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Physiological response of the grapevine cultivars Touriga Nacional and Touriga Franca to increasing summer stress conditions in the Douro Region.

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Abstract. The behaviour of the cultivars Touriga Nacional and Touriga Franca (Vitis vinifera L.), was studied under increasing summer stress conditions across Douro valley in the Demarcated Region of Douro - Portugal. The Douro region is divided into three climatic subregions: Baixo Corgo (BC), Cima Corgo (CC), and Douro Superior (DS) whose weather characteristics are presented and discussed in this study. In the Douro valley temperature increases and precipitation decreases from West (Baixo Corgo) to East (Douro Superior). Growing season precipitation has a mean value of 193 mm, representing 30% of the annual total (624 mm). Low precipitation values along with high temperatures and high radiation exposure give rise to situations of intense summer water and thermic stress, particularly in the Cima Corgo and Douro Superior subregions. The main objective of this study was to characterize the physiological response of non-irrigated grapevine cultivars Touriga Nacional and Touriga Franca growing under different summer stress conditions in the Douro region, during 2017 growing season. At veraison and ripeness stages, predawn and stem water potential showed a significant trend decrease from BC vines located in Régua to DS vines located in Almendra. Stomatal conductance, net CO2 assimilation rate, transpiration rate followed seasonal patterns similar to water potential. There was a marked reduction in these parameters from the lower to the higher dry site.

1 Introduction

In the hot and dry Douro Region, limitations in water supply have a great impact on grape production as the annual rainfall is not adequate to provide grapevines with their water requirements, and water deficits usually develop gradually during summer causing important crop losses [1].

To understand the physiological and molecular bases of plant responses to moderate to severe water deficits is therefore of utmost importance to modulate the appropriate balance between vegetative and reproductive development, to improve crop water use [2] and to control fruit quality under increasing water deficit conditions [3]. The study of grapevine water relations and gas exchange responses in grapevines growing under natural conditions, will help improve our understanding of the strategies employed by this plant species that lead to favourable growth and production.

The main objective of this study was to characterize the physiological response of non-irrigated grapevine cultivars Touriga Nacional and Touriga Franca growing under different summer stress conditions in the Douro region, during 2017 growing season.

2 Materials and methods

Three study areas were considered in this study: (i) Baixo Corgo (BC): Quinta da Pacheca in Régua (Lat. 41°08'28.8"N, Long. 7°49'01.2"W, elevation 136 m); Cima Corgo (CC): Quinta do Porto in Pinhão (Lat. °10'21.1"N, Long. 7°34'13.8"W, elevation 174 m) and Douro Superior (DS): Quinta da Leda in Almendra (Lat. (41°01'31.6"N, Long. 7°00'55.7"W, elevation 235 m). Seasonal changes in the stem water potential, stomatal

conductance, net CO2 assimilation rate, transpiration rate and intrinsic water use efficiency were monitored, on vines of both cultivars, growing under severe (DS) moderate (CC) and weak (BC) summer water stress conditions.

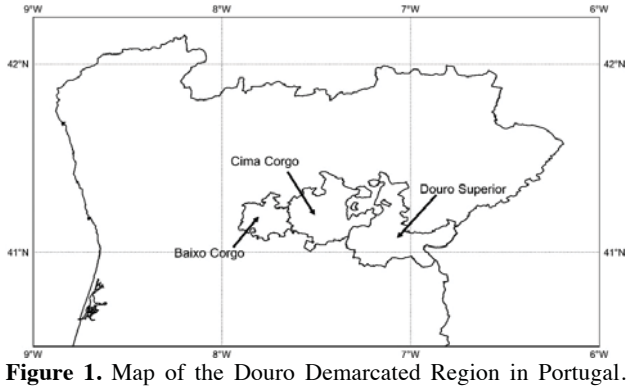

Figure 1. Map of the Douro Demarcated Region in Portugal. The map shows the location of the subregions 'Baixo Corgo', 'Cima Corgo' and 'Douro Superior'

Each plot had four replicates in a randomized complete block design. Each plot consisted of four rows with six vines per row and the surrounding perimeter vines were used as buffers.

