Bunch protection techniques against thermal increase linked to climate change

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Abstract. Increases in temperature and solar radiation, associated with climate change, can cause damage to the berry that causes processes of discoloration, dehydration, cracking or raisining, which can have a negative impact on the oenological potential of the harvest. This damage is called "sunburn" and occurs with some frequency in sensitive varieties such as Graciano. In order to mitigate these impacts, a shading technique has been proposed using protection nets that try to prevent the bunches from receiving excessive sun exposure. The experience shown in this work has been carried out during the years 2021 and 2022, using nets with shading capacity of 50% and 70%. The results have shown that the nets have significantly reduced the temperature of the bunch, also avoiding damage from sunburn. Besides, the organic acid content of the must has reached slightly higher values in the treatments with netting, compared to the control, but not significantly. In wine, the polyphenolic load has shown a variable behavior depending on the year, possibly conditioned by the variations in yield linked to the sunburn. The tasting panel has shown a certain inclination towards the wines from the net treatments in both campaigns.

1 Introduction

Nowadays, climate change is a reality that few people doubt and that refers to the alteration of the climate due, directly or indirectly, to human activity that modifies the composition of the atmosphere, affecting among other aspects the distribution and development of vegetation and ecosystems. It is true that the climate is cyclical and that historically on our planet there have been periods of time with changing environmental scenarios. The problem is that these cycles are accelerating with great intensity and, for most living beings, it is difficult to adapt to this fast pace.

The vine is not an exception, and the modification of the climate of a region can condition both the characteristics of the must and the wine obtained as well as their quality and typicity, since variations in parameters such as radiation, temperature or the rainfall regime that they bring along with climate change, directly affect the development and physiology of the plant [1].

Probably, one of the consequences of climate change with the greatest impact on viticulture is the increase in temperature [2]. In general, this increase in temperature tends to bring about an advance in the sugar accumulation process in the berry, causing ripening to occur in a warmer period of the cycle and thus causing imbalances in the fruit that can harm certain qualitative properties such as color, acidity or organoleptic characteristics of must and wine [3]. In addition, it must be considered that the bunches are quite sensitive to high temperatures and that, in situations of severe stress, they could reach temperatures up to 15 °C higher than the air due to lack of transpiration. Likewise, there is an indicator, such as the number of days with maximum temperatures above 35 ºC, which is being intensified with climate change, correlating to a large extent with negative physiological effects on the vine [4].

All these effects, linked to the increase in summer temperatures, are more noticeable in some especially sensitive varieties such as Graciano which, under certain growing conditions, are susceptible to sunburn, a damage that causes yellow discoloration of the berries, golden or brown, sometimes being accompanied by its dehydration that can even cause cracking or raisining [5].

In this situation, we need to find mechanisms and tools in viticulture that respond to this new scenario, proposing appropriate solutions for these new conditions. One of the crop management alternatives, which prevents the bunches from receiving excessive exposure, is the use of shading nets, with a protective capacity against ultraviolet radiation, installed to avoid both the effects of high temperatures and direct impacts that these can cause to the clusters [6-7].

In the present work, we have tried to analyze the effect of these shading nets to mitigate the impact of high temperatures on the vine and, specifically, on the

Graciano variety, also characterizing the incidence on yield, on the composition of the grape and wine and its organoleptic characteristics.

2 Material and methods

The work has been carried out in a vineyard located in Cenicero (La Rioja), owned by Bodegas La Rioja Alta, planted in 2016 with the Graciano variety on the SO4 rootstock and conducted in a double Royat cordon with a plantation frame of 2.60 x 1.20 m. The trellis lines are arranged in a north-south orientation, with a deviation of -35º.

The trial has been carried out during the 2021 and 2022 campaigns. In the first one, three treatments were established: C- control; N50- 50% shading nets and N70- 70% shading nets. In 2022, it was decided to expand the experience with two more treatments, PN50 and PN70, in which the placement of the nets was partial in time, removing it two weeks before the harvest date, in order to see if, in this way, the phenolic ripening of the grapes could be improved, maintaining the protection during the ripening period. In all treatments with net, it was made of high-density polyethylene, with protection against ultraviolet radiation, and with a height of one meter, placed on the west face of the trellis, after the vine set, mainly protecting the area of clusters exposed to the afternoon sun. The treatments were raised with three repetitions and thirty vines per repetition.

