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# Assessing the influence of partial canopy cover and temperature variability on late-season dehydration in grape berries

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## Abstract
Late-season dehydration (LSDN) is a physiological disorder affecting grape berry water content, resulting in dehydration. Vineyards in the Aegean Region of western Türkiye have experienced problems with LSDN, particularly during periods of high temperatures. This research examines how partial canopy covering materials affect temperature differentials inside and outside the canopy, including the determination of LSDN grape berries of Sultan 7 (*Vitis vinifera* L.). A partial shading net (PS) was employed to prevent LSDN in the grape berries, and shading net and polyethylene material (PSP) were deployed to assess the impact of increasing canopy temperatures on the occurrence of LSDN in grape berries. Although partial covering materials did not substantially affect grapevine yield, the control group produced the largest and the heaviest berries. In the second year, warmer conditions led to more clusters with LSDN-affected berries and increased sunburn damage on clusters. PS showed a high healthy cluster rate of 72.50%, while PSP and control showed lower rates of 63.60% and 58.10%, respectively. Throughout the study period, PS exhibited 9.02% LSDN berries, while the control and PSP showed 17.10% and 16.70% clusters with LSDN berries in the total harvested clusters, respectively. The study showed that PS treatment alleviated LSDN symptoms in clusters.
**Keywords:** Sultan 7, Raisin, Grape, Berry Shrivel, Quality

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## INTRODUCTION

As a component of climate change, maximum temperatures are becoming a significant problem in the Mediterranean Region due to limited water availability and overheating in many areas (Cramer et al., 2018). Moreover, in recent years, the European viticulture industry has encountered significant challenges due to the adverse effects of climate change. Rising temperatures have adversely impacted grape cultivation and the sustainability of viticulture (Fraga et al., 2020; Santillán et al., 2020). New scenarios on climate change worldwide show that the rise in global greenhouse gas emissions is anticipated to result in a temperature increase beyond the 1.5°C threshold, thereby impeding efforts to restrict the temperature rise below 2°C beyond the year 2030 (IPCC, 2023). The elevated temperatures affect the growth cycle, including the flowering and ripening phase, which could cause a decline in the production of fresh grapes, raisins (Teker and Soltekin, 2023), and wine quality (van Leeuwen et al., 2019).

Previous studies in the Aegean Region, the western part of Türkiye, one of the warmest parts of the country where raisin production is prominent, have revealed that extreme temperatures during the flowering period and weather fluctuations in a month (both low and high temperatures) cause berry-shattering problems on clusters (Teker and Soltekin, 2023). Additionally, another study in the region has shown that sun exposure on berries can lead to sunburn issues, particularly on the west side of the vine canopy in north-south (NS) oriented vineyards during the hot summer afternoons (Teker, 2023). In light of these recent studies, it is evident that growers in this region may face many problems over many seasons due to adverse climate events, thus requiring them to take action.

Late-season dehydration (LSDN) is a type of berry shrivel observed in some grape cultivars in the Aegean Region (Teker and Altındişli, 2021) and is classified as a physiological disorder in grapevines (Krasnow et al., 2010). As for raisin production, many growers prefer to prune canes with many winter buds on grapevines for the following summer to obtain more clusters per vine, which leads to various problems. It sometimes triggers this physiological disorder depending on cultural practices and irrigation conditions, especially during the hot season for the Sultan 7 grape variety. Additionally, specific physiological responses of grapevines, such as stomatal conductance and midday leaf water potential, may indicate stress conditions, particularly in overloaded grapevines with excessive bud numbers. This problem could lead to dehydration of grape berries. The findings also suggest that environmental conditions may have accelerated this condition in grapes with LSDN (Teker and Altındişli, 2021).

The present study examined the effect of utilizing a shading net and polyethylene covering material on the temperature inside and outside the vine canopy. The study also investigated the effects on grape yield and quality and the effectiveness of this approach in mitigating the emergence of LSDN berries. Therefore, the study aims to investigate three primary questions: 1) How do partial shading and polyethylene covering materials influence the vine canopy and LSDN symptoms in grape berries? 2) How do variations in the inside and outside temperature values of vine canopies impact yield and quality? 3) Can partial covering of the vine canopy prevent sunburn damage to grape berries?

