Use of phytomonitoring to evaluate the irrigation scheduling in vineyards (*Vitis vinifera* L.) of Itata Valley Chile

Abstract

The phytomonitoring is a technology that provides information in real time of crop water status and allow to make a feedback between crop and grower to improve the irrigation control. The aim of this investigation was to assess the plant water status and its effect on yield and quality parameter in a commercial vineyard under drip irrigation in an Ultic Palexeralf soil during the 2008-2009 growing season at Central Southern of the Ñuble Region, Itata Valley, Chile. The experimental design was split-plot with three treatments of soil texture: clayey loam, sandy clay and clayey, and three sub-treatments of 'Cabernet Sauvignon', 'Merlot' and 'Syrah' cultivars. Stomatal conductance, leaf-air temperature, cluster weight, berry diameter, berry weight, and soluble solids content were evaluated. The results showed that the phytomonitoring is useful to evaluate the irrigation management in vineyards. Stomatal conductance and leaf-air temperature showed good performance as indicators of vine water status and grapevine quality. This study highlights the effect of soil texture on yield and wine quality in grapevines of semi-arid zones with drip irrigation.

Keywords: stomatal conductance, leaf temperature, soil texture, yield components

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Introduction

Different instruments measure various aspects of soil-water relations, but none directly assesses the portion available water to the vine. Thus, they do not provide an accurate map of the spatial and temporal variability in moisture throughout the vineyard and such variation can significantly affect vine growth and irrigation efficiency.¹ Nowadays, the phytomonitoring technique allows the acquisition of a big pool of soil-plant-water data in real time, making possible a more precise estimation of vineyard water fluxes.

Phytomonitoring is a management information system for crop growing and has three main functions: generate a customized set of measured values and their derivatives used by a grower in daily control, productive, early detection of unexpected disorders in plants and decision support-system.²

This system includes the moisture measurements and the development of an intelligent control system, in order to maintain the moisture level around level set, such as water stress or field capacity, according to the desired enological grape quality, in addition helps to overcome difficulties imposed by a growing water demand.³ The use of physiological parameters to assess the dynamics of plant water status has attracted the attention of many growers. This technique relates the soil physical properties and the environmental conditions within the orchard with its effects on plant growth.

Plants express physiological responses to dynamic balance changes in the soil-plant-water-environmental system and the phytomonitoring measures the plant water status, integrating the soil water availability with the air vapour pressure deficit, decreasing the effect of soil spatial variability in the management of frequency and timing irrigation.⁴ This technique combines data acquisition system based on specific sensors and data processing software, which presents measuring information

in terms of plant physiology and agronomy⁵ and has demonstrated great potential for assessing vine water status.⁶

Water status parameters such as midday stem water potential (Ψ_s), stomatal conductance (g_s), and leaf-air temperature (dT) have been used to improve the irrigation management for vineyard in arid areas.⁷ The infrared thermometry can be used for the irrigation scheduling of the grapevine.⁸ However, the variable responses of different cultivars to different climatic conditions and water stress levels make it difficult to use only one indicator for vine water status or irrigation scheduling.⁹ According to Cifre et al.⁷ g_s is a more precise and sensitive indicator of water stress than Ψ_s and relative water content (RWC), when mild or moderate soil water deficit is applied.

Stomatal closure is known to be a sensitive response to soil water deficit and can be used to determine the water status of plants. Direct estimation of leaf stomatal conductance to water vapor from temperature measurements, avoids the need for multiple and time-consuming leaf gas-exchange measurements and allows for assessment of variation in stomatal conductance over large crop area.¹⁰

The aim of this investigation was to assess the use of stomatal conductance and leaf-air temperature on the irrigation scheduling of three grapevine cultivars under drip irrigation in an Ultic Palexeralfs soil, Central Southern of the Ñuble Region, Itata Valley of Chile.

Materials and methods

Site experimental

A field experiment was carried out in a commercial vineyard planted in 2004 at central-southern Chile (36° 36' S, 71° 55' W), Ñuble Region, Itata Valley, in an Ultic Palexeralfs soil, during 2008-2009 growing season. The climate is Mediterranean with average

annual rainfall is 1100 mm. Annual reference evapotranspiration is reported as 1200 mm, with a dry period of 4 to 5 months and with 5-6 frost-free months. Average annual mean temperature for this area is 13.5°C with an average temperature of 3.7°C in the coldest month (June) and 28°C in the hottest month (January). Annual mean relative humidity is 70%.¹¹

Vineyards

The commercial vineyard (Figure 1) has an area of 50 ha divided in 13 drip irrigation sectors. The cultivars 'Cabernet Sauvignon', 'Merlot' and 'Syrah' were planted at 3 m between rows and 0.8 m between plants, trained by modified Scott Henry system. The vines were irrigated by drip irrigation (one emitter per vine at 4 Lh⁻¹ and 10 w.c.m.). The timing varied from 1 to 4 hours and the irrigation frequency of 1 to 2 days. The applied water volume during the growing season were 1640 m³ ha⁻¹ in clayey loam, 1987 m³ ha⁻¹ in sandy clay and 1261 m³ ha⁻¹ in clayey soil.