Climatic data were automatically collected from three weather stations located near the vineyards. Fig. 1 shows the monthly rainfall and the mean air temperature at the experimental sites during the growing season.

Vine water status was monitored using a pressure chamber (Model 1000, PMS Instrument Company, Albany, USA) according to the method of Scholander et al. [4]. Stem water potential was measured in four fully expanded leaves, per plot (16 per treatment) of four representative plants.

Leaf gas-exchange rates were measured using a portable gas exchange system (LCA-4, Analytical Development Co., Hoddesdon, England). Measurements were performed in eight fully expanded leaves per treatment.

Statistical data analysis was performed by analysis of variance. Tukey HSD tests were carried out to determine the significance of differences between treatments means, using JMP®11.0.0 2013 (SAS Institute Inc.).

3 Results and discussion

3.1. Climate conditions and vine water status

The region is classified as a warm temperate climate (Köppen Csb), with average annual temperatures during 1980–2009 of 15.4□C, average Tmin in the coldest month dropping to 2.7□C, and average Tmax in the warmest month reaching 32.1□C [5]. Mean growing season temperatures from April to September (GST) for the same climatological period is 20.6°C. Growing season precipitation (GSP) has a mean value of 193 mm, representing 30% of the annual total (624mm). The average precipitation of the driest month (July) is just 11.2 mm. Low precipitation values along with significant temperature and radiation availability give rise to situations of intense summer plant-soil-water stress, particularly in the Cima Corgo and Douro Superior subregions [6]. The Huglin Index (HI), for the period 1980–2009, averaged 2740 □C d-1 the cool night index 13.6 □C and the dryness index (DI) -126 mm. In the Multicriteria Climatic Classification System (Geoviticulture MCC System) [7] is a climatic type HI+2/DI+2/CI+1 [17].

The year of 2017 was dry during winter and spring months and the summer was extremely dry (Fig. 2). Seasonal temperatures were within 10% of the 30-year site average in each study site.

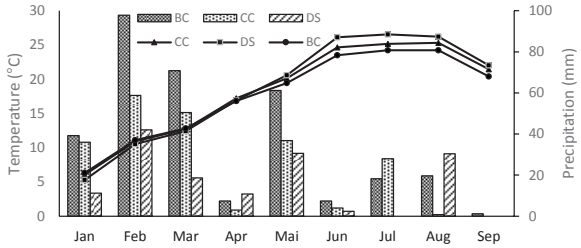

Figure 2. Monthly total precipitation (bars) and mean air temperature (lines) in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

The seasonal trends of predawn leaf water potential (Ψ_{pd}) are illustrated in Figs. 3 and 4.

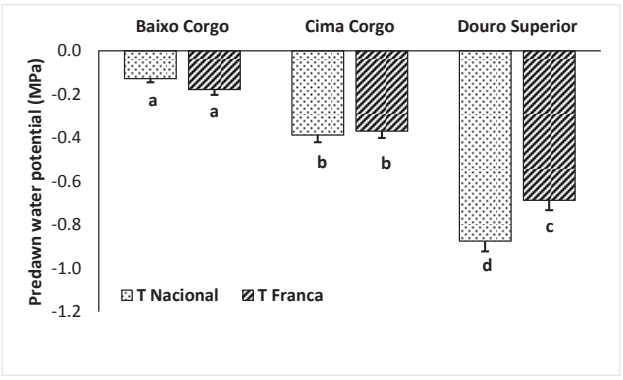

Figure 3. Predawn leaf water potential, at veraison, in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