## MATERIALS AND METHODS

### Plant material and experimental site

The experiment was carried out in the 2019 and 2020 growing seasons in a trial vineyard with six-year-old vines (*Vitis vinifera* L. cv. Sultan 7) grafted onto 1103 Paulsen rootstock at the Viticulture Research Institute in Manisa, Türkiye (38° 37' North, 27° 24' East). The vines were planted with a spacing of 3.0 m X 2.0 m (row by vine), and the row orientation was north and south. Vines were trained using a goblet system on a V-shaped trellis with six wires and a cane pruning system positioned 100 cm above the soil surface, with approximately 18 buds per eight canes (corresponding to around 150 buds per vine). The vineyard soil was characterized as clay loam, moderately deep, and well-drained. A sub-surface drip irrigation system was installed at the experimental site. Emitters with a nominal flow rate of 4 L $h^{-1}$ were spaced at 50 cm intervals on the lateral drip lines. Irrigation for all the vines in the study was started when water availability was reduced to 50% at an effective root depth of 0.90 meters. The irrigation period began with the berry set and continued until 15 days before harvest in 2019 and 2020. The total amount of water, excluding rainfall, was approximately 97 mm $m^{-2}$ in 2019 and 118 mm $m^{-2}$ in 2020.

### Climatic conditions and phenological observations

The climate in the study area is typical of the Mediterranean. A warm-temperate climate prevails at the experimental site, with hot, dry summers and little rainfall (Teker and Altındisli 2021; Teker 2021). Mid-term data (1991–2020) shows that the average annual precipitation and temperature for Manisa province were 724.6 mm and 17.1°C, respectively (TMS, 2024). A weather station (iMETOS IMT280, Pessl Instruments, Weiz, Austria) was used to record temperature (T) and precipitation (P) data at the experimental site. To record the phenological development of grapevines, budburst, flowering, berry set, veraison, and harvest stages were determined using the modified Eichhorn & Lorenz (EL) system (Coombe, 1995).

### Experimental setup

A completely randomized design with three treatments and six replications in three blocks was used; all treatments were assigned to each block. A guard row was left between treatments to eliminate shading effects on the cluster zone. Before the experimental setup, six soil samples were collected along the row to determine soil structure and composition differences. All soil samples showed similar results, and the slope of the field did not differ significantly. Therefore, the experimental conditions were the same for all vines and treatments.

In this study, three treatments were arranged in the vineyard: (A) control, (B) with a 35% partial shading net (PS), and (C) with a 35% partial shading net plus a plastic cover (PSP), positioned at 50 cm above the vine canopy (Figure 1). For all treatments, except the control (Figure 1A), green artificial shading nets (UV-resistant) were used at 35% for the shading cover, and transparent polyethylene (UV-resistant) was used for the plastic cover. Between berry set and harvest, a 35% shade net was applied for both PS and PSP treatments (Figure 1B and 1C), and for the PSP treatment, a plastic cover was also placed over the 35% shading net between veraison and harvest (Figure 1C).

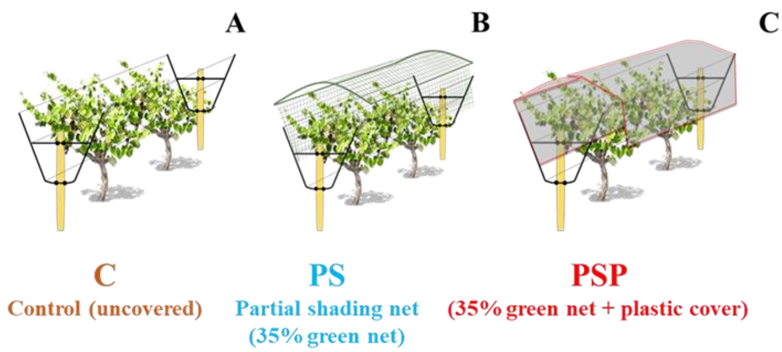


Figure 1. An illustration of the applications used in the study.

