

# Training systems evaluation of *Vitis vinifera* L. cv 'Alvarinho' (Vinhos Verdes PDO region) to physiological and productive parameters

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## Abstract

In the *Vinhos Verdes* wine region, the largest Protected Designation of Origin (PDO) region in Portugal, the most common 'Alvarinho' training system is single downward shoot positioning (DSP) that is currently being replaced by vertical shoot positioning (VSP). The aim of this work was to evaluate physiological and productive parameters of 'Alvarinho' grapevines in both training systems. This study was carried out during 2018 in a commercial vineyard in Monção (north-west of Portugal) divided into two plots, of 1 ha and 0.5 ha respectively, and each with a different training system. On each plot, 4 replicates were established with 7 vines per replicate. Soil texture on both plots is sandy loam from schist and soil water capacity is 290 mm m<sup>-1</sup>. The vineyards were planted in 2009, with 196-17 rootstock, and with a density of 1111 vines ha<sup>-1</sup>, in north-south oriented rows. From July to August, nine irrigation events were performed applying a total of 95 mm of water on each plot. From blooming until harvesting, in 2 vines per replicate, the soil water content was recorded and the water stress index, CWSI (Crop Water Stress Index) and I<sub>G</sub> (Index of relative stomatal conductance), were recorded as well as the stem water potential, chlorophyll content and photosynthetic active radiation. The production and vegetative parameters (bunch number, weight per bunch, wood weight and Ravaz index) were calculated on 7 vines per replicate. From véraison until harvesting the DSP system showed higher stem water potential than that of the VSP, yet no differences in stress indicators (CWSI and I<sub>G</sub>) were found between training systems. The main differences were in yield parameters where the DSP showed more bunches per vine (95 vs 81), higher production (14.5 vs 10.0 tons per hectare) and higher Ravaz index (6.2 vs 2.5).

Keywords: Crop Water Stress Index, stem water potential, Ravaz index

## INTRODUCTION

Every grapevine training system displays a typical canopy structure, which determines the microclimate within the canopy profile. The total leaf area, the interception of light and the percentage of well-exposed leaf area affects the behavior of the vine. Several studies highlight the importance of canopy management practices in physiological and productive parameters (Baeza et al, 2005; Reynolds et al., 2009) and wine quality parameters (Williams and Heymann, 2017, Valentini et al., 2019), using two-dimensional

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and three-dimensional models to simulate the behavior of different canopies (López-Lozano et al. 2011; Sanz et al 2018). Canopy temperature has been proposed since 1960 (Tanner, 1963), based on the effect of the plant's evapotranspiration process. Since that time, the advancement of technology has brought with it new techniques and procedures, in particular the techniques of infrared thermography, with portable sensors. In this context, the calculation of indexes such as the CWSI (Crop Water Stress Index) or the  $I_G$  (Conductance Index), is an efficient, fast and non-destructive method for monitoring the plant water stress (Alderfasi and Nielsen, 2001). The relationship between the canopy temperature and the air temperature can be an important indicator to perceive plant water requirements (Pruguer et al., 2018). In the 1980s, canopy temperatures began to be used to assess plant water stress on the assumption that the difference between canopy and air temperatures is an indicator of canopy stress conditions. Under normal conditions, the plant evapotranspiration causes the canopy temperature to be lower than the air temperature, except for low VPD (Vapor Pressure Deficit). On the other hand, when soil water availability and evapotranspiration rates become low, stomata restricting their opening, reducing the evapotranspiration and the cooling effect, causing the canopy temperature to be higher than the air temperature (Jones, 1992). The training systems of *Vitis vinifera* cv. Alvarinho, in the north-west of the Iberian Peninsula, are the “*emparrado*”, where the vines were trained to quadrilateral cordons leaving 6–8 buds per spur, at a height of 1.8 m (Cancela et al., 2017), the vertical trellis on a single cordon system (Mirás-Avalos et al, 2016) and the downward single cordon (DSP), these training systems facilitate the vineyard management, due to their simpler structure and pruning and are fast becoming more appealing to farmers. The introduction of any new trellis in a given area requires both an agronomic and an ecophysiological evaluation to determine its viability over time and how the canopy structure interacts with the local climate (Cavallo et al., 2001).

