Training systems evaluation of *Vitis vinifera* L. '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), which is currently being replaced by vertical shoot positioning (VSP). This work aimed to evaluate physiological and productive parameters of 'Alvarinho' grapevines in both training systems. This study was carried out in 2018 in a commercial vineyard in Monção (north-west of Portugal). It was 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 replicate^{-1}. Soil texture on both plots is sandy loam from schist, and soil water capacity is 290 mm m^{-1}. The vineyards were planted in 2009, with 196-17 rootstock, and with a density of 1111 vines ha^{-1}, 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 replicate^{-1}, the soil water content, the crop water stress index (CWSI) and the index of relative stomatal conductance (I_G) were recorded along with the stem water potential, chlorophyll content and photosynthetically active radiation. The production and vegetative parameters (bunch number, weight per bunch, pruning wood weight and Ravaz index) were calculated on 7 vines replicate^{-1}. From veraison until harvesting the DSP system showed higher stem water potential than VSP, yet no differences in stress indicators (CWSI and I_G) 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 per vine (13 vs. 9.1 kg vine^{-1}), 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 affect the vine's behavior. Several studies highlight the importance of canopy management practices in physiological and productive parameters (Baeza et al., 2005; Reynolds and Heuvel, 2009) and wine quality parameters (Williams and Heymann, 2017; Valentini et al., 2019), using two-dimensional 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 evapotranspiration process. Since that time, the advancement of technology has brought new techniques and procedures, particularly the techniques of

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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 essential indicator to observe plant water requirements (Prueger et al., 2019). In the 1980s, canopy temperatures began to be used to assess plant water stress on the assumption that the difference between canopy and air temperature 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 restrict their opening, reduce the evapotranspiration and the cooling effect, causing the canopy temperature to be higher than the air temperature (Jones, 2013). The training systems of *Vitis vinifera* 'Alvarinho', in the north-west of the Iberian Peninsula, are the "*emparrado*", where the vines are trained to quadrilateral cordons leaving 6-8 buds spur^{-1}, at the height of 1.8 m (Cancela et al., 2017), the vertical trellis on a single cordon system (Mirás-Avalos et al., 2014) and the downward single cordon (DSP). Due to their simpler structure and pruning, these training systems facilitate vineyard management and are fast becoming more appealing to farmers. The introduction of any new trellis in a given area requires both an agronomic and an eco-physiological evaluation to determine its viability over time and how the canopy structure interacts with the local climate.

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

MATERIAL AND METHODS

The trial was carried out in 2018 in a commercial vineyard of 'Alvarinho', located at Monção, Viana do Castelo district, in the north of Portugal (41.077° N; 8.359 W), with an altitude of 85 m a.s.l. 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 3×3 m, respectively, and northwest-southeast row orientation. This region's climate 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) mostly concentrated in the winter months.

The trial was developed in two plots, plot A (1 ha), with a downward shoot positioning (DSP) and plot B (0.5 ha) with vertical shoot positioning (VSP) (Figure 1). Both training systems had equal pruning loads (55555 buds ha^{-1}). Seven vines in four replications per treatment were sampled as randomized complete block design.

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 1 m and the discharge was 4 L h^{-1}. The irrigation was scheduled based on the crop evapotranspiration (ET_c) calculated using the Penman-Monteith equation (Allen et al., 1998). Midday stem water potential (Ψ_{s-n}, MPa) was measured with a Scholander pressure chamber (PMS Model 600, Albany, Oregon, USA) (Scholander et al., 1965) in 8 leaves replicate^{-1}, covered with an opaque and hermetic bag 1 h before measurement (Williams and Araujo, 2002). The chlorophyll content was performed non-destructively using the Multiplex fluorimetric sensor, once a week on both sides of 8 leaves replicate^{-1}. Both measurements were performed on healthy mature leaves from the middle third of the shoots.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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

The photosynthetically active radiation (PAR) was measured with a ceptometer (Delta T, Decagon), with the sensor measured unobstructed, along the row and above the canopy (PAR_a, mmol m^{-2} s^{-1}) in conjunction with measurements of PAR taken by the ceptometer below the canopy (PAR_b, mmol m^{-2} s^{-1}) (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 photosynthetically active radiation intercepted (fPARi) was obtained through the equation proposed by Carvalho et al. (2017). It is expressed as the fraction of incoming photosynthetically active radiation, which is prevented by the canopy from reaching the ground.

