GRAPEVINE SHADING: REDUCING YIELD LOSS AND CHANGING MUST COMPOSITION IN DOURO

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ABSTRACT

The vine growing season of the sub-region of Douro Superior of the Demarcated Region of Douro in Northeastern Portugal is highly stressful due to very low precipitation, intense solar radiation and high average air temperature. Severe desiccation of the berries is a common occurrence that causes yield losses and undesirable characteristics of the produced musts.

We hypothesized that a partial shading of the vine canopy could reduce the berry desiccation and change the must characteristics. We set up and experimental field in the Alto Douro sub-region where a number of hedge rows were shaded over their lowest third, protecting the clusters. Several rows of *Vitis vinifera* L. cv Touriga Nacional were shaded from flowering to berry maturity, an equal number from veraison to maturity, and others left non-shaded.

At maturity, we sampled 10 vines of each treatment and we measured the total leaf area, the yield components (number of cluster per vine, cluster weight, number of desiccated berries per cluster), and the characteristics of the must (pH, Titrable acidity, Probable alcohol, Poliphenol Index, Total Anthocians, Content of Malic Acid).

Shaded plants suffered a reduction on the total leaf area in relation to non-shaded plants and the effect was larger in plants shaded from veraison to maturity. The number of clusters per vine did not show a significant difference among treatments but the shaded plants had heavier clusters, more voluminous berries and very few desiccated berries.

Titrable acidity showed a tendency to increase in musts from shaded plants. The probable alcohol increased in shaded plants relatively to non-shaded ones. Shading reduced the total anthocianins content and the malic acid concentration.

Keywords: *Vitis vinifera*, Douro, Shading, Yield components, Must composition

SUMÁRIO

A estação de crescimento das vinhas na sub-região do Douro Superior da Região Demarcada do Douro no Nordeste de Portugal tem elevado nível de stress devido a baixa precipitação, radiação solar intensa e elevada temperatura média do ar. É comum a forte dissecação dos bagos que leva a perdas de rendimento e a características indesejáveis dos mostos.

Formulamos a hipótese que o sombreamento parcial do copado pode reduzir a dissecação dos bagos e alterar as características dos mostos. Estabelecemos um campo experimental na sub-região do Alto Douro onde vários bardos foram sombreados no seu terço inferior, protegendo os cachos. Bardos de *Vitis vinifera* L. cv Touriga Nacional foram sombreados da floração à maturação, um número igual do pintor à maturação, enquanto outros foram deixados por sombrear.

Na data da maturação, 10 plantas foram amostradas em cada tratamento para determinação da área foliar, dos componentes da produção (número de cachos por videira, peso dos cachos, número de bagos secos por cacho) e das características dos mostos (pH, acidez total, álcool provável, índice de polifenois, antocianinas totais, teor de ácido málico).

As plantas sombreadas sofreram uma redução da área foliar em relação às não sombreadas e o efeito foi maior nas plantas sombreadas do pintor à maturação. O número de cachos por planta não mostrou diferença significativa entre os tratamentos mas as plantas sombreadas tinham cachos mais pesados, bagos mais volumosos e menos bagos dissecados.

A acidez total mostrou tendência para aumentar nos mostos das plantas sombreadas. O álcool provável aumentou nas plantas sombreadas em relação às plantas não sombreadas. O sombreamento reduziu o teor total de antocianinas e a concentração do ácido málico.

Palavras-chave: *Vitis vinifera*, Douro, Sombreamento, Componentes de produção, Composição do mosto

INTRODUCTION

The growing season of the grapevines in the Demarcated Region of Douro (DRD) occurs under generally cloudless skies, high intensity of solar radiation, low precipitation, high air temperature and low relative humidity (APA, 2009). Sunlight, in the whole range of wavelengths, is recognized as the most powerful factor determining morphological and physiological variations (Pollastrini *et al.*, 2010) and the amount of light that reaches the leaves and berries affects vine yield, berry composition and wine quality (Cartechin and Pallioti, 1995). There are several works addressing the effect of low radiation on the grapevines and they concur that the condition reduces cluster weight, berry size and color, the berries have lower anthocyanin and total soluble contents, the must increases in titrable acidity but it accumulates less tartaric and oxalic acids (De Bolt *et al.*, 2008; Marta *et al.*, 2008; Abd El-Razek *et al.*, 2010). However, excess solar radiation can lead to photoinhibition of photosynthesis and cause damage to the photosynthetic apparatus in the leaves that in turn may cause a reduction in photosynthetic rates, leading to less sugar accumulation and possibly delayed ripening (Olmstead, 2005; Bertamini *et al.*, 2007). Under radiation stressful conditions, shading of the grapevines might be beneficial because the photosynthesis is more efficient under diffuse light conditions and diffuse light can penetrate further into the canopy (Petrie *et al.*, 2009). We hypothesized that in DRD, where dehydrated and shriveled berries are found in many seasons, partially shaded grapevine hedges could protect the clusters from the worst effects of very high intensity solar radiation while avoiding a large reduction on the photosynthetic capacity of the plants. We set up and experimental field in the upper region of the DRD to test our hypothesis.