The aim of the study was to compare low and a high cordon trellis system for the vineyard cv. ‘Alvarinho’ with emphasis on vegetative and productive parameters, stress index and interaction with light availability. The low cordon system studied was the vertical shoot positioning (VSP), that entails single rows of tall, thin panels of grapevine shoots positioned upwards; and the high cordon system was the downward shoot positioning (DSP) where the shoots grow downward and out from the cordon. Both trellises were training in a single curtain above a unilateral cordon wire and were spur pruned. The choice of these two trellis systems is due to the fact that currently the DSP, more traditional in the sub-region, is being replaced by the VSP due to an increasing adaptability to the mechanization of harvesting and pruning.

## **MATERIAL AND METHOD**

The trial was carried out during the year 2018 in a commercial vineyard of cv. ‘Alvarinho’, located at Monção, district of Viana do Castelo district, in the north of Portugal (41.077° N; 8.359 W), with an altitude of 85 m above sea level. Vines had been grafted onto 196-17 rootstock and planted in 2009, in sandy loam soil, with a between-row and within-row spacing of 3 m × 3 m, respectively, and row orientation was northwest-southeast. The climate of this region has an Atlantic influence, characterized as Csb, Köppen-Geiger classification (Kottek et al., 2006), with moderate temperatures and temperature ranges and high rainfall (ranging from 1400 to 1800 mm) concentrated most in the winter months.

The trial was developed in two plots, plot A (1ha), with a downward shoot positioning (DSP) and plot B (0.5ha) vertical shoot positioning (VSP). Training systems with equal pruning loads (55555 eyes ha<sup>-1</sup>). Seven vines in four replications per treatment were used as sampling block complete randomized.



Figure 1 - Description of experimental design. Each treatment, downward shoot position (DSP) and vertical shoot position (VSP), have four replicates

The vineyard was managed by a farmer who followed standard practices. Both plots were equipped with a drip irrigation system; the emitters were spaced at 1m and flow discharge was 4 L.h<sup>-1</sup>. The irrigation was scheduled based on the crop evapotranspiration (ET<sub>c</sub>) which was calculated using the Penman-Monteith equation (Allen et al., 1998). The physiology parameters, midday stem water potential (Ψ<sub>s-n</sub>, MPa) was determined at noon, whereas it requires bagging leaves in opaque and hermetic bags 1–2h prior to measurement. This way, in bagged leaves, leaf water potential reaches an equilibrium with stem xylem water potential (Begg and Turner, 1976). The chlorophyll content was performed nondestructively using the Multiplex fluorimetric sensor, once a week in two plants per block on both sides of the leaf. The Photosynthetic Active Radiation (PAR) was measured with a ceptometer (Delta T, Decagon), with the sensor measured unobstructed, along the row and above the canopy (PAR<sub>a</sub>, mmol·m<sup>-2</sup>·s<sup>-1</sup>) concomitant to measurements of PAR taken by the ceptometer below the canopy (PAR<sub>b</sub>, mmol·m<sup>-2</sup>·s<sup>-1</sup>) (Johnson et al., 2010; Dong et al., 2015). The measurements were taken weekly from DOY 222 until DOY 257 (near harvesting). The fraction of the photosynthetic active radiation intercepted (fPAR<sub>i</sub>) was obtained through the equation proposed by Carvalho et al. (2017), and is expressed as the fraction of incoming photosynthetically active radiation which is prevented by the canopy from reaching the ground.