The influence of the shading net on the bunch temperature has been evaluated through measurements with a thermographic camera (Testo® 885). This camera offers a thermal image of the objects it visualizes based on their infrared radiation emissions, where each pixel provides temperature data, obtaining the temperature of the entire surface of the photographed cluster and not just of a specific point. Three moments were considered to analyze the temperature of the bunches of the different treatments, all of them between the phenological stages of veraison and maturation: on August 5 and 25 and September 27 in 2021 and on July 20 and 10 and 30 August in 2022. In the first year, the measurement of August 5 was carried out centered at 12:30 p.m., without the sun yet hitting the west face of the trellis, while the remaining two were taken at 5:30 p.m., to analyze the thermal effect on this face when receiving sunlight. In 2022, with the previous experience of the 2021 campaign, it was decided to take measures in the two time slots for each of the analyzed days. Mean bunch temperature data were obtained from five images per treatment, repetition and time and day of measurement.

At harvesting time, for each treatment and repetition, the following production components were evaluated: the unit yield (kg/vine), the number of bunches per vine, the average weight of the bunch (g) and the weight of 100 berries (g). Likewise, berry samples were collected in order to analyze the parameters involved in the acidity of the must: pH, malic acid (g/l), tartaric acid (g/l) and potassium (mg/l). Also at harvest, an estimate of the damage produced in clusters by the effect of sunbathing was made. For this, a visual and individual evaluation of all the collected bunches (close to 300 per treatment and repetition) was carried out based on the approximate percentage of affected berries in the total of each bunch, obtaining information on the number of affected bunches and the intensity of that damage in the cluster as a whole.

All the treatments were harvested separately, after which they were microvinified in 100-liter tanks, applying a traditional winemaking for red wines in which the grapes were destemmed, crushed and sulphited, after which they were inoculated with active dry yeasts to achieve a homogeneous and efficient alcoholic fermentation. Subsequently, selected bacteria were applied to induce malolactic fermentation. Once this fermentation was finished, and after stabilizing in cold and sulphiting the wine, the resulting wines were analyzed, determining alcoholic strength (% vol), anthocyanin content (mg/l) and total polyphenol index (IPT 280 nm). Finally, the wines were subjected to an organoleptic analysis by a panel of six expert tasters.

The statistical analysis of the resulting data has been carried out with the IBM® SPSS® statistic program, version 29. Analysis of variance techniques (ANOVA) have been applied in order to find out if there are differences in the different parameters studied depending on the proposed treatment. In the attached tables, the asterisks refer to the level or degree of significance (d.s.). Thus, *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$ and n.s.: not significant. Besides, the different letters that follow the values of each variable serve to reflect the differences between treatments, using Tukey's mean separation test.

3 Results and Discussion

Analyzing the temperatures of the bunches in the different treatments and campaigns studied, it can be observed that they have decreased significantly, on all the dates and time slots studied, due to the protective effect of the shading nets (Table 1). Even at times when the clusters do not directly receive radiation, such as the measurements taken at 12:30 p.m., the network has managed to reduce an average of 1.62 ºC with respect to the control, thus reflecting the continued action of the solar radiation on the clusters that offer greater exposure, as is the case of the clusters of the control treatment.

On the other hand, in the measurements centered at 5:30 p.m., the differences have been much more pronounced, reaching a reduction in temperature, with respect to the control clusters, by more than 6 ºC with the 50% mesh in 2021 and with an average of 3 ºC in the set of the two analyzed campaigns. The differences between the two types of nets have not been significant, although in most cases a greater cooling effect has been achieved with M50 than with M70, despite the fact that the latter treatment theoretically has a higher percentage of shading. Possibly, this was due to a more effective combination of protection and aeration with the 50% net than with the 70% net.

