

## **EFFECTS OF ENVIRONMENT, LEAF CHARACTERISTICS AND METHODOLOGY ON STEM WATER POTENTIAL IN AVOCADO TREES**

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Proyecto financiado INNOVA- CORFO

A research study was developed during 2003 and 2004 on 'Hass' avocado trees grown on Mexicola rootstock, in the V Region. The trees were in productive stage with optimal water and nutritional status. In order to optimize xylem water potential ( $\Psi_{hx}$ ) measurements, several factors affecting this methodology were studied, including vapour pressure deficit (VPD), leaf age, equilibrium of water status of leaf tissues, time between leaf detachment and  $\Psi_{hx}$  measurement, leaf location on the tree, and the effect of high humidity conditions on a detached leaf prior to measurements. Our results showed that in avocado trees the values of  $\Psi_{hx}$  were stable between 12:30pm and 5:30pm. The most homogenous measurements were obtained by using 10- to 12-month- old leaves under sun light exposure. We observed that in the pressure chamber, measurements should be conducted after the leaf water potential reached equilibrium with the petiole water potential, which occurred after 15 minutes. Leaf water potential should be measured no longer than 1 minute after detachment from the tree; however, this time could be extended by keeping the leaf under high humidity before measurement.

**Key words:** xylem water potential, avocado, plant water status, *Persea americana* Mill.

## **EFFECTO DEL CLIMA, DEL MATERIAL VEGETAL Y DE LA FORMA DE MEDICION EN EL POTENCIAL HÍDRICO XILEMÁTICO EN PALTO**

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El estudio se realizó en la V región, durante las temporadas 2003 – 2004, en árboles de palto Hass, sobre portainjerto Mexícola, los cuales se encontraban en etapa productiva y sin restricciones hídricas ni nutricionales. Se realizaron varios experimentos para evaluar la posibilidad de optimizar y simplificar las mediciones de potencial hídrico xilemático ( $\Psi_{hx}$ ), los que se señalan a continuación: Efecto sobre el  $\Psi_{hx}$ , del déficit de presión de vapor (DVP), de la edad de la hoja, del

tiempo de equilibrio al cubrir la hoja, del tiempo transcurrido entre corte de la hoja y medición de ésta, de la ubicación de la hoja en el árbol, y de la mantención de la hoja después de ser cortada del árbol en condiciones de alta humedad relativa.

Los resultados obtenidos muestran, entre otros antecedentes, que el  $\Psi_{hx}$  en el palto presenta valores estables entre las 12:30 y 17:30 horas (mediodía). Las hojas que presentan la menor variabilidad son las de 10 a 12 meses de edad, expuestas al sol. El tiempo mínimo de equilibrio para medir el  $\Psi_x$  es de 15 minutos luego de bloqueada la transpiración. Las hojas una vez cortadas del árbol deben medirse en un lapso de tiempo no superior a los 1 minutos, sin embargo se podría aumentar el tiempo entre el corte de la hoja y la medición del potencial hídrico, al mantener ésta en condiciones de alta humedad relativa.

Palabras clave: potencial hídrico xilemático, aguacate, estado hídrico de la planta, *Persea americana* Mill.

## 1. INTRODUCTION

At world-wide level, the yields average of the avocado orchards (*Persea americana* Mill.) is low in comparison with other fruits crops. This is due in part because the production of fruits with big seed and great amount of oil as avocado, has a high cost in photosyntates requirement. (Wolstenholme, 1986). In Chile there are orchards that maintain stable productions of around 25 t has<sup>-1</sup>, nevertheless, the yield average of the adult orchards is around the 9 t has<sup>-1</sup>. Some of the main reasons to this problem are related with the water status of the crop, which some times is under irrigated and in other present root asphyxiation. This last problem occurs since avocado is very sensible to the lack of air in the soil, and most of the plantations in the country have been made in lands with low air capacity, near 15%, and bulk densities around 1.3 to 1.4 g cm<sup>-3</sup> (Nagera, 2006).

One of the main factors that affect the production and quality of the fruit, mainly in unfavorable conditions of soil for the development of avocado, is an inadequate relation between the water and air in the root zone, product of soil characteristics and irrigation management. An excess or lack of water during the growth of avocado limits the production and the quality of the fruit, particularly if stress happens between spring and beginning of summer (Whiley ET to., 1988a; 1988b).

