CENTENARY OF THE OIV
45th WORLD CONGRESS OF VINE AND WINE
14-18 OCTOBER 2024 FRANCE-DIJON
Available on IVES Conference Series vine & wine
DOI : https://doi.org/10.58233/d0Y4MujM

Shading nets for the adaptation to climate change: effects on vine physiology and grape quality

Paolo Storchi[1], Marco Ammoniaci[1], Sergio Puccioni[1], Alessandra Zombardo[1], Simone Garavelloni[1], Paolo Valentini[1], and Rita Perria[1]

[1] Council for Agricultural Research and Economics, Research Centre for Viticulture and Enology, Viale Santa Margherita 80, 52100 Arezzo, AR, Italy

Abstract. Viticulture is increasingly threatened by climate change since higher temperatures and heat waves negatively affect the vines' performance and alter grape production. Shading nets represent an interesting adaption strategy to reduce abiotic stresses thanks to their protective effects on the canopy microclimate. This study investigates the impact of shading nets with two different shading capacities (18% and 40%, respectively) on the production and quality of Sangiovese grapes cultivated in Montalcino, Tuscany (Italy). The shading nets made it possible to reduce the internal temperatures of the berries in the hottest hours of the summer months. The vines covered with shading nets produced grapes with higher yields and berry weights due to lower cluster dehydration. The grapes had lower sugar concentrations while maintaining higher levels of total acidity in musts and had an improved phenolic composition. According to the results, shading nets emerged as an effective tool for modulating factors influencing grape physiology and maturity dynamics and preserving grape quality even in case of extreme weather events.

1. Introduction

The physiology and productivity of the grapevine (*Vitis vinifera* L.) are influenced by the climatic conditions of the growing environment, where temperature and light play a leading role in modifying the plant response. In the scenario of climatic changes, radiative excess, correlated to the increase in the air temperature, can subject the photosynthetic system to light saturation and cause a drastic reduction in efficiency, giving rise to chronic photoinhibition phenomena. In addition, high berry temperatures cause alteration in the content of phenolic substances in the berries. The ripening behaviour also undergoes evident alterations, including excessive sugar accumulations and lowering organic acids. In recent years, shade treatments have been applied to the vine canopy to overcome these issues [1-2].

This study aims to determine how two different artificial canopy shadings (black nets with 18% and 40% shading capacities, respectively) can affect the vines' vegetative growth and preserve the quality of the grapes in *Vitis vinifera* cv. Sangiovese, compared to vines exposed to natural light radiation.

2. Materials and methods

2.1. Vineyard characteristics and experimental plan

The experimental trial was conducted in a commercial Sangiovese (*Vitis vinifera* L.) vineyard located in the DOCG Brunello di Montalcino (Tuscany, Italy, 43°04’57’’ N, 12°50’63’’ E, 360 m a.s.l.), during the 2023 growing season. The vines, grafted onto 420A rootstock, were planted in 2005. The rows were oriented N-S on terraced land and spaced 1.00 m within rows and 2.80 m between the rows. Vines were VSP trained, and spur pruned (10 buds/vine). The vineyard was not irrigated.

The trial was set up with a triplicate design based on three different treatments. After the fruit set (BBCH 75, berries pea-sized) up to the harvest, the cluster area of vine canopies (3 rows each treatment and replicate) was covered with 1-meter-high shading nets with two shading capacities (Fig.1): 18% (SC 18) and 40% (SC 40). The other rows were left uncovered (SC 00) as a control.

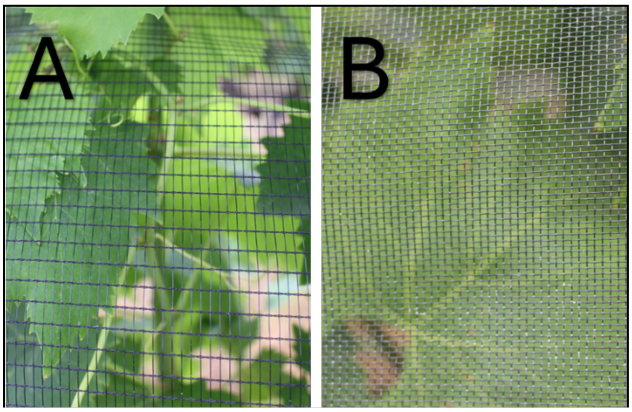


Figure 1. Texture of the nets applied with 18% (A) or 40% (B) shading capacity.