**Canopy microclimate**

Microclimate measurements of the vines were conducted between berry set and harvest during the 2019 and 2020 growing seasons. Temperature (°C) was monitored using portable data loggers (HOBOware, UX-100-003, Onset Computer Corp., MA, USA) at two sections of the canopies within each treatment: (1) above the canopy and (2) inside the canopy, specifically within the vine foliage in the cluster zone. Data loggers were positioned 35 cm above the canopy in the control (air temperature), PS (under shading net), and PSP treatments (under shading net and plastic cover film) to record temperatures (1). The others were installed 120 cm above the ground inside the canopy for all treatments (2). Mid-term temperatures were evaluated during three specific periods: from July 16th to July 31st, from August 1st to August 15th, and from August 16th until the harvest date (August 28th) for the 2019 season; and from July 23rd to July 31st, from August 1st to August 15th, and between August 16th and the harvest date (September 04th) for the 2020.

**Yield parameters**

The vine yield (kg vine$^{-1}$) and the number of clusters per vine were recorded at harvest. The cluster weight (g) was calculated by taking the per vine yield and dividing it by the number of clusters. To determine the berry weight (g), samples of 100 berries were used. Additionally, 20 samples in each replicate were measured for berry length (mm) and diameter (mm) using a digital vernier caliper (Mitutoyo Instruments. Illinois, USA).

**Classification of harvested clusters**

In this study, specific criteria were applied to classify grape clusters, considering their health and the presence of certain conditions. Clusters without any damage on berries were categorized as "healthy clusters." These clusters were deemed optimal, exhibiting no visible damage or abnormalities affecting the berries. Additionally, we identified clusters with berries that had suffered damage due to sunburn, which were distinctly labeled as "clusters with sunburned (SN) berries." Furthermore, we introduced a distinct category to address a different condition observed in some clusters. Berries in the final and third classifications experienced a loss of water content without being affected by sunburn. These clusters have been identified and classified as "late-season dehydration (LSDN) clusters" (Krasnow et al., 2010; Teker and Altındisli, 2021). The clusters above were counted, and the percentages of clusters in the total harvested clusters were calculated for each classification.

**Statistical analyses**

Statistical analyses were conducted using SPSS Statistics 21.0. software (IBM, Chicago, IL, USA). The normality of the data was assessed with the Shapiro-Wilk test, and homoscedasticity of variance was checked using Levene's test. The data was subjected to a two-way ANOVA to compare the means ($p \leq 0.05$). For canopy microclimate hourly temperature values, differences in mean values among the treatments were calculated using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

**Weather conditions of the experimental site and phenological observations**

The weather conditions at the experimental site during the growing seasons of 2019 and 2020 are depicted in Figure 2. The graph illustrates the monthly minimum, mean, and maximum temperatures and the recorded rainfall amount. During the 2020 growing season, temperatures were notably higher than in 2019. In the second year, there was an increase in heat conditions. Throughout the 2020 growing season from June to September, it was observed that temperatures surpassed critical thresholds of 40°C, 35°C, and 30°C on numerous occasions. More specifically, there were 22 days with temperatures exceeding 40°C, 44 days with temperatures surpassing 35°C, and 22 days with temperatures exceeding 30°C.

Based on the recorded rainfall data, a significant difference in the total precipitation between the two years of the study was observed. The total precipitation recorded during the first year amounted to 777.4 mm, while the figure for the second year was 533.2 mm. The experimental site recorded 196.4 mm of rainfall between March 1st and August 31st of 2020, significantly higher than the cumulative rainfall of 128.0 mm recorded over the same period in the previous year. During the summer of 2020, there was a significant lack of rainfall. The month of June had 36.0 mm of precipitation, but the months of July and August did not experience any precipitation.

Regarding the phenological stages of grapevine, budburst (EL-4) was observed on March 26th and March 19th in 2019 and 2020, respectively. In 2019, flowering (EL-26) occurred on May 16th, veraison (EL-35) on July 16th, and the grape harvest based on grape maturity (EL-38) was achieved on August 28th. In the following year, 2020, flowering occurred on May 18th, followed by veraison on July 20th. The harvest was completed on September 4th.

