berry count values were obtained from Stress 1 (92.21 number) and Stress 2 (92.90 number). From a ASTME perspective, the number of berries in the cluster was highest in BD with 119.34 number and the lowest value was determined to be 94.72 number in DS. The highest value in the Area and soil type x Stress interactions was obtained from the BD x Control interaction with 146.17 number. The lowest interaction values were 77.29 number and 81.09 number (DS x Stress 2 and DS x Stress 1).

Table 11. The number of berries in the cluster based on area and soil type under different stress levels

Area and soil type	Stress Levels			ASTME (Main Effect of Area and soil type)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	125.79 b	81.09 d	77.29 d	94.72 *b*
Bottomland-Deep soil	146.17 a	103.34 c	108.50 c	119.35 *a*
SME (Stress Main Effect)	135.98 A	92.21 B	92.90 B	

SME LSD %1 = 10.07909; Area-soil type x Stress Interaction LSD %1 = 14.2598; ASTME LSD %5=8.94

According to Bahar and Öner (2016), the reported value of 123.19 (number) for the number of berries in the cluster for Cabernet-Sauvignon grape variety in Tekirdağ is consistent with the Control value. It has been concluded, in line with Wenter et al. (2018) and Deloire and Pellegrino (2021), that the number of berries in the cluster excessively decreases in grapevines during the rainfall-free vegetative period, which negatively affects yield.

Cluster density

According to the formula provided by OIV (2009), if the derived number is less than 1, the cluster density is considered dense, while it is considered loose if the number is greater than 1. When evaluating the cluster density criterion statistically, SME and ASTME (LSD %1) were found to be significant. It was observed that the Control treatment had a value above 1 (1.02), while Stress 1 (0.81) and Stress 2 (0.84) had values below 1 (Table 12).

Table 12. Cluster density based on berry size classification and area and soil type

Area and soil type	Stress Levels			ASTME (Main Effect of Area and soil type)
	Control	Stress 1	Stress 2	
Dryland-Shallow soil	1.07	0.74	0.82	0.88 b
Bottomland-Deep soil	0.97	0.88	0.86	0.90 a
SME (Stress Main Effect)	1.02 A	0.81 B	0.84 B	

SME LSD %1=0.1735883; ASTME LSD %5=0.16

Furthermore, in terms of ASTME, it has been observed that BD (0.90) clusters are looser than DS (0.88) clusters. And according to OIV (2009) standards, both of them have been classified as dense clusters. Although not significant in terms of the interaction between Area and soil type x Stress levels, the DS and BD areas had the highest values for the x Control interaction. Due to their values being very close to 1, they were categorized as loose.

These findings contradict the result reported by Calderon-Orellana et al. (2019), which stated that post-veraison water restriction did not affect cluster density. It is believed that this discrepancy is due to the differences in grape variety and experimental conditions. However, the findings are in line with Deloire and Pellegrino (2021), indicating that the decrease in cluster density (less than 1) is parallel to the decrease in berry volume (Stress 1 and Stress 2 with respective berry volumes of 111.04 cm^3 and 106.00 cm^3), and this contributes to an increase in quality.

Yield (kg da^{-1})

In terms of yield, SME, ASTME, and the Area and soil type x Stress levels interaction were found to be statistically significant (LSD 1% level) according to Korkutal et al. (2023) (Data not shown).

When examined from the perspective of SME, it is observed that the Control treatment (1187.53 kg da^{-1}) obtained the highest yield value. This value was followed by Stress 1 (657.08 kg da^{-1}). The lowest was obtained from the Stress 2 (457.36 kg da^{-1}). In terms of the interaction between Area-soil type x Stress Interaction, the BD x Control (1465.92 kg da^{-1}) interaction had the highest, while the DS x Stress 1 (526.12 kg da^{-1}) interaction had the lowest yield value. In terms of ASTME, the highest yield value per decare was recorded in the BD at 930.13 kg da^{-1}, and the lowest was in the DS at 604.52 kg da^{-1}. These findings are consistent with the observation reported by Nadal (2010) that yields are lower in hills, and they are also parallel to the finding that non-irrigated and severely stressed vines have the lowest yield, as reported by Carbonneau (1998), Deloire et al. (2004), Deloire and Heyns (2011), and Bellvert et al. (2021).

Conclusion

In this study, the high-quality and globally recognized Cabernet-Sauvignon grape variety was examined in two vineyards with different cultivation types: organic and conventional, located in Tekirdağ province. The effects of area and soil type and different levels of water stress on cluster characteristics were investigated in these two vineyards.

In terms of ASTME, the BD only reduced the cluster width, while the DS reduced the cluster length, cluster weight, cluster volume, cluster berry count, and cluster density. Regarding stress levels, Stress 1 decreased cluster width, weight, volume, berry count, cluster density, and yield (by 44% compared to Control), while Stress 2 reduced cluster length, weight, volume, cluster density, and yield (by 61% compared to Control). As expected, the clusters in the Control treatment were larger than those in Stress 1 and Stress 2.

Both in the organic and conventional vineyards, based on the pre-dawn leaf water potential (Ψ_{pd}) measurements, it was determined that the 10mm-12mm berry size group exhibited the desired characteristics when compared in two separate groups: Stress 1 with Ψ_{pd} above -0.8 MPa and Stress 2 with Ψ_{pd} below -0.8 MPa.

It was found that the cluster berry count was centered in the 12mm-14mm size group (60.93%) and, in general, 76.32% of the berries had a diameter larger than 12mm. This supports the finding that smaller berries are positively correlated with wine quality, especially in red wine grape varieties (Matthews and Anderson, 1988; Chen et al., 2018). Based on these data, it is necessary to develop cultural practices and strategies to reduce berry size in the vineyards where the study was conducted.

It can be said that better results were obtained under DS conditions in terms of all the examined cluster characteristics. Cluster width and length were less affected by area and soil type. Cluster weight, cluster volume, berry number per cluster, and cluster weight criteria were significantly influenced by stress. It was determined that there were obsolete clusters in the organic vineyard with higher stress compared to the conventional vineyard. The berry number per cluster showed significant differences depending on area and soil types, stress levels, and berry sizes. In the organic vineyard under DS conditions, the number of berries in clusters was very low (77.29 number) under the highest stress level, while in the conventional vineyard under BD conditions, the number of berries in clusters of low-stress vines was very high (146.17 number) compared to the others.

In conclusion, in order to obtain high-quality grapes from the Cabernet-Sauvignon cv. in the Tekirdağ province, it is possible to suggest the following practices:

-Cultivation should be carried out under Dryland-Shallow soil conditions where the predawn leaf water potential can drop as low as -0.8 MPa during the ripening period,

-Since grape quality is improved by the presence of smaller diameter berries, and the smallest berries will be obtained from the smallest clusters, it can be said that it is appropriate to use berries of the 10mm-12mm size, which have low cluster width-height-weight-volume, berry number per cluster and cluster density.

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