Among the solutions to surpass this problem one of the main tools is the use of soil air lack tolerant rootstocks. However, for orchards already established, the solution is to take new alternatives of management that allow diminishing the incidence of this stress. A form to obtain this is to maintain in soils moisture contents inferior to field capacity, which would allow to one better relation air: water in the soil. Nevertheless, this forces a suitable control of the irrigation to avoid periods of water deficit.

The irrigation can be controlled defining the opportune moment of application of water, through measurements of the plant water status, as stem water potential (SWP) (Boyer, 1995). Nevertheless, its indicating value as of the water status of fruit crops has been questioned by its variability, due to the influence of micro environmental factors, specially the exposition to the direct solar radiation that receive the leaves in the measurement moment (Shackel et al., 1997). Due to the previous thing, some authors have measured the SWP in the dawn time, before the sunrise (Williams and Araujo, 2002). Nevertheless this measurement is little sensible to the water availability in the ground, since the plant water potential of the plant tends to balance with the most humid zones of the soil (Garnier and Berger, 1987, Ameglio ET to., 1999). On the other hand, from the practical point of view, it is difficult that the SWP measured at dawn can be used as a routine controller of the irrigation, due to the hour in which the measurement in the field must be made.

It is possible to eliminate the micro environmental factors that affect SWP measurements, by blocking the transpiration of the leaf, before harvesting the leaf from the plant (Garnier and Berger, 1985; Olien and Lakso, 1986; Shackel ET to., 1997). The methodology to obtain this consists of, previous to the measurement, to put the leaves for measurements in a plastic bag, and then to surround them in paper aluminum, to prevent the passage of the light, blocking then the transpiration of the leaf. In these conditions the measured water potential represents the average potential of the small branch that maintains the leaf. Previous to the measurement, the leaves must remain surrounded by a period of 2 h, so that water potential balances with the xylem water potential or SWP. (McCutchan and Shackel, 1992). Nevertheless, Fulton et al. (2001) indicate that in walnuts (*Junglans regia* L.), almonds tree (*Prunus dulcis* Mill.) and plum trees (*Prunus domestica* L.) this balance is obtained after 10 min of placed the leaf in a plastic bag whose interior is plastic and its exterior is aluminum paper. In avocado this information does not exist on the matter.

In this way, the xylem water potential is less influenced by micro environmental changes of short term that affect the leaf transpiration and therefore to the water potential. Consequently, the xylem water potential or SWP is one more appropriate measurement of the plant water status. (McCutchan and Shackel, 1992). Different studies have demonstrated that the SWP measured with pressure chamber is a good indicator for water stress in fruit trees. Naor et al. (1995) found a good correlation between SWP and yield and fruit size in apple trees (*Pyrus malus* L.). Similar data found Ferreyra et al. (2002) and Ferreyra et al. (2004) in peach tree (*Prunus persica* L.) and grapevines (*Vitis vinifera* L.). Naor (1998) and Ferreyra et al. (2002) verified that the stomatal conductance in peach trees (*Prunus persica* var *nectarina* (Aiton) Maxim.) and grapevines highly is correlated with SWP, at stress water condition. The minimum SWP or noon SWP, has been proposed by several authors as a standard indicator to determine the water status of the plant with aims of irrigation (Fereres and Goldhamer, 1990; Shackel et al., 1997; Naor and Peres, 2001; Ferreyra et al., 2002). Nevertheless, the times necessary to produce the balance of the potential in the leaf and the little time available to make the measurement at noon, mainly when

the orchard involves a great surface, make difficult the adoption of this technique on the part of the agriculturists.

Taking into account the information previously indicated, the objective of this study was to determine the effect of Vapor Pressure Deficit (VPD) on the noon SWP, the age of the leaf in which it is made the measurement, the location of the leaf in the tree, the time between covering the leaf and making the measurement of SWP, the time between taking the sample and the measurement in the pressure chamber in fields, and, finally, the time for keeping the leaf in conditions of high relative humidity, after being cut from the tree, before the measurement. The answer to these questions will allow growers and researchers to optimize the use of the SWP as a control technique of irrigation in avocado.

## 2. MATERIALS AND METHODS

The experiments were carried out in the area of Quillota (32°53' lat. South; 71°16' long. West), Valparaiso region, central zone of Chile, during summer season of years 2003-2004. This is a semi-arid zone, without rainfalls during summer, correspond to tempered Mediterranean climate, with year average temperatures of 15,3°C, with an maximum average temperature of 27°C (January) and a minimum average of 5,5°C (July). The free period of frosts is of 9 months, from September to May, and the water regime is characterized by an annual precipitation of 437 mm, concentrated in the months of June to August.

