Use of Trunk Growth Rate as Criteria for Automatic Irrigation Scheduling on Table Grapes Cv. Crimson Seedless, Irrigated by Drip

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Keywords: dendrometers, stem water potential, fruit growth, soil water content, vines irrigation.

Abstract
Trunk growth rate (TGR) were measured on table grape vines (Vitis vinifera L cv. Crimson Seedless) in order to evaluate electronic dendrometers as an early detection tool of water deficit. Four irrigation treatments were applied during three crop seasons: 1) control treatment (T1) plants supplied with 100% of the crop evapotranspiration (ETc); 2) 75% of ETc (T2); 3) 50 % of ETc (T3); and 4) between 25% and 100% of ETc (T4). Trials were conducted in the Aconcagua Valley, one of the most important areas of table grape production in Chile.

There was a clear relationship between TGR and the degree of water deficit produced by irrigation treatments from fruit set to veraison. Treatments T1 and T2 had a faster development than the other two according to soil water content, but TGR became negligible in all treatments after veraison. However, TGR and fruit growth rate from fruit set to veraison presented a good positive correlation. These responses occurred during a critical stage which determines the final berry size in Crimson Seedless. It was concluded that electronic dendrometer use to measure trunk growth rate (TGR) is a promising tool that can be remotely controlled and linked to programmers for irrigation scheduling management.

INTRODUCTION
An inadequate water supply at any stage of the productive cycle of table grape limits the production and the quality of the fruit, particularly between flowering and veraison (Peacock et al., 1998). Therefore, in this period it is important to detect any water deficit, even moderate, as soon as possible, in order to obtain higher fruit diameter at harvest. Periodic measurements of soil water status are usually conducted for detection of vine water stress (Martín et al., 1990). With advances in electronics and computing, a high performance equipment for soil water content has been developed (Charlesworth, 2000) and automatic irrigation decisions can be made (Vera, 2003). However, under drip irrigation conditions, a local measurement of soil water content is not representative of the soil volume explored by plant roots. Many measurements are required to integrate soil moisture of the wetted zone beneath the dripper (Selles et al., 2003; Myburg, 1996; Or, 1995). Therefore, physiological indicators of plant water status could be a better tool as a plant water stress indicator in these conditions (Selles and Berger, 1990; Goldhammer et al., 1999). Stem water potential, SWP, (Fereres and Goldhammer, 1990; Schackel et al., 1997; Naor, 2001) measured at midday, using a pressure chamber, has been proposed as a standard parameter to determine the plant water status for irrigation scheduling of fruit trees. Nevertheless these sorts of measurements can not be made in a continuous and automatic approach. Short-term trunk diameter fluctuation can be used as an integrated
indicator of plant water status (Garnier and Berger, 1986). The development in informatics technology and electronic science have made possible to measure these changes in a continuous way on the field using a dendrometer connected to computer programs. A continuous record of trunk diameter changes for irrigation scheduling purpose has been proposed by different authors (Selles and Berger, 1990; Myburg, 1996; Michelakis, 1997; Van Louwen et al., 2000; Goldhammer and Fereres, 2002; Moriana and Fereres, 2002). In several fruit species trunk diameter variation has been shown to be sensitive to moisture availability under moderate water stress conditions (Van Louwen et al., 2000; Goldhammer and Fereres, 2001). In addition, trunk diameter changes were found to be more responsive to moisture soil availability compare to SWP (Moriana and Fereres 2002).

The aim of this work was evaluate the possible use of trunk growth rate as an indicator for automatic irrigation scheduling of Crimson Seedless table grapes.

**MATERIAL AND METHODS**

The experience was carry out during three grape growth seasons (2002/03; 2003/04; 2004/05). The experimental site was located at a commercial vineyard, in Curimon, San Felipe Province (Aconcagua Valley), 5th Region, Chile (70°39'17’” West Long. and 30°44’ 19’” South Lat.). The soil of the trial area was an homogenous well drained clay loam, 2 meter deep. A 7-year-old overhead trellised vineyard table grapes (Crimson Seedless) was used. Vines were planted at 3.5 m by 3.5 m and irrigated by two dripper lines, 0.9 m apart and drippers every 1 m.

Data from an automatic meteorological station were used to calculate daily reference evapotranspiration, $E_{to}$, (Penman-Montheith method). Crop evapotranspiration ($E_{tc}$) was estimated using $E_{to}$, multiplied by a crop coefficient ($K_c$). This coefficient was calculated using the shaded area percent measured beneath the vines, as proposed by Williams et al. (2003).