$$fPAR_i = 1 - \left( \frac{PAR_b}{PAR_a} \right)$$

Thermal images were obtained with a Flir® e75 camera. Images were taken at predefined locations at midday at a distance of 2 meters perpendicular to the direction of the row. All images were acquired on clear days, with minimum wind conditions, evaluated at the collection site. The reference temperatures (wet temperature - T<sub>wet</sub> and dry temperature - T<sub>dry</sub>; °C) were obtained by selecting two healthy leaves close to each other. Vaseline was applied to both sides 30 minutes earlier on the T<sub>dry</sub> leaf, artificially forcing the closure of the stoma, preventing evapotranspiration and consequently increasing leaf temperature, and the T<sub>wet</sub> was sprayed with water two minutes before to simulate the maximum evapotranspiration rate.

The CWSI (Crop Water Stress Index) calculation used was taken from the equation proposed by (Idso, 1982) modified by (Garcia-Tejero, et. al., 2016),

$$CWSI = \frac{(T_c - T_{wet})}{(T_{dry} - T_{wet})}$$

where  $T_c$ , is the canopy temperature, obtained from the thermal image and  $T_{dry}$  and  $T_{wet}$ , are reference temperatures ( $^{\circ}C$ ).

The  $I_G$  (Stomatic Conductance Index) was obtained through the equation proposed by (Jones and Grant, 2016).

$$I_G = \frac{(T_{dry} - T_c)}{(T_c - T_{wet})}$$

Productive parameters (bunch number, bunch weight and yield) were determined at the time of commercial harvesting. The Ravaz index was calculated as the ratio between vine yield and pruning weight. This index is used to determine vine balance and vigor (Yuste 2005, Brighenti et al., 2012).

## RESULTS AND DISCUSSION

Nine midday stem water potential readings were taken from DOY 200 and DOY 271. Values range from -0.48 to -0.70 MPa for the DSP system and from -0.34 to -0.63 MPa for the VSP system. These values are close to those recorded by Cancela et al., (2017) for Alvarinho. The DSP has higher stem water potential values due to a greater distance between the root system and the leaves (Figure 2). The test was carried out without water restrictions, as soil water content was close to the field capacity during the growing season. The stem water potential reached by the DSP treatment was around -0.8MPa, and significant differences ( $p < 0.001$ ) were only observed at the end of the season (DOY 271). These values are in agreement with the values obtained for other cultivars of the north-west peninsular (Mirás-Avalos et al., 2014; Trigo-Córdoba et al., 2015).

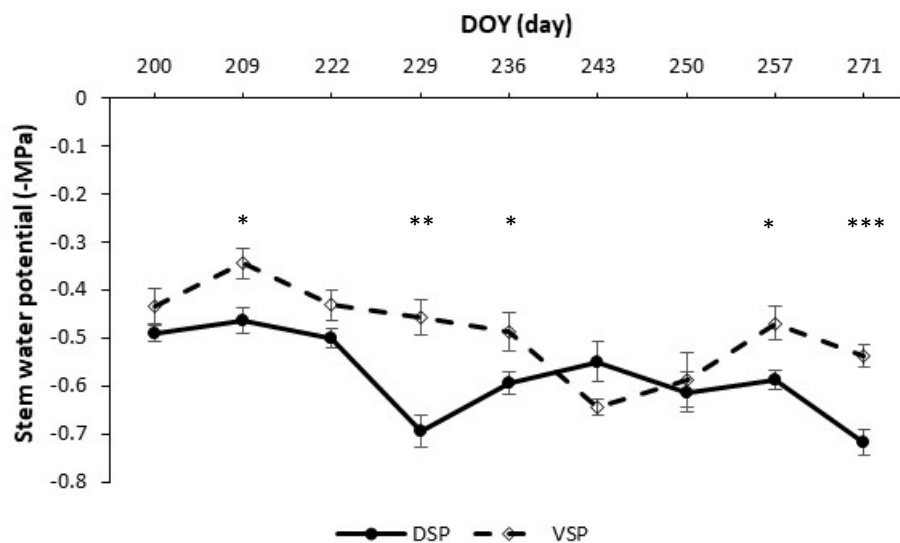


Figure 2 – Midday steam water potential ( $\Psi_{s-n}$ ; MPa) for the downward shoot positioning (DSP) and the vertical shoot positioning (VSP). \* indicate significant differences

among treatments to Tukey test (\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ ). Error bars represent standard errors.