2.2. Environmental and physiological measurements

To monitor the difference in the canopy interception as photosynthetically active radiation (PAR, µmol/m^2/s) that reached the leaves under the nets or externally, an AccuPAR ceptometer LP-80 was used. The light bar (80 cm) was placed at the cordon height in a parallel position to the row.

The PAR was measured on two dates (July 13 and August 17) at 10:00, with nine replicates per treatment.

The berry temperatures (°C) were continuously recorded from August 18 to August 23 using four thermocouples (microprobes with 0.7 mm diameter) inserted directly into berries and connected to three data loggers per treatment. Once the data were downloaded, the average T max and T min of the measurement period were calculated.

The leaf chlorophyll content was measured as SPAD units using a SPAD-502 Plus meter (Konica Minolta) on five dates during the vegetative season (from July 4 to August 17) on thirty replicates of five adult leaves of the cluster area per treatment.

The chlorophyll fluorescence was measured on three dates (July 13, August 2, and August 17) between 11:00 am and midday, using a Handy Pea chlorophyll fluorimeter (Hansatech Instruments) on eighteen adult leaves of the cluster area per treatment. The leaves were dark-adapted for 30 minutes with proper plastic clips and then subjected to a saturating light pulse (duration 1 s, intensity 3000 µmol/m^2/s, wavelength 650 nm) to collect the data.

2.3. Production and grape quality

At the harvest, the yield (as average production per vine) was assessed. A sample of 200 berries from each treatment (central row) was collected in triplicate, resulting in 27 samples. After weighing the berries to determine their average weight, half were analyzed to assess the grapes' technological maturity (sugar content, titratable acidity, and pH) using official OIV methods and the organic acids content by HPLC-DAD [3]. The remaining berries were used to determine phenolic maturity indices by spectrophotometry, following the method described by [4], and to analyze polyphenol profiles by HPLC-DAD [5].

3. Results and discussion

3.1. Canopy interception and berry temperatures

As expected, there was a statistically significant difference in the canopy interception between the incident PAR that reaches the leaves under the two kinds of shading nets or in the control (Fig.2). Therefore, the collected data showed that both types of nets applied, in proportion to their shading capacity, can filter the light that reaches the productive zone of the covered vines.

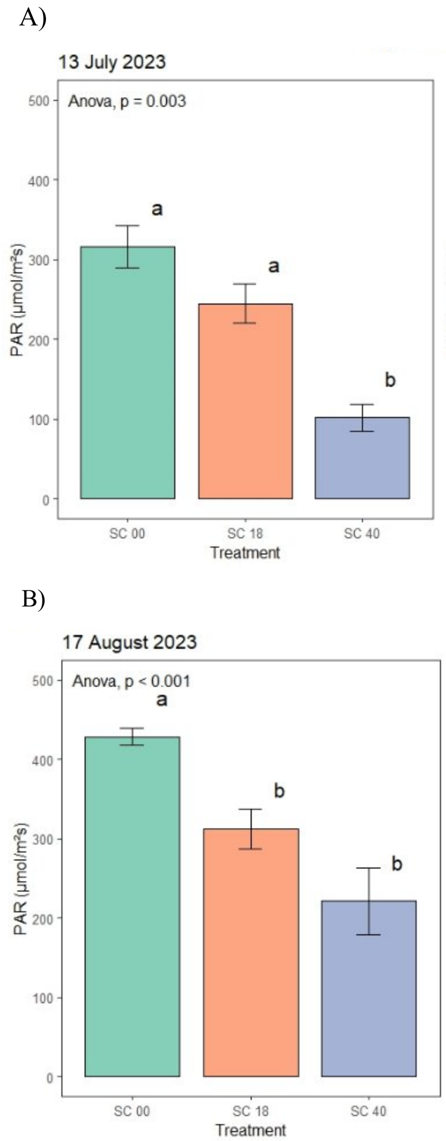


Figure 2. Canopy interception (PAR, µmol/m^2/s) measured on July 13 (A) and August 17 (B). Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA ($p<0.05$) and Tukey post-hoc test.