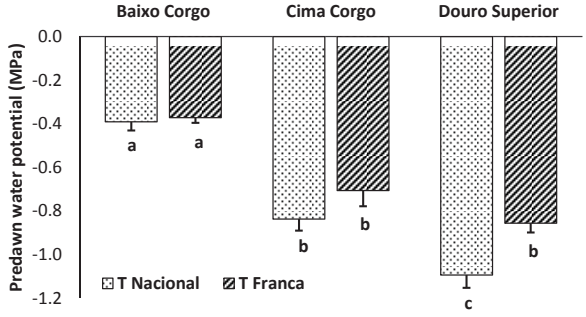

Figure 4. Predawn leaf water potential (ripeness) in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

At veraison the values of Ψ_{pd} of the BC and CC vines were more negative than than DS vines in both varieties, indicating that this plants were grown under better soil water availability. During ripening period, due to a higher soil water depletion, the Ψ_{pd} of CC vines was more negative and similar to DS vines. Under severe water stress conditions, the Touriga Franca (TF) variety showed a better water status than Touriga Nacional (TN). The values of Ψ_{pd} of TN were more negative in DS vines during the ripening period (Figs. 3 and 4).

3.2. Stomatal conductance, net CO_2 assimilation and transpiration rates

Stomatal conductance (g_s), net CO_2 assimilation (*PN*) and transpiration (E) rates followed seasonal patterns similar to predawn leaf water potential (Ψ). There was a clear decline in these parameters from the lower to the higher dry and hot site (Figs. 5 to 10). Under mild to moderate water deficits stomata closure is among the early plant responses, restricting water loss and carbon assimilation [8]. The results showed that grapevines in the Douro Superior sub region experienced more severe water stress and consequently lower photosynthetic rates, due to stomatal and non-stomatal limitations, than Baixo Corgo (BC) and Cima Corgo (CC) grapevines. Similar results were obtained by Moutinho-Pereira et al. [9] for the Touriga Nacional variety in the Douro region.

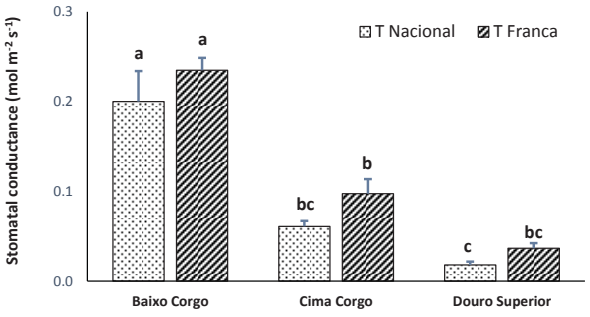

Figure 5. Stomatal conductance at veraison in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

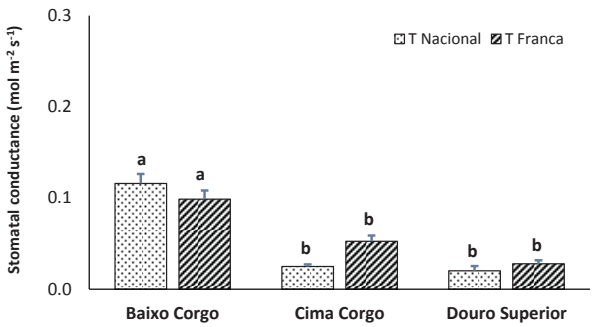

Figure 6. Stomatal conductance at ripeness in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

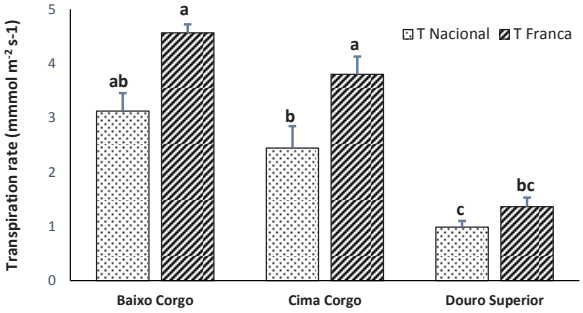

Figure 7. Transpiration rate at veraison in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