Figure 3 shows a decrease of  $I_G$  throughout the phenological cycle, which may indicate a greater tendency for the grapevine to go under water stress, at the end of its phenological cycle, in both training systems. A conclusive variation is not explicit in comparison with the two training systems. However, as shown in Figure 4, there are slight differences between the two training systems. It should be pointed out that the DSP tends to get into water stress faster and more often than the VSP. CWSI values increase along the phenological cycle, which will indicate that both systems have a tendency to enter more easily into water stress, an indication which is also clear in the analysis performed in the IG figure.

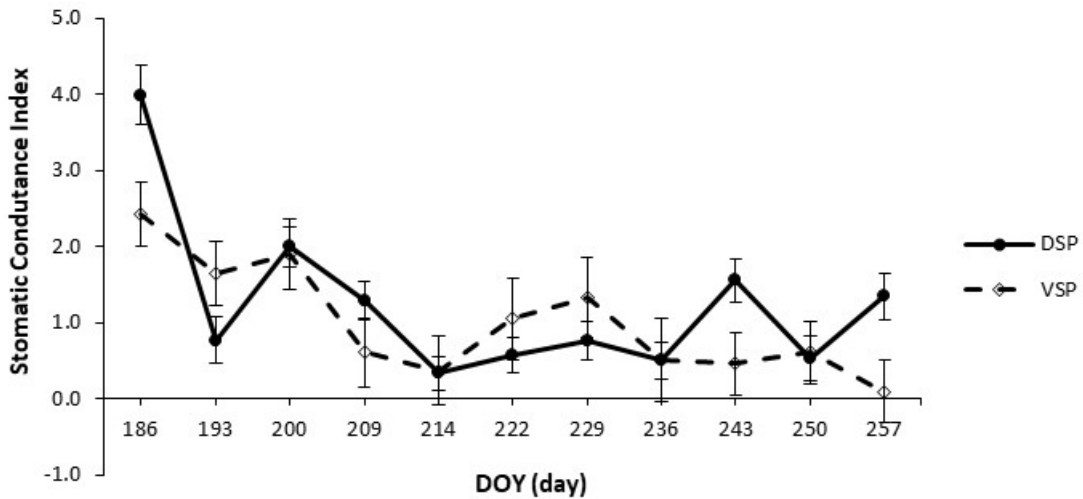


Figure 3 – Stomatic conducance index ( $I_G$ ) for the downward shoot positioning (DSP) and the Vertical shoot positioning (VSP). Error bars represent standard errors.