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

Thermal images were obtained with a Flir® e75 camera. Images were taken at predefined locations at midday at a distance of 2 m 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 – Twet and dry temperature – Tdry; °C) were obtained by selecting two healthy leaves close to each other. Vaseline was applied to both sides 30 min earlier on the Tdry leaf, artificially forcing stomatal closure, preventing evapotranspiration and consequently increasing leaf temperature. Twet was sprayed with water 2 min before to simulate the maximum evapotranspiration rate.

The CWSI (crop water stress index) calculation was taken from the equation proposed by Idso (1982) and modified by García-Tejero et al. (2016):

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

where Tc is the canopy temperature, obtained from the thermal image, and Tdry and Twet, are reference temperatures (°C). The I_G (stomatal conductance index) was obtained through the equation proposed by Jones and Grant (2016):

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

Production parameters (bunch number, bunch weight and yield) were determined at 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 measurements 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 VSP has higher stem water potential values due to a greater distance between the root system and the leaves (Figure 2). The trial was carried out without water restrictions, as soil water content was close to the growing season's field capacity. The DSP treatment reached a stem water potential of around -0.8 MPa and significant differences (p≤0.001) were only observed at the end of the season (DOY 271). These values agree with the values obtained for other cultivars in the northwestern part of the peninsula (Mirás-Avalos et al., 2014; Trigo-Córdoba et al., 2015).

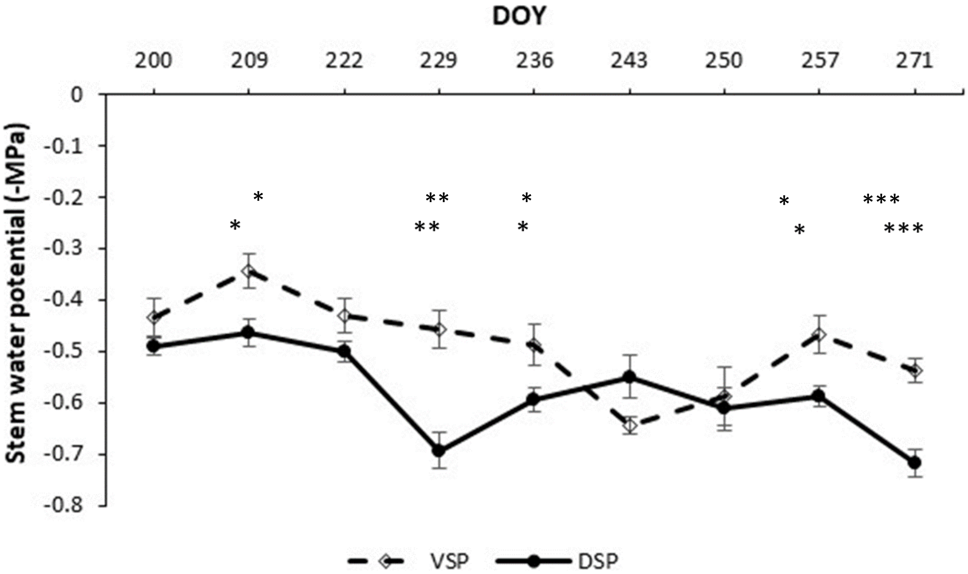

Figure 2. Midday stem water potential ($\Psi_{s\text{-}n}$; MPa) for the downward shoot positioning (DSP) and the vertical shoot positioning (VSP). * indicates significant differences among treatments by Tukey's test (* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$). Error bars represent standard 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 tend to be more easily under water stress. This indication is also evident in the analysis performed in the IG figure.

