# METEOROLOGICAL PARAMETERS EFFECT ON DIURNAL AND NOCTURNAL TRANSPIRATION AND STOMATAL CONDUCTANCE GRAPEVINE

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## Introduction

Until recently, it had been commonly assumed that plant stomata close at night, preventing water loss through transpiration during non-photosynthetic periods. Nocturnal transpiration ($T_N$) accounts for 10-30% of the total daily transpiration (T) flux (Novick et al 2009; Montoro et al. 2016), although higher rates have been reported in some extremes cases (Snyder et al. 2003). Numerous and dynamic meteorological variables impact on evapotranspiration (ET) and T (e.g., relative humidity, air temperature, vapor pressure deficit, wind speed, solar radiation) and many variables that influence the diurnal evapotranspiration ($ET_D$) cannot explain variation in nocturnal evapotranspiration ($ET_N$) (i.e. assimilation rates, light) (Novick et al. 2009).

There is little information available on night-time water losses of grapevines, but it could potentially be important for regions with frequently high wind velocities (Chu et al. 2009) and high night-time temperatures and vapour pressure deficit (VPD). Schmid (1997) observed that high wind velocities correlated with high night-time sap flow rates of field-grown Riesling grapevines in Germany. However, most studies have shown that water deficit and salt stress will cause night-time g to decrease (Caird et al. 2007). The strong response to environmental factors indicates that these phenomena should be studied specifically in warmer and dryer areas (Schultz and Stoll 2010).

Moreover, water use efficiency (WUE) depends on complex interactions between environmental factors and physiological mechanisms such as stomatal behaviour (Bacon 2004). Night-time water use also affect to WUE, and changes in plant water status will alter it, yet there is only little information available on that process for grapevines (Schultz and Stoll 2010). Thus, there is a need to understand the physiological mechanisms and the interactions between plants and the environment, and more than ever before, to pay attention to research fields which will be pivotal for the development of sustainable concepts under changing conditions (Schultz and Stoll 2010).

The aims of this work were to: (i) study relationship between measured of nocturnal T ($T_N$) and diurnal T ($T_D$) every 15 minutes and meteorological variables; and (ii) evaluate daily stomatal conductance with same variables, in order to understand how the environmental conditions can affect both parameters in grapevine cv. Tempranillo under semiarid conditions.

## Materials and methods

The study was carried out during 2015, at the Las Tiesas farm, Albacete, Spain (lat. 39°3´31´´N; long. 2°6´04´´W) at an altitude of 695 m above sea level. The climate is semiarid continental with an average annual rainfall of 320 mm, which is mostly concentrated in spring and fall. The soil is classified as a Petrocalcic Calcixerept (Soil Survey Staff 2006).

Two vines (*Vitis vinifera* cv. Tempranillo) grafted to 110 Richter rootstock planted in a lysimeter of 9 $m^2$, in 1999 were studied. The spacing between the vines and rows was 1.5 and 3 m, respectively. Eight weeks prior to bud break, the plants were pruned to bilateral cordons, each carrying five spurs with two buds. The shoots were maintained on a vertical plane by three wires, the highest of which was located 1.40 m above the soil surface. Vines were irrigated with two emitters each one of 4 l $h^{-1}$. Nutrient, pest, and disease management practices were applied according to standard commercial practice. Further descriptions of the experimental site and vines are presented in Montoro et al. (2008) and López-Urrea et al. (2012). The sample frequency of lysimeter was 1 s, and the mean value was recorded with a datalogger (CR10X, Campbell Scientific Ltd., Logan, UT, USA) every 15 minutes. ET was calculated as the difference of consecutive mass loss.

With the aim of isolating T, the lysimeter was covered with a waterproof canvas, only a few days in three main phenological stages: bounch closure, veraison and maturation. T was calculated as the difference of consecutive mass loss.

Meteorological variables were measured during the experiment using an automated weather station located over a reference grass surface less than 100 m from the vineyard lysimeter. All data were registered in 15 min, hourly and daily time steps and stored in two dataloggers (model CR10X, Campbell Scientific Instrument, Logan, UT, USA). Variables measured, sensor type, model, manufacturer and the sampling frequency (SF) were as follows: air temperature (PRT 100 Ohm, model MP100, Campbell Scientific Instrument, Logan, UT, USA, SF: 1 s); relative humidity (Rotronic Hygromer C-80, model MP100, Campbell Scientific Instrument, Logan, UT, USA, SF: 1 s); wind speed (Switching Anemometer, model A100R, Vector Instruments Ltd., UK, SF: 1 s); wind direction (Potentiometer Windvane, model W200P, Vector Instruments Ltd., UK, SF: 1 s); shortwave radiation (Pyranometer, model CM14, Kipp & Zonen Delft, Holland, SF: 10 s); longwave radiation (Pyrgeometer, model CG2, Kipp & Zonen Delft, Holland, SF: 10 s); rainfall (Rain gauge, model ARG100, Campbell Scientific Instrument, Logan, UT, USA, SF: 1 s).