Seven experiments were made in avocado plants cv. Hass, grafted in Mexicola rootstock, irrigated with one microsplinker per plant. The age of plants, depending on the experiment, varied from 4 to 7 years all them in productive age, without water or nutritional restriction.

Detail of the experiments set up:

Determination of the period during the day when the SWP is stable. The daily variation of the SWP was evaluated, between 07:00 and 19:00 h. These measurements were made in the period of summer (December-January) in 11 opportunities. In simultaneous time the VPD of the air was evaluated. Each determination of SWP was made in four leaves by tree.

Effect of the maximum VPD in the SWP. During spring and summer, in 32 opportunities SWP and VPD of the air were measured; four leaves by determination were used.

Determination of the minimum time of balance between the water potential and the noon SWP. 28 leaves were chosen, which were introduced in bags whose inner was plastic and outside, a layer of aluminum paper; by this way leaf transpiration was blocked. Once covered, the leaves were left in the tree during different times, which varied between 4 and 80 min. The measurements were

made at noon. The first measurement was made after 4 min, to continue the measurements between 2 and 10 min intervals.

Effect of the location of the leaf in the tree on the noon SWP. In each tree the SWP was measured in the part of the foliage exposed to the direct solar radiation and in the shaded side. The measurements were made in a plantation with the rows in North-South direction, so a single part received direct radiation.

Effect of the leaf age in the SWP. SWP in leaves of different ages was determined: 1 month, 4 months and 10 to 12 months of age; 10 leaves of each age were used.

Effect of the time passed between the taking of the sample and the measurement in the SWP. In this experiment SWP for 33 leaves was measured; leaves had different time between the harvesting time and the measurement (1 to 27 min). The SWP of the first sample was measured after 1 min of harvesting, to continue then the measurements in leaves with greater time between the cut and the measurement.

Effect of the conservation of the leaf in conditions of high relative humidity on the SWP. In this experiment, SWP of four avocado trees under different water stress conditions were measured. In each tree the SWP of four leaves was measured; two of the four leaves were measured immediately after harvesting from the tree, and the rest were measured after 1 h of being separated from the plant, time during which the leaves were maintained in an thermally isolated PVC box with ice in the interior, with the objective of keeping a relative humidity (HR) near 100%.

In all the experiments the SWP was measured in sunny days, between 13:00 and 16:00 h, using a pressure chamber (Soil Moisture Equipment Corp., Model CHANGE C, Santa Barbara, California, the USA), according to the methodology described by McCutchan and Shackel (1992). The measured leaves were placed in branches with homogenous conditions of radiation exposition (side exposed to sun), age and height (1.5 ms from the ground).

VPD was determinate each 15 min, during the measurements of SWP, with a ventilated psychrometer (Fuese, Model G-5069, Berlin, Germany) which measured the temperature of the air and the air relative humidity.

Data were analyzed by linear regression analysis. Data were analyzed using PROCREG from the SAS statistical package (SAS Institute, Cary, North Carolina, USA).

### 3. RESULTS Y DISCUSIÓN

Determination of the period during the day when the SWP is stable and effect of the maximum VPD in the SWP. For the climatic conditions of Quillota, the SWP in avocado presents very similar values, without significant differences, between 12:30 and 17:30 h (Figure 1). During this period the daily values measured were the minimums, fluctuating between -0,36 and -0,40 MPa, on an average of -0,38 MPa. At noon, the variations in the VPD of the air have little effect on the SWP (Figure 2). The SWP fluctuates between -0,40 and -0,50 MPa (variation of 20%) for VPD that oscillates respectively between 1.5 and 3.0 KPa (50% of variation).

**Figure 1. Effect of the vapor pressure deficit (VPD) during the day on the steam water potential (SWP). The vertical bars represent the standard deviation.**

**Figure 2. Effect of the vapor pressure deficit (VPD) on steam water potential at noon (SWPn).**

From these results it is possible to be conclude that during summer 5 h at day (12: 30 to 17:30 h) are suitable to measure the SWP as a technique for irrigation control, and that in avocados growing without water restriction this value varies between -0,4 and -0,5 MPa.