MATERIALS AND METHODS

The experimental field was set up in 2010 in commercial vineyard with 27 year old grapevines (*Vitis vinifera* L., *cv Touriga nacional*) in the Demarcated Region of Douro - Portugal (41º 08' North, 7º 08' West). This is a sloping vineyard, vine hedges oriented East-West, where rows are spaced 2 m apart with 1 m between vines within a row. When the canopies are fully developed, the rows formed a hedge that is maintained at a height of 1.6 m and 0.6 to 0.8 m wide. Weeds were controlled by shallow tillage from budbreak to harvesting.

Randomly, ten rows were shaded from flowering to maturation (S_f), another ten rows shaded from veraison to maturation (S_v), and an equal number of rows were chose as non-shaded treatment (S_0). The lower third, from the ground to about 30 cm above the clusters point of insertion, of the south facing side of the hedges, were covered with a double layer band of a white plastic net (COTESI's brand "MOVPROTECT", woven Fabric produced from HDPE Monofilaments, transparent, highly UV Stabilized) that could reduce total solar radiation (kW m^{-2}) in 23% and PAR radiation (mmol s^{-1}) in 27%.

Total solar radiation, PAR, air temperature and relative humidity were measured above the canopy. The same measurements were taken inside the canopy close to the clusters plus the temperature of clusters adjacent to the rachis on two plants, one located in shaded rows, the other in a non-shaded row. All data was logged automatically at one hour interval.

When the grapes reached commercial maturity, ten plants from each treatment were randomly chose. The leaves of these plants were collected and their leaf area measured in the laboratory with and area meter. The clusters from the same plants were harvested to perform the following determinations: total cluster weight, number of clusters per plant and the number of clusters with more than 30% of shriveled berries. Three samples of 300 berries each from all sampled plants were collected to determine berry weight and volume. The must draw from each sample was used to determine (OIV, 2005) probable alcohol, titrable acidity, pH, total anthocyanin index, total anthocyanins, extractable anthocyanins, anthocyanin extractability, phenolic maturation index, and malic acid content.

RESULTS AND DISCUSSION

Air temperature, relative humidity and radiation were significantly altered by the presence of the net cover (Tab. 1).

Tab. 1 – Averages for air temperature, relative humidity, solar radiation and PAR during day time from 15 July to 31 August 2010 above the canopy and inside the canopy at cluster level

	Above canopy	S_0	S_f
Average air temperature (ºC)	26.60	27.47	27.53
Average relative humidity (%)	41.30	37.84	36.75
Air temperature inside the cluster (ºC)		26.95	27.27
Average solar radiation (Kw m^{-2})	0.720	0.044	0.022
Average PAR (mmol m^{-2} s^{-1})	1.300	0.094	0.015

Inside the canopy the air temperature was 3.3% higher than the air above the canopy and the net caused a 3.5% increase. The temperature close to the cluster rachis was also higher and the effect was stronger in the plant protected with the net. As the temperature raise, the

relative humidity decreased as expected. Inside the canopy the total solar energy and PAR were drastically reduced and the decrease was more intense where the net was present. The dense foliage of the canopy reduces the wind speed and the temperatures around the clusters tend to increase and the presence of the net augments this phenomenon (Chavarrial *et al.*, 2009; Tarara and Lee, 2011). Lower values for solar radiation and PAR are as expected.

The total leaf area (LA) for the treatments, measured at harvest, showed no significant (*P>0.05*) differences between the shaded treatments but LA was significantly (*P<0.05*) higher for the non-shaded plants (Fig. 1).