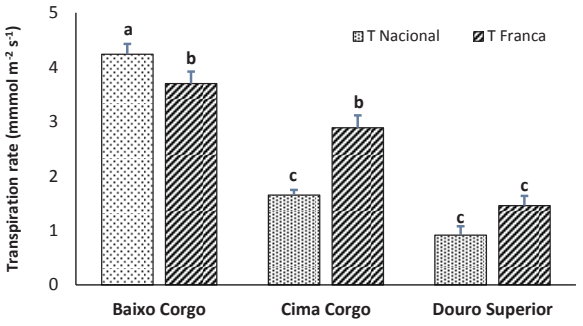

Figure 8. Transpiration rate at ripeness in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

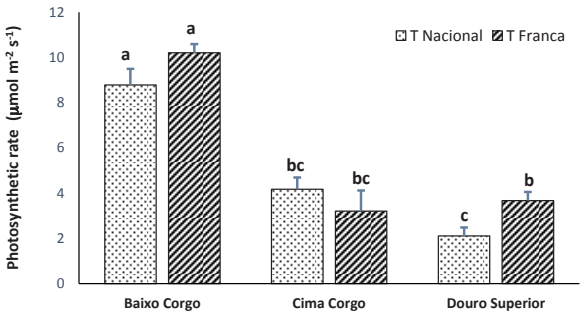

Figure 9. Net CO2 assimilation rate (*PN*) at ripeness in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

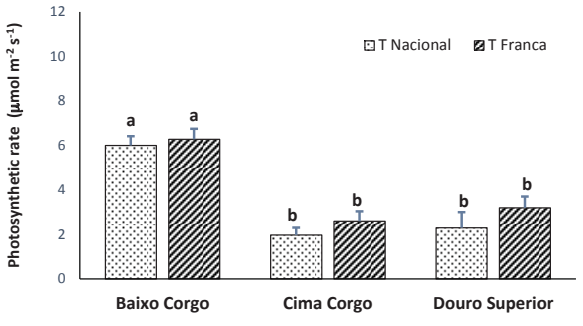

Figure 10. Net CO_2 assimilation rate (*PN*) at ripeness in the three experimental sites (BC-Baixo Corgo; CC-Cima Corgo; DS-Douro Superior) during 2017 growing season.

The relationship between leaf stomatal conductance to water vapour and predawn leaf water potential is shown in Fig. 11. A clear correlation was found between Ψ_{pd} and *gs*. This behaviour reflects the high degree of adaptation of grapevines to drought [10]; a small variation in induces a tight stomatal closure, so plant can maintained within a narrow range.

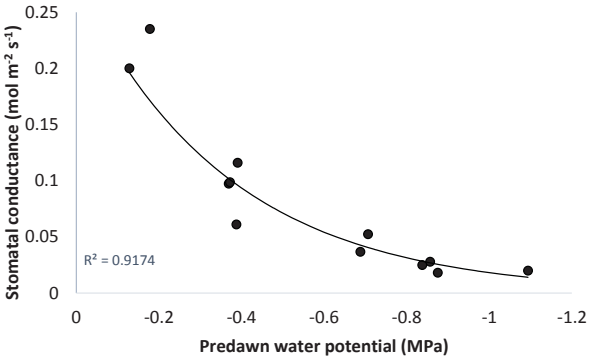

Figure 11. Relationship between leaf stomatal conductance to water vapour and predawn leaf water potential

4 Conclusions

The results in field-grown grapevines of the two most important varieties in the Port wine region, Touriga Nacional and Touriga Franca, reveal a pattern of gradual response of the main physiological parameters to increasing summer stress conditions across Douro valley. The results showed a significant influence of water availability on the stomatal conductance and photosynthetic rate cross the three different subregions and the importance of irrigation to regulate the grape yield and grape quality in the driest Douro Superior subregion.

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