Four irrigation treatments were applied: T1, irrigation at 100 % of $E_{tc}$ all over the season (Control); T2, irrigation at 75 % of $E_{tc}$ all over the season; T3 irrigation at 50 % of $E_{tc}$ all over the season, and T4 not irrigated from the beginning of the season until 79 days after bud-break. From these date to the end of the season irrigation rate was alternated between 100 and 50 % of $E_{tc}$. In the last season T4 was irrigated as T1 until fruit veraison. Irrigation was managed in a low frequency regime, with irrigation every three or four days as recommended by Selles et al., (2003) for fine texture soils in the Aconcagua Valley.

Soil water content was monitored with a Capacitive Probe, FDR, (Delta –T probe model PR1). Five access tubes were installed in one plant per treatment, perpendicular to the plant row, every 0.30 m from plant line to the centre of the row. Soil water content was measured at depth of 10, 20, 0.30,40, 0.60 and 1.0 m in each access tube. The soil water content was expressed as mm of water in 600 mm soil depth, because at 1 m depth the soil water changes were minimal compared with other soil layers. In each treatments two wireless electronic dendrometers (Phytec DE -1M, Israel) were installed on the trunk of the vines (at 1.5 m high) and the diameter changes were continually recorded every 30 minutes. At midday, stem water potential (SWP) was measured twice a week, in the same plants using a pressure chamber (Shackel et al 1997). Finally, in these plants berry size were measured once a week, using micrometers from fruit set to harvest time. The
RESULTS AND DISCUSSION

The average of soil water content (SWC) for the five access tubes (2003/04 season) is shown in Figure 1. SWC was related to the irrigation water applied in each treatment, T1 presented the highest SWC, followed by T2, T3 and T4. This response was similar in the other years of evaluation. The lowest SWC in most irrigation treatments was found between fruit set to veraison.

Figure 2 shows a short-term fluctuation of trunk diameters, between 71 to 80 days after bud break (DABB) for T2 and T3 treatments. SWC and Stem Water Potential (SWP) measured at midday were higher in T2 (75% of Etc) than in T3 (50% Etc). Trunk diameter fluctuations presented a typical shrinkage during the day followed by a swelling and growth in the afternoon and night. The difference between two consecutive maximum morning readings is defined as trunk daily growth (MDG). MDG was higher in T2 than T3 in response to SWC and SWP (Figure 2). MDG in all treatments was related to SWC (Figure 3) at least from 27 DABB to berry veraison period (100 DABB). After veraison, the vine trunk growth naturally stopped in all irrigation treatments (Figure 4).

The accumulated MDG for the different treatments between 3 and 180 DABB for the 2003/04 seasons is displayed in Figure 4. The slope of the accumulated MDG is defined as trunk growth rate (TGR). T1 and T2 had the highest TGR compared to the other two treatments presenting a clear difference between them from 27 DABB. T1 and T2 shows a difference only from fruit set period (53 DABB). However, as it is shown in Figure 4, from veraison to end of the season, TGR decreased and became also negative in all irrigation treatments, independent of soil water content. Myburg (1996) also found a similar response in table grapes (cv. Berlinka) and Ton et al. (2004) in other vine cultivar. The same phenomenon has been observed in other fruit species (Selles and Berger, 1990, Marsal et al., 2002).

The effect of irrigation treatments on average TGR for different phenological stage, in all experimental seasons, is shown in Table 1. The highest TGR was measured between fruit set and veraison in all irrigation treatments, but the TGR in T1 and T2 were faster than the other two treatments. Moriana and Fereres (2002) found that TGR is more responsive to soil water availability than other physiological indicators of plant water status such as SWP. The same authors found that TGR is more responsive than maximum daily trunk shrinkage (MDS) in fast growing olive trees. Growth is the more sensitive process to water stress (Hsiao, 1973) being the trunk growth even more sensitive to water deficit than fruit growth (Selles and Berger, 1990).

From fruit set to veraison, berry size reached almost the 85% of its final size (Figure 5) and a good relationship was found between TGR and fruit growth rate for this period (Figure 6). A reduction of 80% TGR, as result of irrigation regimen, was associated only with a 24% reduction of fruit growth rate, this means that TGR was more sensitive to water deficit than fruit growth rate.

These results suggest that TGR measured with electronic dendrometers can be used as a sensitive tool for irrigation scheduling purpose. However a threshold values must be fixed. This is not easy to found because TGR can change with plant age or other agronomical practices, such as plant nutrition, or plant age. This kind of problems can be avoided if a well watered control plants are established in the vineyard to compare the number of bunches per plants were similar in all treatments for the three study season (60 to 70 bunches per plant).
TGR with the rest of the orchard, as Goldhammer and Fereres, (2001) and Moriana and Fereres, (2002) suggested.