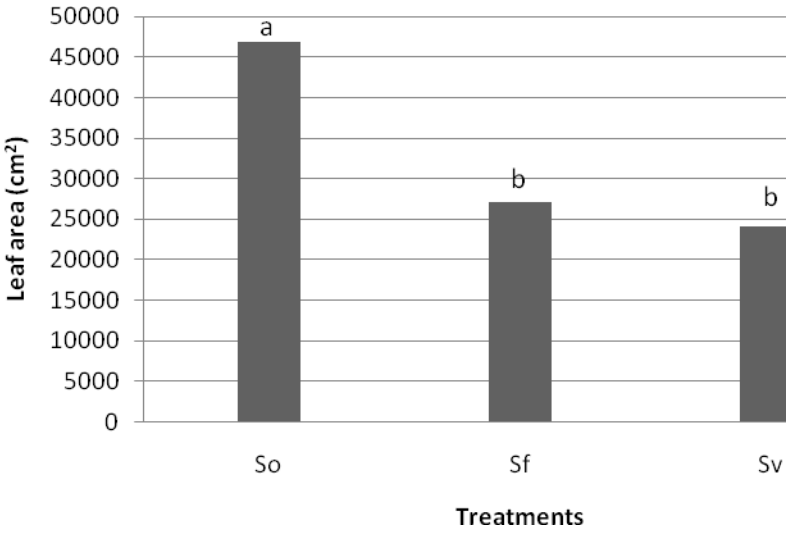

Fig.1 – Total leaf area for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

The loss of LA was very clear on the portion of the canopy that was banded with the net where a large number of desiccated leaves were found. Visually, there was no difference on the upper portions of the canopy among treatments. There was no significant difference on LA between the shaded treatments. Radiation intensity and temperature have direct effects on plant leaf area dynamics and either too low radiation or too high temperatures can have a detrimental effect on leaf area (Meziane and Shipley, 1999; Pallas *et al.*, 2010).

The yield components did not show significant differences among treatments for the number of clusters per plant that was between 24 and 26, but the total production was significantly lower for treatment S_o in relation to other treatments that showed no significant difference between them (Fig. 2).

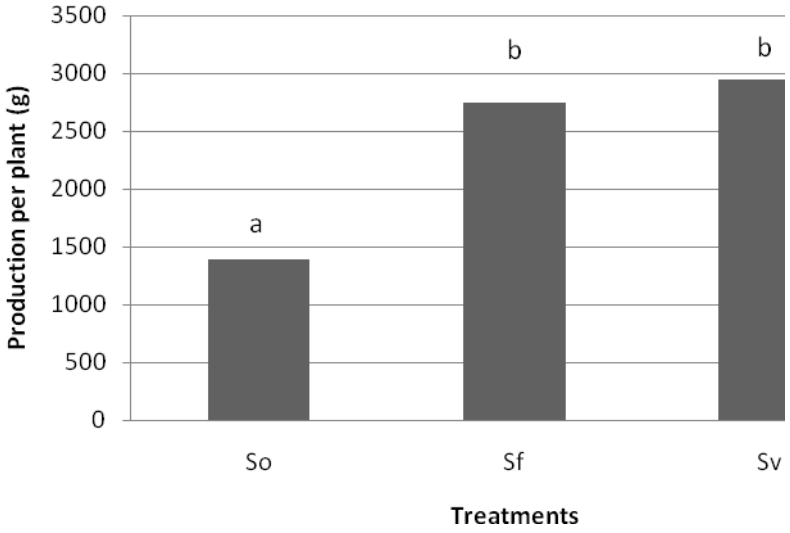

Fig.2 – Production per plant for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

However, the non-shaded plants had in average 9.4 clusters with at least 30% of shriveled berries and it was significantly different from the treatments S_f and S_v that showed 4 and 4.7 clusters with shriveled berries, respectively. Other authors did not find a reduction in plant yield, cluster weight or berry size in shaded plants (Cartechin and Pallioti, 1995; Chorti *et al.*, 2010), but the results of this work are probably due to the larger number of shriveled berries that affect the berry average weight and volume (Fig. 3)