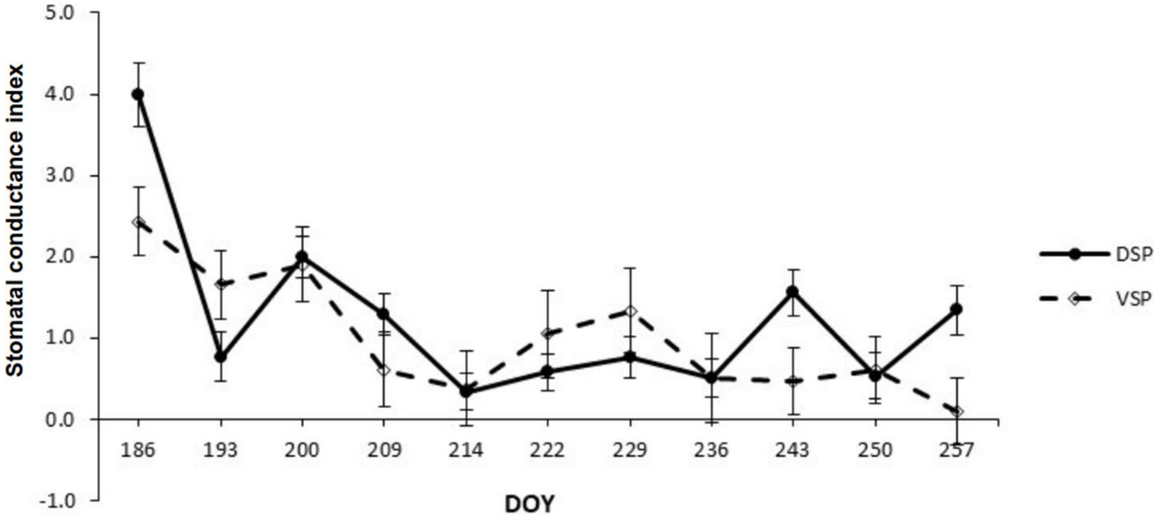

Figure 3. Stomatal conductance index (I_G) for the downward shoot positioning (DSP) and the vertical shoot positioning (VSP). Error bars represent standard errors.

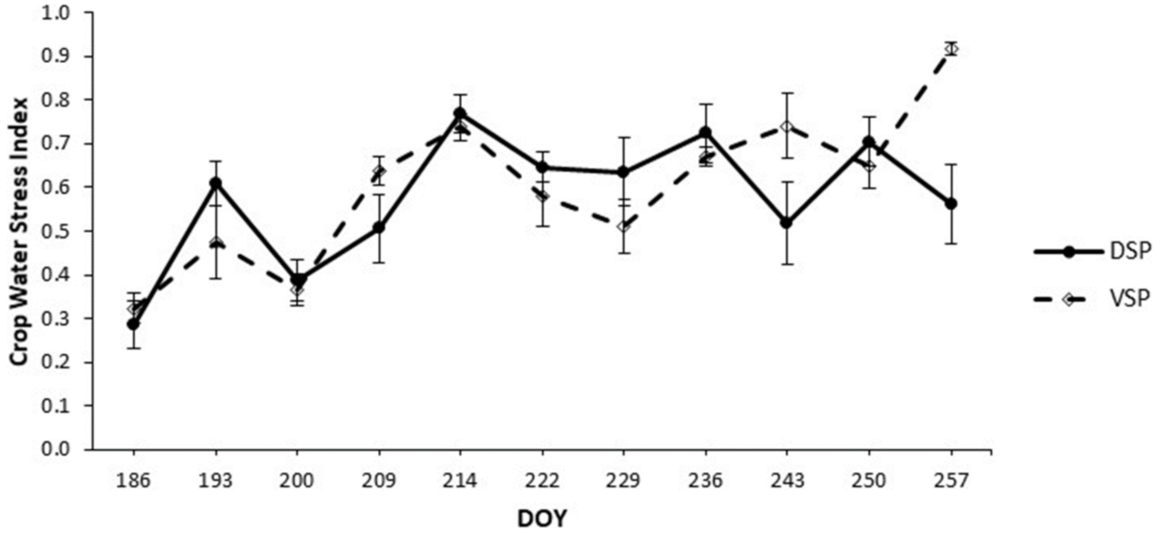

Figure 4. Crop water Stress index for the downward shoot positioning (DSP) and the vertical shoot positioning (VSP). Error bars represent standard errors.

Figure 5 shows that the training systems interfere directly with canopy development and, consequently, with the amount of light intercepted. During the study period, the fPARi was always higher in the VSP than the DSP although at DOY 257 values were the same in both systems. From the analysis of Figure 5, we highlight the high amplitude of DSP training system's values. The DSP canopy architecture is very irregular, and the methodology to obtain PAR along the row was perhaps not the most efficient.

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

Regarding the evaluation of production 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 bunches per vine and bunch weight were lower (81 and 111 g, respectively), which produced a yield per plant (9.1 kg) that was 30% less than that of the DSP treatment. Out of the parameters that were evaluated and analyzed, only the bunch number showed insignificant differences.