Figure 1 Vineyards Santa Cruz de Bellavista farm, Riveras del Valle wines, Itata valley, Ñuble region, Chile.

Experimental design

The experimental design was a split-plot with three treatments of soil texture (clayey loam, sandy clay and clayey), three sub-treatments: 'Merlot', 'Cabernet Sauvignon' and 'Syrah' cultivars, and three replicates of 10 vines.

Evaluations

Stomatal conductance (g_s) and leaf-air temperature (dT) was measured every 15 days between 11:00 and 16:00 hr using a diffusion porometer (Delta-T AP4 Devices, Cambridge, UK) in 6 leaf per vine. At harvest, cluster weight, berry diameter and berry weight in 4 clusters per vine were measured. The equatorial diameter of 100 berry per cluster by calibrator 15-28 mm (Field Instruments, Santiago, Chile) and soluble solid concentration using a thermo-compensated refractometer to meter 0-32° Brix (Atago N-4e, Atago Co. Ltd., Atago, Japan) were measured.

Statistical Analysis

Data analysis was done by ANOVA. The comparison of treatments mean was made by the Duncan's test at 5% probability. Normality was contrasted with the Shapiro-Wilks modified.¹²

Results and Discussion

The gas exchange plant-atmosphere was similar during the growing season, that g_s values in January were of 172 and 175 mmol m⁻² s⁻¹ in clayey loam and clayey soil, respectively and 179 mmol m⁻²

s⁻¹ in sandy clay soil (Figure 2). However, November showed greater values of g_s in three soil textures due to low crop evapotranspiration (24 mm) as compared with critical month (113 mm). An optimum threshold for g_s ranged between 50 and 150 mmol m⁻² s⁻¹ is adequate to increase water use efficiency in grapevines.¹²

Figure 2 Stomatal conductance (g_s) in grapevine with drip irrigation in three soil texture of an Ultic Palexeralfs during the growing season.

Regarding soil texture, the lower g_s was found in sandy clay (193 mmol m⁻² s⁻¹) that indicate a mild water stress in comparison with clayey loam (208 mmol m⁻² s⁻¹) and clayey soil (205 mmol m⁻² s⁻¹) (Figure 3), probably because the applied water volume was lower (1987 m³ ha⁻¹) that the vine water requirements. Besides, the sandy soils have lower water-holding capacity that decreased the leaf gas exchange.¹³

Figure 3 Stomatal conductance (g_s) in grapevine with drip irrigation in three soil texture of an Ultic Palexeralfs. Different letters on each column indicate significant differences at $p \leq 0.05$ according to Duncan's test.

Regarding cultivars 'Cabernet Sauvignon', 'Merlot' and 'Syrah' showed significant differences ($p < 0.05$) of g_s in three soil textures (Figure 4) indicating a differential response to edapho-climatic conditions and the applied water volume, that will be associated with the stomatal performance¹⁴ and drought-resistant cultivar.¹⁵ Consequently, 'Merlot' had the best performance in clayey due to greater water availability (11,25%), but for Cabernet Sauvignon and Syrah was obtained in sandy clay texture due to anisohydric stomatal behavior.¹⁶ However, Levin et al.¹⁷ showed that *V. vinifera* cultivars possess both iso- and anisohydric stomatal behaviours that depend on the intensity of water deficits, and call into question previous classifications assuming a single behaviour.

These results remark the effect of soil texture and cultivars in the

stomatal conductance with values between 150 -250 mmol m⁻²s⁻¹ that is in accordance with Medrano et al.¹⁴ who showed values between 60 and 200 mmol H₂O m⁻²s⁻¹, which would correspond to severe when drops below 50 mmol H₂O m⁻²s⁻¹, moderate between 50 and 150 mmol H₂O m⁻²s⁻¹ and mild typically 200–500 mmol H₂O m⁻²s⁻¹ in grapevines water stress.^{14,18} The threshold level in grapevines would be 200 mmol m⁻²s⁻¹ for mild stress in the three types of soil, but Cabernet, Sauvignon and Syrah it have a better adaptation on sandy clay and Merlot on clayey soil (Figure 4). This is in accordance with Quezada et al.¹⁹ who remarked the influence of soil physical properties in the selection of sites with viticultural aptitude including cultivars.