The thermal monitoring of the berries showed a substantial difference in the temperature variation between day and night (T min) in the three treatments considered (Tab.1). In particular, the control (SC 00) had a higher delta, while the vines covered by nets (SC 18 and SC 40) maintained more constant temperatures inside the berries.

During the day, in correspondence with the hours of maximum incidence of sunlight on the clusters (T max, 9:30-10:30), the control reached significantly higher temperatures (on average 3-4 °C) compared to both the treatments with the shading nets (Tab.1).

The differences were then not significant between the treatments when the sunlight no longer had direct contact with the productive zone due to the natural shading of the canopy (data not shown).

Table 1. Average T max (9:30-10:30) and T min (5:00-6:00) of berry temperatures continuously measured in the period August 18 – August 23. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (*** = p<0.001) and Tukey post-hoc test.

Treatment	T max	T min
SC 00	39.1 a	17.7 b
SC 18	36.1 b	19.2 a
SC 40	35.3 b	19.7 a
Significant	***	***

3.2. Leaf chlorophyll content and photosynthetic efficiency

As for the leaf chlorophyll content, statistically significant differences emerged between the treatments on all five measurement dates, especially comparing the uncovered control and the rows with the two types of nets (Fig.3). The lower chlorophyll content was also detectable by visual inspections: the hue tended towards dark green in SC 40 leaves, decreased in green intensity in SC 18, and turned towards yellow in SC 00, as typical of Sangiovese, a near-anisohydric grapevine variety [6], in case of abiotic stress onset.

To evaluate the photosynthetic efficiency of the vines, among the parameters acquired by the fluorimeter, the following two were considered: the variable fluorescence (Fv), calculated as the difference between the maximum fluorescence (Fm) and the minimum fluorescence (F0), and the performance index on absorption basis (PI ABS), a multiparametric index that describes the efficiency of photosystem II [7]. The results highlighted significantly different values between the treatments. In particular, the vines covered showed better photosynthetic efficiency values than the control (Fig.4), indicating that the shading nets can better preserve the functionality of photosystem II within the leaf structures.

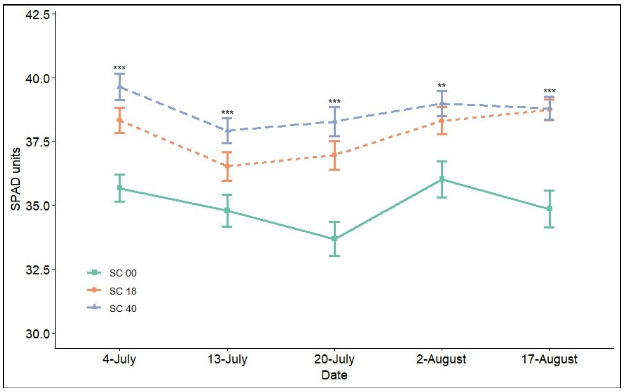
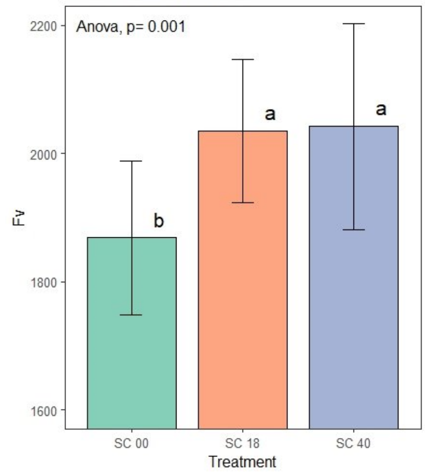


Figure 3. Leaf chlorophyll content recorded as SPAD units on five dates during the vegetative season 2023. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (*** = p<0.001; ** = p<0.01).