Table 1. Mean bunch temperature (ºC).

Year	2021			2022					
Day	5-Aug	25-Aug	27-Sep	20-Jul		10-Aug		30-Aug	
Hour	12:30	17:30	17:30	12:30	17:30	12:30	17:30	12:30	17:30
C	25,97 a	38,73 a	28,31 a	28,71 a	30,56 a	31,89 a	33,71 a	32,75 a	36,35 a
N50	24,80 b	32,42 c	26,36 b	26,69 b	28,76 b	30,21 b	32,03 b	30,39 b	32,43 b
N70	25,35 ab	33,85 b	26,03 b	27,14 b	29,01 b	30,38 b	32,20 b	30,80 b	32,66 b
d.s.	*	***	***	***	***	***	***	***	***
d.s.	***			***					

The estimation of the damage in clusters due to sunburn has offered very relevant results (Tables 2 and 3). Thus, it was detected that in 2021 slightly more than 10% of the bunches of the control treatment suffered damage from sunburn, to a greater or lesser extent, reaching more than 50% in 2022, a particularly intense year in terms of summer temperatures. Meanwhile, in the treatments in which net was installed, there was barely any deterioration in 2021 and it was around 15% in 2022. In another vein, the total damage to the cluster or affected berries did not exceed 1% in 2021 for the control treatment, reaching almost 13% in 2022. On the contrary, the treatments established with net had an incidence, mostly, below 1%.

Table 2. Bunches damaged by sunburn (%).

	2021	2022	2021	2022
C	10,64 a	53,26 a	1,41 a	12,93 a
N50	0,11 b	18,94 b	0,01 b	1,07 b
N70	0,47 b	14,95 b	0,03 b	0,89 b
PN50	-	15,02 b	-	0,84 b
PN70	-	16,00 b	-	0,91 b
d.s.	***	**	***	**

Table 3. Total cluster damage (%).

	2021	2022	2021	2022
C	10,64 a	53,26 a	1,41 a	12,93 a
N50	0,11 b	18,94 b	0,01 b	1,07 b
N70	0,47 b	14,95 b	0,03 b	0,89 b
PN50	-	15,02 b	-	0,84 b
PN70	-	16,00 b	-	0,91 b
d.s.	***	**	***	**

Considering the values obtained in the productive parameters of the trial (Table 4), it should be noted that few differences have been observed in 2021 for the set of determined components. On the contrary, in 2022 the unit yield (kg/vine) significantly affected the control, which suffered an average decrease of close to 30% with respect to the rest of the treatments covered with net. In this sense, the damages due to sunburn in the control treatment were especially severe in this campaign, affecting mainly to the weight of the bunch, due to relevant losses suffered by wilting, burning or drying. This quantitative depreciation of the bunch must be considered, to a large extent, in order to subsequently interpret its possible incidence on the qualitative values obtained in the must and in the wine.

One of the parameters that could be most affected by the action of shading is the acidity (Table 5) and, specifically, the malic acid accumulated in the berry. This organic acid limits its synthesis with temperatures above 38 ºC and, in addition, its content decreases from veraison, either by its transformation into sugars or by respiratory combustion, which is accelerated by particularly high temperatures or by prolonged exposures. Although, in principle, it could be interpreted that the action of the shading net would have some influence on an increase in the malic acid content with respect to the control, the results in the must show a substantial significant variation of it only in 2022, although it is true that the trend observed in 2021 also indicated a slight increase in malic acid related to net protection. On the other hand, tartaric acid, the other most important organic acid in the grape along with malic acid, has offered closer values between treatments, with the control being slightly higher in 2021 and the net treatments in 2022.

In any case, the real acidity of the must, in terms of pH, has not been significantly altered by the effect of the shading net. It is only worth noting the value of the potassium cation content in 2022, which has increased in the cases in which shading net has been applied, although in a variable way between repetitions, which has caused the differences to be non-significant.