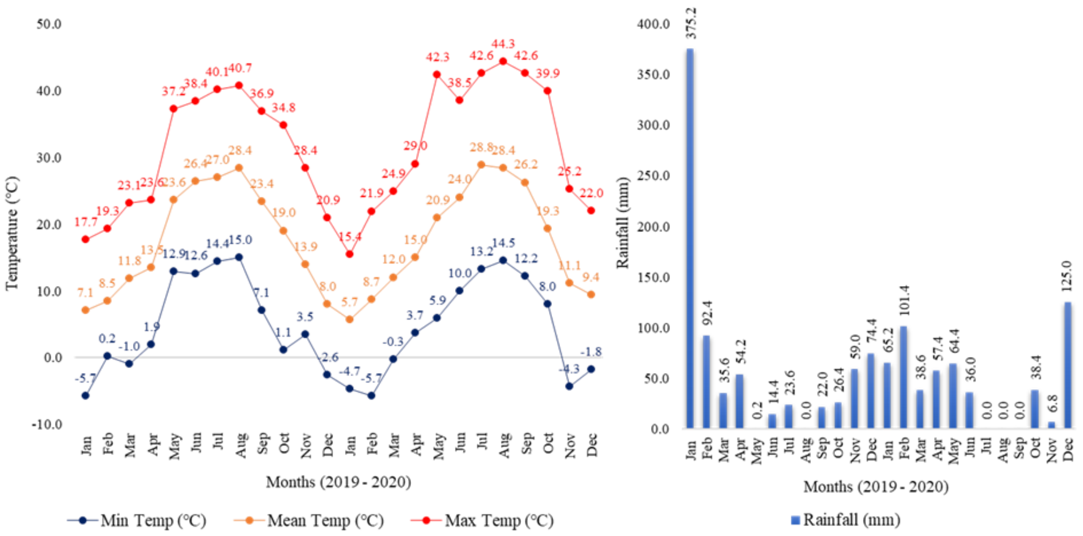


Figure 2. Minimum (Min Temp,℃), mean (Mean Temp, ℃), maximum (Max Temp, ℃), and rainfall (mm) values in the 2019 and 2020 growing seasons.

**Canopy microclimate**

Polyethylene covering material with shading nets on canopies in PSP treatment substantially increased the outside temperature of grapevine canopies. In both study years, the temperature outside the canopies significantly differed between the PSP and PS treatment and between the control (Figure 3A and 3B). Upon comparison with the control, it was observed that an average difference of approximately +2.30°C to +2.93°C occurred in 2019, and a difference of +3.18°C to +3.57°C was seen in 2020. This difference coincided with higher air temperature values, particularly in the second year of the study. On the other hand, shading nets (35%) used in the PS treatment also prevented an increase in outside canopy temperatures. It was found that there was no significant difference in the temperatures recorded outside the vine canopy between the PS treatment and the control. However, the temperature difference between the two experimental groups ranged from 0.5 to 1°C. In 2019, the mean temperatures for the control group showed variability within the range of 27.44°C to 28.45°C, while shading treatments displayed temperatures ranging from 26.36°C to 27.5°C. In the following year, temperature fluctuations were noted between 28.24°C and 29.79°C for the control group, while the PS treatment showed temperature variations between 27.81°C and 29.16°C (Figure 3A and 3B).

The findings indicate that the temperature inside the vine canopy significantly differs from outside in PSP treatment. The grapevine foliage in the canopy provided cooling shade and played a significant role in regulating the temperature. Applying partial shading net covers to vine canopies and leaving both sides of cluster zones open significantly reduced temperatures inside the canopy due to improved air circulation, compared to outside temperatures of the canopy, for PSP treatment. The temperature readings were lower in the control group and PSP treatments, particularly in 2019. Nevertheless, the foliage within the canopy offered some shading, resulting in temperature readings within the PSP treatment becoming more comparable to those in the control group.

Consequently, the temperature inside the PSP canopy was cooler than above the canopy when covered with the materials. Although no statistical significance was observed on many measurement days, the PS application caused a temperature difference ranging from 0.5°C to 1°C inside the canopy. Therefore, it was concluded that a 35% shading cover within the above vine canopy positively affected the microclimate temperature conditions (Figure 3C and 3D).

