Canopy and soil thermal patterns to support management of irrigated vineyards

Costa, J.M.[1,2], Egipto R. [1,3], Sanchez-Virosta [2,4], Lopes, C.M. [1], Chaves M.[2].

[1] LEAF, Linking Landscape, Environment, Agriculture and Food, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda 1349-017 Lisboa, Portugal, miguelcosta@isa.ulisboa.pt,
[2]LEM, ITQB Nova, Universidade NOVA de Lisboa, Oeiras, Portugal,
[3]INIAV, I.P. Pólo de Dois Portos, Quinta da Almoínha, 2565-191 Dois Portos
[4]Centro de Investigación Agroforestal Albaladejito(CIAF), Ctra. Toledo-Cuenca, km 174, 30814 Cuenca, Spain

Abstract

Irrigated viticulture expanded fast in Southern European countries such as Portugal to optimize berry yield and quality and to increase vine's longevity. However, intensive irrigation increases pressure over the local and regional water resources, that are getting scarcer, and increases also management costs. Additionally, row crops such as grapevine, are more vulnerable to heat stress due to the additional effects of soil heat fluxes which can negatively influence canopy and berry thermal condition. Therefore, a better understanding of grapevine responses (diurnal and seasonal) to environmental factors (air temperature, soil water) and agronomic practices (deficit irrigation, soil management) are on demand by the industry.

Ground based thermography was used to monitor the vertical profile of canopy temperature as well as soil temperature patterns along the day and season as means to assess plant water status and predict risks of heat stress damage. As part of the EU-INNOVINE project, field trials were carried in 2013, 2014 and 2015 in Alentejo (South Portugal). We examined the diurnal and seasonal response of two *V. vinifera* varieties Aragonez (syn. Tempranillo) and Touriga Nacional subjected to sustained deficit irrigation (SDI), and regulated deficit irrigation (RDI, about 50% of the SDI). Diurnal canopy (T_C), and soil surface (T_{soil}) temperatures were assessed by thermography. Punctual measurements of leaf temperature with thermal couples, leaf water potential and leaf gas exchange were also done.

T_C values were above the optimal temperature for leaf photosynthesis during part of the day light period (11:00-14:00h to 17:00h), especially under stressful atmospheric conditions (high VPD, high Tair) and under regulated deficit irrigation. T_{soil} was on average about 10-15°C higher than T_C. We found strong correlation between T_C (derived from thermography) and major physiological traits (leaf water potential and leaf gas exchange). Our results suggest that Tc can be explored as a simple but robust non-intrusive thermal indicator of grapevine performance and also as a parameter to feed grapevine growth models and to estimate heat and water fluxes in irrigated vineyards.

Keywords: Mediterranean viticulture, water and crop management, thermal imaging, heat and water fluxes

Introduction

Climate change scenarios for South Mediterranean Europe predict longer and more severe soil water deficits and higher air and soil temperatures (Teskey et al., 2014; Hannan et al., 2014; Rogiers and Clarke, 2014). In addition heat waves are also striking more frequently and for longer periods in South European Mediterranean regions (Teskey et al., 2014) which limits Mediterranean viticulture. Irrigation helps to mitigate the negative effects of drought and high air temperature (T_{air}); (Costa et al.,2007; Retallack 2012) by promoting evaporative cooling at the canopy via transpiration and contributing to decreasing surfacial soil temperature (T_s) minimizing the impact of heat wave conditions on the overheating of the cluster zone of the canopy. As a result, irrigation has been expanding in warm and dry wine regions worldwide including South Portugal (Costa et al., 2016). In parallel, sustainable water use in modern irrigated viticulture depends on more precise irrigation as well as soil and crop management. Genotype may influence grapevine responses to drought and heat stress namely via different leaf gas exchange behavior (Chaves et al., 2010; Bota et al., 2016). However, there are still knowledge gaps regarding the combined effect of drought and high temperatures on grapevine physiology. Moreover, we need more insight on the effect of T_s on grapevines in particular at the cluster level especially under extreme high T_{air} & T_s conditions. To that extent we examined the diurnal and seasonal response of two grapevine varieties Aragonez (syn. Tempranillo) and Touriga Nacional subjected to two deficit irrigation strategies.