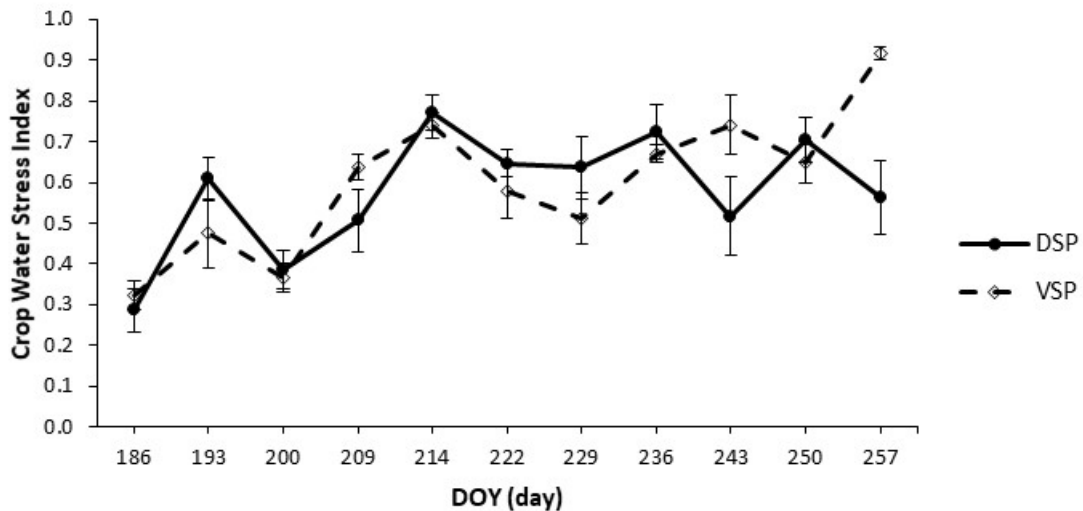


Figure 4 – Crop water Stress index for the downward shoot positioning (DSP) and the Vertical shoot positioning (VSP). Error bars represent standard errors.

Figure 5 shows that the training systems interfere directly with the development of the canopy and, consequently, in the amount of light intercepted. The fPARi during the study period was always higher in the VSP than the DSP although at the end of the study period (DOY 257) the values were the same in both systems. From the analysis of figure 5, we

highlight the high amplitude of the values obtained in the DSP training system. The DSP canopy architecture is very irregular and the methodology along the row, to obtain PAR, was perhaps not the most efficient.

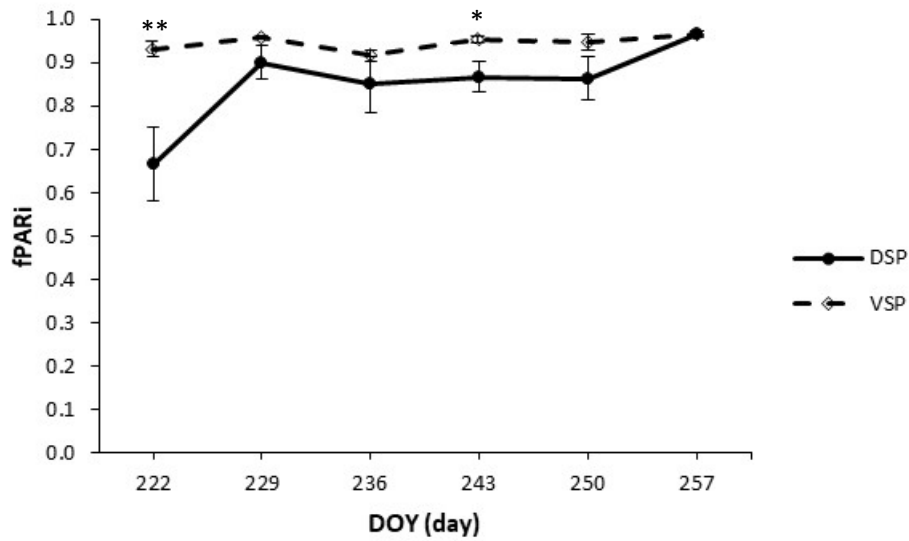


Figure 5 – Fraction of photosynthetic active radiation intercepted (fPARI) by the canopy of cv ‘Alvarinho’ for the downward shoot position (DSP) and the Vertical shoot position (VSP). \* indicate significant differences among treatments to Tukey test (\* $p < 0.05$ ; \*\* $p < 0.01$ ). Error bars represent standard errors.

As expected, chlorophyll shows a decreasing trend (figure 6) probably due to the chlorophyll breakdown during leaf senescence.