Temperature records were taken outside the vine canopy during the warmest parts of the day (from 12:00 h to 16:00h) to determine the thermal effect of the PSP treatment, which involved using polyethylene covering material. Our findings suggest that the PSP treatment had a significant thermal effect compared to the control group and PS treatment. The temperature readings obtained from the PSP treatment indicate that the highest temperatures were recorded between 15:00h and 16:00h in the 2019 and 2020 growing seasons. Notably, in 2020, the peak temperature reached 46.34°C, surpassing the previous year's highest temperature record of 43.85°C outside the vine canopies (Figure 4A and 4B). In both years of our study, we observed a significant decrease in heat effect in PS treatment. Therefore, our findings indicate that using shading nets resulted in a more pronounced reduction in inside canopy temperatures compared to the control group (Figures 4C and 4D). It was determined that as the day reached its peak temperature, the temperature variance between the control group and PSP gradually diminished. This was considered due to the polyethylene covering utilized in the PSP treatment, which generates a temperature effect. After analyzing the inside canopy temperatures over two years, it was observed that the control group and PSP treatment had similar values.

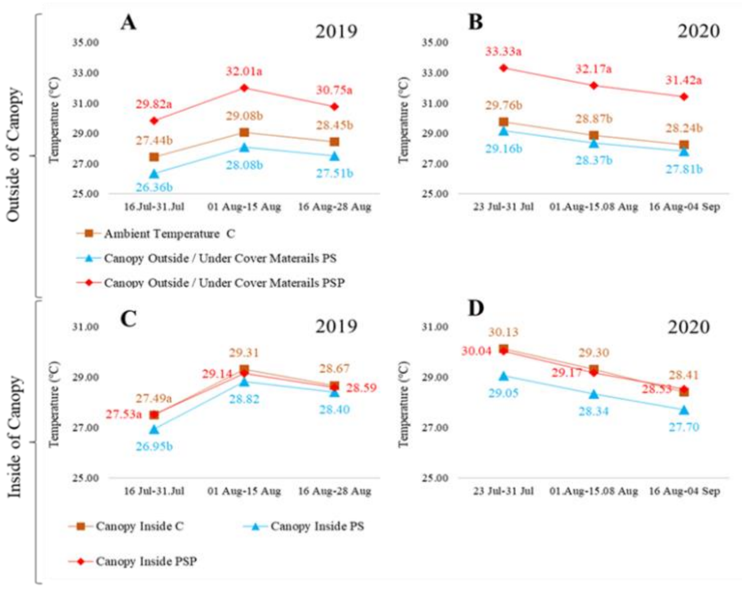


Figure 3. Temperature changes in the outside (A and B) and the inside (C and D) of vine canopy in the 2019 and 2020 growing seasons, respectively, for each treatment between veraison and harvest over a three-period. According to Duncan's test, lowercase letters indicate statistically significant differences (p < 0.001).

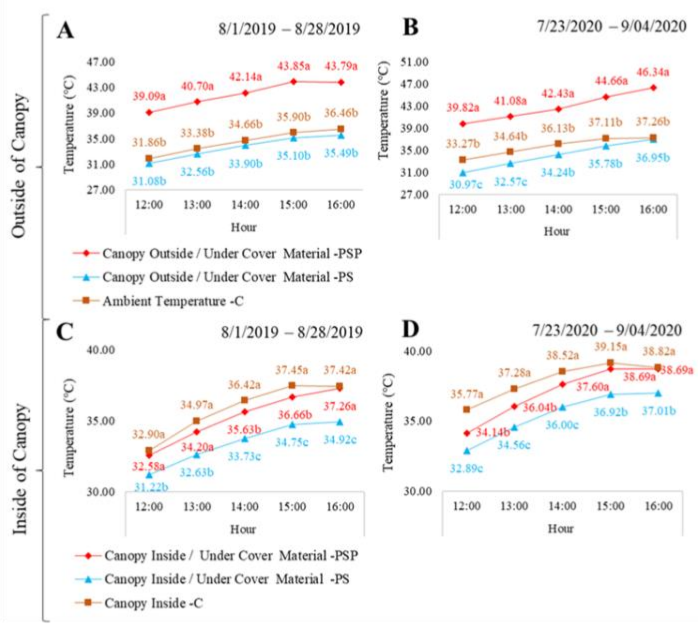


Figure 4. The graph displays the temperature fluctuations in time intervals (between 12:00h and 16:00h) both outside (A and B) and inside the vine canopy (C and D) from veraison to harvest over a three-period for each treatment in the 2019 and 2020 growing seasons. According to Duncan's test, lowercase letters indicate statistically significant differences (p < 0.001).