Material and methods

The experiment was located in a commercial vineyard in Alentejo, Reguengos de Monsaraz, South Portugal (38° 23’ 55.0’’ N, 7° 32’ 46.00’’ W, elevation 200 m). The climate is typically Mediterranean, with mild temperatures in winter, rarely below to 5 ºC, and dry and warm summers, with especially high temperatures in July and August, when average temperature reaches 25 ºC, with maximum values above 40 ºC punctually. We used 11 years-old vines of two red varieties Touriga Nacional (TOU) and Aragonez (ARA), grafted onto 1103 P, and planted at a density of 2,200 vines/ha. Vines were trained on a bilateral Royat Cordon system. Soil texture was a sandy–loam to silty-clay-loam, with a pH of 7,0 to 7,6, a low content in organic matter. Deficit irrigation was applied by drip irrigation (single pipe line,1.8 emitters/per vine, flow rate of 2.1 L/h).

Two irrigation treatments were tested: Sustainable deficit irrigation (SDI – control, according to farm’s scheduling and 30% ETc), with water applied 1 to 2 times a week from berry touch (berries beginning to touch - stage 77 of the BBCH-scale for grapes) and regulated deficit irrigation (RDI, 50% of the SDI in 2013 and 65% in 2014 and 2015) (Table 1). Diurnal curves of leaf water potential (ψ_{leaf}), canopy temperature (Tc) and leaf gas exchange were done along three consecutive years (2013, 2014 and 2015) for both varieties. Observations were done at flowering/berry touch, veraison and at full maturation. Leaf water potential was measured with a Scholander pressure chamber. Ground based measurements of Tc were done by using thermal imaging ((Flir B20, 7-13 μm, 320x240 pixels; ε=0.96). Thermal images were followed by visible RGB imaging. Thermal images were analysed with the ThermaCAM image analysis software (Flir, USA) and thermal patterns were analyzed in Excel. Leaf gas exchange was determined with a Licor 6400, Licor Inc, USA), equipped with a 2x3cm transparent leaf chamber. The experimental set up was a randomized complete block design with two irrigation treatments and four replications per treatment. The relationships between Tc and water potential and stomatal conductance (gs) were assessed by correlation analysis for the two genotypes. Statistics were done by using Pearson correlations between variables (T_c, gs, VPD), with the Statistix 9.0, analytical software.

Results and discussion

The seasons 2013, 2014 and 2015 showed marked differences with regards to climate conditions. Although solar radiation was similar along the three years, 2013 and 2015 were the warmest years and 2015 was also the driest. Because of that longest irrigation period and the highest volume of irrigation water was applied in 2015 (Tab.1). The year 2014 had also lower VPDair and T_{air} which resulted in the lowest value of cumulative ET_0 for the triennia (Tab.1).

ARA showed a tendency for lower leaf water potential as compared to TOU (data not shown) suggesting that ARA is losing more water along the season. This can be due to different phenology (earlier shoot development that the cv TOU) and/or to larger total leaf area along the growing cycle, which results in larger transpiration.

Extreme Tair and low VPDair resulted in Tc values clearly above the optimum Tleaf for photosynthesis and for long periods (> 8h). T_c was 3-8ºC above the optimum temperature for photosynthesis (25-30ºC) (Mullins et al., 1992). This occurred especially in the warmest years of 2013 and 2015. Tc was strongly negatively correlated with water potential and leaf stomatal conductance to water vapour (Fig 1) and correlations seem to be stronger in the afternoon and in the driest years. Frequency distribution of canopy and soil temperatures under clean sky conditions, for vines of the variety Aragonez subjected to RDI conditions, show different thermal patterns for the canopy (top and cluster zone) and soil (Fig. 2). Ts values were also significantly higher than Tc,

Conclusions

Inter-annual climate variation induced major variation in irrigation needs (Table 1). Differences between genotypes were only clear for ψ_{pd}. ARA had the lowest values of ψ_{pd} which should be due to larger canopy area/evaporative water loss. Overall Tc patterns were similar for the two genotypes. Tc is negatively correlated with gs and leaf water potentia Indicating that Tc is a simple but still robust thermal indicator to assess water status/leaf gas exchange in grapevine (Garcia-Tejero et al., 2016).