CONCLUSIONS
Our findings suggest that the use of the electronic dendrometer to measure trunk growth rate (TGR) is a promising tool that can be remotely controlled and linked to programs for irrigation scheduling in Crimson Seedless.

ACKNOWLEDGEMENTS
This research was financed by Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT – CHILE, Project N° 1020837). The authors gratefully acknowledge Cristina Aspillaga, Veronica Muñoz and Virginia Lopez for their considerable help provided the present trial.

Literature Cited


### Tables

Table 1.- Average trunk growth rate (TGR µm/day) in different phonological stage.

<table>
<thead>
<tr>
<th>Tratamiento de riego</th>
<th>2002/03</th>
<th>2003/04</th>
<th>2004/05</th>
</tr>
</thead>
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<tr>
<td></td>
<td>FS-B.V</td>
<td>B.V-F.V</td>
<td>F.V-B.H</td>
</tr>
<tr>
<td>T1</td>
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<td>-2.63</td>
</tr>
<tr>
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</tr>
<tr>
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<td>2.5</td>
</tr>
<tr>
<td>T4</td>
<td>8.41</td>
<td>-9.39</td>
<td>-3.33</td>
</tr>
</tbody>
</table>

FS = Fruit set; B.V = beginning of veraison; F.V, full veraison; B.H = beginning harvest

Note: During 2004/05 season T4 was irrigated as T1.
**Figures**

Figure 1. Average Soil Water Content (SWC, mm) for the five access tubes on 600 mm soil depth from 13 days after bud-brake (DABB) to 180 DABB (2002/03 season). FC corresponds to field capacity.

Figure 2. Trunk diameter variation (TD mm) and Stem Water Potential (SWP) for T2 and T3 treatment from 71 to 80 days after bud-brake (DABB), 2002/03 season. The numbers between brackets are the soil water content and Ir represents an irrigation event.
Figure 3. Relationship between average soil water content (SWC) on 600 mm soil depth (SWC, mm) and maximum daily trunk growth (MDG, mm/day) in two seasons (2002/03 and 2003/04) and for 27 to 100 DBBB when the trunk is active ($R^2 = 0.48; p<0.05$).

Figure 4. Seasonal trends of trunk diameter (TDG, mm) in the different irrigation treatments from 3 to 173 DABB (2003/04 season).
Figure 5 Seasonal trends trunk diameter (TDG) and berry size (FDG mm) for treatment 1 (T1) in 2003/04 season.

Figure 6 Relationship between trunk growth rate (TGR, µm/day) and berry growth rate (FGR, mm/day) from fruit set to veraison (in 2002/03, 2003/04 and 2004/05 seasons). ($R^2=0.70$, $P<0.05$).
Utilisation du taux de croissance des troncs pour piloter l’irrigation sur raisin de table cv. Crimson sans pépin, irrigué au goutte à goutte.

Mots clés : dendromètres, potentiel hydrique de tige, croissance des fruits, teneur en eau du sol, irrigation de la vigne.

Résumé

Le taux de Croissance des troncs (TCT) a été mesuré sur une variété de raisin de table (Viti vinifera cv. Crimson sans pépin) dans le but d’évaluer un dendromètre électronique comme outil de détection précoce des stress hydriques. Quatre modalités d’irrigation ont été utilisées au cours des trois années de l’étude : 1) témoin irrigué, (M1) correspondant à 100% de l’évapotranspiration des plante (Etc); 2) 75 % de l’Etc (M2); 3) 50 % de l’Etc (M3) et entre 25 et 100 % de l’Etc (M4). Ces essais on été réalisés dans la vallée de l’Aconcagua, l’une des zones de production les plus importantes du Chili en raisin de table.

Un lien clair est apparu entre le TCT et le niveau de contrainte hydrique appliqué de la floraison à la véraison. Les modalités M1 et M2 ont eu un développement plus rapide que les autres modalités en relation avec la teneur en eau du sol, mais le TCT est devenu négligeable pour toutes les modalités après la véraison. Le TCT et le taux de croissance des fruits sont toutefois corrélées positivement. Ces résultats sont apparus au cours d’un stade critique qui détermine la taille finale des baies de Crimson sans pépin. Il a été conclu de cette étude que le dendromètre électronique utilisé pour mesurer la taux de croissance des troncs (TCT) est un outil intéressant qui permettra de piloter l’irrigation à distance.