Other parameters measured were $CO_2$ flux, obtained using directly measured fluxes with the eddy covariance technique, installed in the same plot and stomatal conductance (g), measured four times on some days with a porometer SC-1 model (Decagon Devices, Inc., Pullman, Washington).

## Results and discussion

Figures from 1 to 5 show the relationship between meteorological variables (air relative humidity, global radiation solar, air temperature, wind speed and vapour pressure deficit, respectively) and transpiration (diurnal and nocturnal) every 15 minutes. It is shown in all of them that $T_N$ and $T_D$ response to variables studied. On $T_D$ the parameter that influenced the most was air temperature ($r^2$=0.85) followed by wind speed ($r^2$=0.73) and relative air humidity, global radiation solar and vapour pressure deficit ($r^2$ from 0.65 to 0.60, respectively). $T_N$ had a similar behavior regarding air temperature and wind speed, whereas the $r^2$ for the regression with relative humidity and VPD resulted very low in both cases. Some of these results are consistent with previous studies in which measured $ET_N$ was strongly correlated to wind speed (Novick et al. 2009), but differ from the same work and others in the relationship with VPD (Fisher et al. 2007; Ward et al. 2008).

Note different aspects from the figures; for example, no significant differences between $T_N$ and $T_D$ are observed for air relative humidity values over 80% (Figure 1) or air temperature values below 15ºC (Figure 3). Figure 2 shows there is a rapid increase of T for the range 0-200 W/$m^2$ in global solar radiation, becoming almost flat after then. Temperatures above 22 ºC produced a substantial increase in $T_D$ (Figure 3).

Figure 6 shows the negative relationship between nocturnal $CO_2$ flux and $T_N$ and $T_D$ every 15 minutes, revealing stomatal closure with an accumulation of $CO_2$ in the leaves. In this sense, Zeppel et al. (2012) showed that different ambient $CO_2$ concentrations and temperatures can determine changes in stomatal conductance at nighttime for Eucalyptus trees.

Significant relationships between $T_N$ and $T_D$ rates were observed, consistent with previous findings (Novick et al. 2009). This result is consistent with previous observations showing that nocturnal transpiration is higher for species with high extension growth rates and low shade tolerance, and may represent a tendency for these species to trade water for enhanced nocturnal carbon export driven by dark respiration (Marks and Lechowicz 2007).

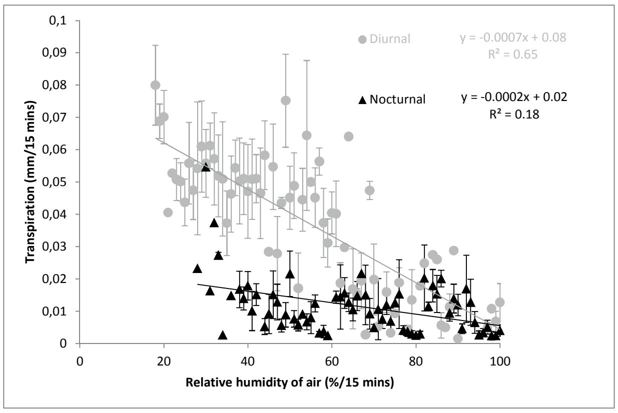


Figure 1: Relationship between air relative humidity and transpiration (diurnal and nocturnal) every 15 minutes.

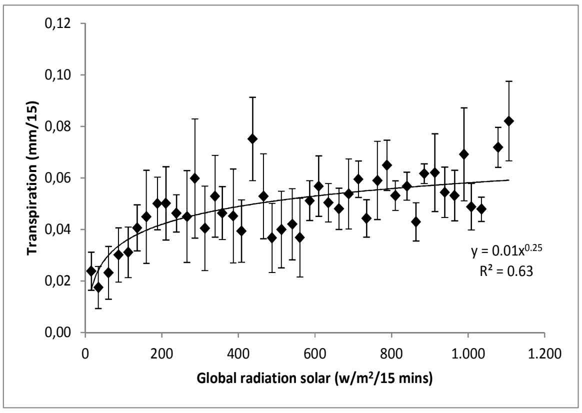


Figure 2: Relationship between solar global radiation and transpiration (diurnal) every 15 minutes.