According to Smart *et al.* [8], the shaded microclimate causes the accumulation of potassium in the shoots before veraison, subsequently affecting high levels of this element in the berry. However, this situation refers to a more complete shading, which includes clusters and the rest of the vegetation. This is not the case in this experience, where the vegetation above the cluster zone has remained unprotected by the net. Therefore, other alternative physiological hypotheses can be considered, linked to a summer of severe thermal stress, such as those that imply the regulation, through the phytohormone abscisic acid, of the charge of potassium cations by the xylem [9].

Table 4. Production Components.

	Nº bunches/vine		Kg/vine		Bunch weight (g)		Weight 100 berries (g)	
	2021	2022	2021	2022	2021	2022	2021	2022
C	11,06	12,23	3,08	3,48 b	278,56	288,01 b	161,87	143,15
N50	11,22	12,89	3,21	4,50 a	286,20	349,37 a	158,70	148,18
N70	11,05	11,83	3,15	4,21 ab	284,20	357,07 a	161,57	141,67
PN50	-	13,24	-	4,88 a	-	368,93 a	-	149,80
PN70	-	11,96	-	4,40 ab	-	367,56 a	-	150,78
d.s.	n.s.	n.s.	n.s.	*	n.s.	*	n.s.	n.s.

Table 5. Must acidity parameters.

	pH		Tartaric acid (g/l)		Malic acid (g/l)		Potassium (mg/l)	
	2021	2022	2021	2022	2021	2022	2021	2022
C	3,34	3,57	7,30	7,01	1,25	0,81 b	1308,64	1596,67
N50	3,39	3,63	6,80	7,32	1,37	1,11 a	1391,28	1845,37
N70	3,40	3,66	6,87	7,19	1,35	1,12 a	1380,80	1815,97
PN50	-	3,68	-	7,29	-	1,19 a	-	1923,15
PN70	-	3,65	-	7,16	-	1,13 a	-	1811,25
d.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.

Table 6. Wine quality parameters.

	Alcoholic strength (% vol)		TPI 280 nm		Anthocyanins (mg/l)	
	2021	2022	2021	2022	2021	2022
C	12,72	13,07	49,86	59,33	763,7	738,60
N50	13,02	12,77	50,02	53,78	835,5	640,87
N70	12,87	12,90	49,94	51,51	799,6	608,67
PN50	-	12,83	-	54,91	-	661,57
PN70	-	13,18	-	55,92	-	643,17
d.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

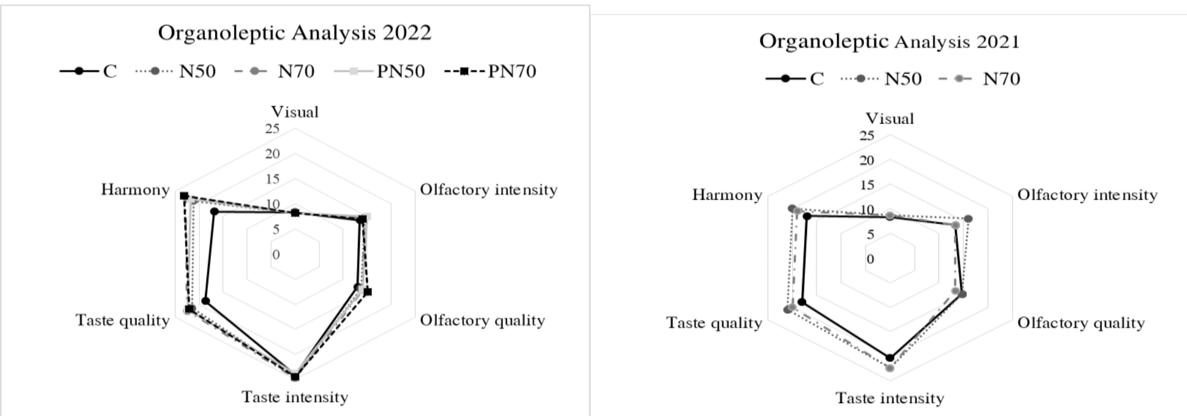

Figure 1. Organoleptic analysis of wine.