A)



B)

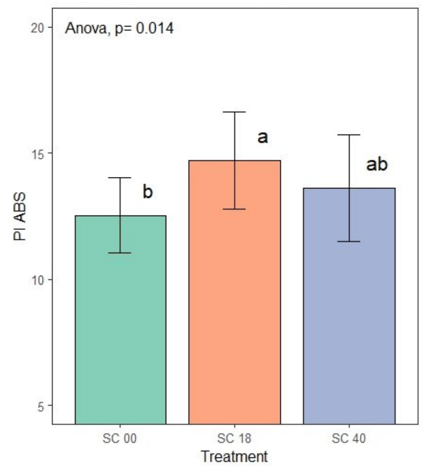


Figure 4. Photosynthetic efficiency of the leaves. Averages values of variable fluorescence (Fv) and performance index (PI ABS) of three measurement sessions. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (p<0.05) and Tukey post-hoc test.

3.3. Yield and technological maturity of the grapes

On the harvest date established by the host winery (September 25), some production parameters were evaluated. The yield was significantly higher in the vines covered with the 40% shading nets, intermediate values were found in the vines with the 18% shading nets, and lower values in control plants (Fig.5, left panel). Moreover, the shaded vine treatments (SC 18 and SC 40) produced berries with weights significantly higher than the control (Fig.5, right panel). This result highlights the role of the nets in protecting the grapes from dehydration, which is especially important in the final stages of ripening [8].

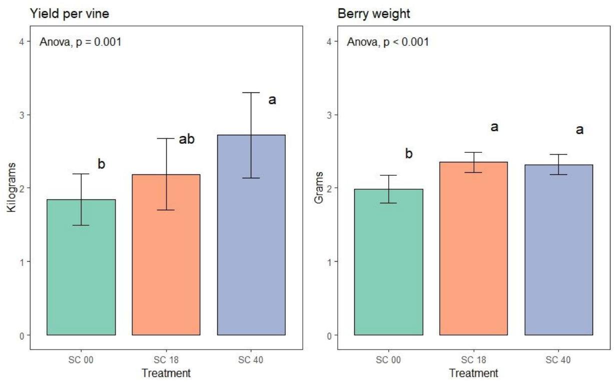


Figure 5. Grape yield (as average production per vine) and berry weight. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA ($p<0.05$) and Tukey post-hoc test.

As for technological maturity, the grapes harvested from the vines with shading nets had lower sugar contents and higher titratable acidity (Tab.2). Since no significant differences were found in tartaric acid contents between the three treatments, the higher acidity was a consequence of increased malic acid concentrations both in SC 18 and SC 40 (Tab.3).

Table 2. Technological maturity of the grapes. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (* = $p<0.05$; ns = not significant) and Tukey post-hoc test.

Treatment	Sugars (°Brix)	Titratable acidity (g/L)	pH
SC 00	23.1 a	6.23 b	3.33
SC 18	22.3 ab	6.58 ab	3.34
SC 40	21.9 b	6.89 a	3.32
Significant	*	*	ns

Table 3. Organic acids content (HPLC-DAD) of the grapes. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (*** = $p<0.001$; * = $p<0.05$; ns = not significant) and Tukey post-hoc test.

Treatment	Tartaric acid (g/L)	Malic acid (g/L)	Citric acid (g/L)
SC 00	6.36	1.50 b	0.24 b
SC 18	6.47	1.78 ab	0.24 b
SC 40	6.39	2.05 a	0.27 a
Significant	ns	***	*

3.4. Grape quality and phenolics content

As for phenolic maturity (Tab.4), no significant differences were detected in both total and extractable anthocyanins between the treatments. However, the anthocyanin profile of control grapes (SC 00) was characterized by a higher percentage of cyanidin-3-O-glucoside at the expense of the malvidin-3-O-glucoside content. The situation is the opposite in the grapes covered with the nets (SC 18 and SC 40), where malvidin-3-O-glucoside reached over a third of the total percentage (Tab.5). This can be a desired result since higher concentrations of trisubstituted colouring pigments boost the production of wines with a more stable color intensity over time [9-10].

The index of total polyphenols (IPT) was higher in SC 00, but the contribution to the final concentration was mainly due to the seeds that were less ripe at harvest (Tab.4). The protection from sunlight guaranteed by the nets (both the 18% and 40% shading capacities) also slowed the accumulation of flavonols. At harvest, the concentrations of quercetin glucoside were lower (about 30% less) in the covered grapes (Tab.5), a very positive aspect in Sangiovese, a cultivar that has problems with wine precipitates during aging [11].