Determination of the minimum time of balance between the water potential and the noon SWP. The water potential balances with the xylem potential after 15 min of having blocked transpiration by introducing the leaf in plastic bags covered with aluminum paper (Figure 3), which coincides with the data reported by Fulton et al. (2001). This suggests that the SWP in avocado leaves can be measured after 15 min after blocking transpiration from the leaves. In addition, in Figure 3 it is possible to observe that the values of water potential measured in leaves just covered ( $\Psi_h$ ) present greater variation (- 0.6 to -0,8 MPa) than the potentials evaluated after 15 min (- 0.47 to -0,55 MPa), which coincides with the data reported by Shackel et al. (1997) that indicate that the  $\Psi_h$  is more variable than the SWP.

**Figure 3. Effect of the balance time in the water potential ( $\Psi$ ) at noon under field conditions.**

Effect of the location of the leaf in the tree on the noon SWP. The leaves in the tree exposed to the sun presented SWP more negative (- 0.52 MPa), that the measured leaves of the shaded face (- 0.40 MPa), although the transpiration of these was blocked before being cut from the plant. The standard deviation (DS) of the measurements was low. The leaves exposed to the sun presented DS of 0.065 MPa and those from the shaded face presented DS of 0.018 MPa (Data non shown).

Effect of the leaf age in the SWP variation. The determinations in leaves of 1 month presented average SWP of -0,55 MPa and a DS of 0.12 MPa; in 4 months

leaves the SWP was -0,52 MPa, with a DS of 0.13 MPa, and in leaves from 10 to 12 month, the SWP was -0,49 MPa with a DS of 0.1 MPa. The youngest leaves present a potential of 0.06 MPa lower than the most adult leaves and a greater DS. The SWP presents minor variation in leaves of 10 to 12 months. This would be due because new leaves can be affected by the pressure that exerts the rubber of the pressure chamber in the leaf petiole, delaying the appearance of the sap in the xylem. A variation of 0.06 MPa can be important for the irrigation control, according to data reported by Lampinen (2004), that indicates that walnut presents SWP between -0,3 and -0,5 MPa without water restriction, and that they should be watered when the value diminishes in -0,2 or -0,3 MPa.

Effect of the time passed between the taking of the sample and the measurement in the SWP and effect of the conservation of the leaf in conditions of high relative humidity on the SWP.

The time that passes between the cut of the leaf and the measurement is a variable that affects the determination of the SWP (Figure 4). If the measurement is made when happened more than 1 min of the leaf harvesting, the measured values are smaller to the real ones, product of the dehydration of the leaf, and they do not reflect real the water status of the branches. Nevertheless, this work shows data that would allow to increase to the time between the cut of the leaf and the measurement of SWP, if the leaves are cut and immediately kept in an thermally isolated PVC box with relative humidity near the 100%. The SWP in leaves from a same tree measured immediately after cut and in others leaves measured after 60 min of storage in darkness conditions with 100% HR and 5°C, shows similar values (Figure 5). The use of this methodology to measure SWP is feasible to implement, but it would require measuring a greater number of leaves by tree, since it increases the variability. According to the methodology for continuous data described by Cochran (1971), the sample size must be of three leaves by plant if the measurements are made immediately of cut the leaves and six leaves by plant, for evaluations after 60 min of storage in conditions of high relative humidity.

**Figure 4. Effect of the time passed between cut and the measurement of the leaf, on the SWP at noon, under field conditions.**

**Figure 5. Effect of the leaf conservation in conditions of high relative humidity on the SWP).**

#### 4. CONCLUSIONS

The present study allows concluding the following:

- The measured values of SWP at noon in avocado are stable between 12:30 and 17:30 h, which allows having 5 h to make measurements of minimum SWP.
- The avocado without water restriction present SWP values between -0,4 and -0,5 MPa, for VPD values between 1.4 and 3.0 KPa, respectively.

- In leaves of avocado the balance of the SWP is reached after 15 min of introducing the leaf in plastic bags covered in aluminum paper.
- At field conditions, the SWP must be measured in a lapse no superior to 1 min after cutting the leaf.
- The time between the leaf harvesting and the measurement of SWP in the pressure chamber can be increased up to 60 min, by maintaining the leaves in a thermally isolated box of PVC with an inner high relative humidity.
- The leaves that present the smaller variability are those of 10 to 12 months of age, exposed to the sun. The leaves exposed to the sun present more negative values of SWP than leaves exposed in the shaded face, even though its transpiration has been blocked.

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