The present study has demonstrated that applying PS treatment has resulted in significant reductions in temperature levels at specific time intervals, thereby providing convincing evidence of its effectiveness in regulating the temperature inside the canopy. This study also found that the PS treatment could keep cooler canopy temperatures during specific periods when the heat was at its peak, even though there was a decrease in temperature difference between the PSP treatment and control group during the hottest hour of the day.

**Yield parameters**

The study results indicated that none of the treatments significantly impacted vine yield, number of clusters, and cluster weight values over the years. The average cluster weights for the control group, PS, and PSP treatments were 386.68 g, 416.43 g, and 398.72 g, respectively. However, berry weights were similar in the PS (1.74 g) and PSP (1.72 g) treatments, while the control group (1.85 g) had the highest values statistically. In both years, the control group consistently caused the highest berry diameter (12.37 mm) and length (15.45 mm) values. In the second year of the study, it was noted that the cluster number value was lower than expected despite a high cluster weight value. This difference was due to a high load per vine (150 buds per vine) during the first year, resulting in decreased bud fertility and lower yield in the following year. The findings of this study are supported by another study by Teker and Altındisli (2021). In addition, this study showed that shading covers, typically considered to have a negligible impact on yield, can result in variations in berry weight, like in the previous study (Miccichè et al., 2023).

Table 1. Effects of uncovered (C), partial shading net (PS), and partial shading net + polyethylene (PSP) on yield components of 'Sultan 7/ 1103P' grapevines[abc].

| | | Vine Yield (kg vine$^{-1}$) | Cluster | Cluster Weight (g) | Berry Weight (g) | Berry Diameter (mm) | Berry Length (mm) |
|---|---|---|---|---|---|---|---|
| 2019 | C | 17.83 ± 2.36 | 53.11 ± 5.91 | 337.19 ± 38.09 | 1.85 ± 0.13 | 12.03 ± 0.24 | 15.31 ± 0.31 ab |
| | PS | 18.38 ± 2.21 | 50.65 ± 7.45 | 394.66 ± 32.74 | 1.77 ± 0.15 | 11.56 ± 0.54 | 14.72 ± 0.72 bc |
| | PSP | 20.24 ± 2.63 | 57.26 ± 6.83 | 373.95 ± 36.30 | 1.74 ± 0.18 | 11.19 ± 0.37 | 14.19 ± 0.61 c |
| 2020 | C | 18.24 ± 2.89 | 43.01 ± 6.38 | 436.18 ± 98.76 | 1.85 ± 0.12 | 12.72 ± 0.25 | 15.60 ± 0.28 a |
| | PS | 19.54 ± 1.79 | 44.90 ± 4.01 | 438.21 ± 53.38 | 1.72 ± 0.06 | 12.26 ± 0.50 | 15.44 ± 0.59 a |
| | PSP | 19.12 ± 2.98 | 45.63 ± 4.35 | 423.49 ± 83.22 | 1.70 ± 0.12 | 12.50 ± 0.21 | 15.69 ± 0.35 a |
| Mean (T) | C | 18.04 ± 2.65 | 48.06 ± 7.93 | 386.68 ± 89.73 | 1.85 ± 0.12 A | 12.37 ± 0.42 A | 15.45 ± 0.33 A |
| | PS | 18.96 ± 2.09 | 47.77 ± 6.26 | 416.43 ± 49.34 | 1.74 ± 0.12 B | 11.91 ± 0.63 B | 15.08 ± 0.75 A |
| | PSP | 19.68 ± 2.90 | 51.45 ± 6.70 | 398.72 ± 72.34 | 1.72 ± 0.15 B | 11.85 ± 0.72 B | 14.94 ± 0.90 B |
| Years (Y) | 2019 | 18.82 ± 6.97 | 53.67 ± 2.57$^{A}$ | 368.60 ± 43.14$^{B}$ | 1.78 ± 0.16 | 11.59 ± 0.53$^{B}$ | 14.74 ± 0.73$^{B}$ |
| | 2020 | 18.97 ± 5.14 | 44.51 ± 2.66$^{B}$ | 432.62 ± 80.94$^{A}$ | 1.75 ± 0.12 | 12.49 ± 0.39$^{A}$ | 15.57 ± 0.44$^{A}$ |
| *p-value* | T | ns | ns | ns | * | * | * |
| | Y | ns | * | * | ns | * | * |
| | T*Y | ns | ns | ns | ns | ns | * |

[a]Values in each column are indicated mean ± standard deviations of the mean.
[b]ns shows non-significant; * indicates p value ≤ 0.05
[c]T and Y indicate 'Treatments' and 'Years', respectively.