Table 4. Phenolic maturity of the grapes. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (** = $p<0.005$; * = $p<0.05$; ns = not significant) and Tukey post-hoc test.

Treatment	Total Anth. (mg/Kg)	Extr. Anth. (mg/Kg)	IPT (DO 280 nm)	Extractab. %	Seed mat. %
SC 00	1125	672	51.0 a	39.9	47.2 a
SC 18	1089	628	43.2 b	41.9	42.0 b
SC 40	1025	605	42.1 b	40.9	42.5 b
Significant	ns	ns	**	ns	*

Table 5. Anthocyanin profiles and phenolics of the grapes. Treatments: SC 00 = control; SC 18 = 18% shading capacity; SC 40 = 40% shading capacity. Data subjected to one-way ANOVA (*** = p<0.001) and Tukey post-hoc test.

Treatment	Quercetin glucoside (mg/Kg)	Cyanidin-3-O-glucoside (%)	Malvidin-3-O-glucoside (%)
SC 00	147 a	27.6 a	27.0 b
SC 18	114 b	22.9 b	32.5 a
SC 40	98 b	21.1 b	34.0 a
Significant	***	***	***

4. Conclusions

The different light and temperature conditions due to the presence of both the shading nets (18% and 40% of shading capacity) had a beneficial impact on the photosynthetic performance of the vines during the vegetative season, especially during berry formation and ripening.

As for the grape quality, a lower berry dehydration rate allowed to reduce the sugar content and maintain a good level of acidity in the berries while improving the phenolic composition.

According to our results, shading nets are an excellent tool to use in the vineyard to fight climate change, especially for protecting the crop in case of extreme temperatures and heat waves.

Despite the considerable costs to be borne for shading nets, further positive aspects of the installation (not investigated in our trial) are related to the protection from hail and unwelcome wildlife within the vineyard.

5. Acknowledgements

The research was carried out with the financial support of Biondi Santi srl in Montalcino (Tuscany, Italy).

The authors want to thank Dr. Federico Radi, Dr. Sofia Simoni, and Dr. Antonio Piccinno from the Biondi Santi Winery that kindly hosted the experimental trials.

6. References

1. L. Pallotti, O. Silvestroni, E. Dottori, T. Lattanzi, V. Lanari, OENO One 57-2, 467-476 (2023)
2. D. Micciché, M.I. de Rosas, M.V. Ferro, R. Di Lorenzo, S. Puccio, A. Pisciotta, Front. Plant Sci. 14, 1210574 (2023)
3. V. Ivanova-Petropulos, D. Petruševa, S. Mitrev, Food Anal. Methods 13(5), 1078-1087 (2020)
4. N. Saint-Cricq de Gaulejac, N. Vivas, Y. Glories, Rev. Fr. Oenol. 173, 22-25 (1998)
5. S. Gòmez-Alonso, E. Garcia-Romero, I. Hermosìn-Gutierrez. J. Food Compos. Anal. 20, 618-626 (2007)
6. A. Palliotti, S. Tombesi, T. Frioni, F. Famiani, O. Silvestroni, O. Zamboni, S. Poni, Funct. Plant Biol. 41(6), 634-647 (2014)
7. F. Bussotti, M.H. Kalaji, R. Desotgiu, M. Pollastrini, K. Bosa, Misurare la vitalità delle piante per mezzo della fluorescenza della clorofilla (Firenze University Press, 2012)
8. L. Caravia, C. Collins, P.R. Petrie, S.D. Tyerman, Aust. J. Grape Wine Res. 22, 422-437 (2016)
9. M. Squadrito, O. Corona, G. Ansaldi, R. DI Stefano, OENO One 44(3), 167-177 (2010)
10. V. Cheynier, M. Duenas-Paton, E. Salas, C. Maury, J.M. Souquet, P. Sarni-Manchado, H. Fulcrand, Am J Enol Viticult 57(3), 298-305 (2006)
11. T.C. Somers, G. Ziemelis, Vitis 24, 43-50 (1985)