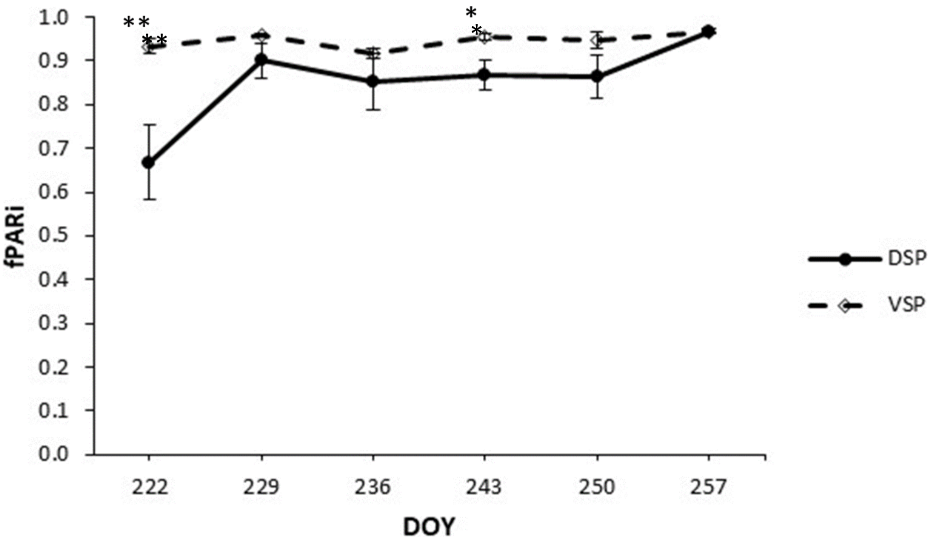

Figure 5. Fraction of photosynthetically active radiation intercepted (fPARi) by the canopy of 'Alvarinho' for the downward shoot position (DSP) and the vertical shoot position (VSP). * indicates significant differences among treatments by Tukey's test (* $p \leq 0.05$; ** $p \leq 0.01$). Error bars represent standard errors.

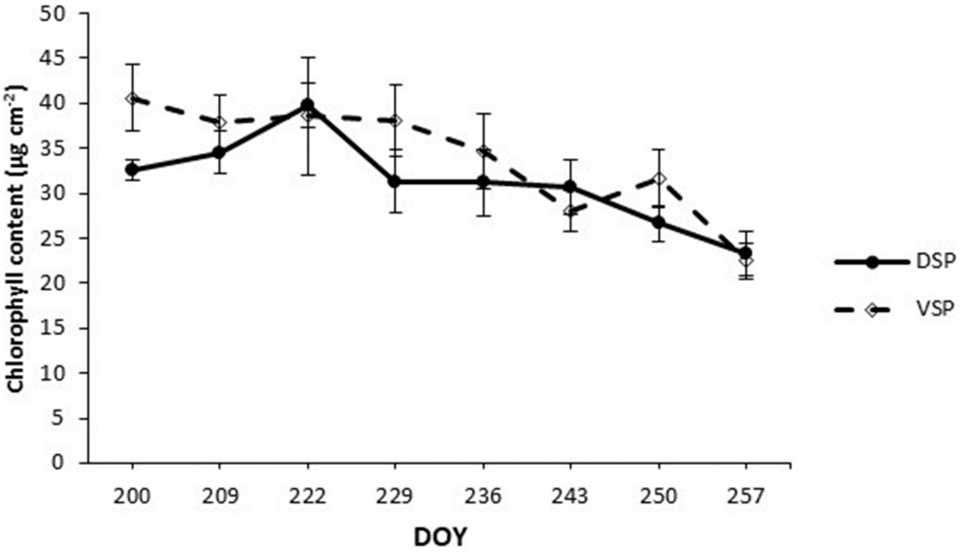

Figure 6. Chlorophyll concentration in 'Alvarinho' leaves for the downward shoot position (DSP) and the vertical shoot position (VSP). Error bars represent standard errors.

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

Parameters	DSP	VSP	Sig.
Bunch number vine^{-1}	95±31	81±25	*ns*
Bunch weight (g)	138±0.03	111±0.04	**
Yield (kg vine^{-1})	13±4.8	9.1±4.2	**
Pruning weight (kg vine^{-1})	2.3±0.64	3.8±1.3	**
Ravaz index	6.2±3.1	2.5±1.1	**

Sig., significance; ns, non-significant; **, significant at the 0.01 level of probability.

Means ± standard errors.

The pruning weight was lower in DSP and, as a consequence, the relationship between pruning wood and yield had 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 production parameters. According to Yuste (2005), an index between four and seven indicates that the vine is balanced, as in the DSP treatment. Indexes higher than seven indicate excessive yield, and less than four indicate excessive vine vigor, as in the VSP treatment in our study.

CONCLUSIONS

In the VSP, the lowest yield and the low value of the Ravaz Index expressed the disequilibrium between vegetative and production parameters. In our study conditions, I_G and CWSI indexes provided almost the same information, awarding results with the same trend. Given that the amount of water was identical in both training systems, the increase in CWSI may in part be explained by the aging of the leaves at the end of the cycle, leading to greater difficulty in the evapotranspiration processes.

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

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