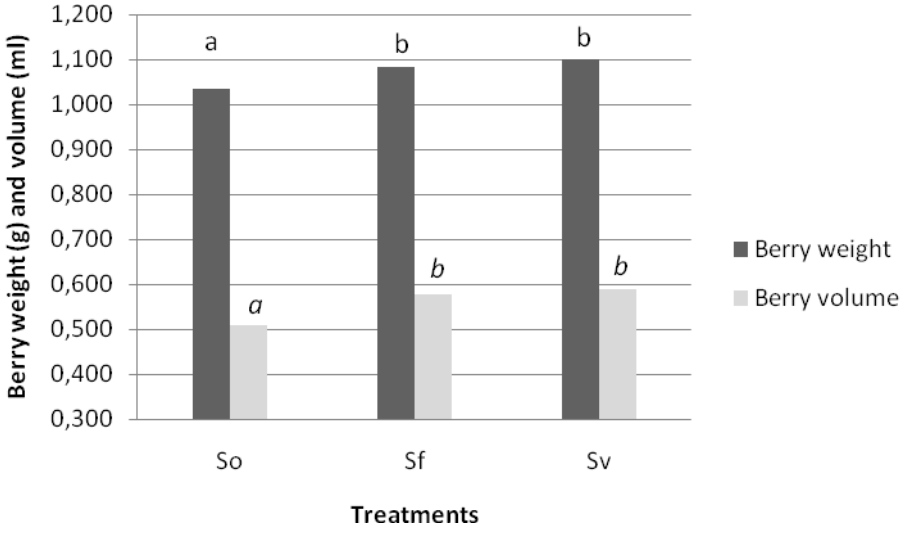

Fig.3 – Berry weight and volume for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

The average berry weight and volume in non-shaded plants were significantly lower than in shaded plants that showed no significant difference between shaded treatments. High temperatures and excess radiation can cause an important loss of water in the berries

(Howell *et al*., 1994; CSRIO, 2011) and this might be the reason there were many clusters with desiccated berries.

Titrable acidity was lowest in must from treatment S_0 and highest in must of treatment S_v but no significant differences existed between treatments S_0 and S_f, and treatments S_f and S_v. Probable alcohol was lowest in treatment S_0 but not significatively different from treatment S_v. It was highest in treatment S_f that did not show significative difference for S_v. (Fig. 4). The acidity found in all treatments was far below the desirable value of 6 to 7 gL^{-1} (Esteban *et al*., 1999).The experienced high temperatures favored the degradation of acids (Volschenk *et al.*, 2006).

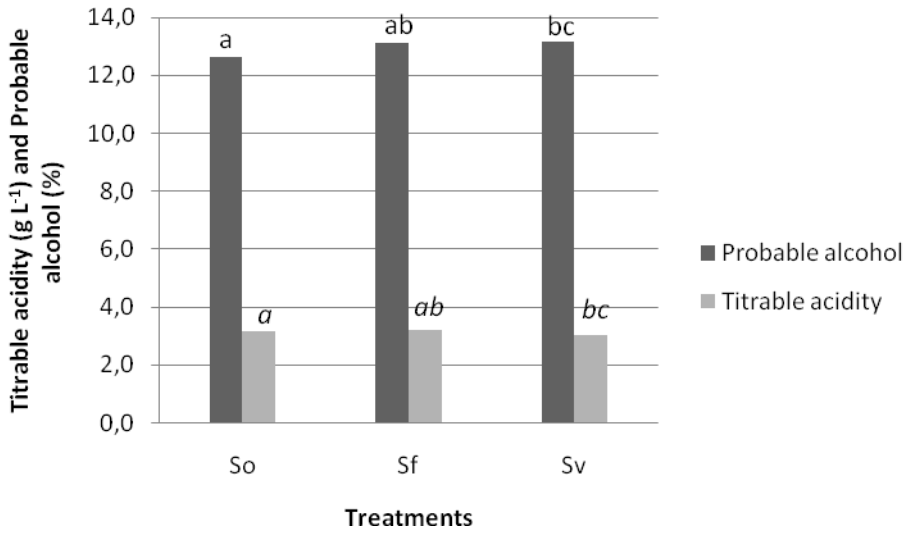

Fig.4 – Titrable acidity (g L^{-1} equivalent of tartaric acid) and probable alcohol (%) for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

Higher content of sugars and lower acidity in must from berries exposed to higher radiation in relation to shaded berries have been reported in other works (De Bolt *et al.*, 2008; Abd El-Razek *et al.*, 2010) and higher temperature also decreased the concentration of glucose and fructose (Sepúlveda and Kliewer, 1986). The lower value for probable alcohol found in treatments S_0 because there was lower content of sugars in the must is likely the result of less efficient vine photosynthesis under too high radiation flux (Petrie *et al.*, 2009).

The production of anthocianins was significantly higher in treatment S_0 than in the other treatments that showed no significant difference between them (Fig. 5). Anthocyanin accumulation is suppressed by high temperature and low light intensity (Spayd *et al.*, 2002; Jeong *et al.*, 2004) and this might explain the results found in this work.