Figure 4 Stomatal conductance (g_s) in grapevine ‘Cabernet-Sauvignon’, ‘Merlot’ y ‘Syrah’ with drip irrigation in three soil texture of an Ultic Palexeralfs. Different letters on each column indicate significant differences at $p \leq 0.05$) according Duncan’s test.

Regarding leaf-air dT (°C), the vines showed positive values in December and January about 1,4° C in the sandy clay (Figure 5) indicating temporary and mild water stress due to lower water-holding capacity of the soil.¹³

Figure 5 Leaf-air dT (°C) in grapevine with drip irrigation in three soil texture of an Ultic Palexeralfs during the growing season.

The effect of soil texture was significant ($p \leq 0.05$) on the leaf-air dT (Figure 6) with positive values in sandy clay (0,8 °C) that indicating mild water stress in comparison with vines planted in clayey loam and clayey soil. This is in accordance with the results of g_s , due to lower water availability of sandy clay (7,0%) as compared with clayey loam (8,4%) and clayey soil (11,25%). According to Ubalde et al.²⁰ the soil properties related to soil moisture regime have a direct influence on vineyard management and grape quality.

The cultivars, ‘Merlot’ and ‘Syrah’ showed higher leaf-air dT in sandy clay soil due to lower soil water availability, but in Cabernet

Sauvignon dT was lower in clayey loam (Figure 7). In general, the cultivars revealed the best response to irrigation management in clayey loam texture, that the leaf-air dT was 0.6°C probably due to greater wetted soil volume. However, the higher leaf-air dT was found in sandy clay texture, that indicate mild water stress and the need of improve the irrigation scheduling.

Figure 6 Leaf-air dT (°C) in grapevine with drip irrigation in three soil texture of an Ultic Palexeralfs soil. Different letters on each column indicate significant differences at $p \leq 0.05$) according Duncan’s test.

Figure 7 Leaf-air dT (°C) in grapevine ‘Cabernet Sauvignon’, ‘Merlot’ y ‘Syrah’ with drip irrigation in three soil texture of an Ultic Palexeralfs. Different letters on each column indicate significant differences at $p \leq 0.05$ according Duncan’s test.

Concerning yields components, cluster weight showed significant differences with the soil texture ($p < 0.05$) only for ‘Cabernet Sauvignon’ (Table 1), showed lower values in sandy clay texture, due to the minor number of berries per cluster and low water availability (7%). Respect to berry weight, only ‘Cabernet Sauvignon’ not showed significant effects, but in berry diameter the soil texture had significant effect on the three cultivars.

The soil texture had significant effects ($p < 0.05$) in the wine quality of ‘Merlot’ and ‘Cabernet Sauvignon’ with maximum °Brix in sandy clay soil (Table 1) due to the effect of water stress in advanced fruit maturation.²¹ On the other hand, ‘Syrah’ not showed significant differences in °Brix with the soil texture, according with results obtained by Reynolds et al.¹⁶ with different irrigation regimes.²²

Table 1 Yield components and quality of grapevine ‘Cabernet Sauvignon’, ‘Merlot’ and ‘Syrah’ with drip irrigation in three soil textures of an Ultic Palexeralfs. Different letters in the same column indicate significant differences at $p \leq 0.05$ according to Duncan’s test

Soil texture	Cluster weight (g)			Berry weight (g)			Berry diameter (mm)			Soluble solids (°Brix)		
	CS	ME	SY	CS	ME	SY	CS	ME	SY	CS	ME	SY
Clayey loam	98,8 b	92,4 a	91,5 a	1,1 a	1,2 b	1,1 ab	12,5 b	12,6 b	12,9 ab	26,0 ab	23,6 a	25,2 a
Sandy clay	82,5 a	107,0 a	76,8 a	1,1 a	1,0 b	1,2 b	12,2 a	12,4 a	13,1 b	27,0 b	25,6 c	24,4 a
Clayey	97,6 b	105,7 a	79,8 a	1,1 a	1,1 ab	1,0 a	12,2 a	12,4 a	12,8 a	24,9 a	24,7 b	24,3 a

CS, cabernet sauvignon; ME, merlot; SY, syrah

Conclusion

The results showed that the phyto monitoring is useful to evaluate the irrigation management in vine yards. Stomatal conductance and leaf-air temperature differential showed good performance as indicators of vine water status and berry quality. This study highlights the influence of soil texture on yield and wine quality in grapevines of Mediterranean areas irrigated by drip irrigation. The stomatal conductance threshold determined in this investigation was $200 \text{ mmol m}^{-2} \text{ s}^{-1}$ as an indicator of good scheduling irrigation.

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Conflicts of interest

Authors declare no conflict of interest exists.

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