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 your 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 Neule 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 highlight 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

Introduction

Different instruments measure various aspects of soil-water relations, but none direct 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 affects vine growth and irrigation efficiency. Nowadays, the phytomonitoring technique allow 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 sets 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.

This system include 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. 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 measure 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. This technique combines data acquisition system based on specific sensors and data processing software, which presents measuring information in terms of plant physiology and agronomy and has demonstrated great potential for assessing vine water status.

Water status parameters such midday stem water potential (Ψs), stomatal conductance (gs), and leaf-air temperature (dT) have been used to improve the irrigation management for vineyard in arid areas. The infrared thermometry can be used for the irrigation scheduling of the grapevine. 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. According to Cifre et al., gₛ is a more precise and sensitive indicator of water stress than Ψₛ 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.

The aim of this investigation was to assess the use of stomatal conductance and leaf-air temperature on the irrigation scheduling of three grapevine cultivar under drip irrigation in an Ultic Palexeralfs at Central Southern of the Neule 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,) Neule 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 a area of 50 ha divided in 13 drip irrigation sectors. The cultivars ‘Cabernet Sauvignon’, ‘Merlot’ and ‘Syrah’ was 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 L h⁻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.

**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 (gs) 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 (Atago N-4e, Atago Co. Ltd., Atago, Japan) in 1261 m³ ha⁻¹ in clayey soil (Figure 2). However, November showed greater values of gs in three soil textures due to low crop evapotranspiration (24 mm) as compared with critical month (113 mm). An optimum threshold for gs ranged between 50 and 150 mmol m⁻² s⁻¹ is adequate to increase water use efficiency in grapevines.12

**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-Wilk’s modified.12

**Results and Discussion**

The gas exchange plant-atmosphere was similar during the growing season, that gs 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 gs in three soil textures due to low crop evapotranspiration (24 mm) as compared with critical month (113 mm). An optimum threshold for gs ranged between 50 and 150 mmol m⁻² s⁻¹ is adequate to increase water use efficiency in grapevines.12

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

Regarding soil texture, the lower gs 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.11

**Figure 3** Stomatal conductance (gs) in grapevine with drip irrigation in three soil texture of an Ultic Palexeralfs. Different letters on each column indicate significant differences at p ≤0.05 according Duncan’s test.

Regarding cultivars ‘Cabernet Sauvignon’, ‘Merlot’ and ‘Syrah’ showed significant differences (p<0.05) of gs in three soil texture (Figure 4) indicating a differential response to edapho-climatic conditions and the applied water volume, that will be associated with the stomatal performance16 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 remarks the effect of soil texture and cultivars in the
stomatal conductance with values between 150–250 mmol m$^{-2}$ s$^{-1}$ that is in accordance with Medrano et al.\textsuperscript{14} who showed values between 60 and 200 mmol H$_2$O m$^{-2}$ s$^{-1}$, which would correspond to severe when drops below 50 mmol H$_2$O m$^{-2}$ s$^{-1}$, moderate between 50 and 150 mmol H$_2$O m$^{-2}$ s$^{-1}$ and mild typically 200–500 mmol H$_2$O m$^{-2}$ s$^{-1}$ in grapevines water stress.\textsuperscript{14,16} The threshold level in grapevines would be 200 mmol m$^{-2}$ s$^{-1}$ 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 accord with Quezada et al.\textsuperscript{19} who remarked the influence of soil physical properties in the selection of sites with viticultural aptitude incuding cultivars.

Regarding leaf-air $dT$ ($ºC$), the vines showed positive values in December and January about 1.4º C in the sandy clay (Figure 5) indicating temporary and mild water stress due to lower water-holding capacity of the soil.\textsuperscript{13}

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 ºBrix in sandy clay soil (Table 1) due to the effect of water stress in advanced fruit maturation.\textsuperscript{21} On the other hand, ‘Syrah’ not showed significant differences in ºBrix with the soil texture, according with results obtained by Reynolds et al.\textsuperscript{16} with different irrigation regimes.\textsuperscript{22}
Use of phytomonitoring to evaluate the irrigation scheduling in vineyards (Vitis vinifera L.) of Itata Valley, Chile

| Soil texture   | Cluster weight (g) | Berry weight (g) | Berry diameter (mm) | Soluble solids (ºBrix) |
|---------------|--------------------|------------------|--------------------|------------------------|
|               | CS | ME | SY | CS | ME | SY | CS | ME | SY | CS | ME | SY |
| Clayey loam   | 98.8 b | 92.4 a | 91.5 a | 1.1a | 1.2 b | 1.1ab | 12.5b | 12.6b | 12.9ab | 26.0ab | 23.6 a | 25.2a |
| Sandy clay    | 82.5 a | 107.0 a | 76.8 a | 1.1a | 1.0 b | 1.2 b | 12.2a | 12.4 a | 13.1 b | 27.0b | 25.6c | 24.4a |
| Clayey        | 97.6 b | 105.7 a | 79.8 a | 1.1a | 1.1ab | 1.0 a | 12.2a | 12.4 a | 12.8a | 24.9a | 24.7b | 24.3a |

Differents letters in the same column indicate significant differences at p≤0.05 according Duncan’s test.