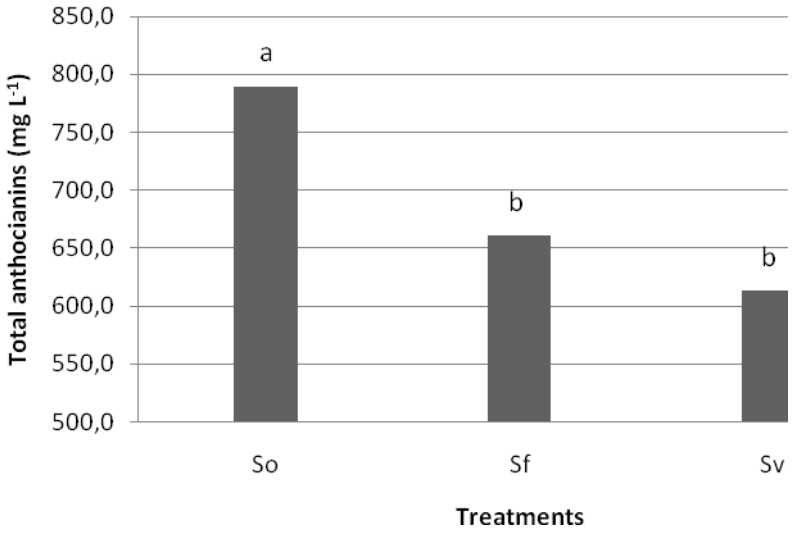

Fig.5 – Total anthocianins (mg L^{-1}) for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

The concentration of malic acid in the must produced from treatment S_0 was significantly higher than in the must produced from the other treatments that showed no significant difference between them (Fig. 6). Both tartaric and malic acids reach their highest concentration at veraison and they decreased until harvest, more markedly for malic acid. The rate and extension of malic transformation is mainly temperature dependent (Koundouras *et al.*, 2006), and the temperature of the berries themselves plays an important role (de Souza *et al.*, 2005) and lower temperatures of the berries decrease the rate of the malic acid transformation (Spayd *et al.*, 2002; Koundouras *et al.*, 2006). In this work, temperature was higher for the berries in shaded plants, thus the concentration of malic acid was lower.

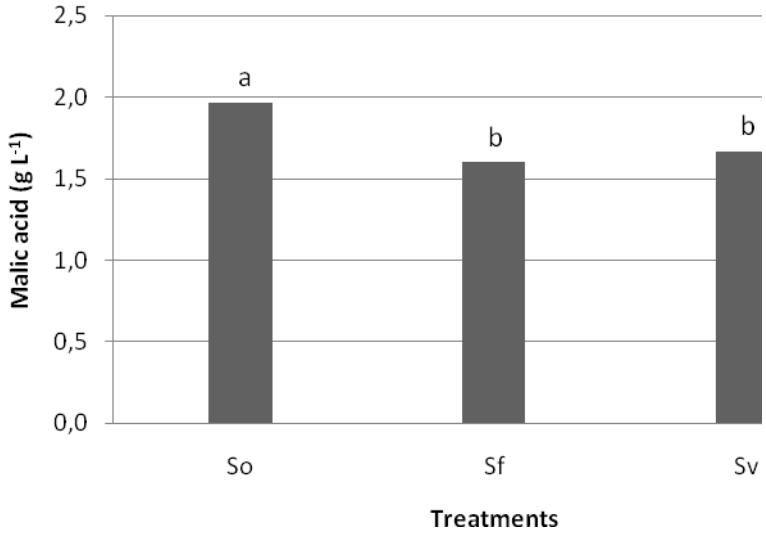

Fig.6 – Malic acid (g L^{-1}) for shadding treatments. Different letters above the columms mean significant differences among averages (Tukey $HSD_{0.05}$)

Other measured parameters, pH, total anthocyanin index, extractable anthocyanins, anthocyanin extractability, and phenolic maturation index, did not show significant differences among treatments and we concluded that in this work shading had no influence on them and we did not discuss them any further.

Conclusions

Shading the grapevines had a significant effect on the morphology of the plants, on their production, and on the quality of the must. Shaded plants had lower leaf area at harvest. The temperature inside the canopy and the temperature closer to the rachis of the cluster were slightly higher. However, the lower radiation intensity reaching the cluster might have reduced the number of shriveled berries and the production was higher for the shaded plants. The must from shaded berries showed some benefits such as higher probable alcohol, higher titrable acidity, and lower malic acid concentration. On other hand, the total anthocianins were lower that can be detrimental. Further research is needed to confirm these results.

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