Regarding the quality parameters of the wine analyzed, which have been considered to have some relevance in the treatments of this trial (Table 6), the alcoholic degree did not show significant differences in either of the two years studied. Even in 2022, a campaign in which the control suffered a considerable loss of unit yield, it did not correspond to an increase in the accumulation of sugars, perhaps because the high thermal stress suffered limited said accumulation.

Besides, the polyphenolic load of the wine has not shown significant variations either, although in 2021 the anthocyanin content was increased by shading, detecting an inverse effect in 2022. Similarly, the IPT 280 has not made it possible to clearly discriminate between treatments. Consequently, and although the net may have exerted a protective impact on the grapes against the degradation of anthocyanins by high temperatures, such as those observed in 2021, the values obtained in the following vintage do not guarantee this consideration.

Despite the fact that the analytical data of the must and the wine have not shown conclusive results between the treatments analysed, the organoleptic assessment of the wine, carried out by a panel of expert tasters, has indeed revealed a notable preference for wines from net treatments. In this sense, sensory analysis has been more decisive than chemical analysis, at least for the overall two years considered. Globally, the treatments that provide shading, either totally or partially over time, have shown a positive global assessment above the control, mainly highlighting aspects related to taste quality and wine harmony (Fig. 1).

4 Conclusions

The experience of shading bunches has allowed to verify, above all, the protective role of the nets used and their ability to significantly reduce the temperature of the bunch in the summer stage. Likewise, in extremely hot campaigns such as the one that occurred in 2022, which are becoming more frequent due to climate change, sun damage on the Graciano variety has been minimized in a highly significant way, thanks to these nets. In this type of vintage year, with intense thermal stress, shading nets have also managed to mitigate the yield losses observed in the control.

Despite the fact that the results of the must and wine quality parameters have not been very categorical, and it would be necessary to expand the data obtained with a few additional years of experience, the organoleptic analysis has allowed us to clearly differentiate the control treatment from the treatments protected with a net, being better valued the wines from the latter. For this reason, it would be interesting to address, in future works, detailed studies of phenolic composition, which could provide more precise information on how the net works and which compounds exactly it affects and to what extent.

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References

1. C. Van Leeuwen, A. Destrac-Irvine, M. Dubernet, E. Duchêne, M. Gowdy, E. Marguerit, P. Pieri, A. Parker, L. De Rességuier, N. Ollat, N. *Agronomy* **9**, 514 (2019)
2. I. Ghiglieno, F. Mattivi, G. Cola, D. Trionfini, D. Perenzoni, A. Simonetto, G. Gilioli, L. Valenti, L. *OENO One* **54**(4), 761-777 (2020)
3. M.C. Ramos, F. Martínez de Toda, F. *Eur. J. Agron.* **115**, 126014 (2020)
4. N. Ollat, S. Zito, Y. Richard, P. Aigrain, F. Brugière, E. Duchêne, I. Garcia de Cortazar, J. Gautier, E. Giraud, H. Hannin, J.M. Touzard, B. Bois. *Climatologie* **18**, 3 (2021)
5. S. Ibáñez, L. Rivacoba, E. García-Escudero. *Vida Rural* **511**, 50-58 (2022)
6. M. Oliveira, J. Teles, P. Barbosa, F. Olazabal, J. Queiroz, *OENO One* **48**(3), 179-187 (2014)
7. T. Dufourcq, A. Thomas, F. Lopez, D. Vergnes, C. Feilhes, *Conference: terclim2022. XIVth International Terroir Congress 2nd ClimWine Symposium* (2022)
8. R.E. Smart, J.B. Robinson, G.R. Due, C.J. Brien. *Vitis* **24**, 119-128 (1985)
9. F. Gaymard, G. Pilot, B. Lacombe, D. Bouchez, D. Bruneau, J. Boucherez, N. Michaux-Ferrière, J.B. Thibaud, H. Sentenac. *Cell* **94**(5), 647-655 (1998)