Ts under sunlit conditions was about 10-15ºC higher than Tc, suggesting that soil temperature and derived heat fluxes may influence canopy thermal condition especially under warm conditions. Further research on heat fluxes in vineyards is important to optimize irrigation and mitigate the effects of supra-optimal temperatures.

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Tables and Figures

Table 1 - Cumulative data for rainfall, ETo and irrigation water used along the trial in the SDI and RDI treatments.

ANO	Rainfall (growth phase) (Mar - Ago) (mm)	Cumulative ET0 (Mar - Ago) (mm)	SDI (May/Jun - Ago) (mm)
2013	**255**	**820**	**112**
2014	**157**	**776**	**67**
2015	**95**	**940**	**163**

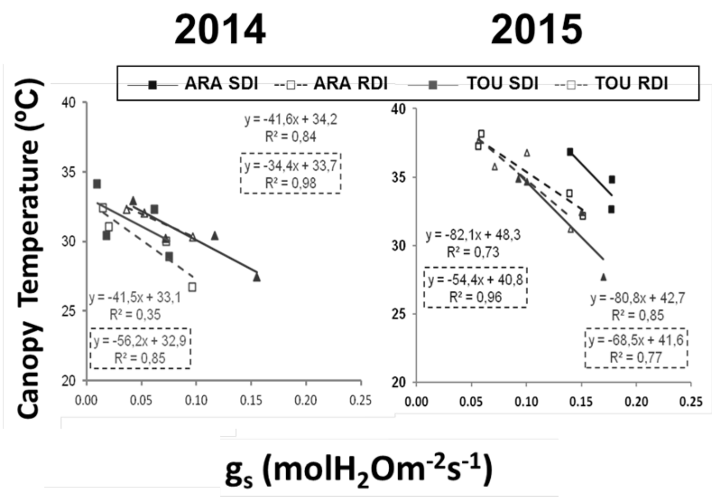

Figure 1 - Relation between sunlit Tc (ºC) and stomatal conductance to water vapour (MPa) for the two *V. vinifera* varieties (Aragonez- ARA and Touriga Nacional- TOU) measured in 2014 and 2015, when subjected to deficit irrigation (RDI e SDI). Measurements were done between 14.00 and 17.00h.

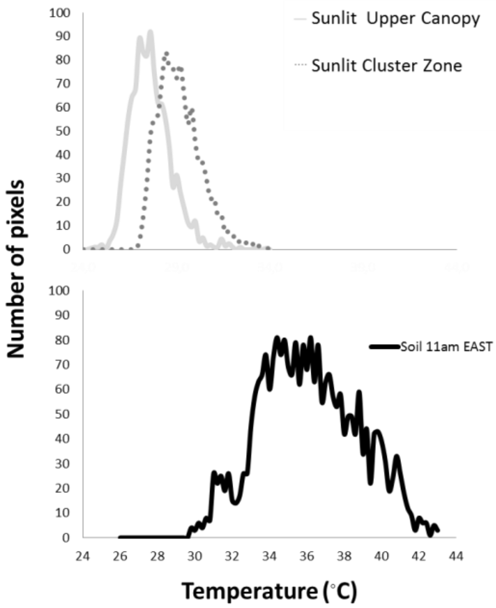

Figure 2 - Pixel frequency for temperatures of the sunlit canopy (upper canopy and cluster zone) (on the top) and from the sunlit soil (at the bottom). Temperature values derived from ground based thermography measurements made on 8-9 July 2015 at 11.00 a.m, for vines of the variety Aragonez subjected to RDI irrigation conditions.