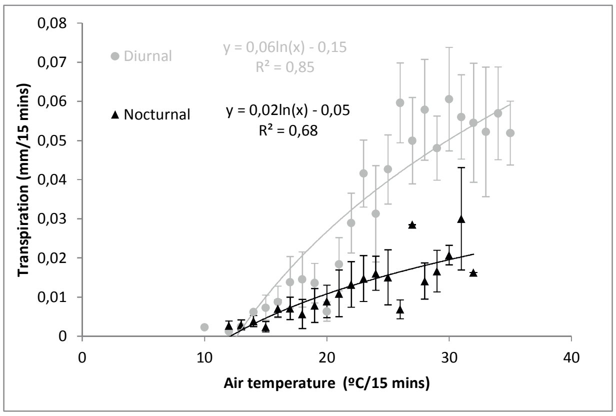


Figure 3: Relationship between air temperature and transpiration (diurnal and nocturnal) every 15 minutes.

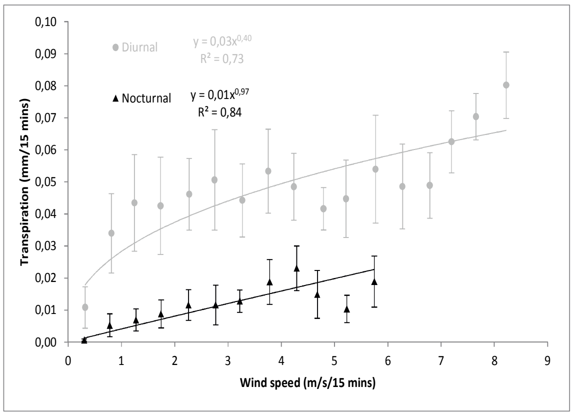


Figure 4: Relationship between wind speed and transpiration (diurnal and nocturnal) every 15 minutes.

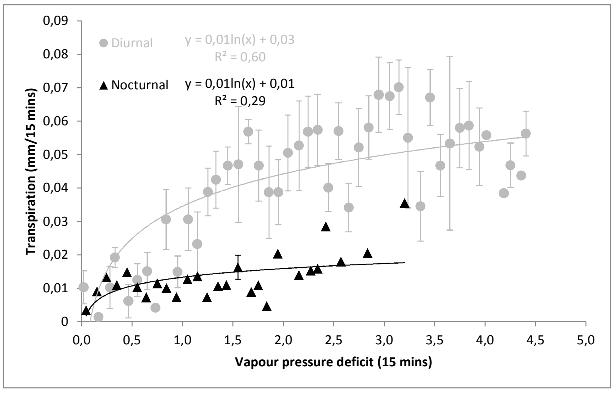


Figure 5: Relationship between vapour pressure deficit and transpiration (diurnal and nocturnal) every 15 minutes.

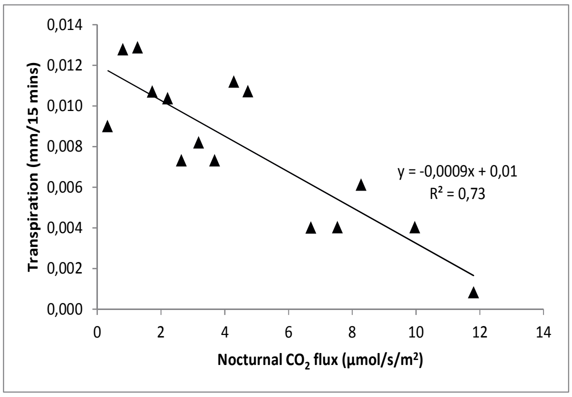


Figure 6: Relationship between nocturnal CO2 flux and transpiration every 15 minutes.

As an example, one day of stomatal conductance measurements is shown in Figures 7-10. Four measurements of g were taken from 8:00 am to close 7:00 pm. A maximum value was reached in the first measurement (314 mmol/m$^2$ s), decreasing afterwards and reaching the minimum value at 7:00 pm (82 mmol/m$^2$ s). Evapotranspiration peaked around the second measurement of g (11:30 am). G dependence on wind speed, air temperature, relative humidity and global solar radiation was analyzed. Note air relative humidity matches stomatal conductance evolution from 8:00 am to 7:00 pm. However, no dependence of g is observed with wind speed nor air temperature, according to the results found under these conditions.