**Conclusion**

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

**Acknowledgments**

None.

**Conflicts of interest**

Authors declare no conflict of interest exists.

**References**

1. Jackson R. Wine science. Principles and applications. Fourth edition. Academic Press Elsevier, San Diego, CA, USA. 2014.
2. Channarayappa, Biradar DP. Soil basics, management and rhizosphere engineering for sustainable agriculture. CRC Press. 2019.
3. Capraro F, Schugurensky C, Vita F, et al. Intelligent irrigation in grapevines: a way to obtain different wine characteristics. Proceedings of the 17th World Congress. The International Federation of Automatic Control. 2008;2950–2955.
4. Bonany J, Camps F, Salvia J, et al. Relationship between trunk diameter fluctuations, stem water potential and fruit growth rate in potted adult apple trees. Acta Hortic. 2000;511:43–49.
5. Ton Y, Nilov N, Kopyt M. Phytomonitoring: the new information technology for improving crop production. Acta Hortic. 2001;562:257–262.
6. Ton Y, Kopyt M. Phytomonitoring in realization of irrigation strategies for wine crops. Acta Hortic. 2004;652:167–173.
7. Cifre J, Bota J, Escalona JM, et al. Physiological tools for irrigation scheduling in grapevine (Vitis vinifera L.). An open gate improves water-use efficiency?. Agric Ecosyst Environ. 2005;106:159–170.
8. Anconelli S, Battilani A. Use of leaf temperature to evaluate grapevine (Vitis vinifera) yield and quality response to irrigation. Acta Hortic. 2000;537:407–413.
9. Romero P, Fernández-Fernández JL, Martínez-Cutillas A. Physiological thresholds for efficient regulated deficit-irrigation management in winegrapes grown under semiarid conditions. Am J Enol Vitic. 2010;61:300–312.
10. Pou A, Diago MP, Medrano H, et al. Validation of thermal indices as water status identification in grapevine. Agric Water Manage. 2014;134(1):60–72.
11. Pozo del A, del Canto P. Áreas agroclimáticas y sistemas productivos en la VII y VIII regiones, Serie Quilamapu N°113, INIA Quilamapu, Chillán, Chile. 1999.
12. SAS Institute. The SAS systems for windows. [CD-Rom] Vers. 8. SAS Institute Cary, North Carolina, USA. 1999.
13. Leeuwen van C, Friant P, Chné X, et al. Influence of climate, soil, and cultivar on terroir. Am J Enol Vitic. 2004;55:207–217.
14. Medrano H, Escalona JM, Bota J, et al. Regulation of photosynthesis of C3 plants in response to progressive drought: stomatal conductance as a reference parameter. Annals of Botany. 2002;89(7):989–905.
15. Schultz HR. Differences in hydraulic architecture account for near-iso-hydric and aniso-hydric behaviour of two-field-grown Vitis vinifera L. cultivars during drought. Plant Cell Environ. 2003; 26:1393–1405.
16. Reynolds AG, Sorokowsky D, Gensler, W. Evapotranspiration-based irrigation scheduling for Syrah: assessing vine water status by petiole electrical potential. Am J Enol Vitic. 2012;63:343–356.
17. Levin AD, Williams LE, Matthews A. A continuum of stomatal responses to water deficits among 17 wine grape cultivars (Vitis vinifera L.). Functional Plant Biology AN. 2019;47(1):11–25.
18. Bota J, Tomas M, Flexas J, et al. Differences among grapevine cultivars in their stomatal behavior and water use efficiency under progressive water stress. Agric Water Manage. 2016;164:91–99.
19. Quezada C, Soriano MA, Diaz J, et al. Influence of soil physical properties on the selection of sites with viticultural aptitude. Open Journal of Soil Science. 2014;4:127–135.
20. Ubalde JM, Sort X, Poch RM. How soil forming processes determine soil-based viticultural zoning. J Soil Sci Plant Nutr. 2011;11:100–126.
21. Bowen P, Bogdanoff C, Estergaard B. Effects of converting from sprinkler to drip irrigation on water conservation and the performance of Merlot grown on a loamy sand. Am J Enol Vitic. 2012;63:385–393.
22. Gurovich LA, Ton Y, Vergara LM. Irrigation scheduling of avocado using phytomonitoring techniques. Cien Inv Agr. 2006;33(2):117–124.