A PRAGMATIC MODELING APPROACH TO ASSESSING VINE WATER STATUS

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Abstract:
Context and purpose of the study - Climate change scenarios suggest an increase in temperatures and an intensification of summer drought. Measuring seasonal plant water status is an essential step in choosing appropriate adaptations to ensure yields and quality of agricultural produce. The water status of grapevines is known to be a key factor for yield, maturity of grapes and wine quality. Several techniques exist to measure the water status of soil and plants, but stem water potential proved to be a simple and precise tool for different plant species. The interpretation however of this value remains difficult because it is influenced by both soil water content and climatic conditions at the time of measurement. Where soil water content usually follows a decreasing curve during the summer season and climatic conditions follow a more erratic evolution. With predawn leaf water potentials (PLWP) serving as a proxy for soil water content and midday stem water potentials (SWP) reflecting water supply and climatic conditions, it becomes possible to separate the effect of soil water content and climatic conditions on vine water status. Direct use of PLWP measurements on soils with heterogeneous water content is not an option because it is less accurate than SWP measurements and a late-night measurement is not practical. The objectives of this study are (i) to provide a model that separates the effect of soil water content from the effect of climatic conditions on the SWP value and (ii) to standardize the SWP value to a value under predefined reference climatic conditions to better reflect soil water availability, and to compare SWP values under different climatic conditions.

Material and methods -Vine water status was assessed on three soil types in the AOC Saint-Émilion in 2015 and on 5 soil types in the AOC Margaux in 2018. Over the growing season, SWP and PLWP were measured on mature leaves using a pressure chamber.

Results - New models with easily accessible variables can separate the effect of soil water content from the effect of climatic conditions on the SWP values. The measurement of the PLWP is no longer necessary. More research is needed however to understand the changing relationship between SWP and daily maximum temperature over time. SWP values can be brought back to a theoretical value representative of standard climatic conditions. This standardization can be particularly interesting in a context of climate change, where a greater variability of climatic conditions between years is observed. A more precise interpretation allows the winegrower and consultant to more adequately decide on adaptations to implement in both the short- and long term to ensure yields and grape quality.

Keywords: Grapevine water status, stem water potential, predawn leaf water potential, maximum temperature, vapour pressure deficit, evapotranspiration.

1. Introduction.

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Objectives

1. To provide a model that separates the effect of soil water content from the effect of climatic conditions on the stem water potential (SWP) value
2. Standardize the SWP value to a value under predefined reference climatic conditions to better reflect soil water availability, and to compare SWP values under different climatic conditions

A. Introduction

Climate change scenarios suggest an increase in temperatures and an intensification of summer drought (IPCC, 2014). The water status of grapevines is known to be a key factor for yield, maturity of grapes and wine quality (Van Leeuwen et al., 2009). The SWP proved to be a simple and precise tool for different plant species (Shackel, 2011). The interpretation however of this value remains difficult because it is influenced by both soil water content and climatic conditions at the time of measurement.

B. Methods

Vine water status was assessed on different soil types in Saint-Émilion in 2015 (6 experimental plots) and in Margaux in 2018 (12 experimental plots). Measurements were performed on couples of two consecutive days (Figure 1 & 2).

Figure 1. Stem water potential (SWP) and predawn leaf water potential (PLWP) were measured using a pressure chamber

C. Results

C1. 2018 Season

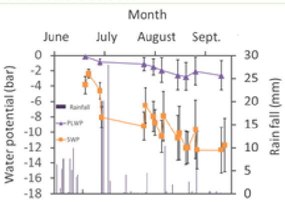

Figure 2. SWP and PLWP decreased over the course of the season. Error bars shown are standard deviations

C2. SWP, PLWP and Daily maximum temperature (T_{max})

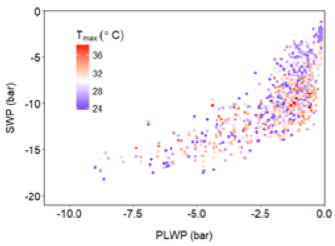

Figure 3. Relationship between SWP and PLWP where the blue-to-red gradient represents increasing T_{max}. Every data point represents a single vine (n = 1,067)

- SWP decreases nonlinearly with more negative PLWP (Figure 3)
- There is a temperature effect, where higher daily maximum temperatures result in more negative SWP
- The relationship between maximum temperature and SWP flattens with more negative PLWP

C3. Seasonality

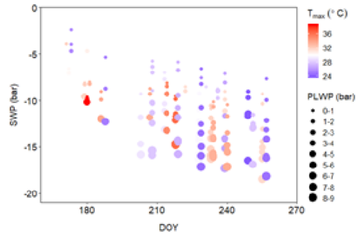

Figure 4. Relationship between SWP and day of year (DOY) where the blue-to-red gradient represents increasing daily maximum temperature, and the point size represents ranges of PLWP (per 1 bar). Data averaged over sampling dates and experiment plots

- SWP decreases over time, where PLWP has an negative additive effect
- The relationship between maximum temperature and SWP changes over time
- For the same PLWP and maximum temperature, SWP is more negative later in the season

C4. Model selection

Table 1. Comparison of goodness-of-fit and predictive power of models divided into 80% training data and 20% validation data

nr.	Models	AIC	BIC	r^2	RMSE - training	RMSE - validation
1	$SWP = 12{,}43 \cdot e^{-0{,}401 \cdot PLWP} - 16{,}16$	4636.7	4656.5	0.66	2.14	2.17
2	$SWP = 201{,}64 \cdot e^{0{,}389 \cdot PLWP} \cdot T_{max}^{-0{,}819} - 16{,}28$	4497.5	4522.3	0.70	1.99	2.08
3	$SWP = 247{,}89 \cdot e^{0{,}214 \cdot PLWP} \cdot T_{max}^{-0{,}896} - 0{,}0543 \cdot DOY - 5{,}79$	4076.9	4106.7	0.80	1.60	1.82

- Models with different climatic variables performed as follows (by increasing order of AIC/BIC): $T_{max} < VPD_{max} < VPD < ET_0$
- Inclusion of T_{max} improved AIC by 3.1%
- Inclusion of DOY improved AIC by another 10.3%

C5. Model validation

SWP_{n+1} standardized to T_{max} at SWP_n, $SWP_{n+1_s} = \dfrac{SWP_{n+1} - d}{\left(\dfrac{T_{max_{n+1}}}{T_{max_n}}\right)^c} + d$

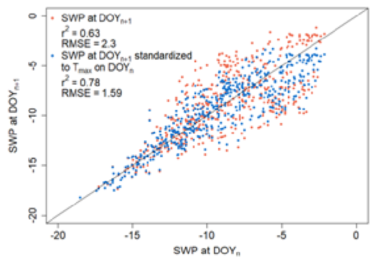

Figure 5. SWP measured at DOY_n plotted as a function of SWP measured at DOY_{n+1} (in red) and SWP measured at DOY_{n+1} standardized to T_{max} on DOY_n (in blue)

- When corrected to T_{max} of the previous day, the rearranged model is able to reduce RMSE by almost 31% (0.71 bar)

Conclusions

1. New models with easily accessible variables can separate the effect of soil water content from the effect of climatic conditions on the SWP value (Table 1)
2. SWP values can be brought back to a theoretical value representative of standard climatic conditions (Figure 5)
3. More research is needed to understand the changing relationship between SWP and daily maximum temperature over time (Figure 4)

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