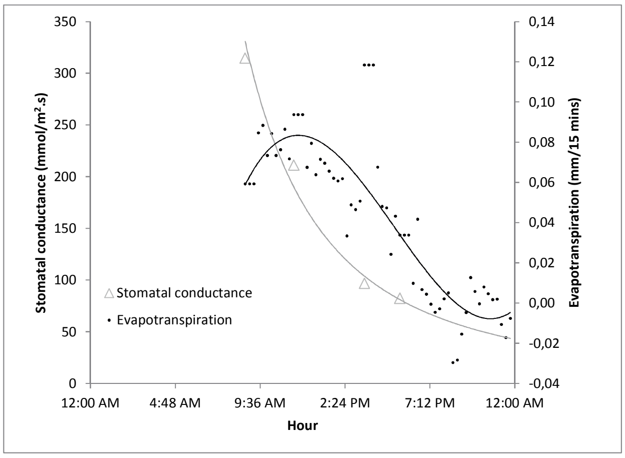


Figure 7: Daily evolution of stomatal conductance and evapotranspiration.

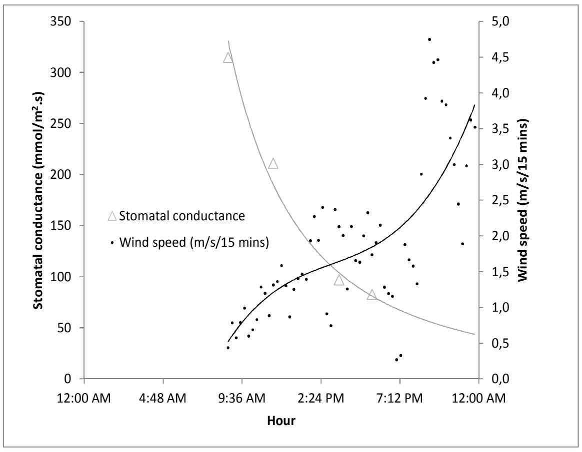


Figure 8: Daily evolution of stomatal conductance and wind speed.

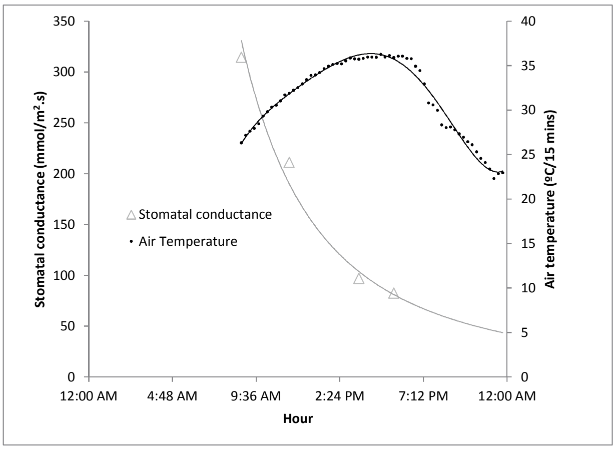


Figure 9: Daily evolution of stomatal conductance and air temperature.

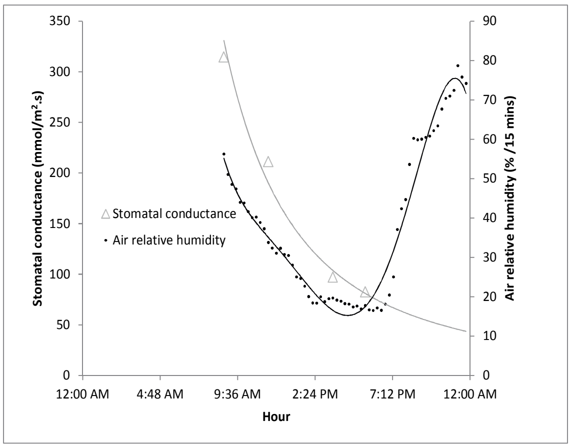


Figure 10: Daily evolution of stomatal conductance and air relative humidity.

## Conclusions

In summary, the results of the present work show significant transpiration during the night in irrigated grapevines. Moreover, the effect of different meteorological parameters in the process has been shown, highlighting that the global solar radiation appears as a switch in the process of transpiration, but other parameters such as wind speed and air temperature have a direct effect on the process of T and not always they are related to conductance stomatal.

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***Abstract***

*An experiment was carried out in a semi-arid area of Spain (Albacete) with the objective of quantifying the effect of different meteorological parameters on transpiration and stomatal conductance grapevine cv. Tempranillo. Measurements of evapotranspiration were taken in a weighing lysimeter during 2015. Air temperature, relative humidity, wind velocity and solar radiation were measured with an automated weather station located over a reference grass surface less than 100 m from the vineyard lysimeter. The sample frequency was 1 s, and a mean value was recorded with a datalogger (CR10X, Campbell Scientific) every 15 minutes. Stomatal conductance was measured four times on some days. The result shows how evapotranspiration and conductance are affected by the different meteorological parameters.*

***Keywords: Diurnal evapotranspiration, nocturnal evapotranspiration, meteorologigal variables, lysimeter, stomatal conductance***