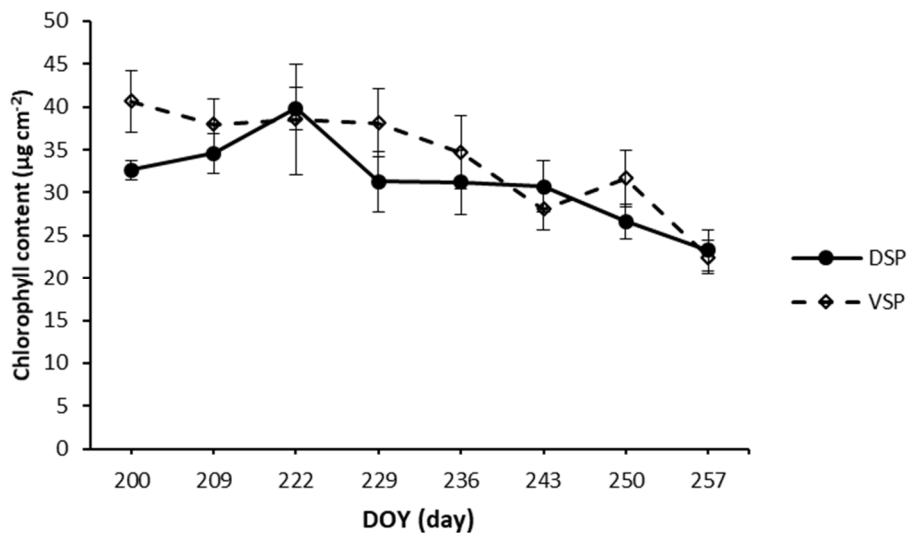


Figure 6 – Chlorophyll concentration in ‘Alvarinho’ leaves for the downward shoot position (DSP) and the Vertical shoot position (VSP). Error bars represent standard errors.

Regarding the evaluation of productive parameters, the number of bunches per plant is higher in the DSP, although the difference is not significant between training systems (Table 1). In VSP, the number of bunch per vine and bunch weight was lower (80.71 and

110.50 g, respectively), which produced a yield per plant (9.13 kg) that was 30% less than that of the DSP treatment. Of the parameters that were evaluated and analyzed, only the bunch number showed insignificant differences.

The pruning weight is lower in the DSP and, as a consequence, the relationship between pruning wood and yield, has a higher Ravaz Index than the VSP system. In the latter case, the low value of the Ravaz Index expressed the disequilibrium between vegetative and productive parameters. According to Yuste (2005), an index between four and seven indicates that the vine is balanced, as in DSP treatment. Indexes higher than seven indicate excessive yield and less than four indicate excessive vine vigor, as in VSP treatment in our study.

Table 1 - Analysis of the variance of production parameters for 'Alvarinho' grapevines under different training systems in the 2018 season.

Parameters	DSP	VSP	Sig.
Bunch number vine <sup>-1</sup>	95.07 (±30.51)	80.71 (±24.74)	<i>ns</i>
Bunch weight (g)	137.99 (±0.034)	110.50 (±0.037)	**
Yield (kg vine <sup>-1</sup> )	13.03 (±4.84)	9.13 (±4.22)	**
Pruning weight (kg vine <sup>-1</sup> )	2.28 (±0.64)	3.78 (±1.33)	**
Ravaz Index	6.22 (±3.06)	2.54 (±1.13)	**

Sig. - significance; ns - not significant; \*\* - significant at the 0.01 level of probability. Values in brackets are referred to standard error.

## CONCLUSIONS

In the VSP the lowest yield and the low value of the Ravaz index expressed the disequilibrium between vegetative and productive parameters. In our study conditions, IG and CWSI indexes provide almost the same information, awarding results with the same trend.

Given the fact that the amount of water was identical in both training systems, the increase in CWSI may also be explained by the aging of the leaves at the end of the cycle, which may lead to greater difficulty in the evapotranspiration processes.

All these indicators should provide the necessary tools for the winegrower to improve the sustainable management of a vineyard. Better understanding of spatial variability across the vineyard could offer perspectives of classification of plots and differential farming practices, either to homogenize or to promote diversification of a vineyard's production. These results need to be confirmed as they only relate to one year of data.

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