There is a divergence of opinions concerning the influence of partial cover or shading applications on vine yield. However, the reported studies do not present a universally applicable paradigm regarding the impact of shading nets on vine yields (Pallotti et al., 2023). Some findings of previous studies indicate that there was no statistically significant decrease in total yield in Cabernet Sauvignon grapevines when covered with a 60% shading net at full fruit set, despite only a 10% decrease in yield (Martínez-Lüscher et al., 2020). A study in Australia on Syrah grapevines indicated no difference in total yield with a 62% shading capacity treatment (white cloth above the canopy) compared to the control group (Caravia et al., 2016). Conversely, some studies claimed that covering material like green or white net decreases the vine yield (Miccichè et al., 2023).

On the other hand, some studies showed that shading covers exceeding 70% coverage on cluster zones are positively correlated with an increase in marketable yield (Cataldo et al., 2022). Scafidi et al. (2013) found that artificial shading increased berry weight in the Grillo cultivar. Findings in the present study indicate that the control group yielded the heaviest berries while covering treatments such as PS and PSP decreased berry weight.

**Healthy and unhealthy clusters**

As part of the research, three groups of grape clusters were analyzed, and one of them was kept as the control group while the other two were treated with PS and PSP. After the harvest, the results revealed that 58.1% of the grape clusters in the control group were healthy, whereas 26.40% showed sunburn (SN) symptoms and 17.1% displayed late-season dehydration (LSDN) symptoms (mean values of the years). According to the visual analysis, 72.5% of grape clusters in the PS group were found to be healthy, with 17.50% displaying SN symptoms and 9.02% showing LSDN symptoms. In contrast, the PSP group had 63.60% healthy grape clusters, while 19.6% exhibited SN damage and 16.7% displayed LSDN symptoms (Figure 5). Therefore, the main effects of the treatments indicate that the PS treatment had the highest percentage of healthy clusters (72.50%), while the control group (58.10%) and PSP (63.60%) had the lowest percentage in the same category, statistically.

Additionally, the PS treatment showed the lowest incidence of grape berries affected by LSDN (9.0%) in both years. The study observed an increase in LSDN-affected berries in both the control group and PSP treatment. The control group showed the highest percentage of berries affected by SN damage, while both the PS and PSP treatments had similar SN damage levels, resulting in statistical grouping. In reviewing the data over the study years, it is evident that the number of healthy clusters in all treatments decreased from the first year to the second year. Similarly, there was an increase in clusters showing LSDN symptoms and SN damage. This variation can be attributed to the warmer and drier weather in 2020.

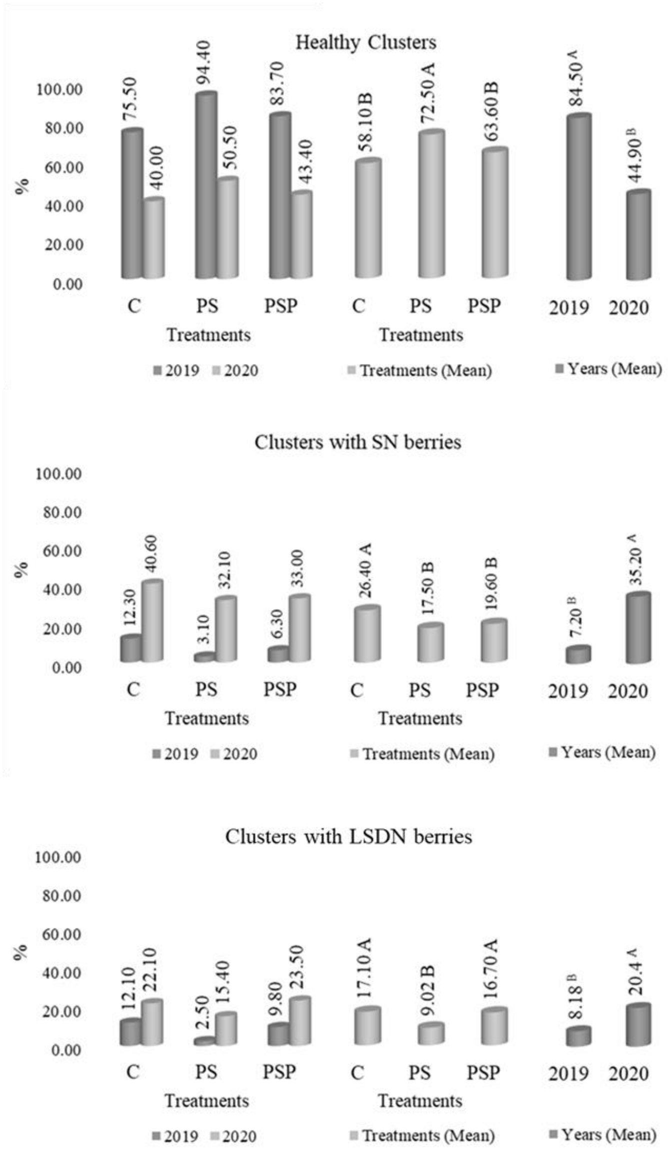


Figure 5. Comparison of uncovered, partially shading net (35%), and shading net (35%) + polyethylene (PSP) on healthy clusters, sunburned (SN) clusters, and LSDN clusters in the total harvested clusters, as a percentage (%). The uppercase values indicate statistically significant differences in treatments and study years ($p \leq 0.05$).

Previous studies showed that water loss in grape berries can be prevented by covering the cluster zone with shading material, effectively preventing the shriveling of grape berries (Lobos et al., 2015; Caravia et al., 2016). The quantity of berry dehydration was reduced by half when the Touriga Nacional vines cluster zone was shaded after fruit set and veraison (Oliveira et al., 2014). Likewise, it was noted that shaded Cabernet Sauvignon clusters exhibited significantly lower fruit damage and dehydration compared to exposed clusters (Martínez-Lüscher et al., 2020). As in these studies, the present study shows that PS treatment has a positive impact on reducing berry dehydration, particularly in comparison with the control group.

## CONCLUSION

In recent years, Sultan 7 (*Vitis vinifera* L.) grapes have emerged as the preferred cultivar for seedless grape production. The grape variety is favored for its high yield in the Aegean Region of western Türkiye. However, the cultivar is prone to late-season dehydration during its final growth stages of grape berries. Previous studies indicated that this occurs because of an excessive cluster yield due to overloaded buds. Overloaded grapevines may be more susceptible to adverse weather conditions during the summer, particularly when temperatures reach 38°C or higher. As a result of this condition, grape berries may lose their water content by the end of the season, resulting in symptoms of late-season dehydration.

This research underscores the significance of preserving healthy grape clusters and shielding them from the adverse impacts of air and vine canopy temperatures. Compared to the first year of the study, there was a 39.6% decline in healthy clusters in 2020, the warmest year. Furthermore, there was a 12.2% rise in late-season dehydration issues and a 28.0% increase in clusters affected by sunburn across all applications. These shifts were linked to temperature factors, increasing late-season dehydration, and sunburn problems on grape berries. As such, viticulturists must adopt adaptive strategies to mitigate the adverse effects of high temperatures and other environmental stressors on vineyards.

Regulating optimal canopy temperatures, with particular attention to the vine canopy, is important to mitigate late-season dehydration in grape berries. The findings of the present study will be valuable for future research on exploring different ratios of shading materials exceeding 35%. Fully covered canopy systems may be more effective in preventing grapevine berries from late-season dehydration symptoms than partial coverings. It is also essential to assess the potential impact of covering the sides of the canopy (especially for cluster zones) to gain a more comprehensive understanding and mitigate late-season dehydration symptoms.

**Compliance with Ethical Standards**

**Peer-review**

Externally peer-reviewed.

**Conflict of interest**

The authors declare no competing, actual, potential, or perceived conflict of interest.

**Author contribution**

TT conceived, designed, and performed the experiment; analyzed the data; wrote the paper. OS designed and performed the experiment analyzed the data, and reviewed the article. ETÖ assisted with the measurements in the experimental vineyard. All authors read and approved the manuscript.

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