Calibrating avocado irrigation through xylem water potential measurements

Preliminary report

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ABSTRACT

In the avocado industry irrigation is mostly scheduled on gut feeling rather than measurement, even though the use of soil moisture probes is gaining ground. Soil moisture indicators are, however, only point measurements and many readings are required to obtain statistical surety. International experience showed that midday xylem water potential is a reliable indicator of plant stress levels and in many crops it is highly correlated to fruit size and quality through its direct correlation with stomatal conductance. This research attempts to calibrate avocado irrigation requirements through the combined use of xylem water potential and continuous soil moisture monitoring, thereby optimising water usage in avocado orchards. Field trials were carried out on the cultivar 'Hass' in the Nelspruit and Levubu areas with the aim of establishing xylem water potential norms over a range of water level treatments at 0.5, 1 and 1.5 replacement of evapotranspiration (ET) in orchards using micro and drip irrigation. Although there were not highly significant differences between the treatments in both Nelspruit and Levubu, it was shown that trees experienced moderate to relative severe stress during the rapid fruit growth stage, which may have had an adverse effect on yield. Regulated stress during rapid fruit growth was evaluated in a separate trial in Nelspruit. The effect of this treatment on stem xylem water potential was only evident at the end of rapid fruit growth. This study concluded that irrigation is not optimal in avocado orchards and the next season will focus on studies to optimise irrigation.

INTRODUCTION

It is well known that moisture stress (as a result of over- or under-irrigation) results in an adverse effect on plant health and productivity. In avocado, specifically, it was found that water deficits as a result of under-irrigation result in stunted growth, reduced biomass of fibrous roots, smaller leaves, reduced photosynthesis (Chartzoulakis *et al*., 2002) and eventually poor yields (Van Eyk, 1994). In addition, water deficits also have a negative effect on the post-harvest storage life of fruit and thus fruit quality (Bower, 1984). On the other hand, over-irrigation enhances the incidence of *Phytophthora* root rot infection (Sterne *et al*., 1977) and also results in unnecessary waste of water. Optimal irrigation management is therefore of critical importance to ensure optimal production of avocado orchards, as well as optimal water usage.

Through irrigation trials that have been carried out in South Africa, the water usage of avocado trees has been determined (Hoffman, 1999). However, during these trials, only the soil water status has been monitored. The problem with monitoring soil water status is that it only gives an indirect estimate of plant water status (Naor, 2000), meaning that the real water need of the plant is not determined. In addition, soil moisture monitoring is a point measurement. Taken into consideration the variability of water availability in the soil, many measurements will be needed in order to represent soil water status properly, again giving no indication of the real water usage and need of the plant. Xylem water potential, specifically midday xylem water potential, was shown to be a much more reliable indicator of plant water status and plant stress levels than measurement of soil moisture. Xylem water potential is an indication of how the plant experiences the current soil moisture status. It is not a point measurement but an integrated 'average' of the whole soil profile through the extensive root system of the plant. Xylem water potential is in many crops also highly correlated to fruit size and quality as well as stomatal conductance and photosynthesis (Naor, 2000).

Based on the work done in South Africa, the current recommendation is that the soil water potential should not exceed -30 kPa in a sandy soil and not

-35 kPa in a clay soil (Kruger, 2011). As the plant water status (xylem water potential) has not been taken into consideration in determining this recommendation, there is still a probability of over- or under-irrigation. The mentioned recommendation should therefore be investigated again, taking into account the water status of the plant and, if necessary, be adjusted. The aim of this study was therefore to determine stem xylem water potential of 'Hass' avocado trees under field conditions in order to set water potential norms to be used to calibrate irrigation requirements.

MATERIALS AND METHODS

This study was carried out on two farms in the Schagen (Mpumalanga) and Levubu (Limpopo) areas. In the Schagen area, a six-year-old micro irrigated orchard was selected. Trees in the orchard were of the cultivar 'Hass' grafted on 'Bounty' rootstocks and were planted on ridges at a spacing of 8 x 3 m. Between each tree a micro jet delivering 30 L/h was installed. Three trials were designed, using a randomised block design with ten single tree replicates per treatment. The first trial aimed at establishing irrigation norms over a range of water levels, namely 0.5x, 1.0x and 1.5x replacement of evaporation (ET). Therefore, for these three treatments, micro jets with a delivery rate of 20 L/h (0.5x treatment), 30 L/h (1.0x treatment or control) and 40 L/h (1.5x treatment) were installed. Timing of irrigation application was not controlled and was dependent on the time and periods the farm irrigated. Soil moisture probes (DFM Probes) were installed for each treatment to measure soil moisture from 0 to 60 cm depth. Stem xylem water potential was measured during flowering, rapid fruit growth and fruit maturation using a pressure bomb (PMS Instruments Co., USA). During each of these phenological stages, measurements were carried out in three intervals, namely at the onset of, during, and at the end of each phenological stage. During each measuring day, water xylem potential was measured during mid-morning (09:00), midday (12:00) and mid-afternoon (15:00). In addition, fruit set, fruit retention, spring flush growth, yield and *Phythophthora cinnamomi* incidence data were collected.

Regulated stress was evaluated in the second trial at 0.5 ET (20 L/h) during rapid fruit growth and at fruit maturation. Again, water potential measurements were taken during the onset, middle and at the end of the mentioned phenological stages, as well as fruit set, fruit retention and yield data. However, only the water potential measurements taken for the rapid fruit growth stage will be reported on, as the rest of the data will be taken only later during the current season (February to June 2012).

In the Levubu area an eight-year-old drip irrigated orchard was used. Trees in the orchard were spaced at 8 x 6 m and planted on ridges. The irrigation design consists of drippers delivering 2 L/h and irrigation scheduling in the orchard is done based on regular tensiometer readings. Trees were of the cultivar 'Hass' grafted on seedling 'Velvic' rootstocks. The treatments were the same as for the Schagen area, namely 0.5x, 1.0x and 1.5x replacement of evaporation (ET). Therefore drippers delivering 1, 2 and 3 L/h respectively were installed for each treatment. The trial was laid out in two tree plots in a randomised block design. Stem xylem water potential measurements were taken during the onset and end of rapid fruit growth.

Data analysis was carried out using the SAS software. The t-test was used to determine differences in stem water potential between different intervals, times of the day and treatment for each phenological stage. Differences between treatments in fruit set and retention and flush growth were determined using analysis of variance. In all the analyses, differences were determined at the 5% significance level.

RESULTS AND DISCUSSION

Trial at Schagen

There were no significant differences obtained in xylem water potential values between the different baseline treatments for the first trial. The results are therefore presented as seasonal and daily water potential trends for flowering and rapid fruit growth, which are illustrated in Figure 1 and 2, respectively. During flowering, water potential decreased slightly from the onset to full flowering and stayed the same from full flowering until the onset of fruit set (Figure 1). During the onset of rapid fruit growth, xylem water potential values were relatively low, increasing towards the middle of the phenological stage and decreasing again towards the end of the phenological stage (Figure 1). During flowering and fruit set, water potential values were between -0.3 and -0.5 MPa (Figure 1). With water potential values in this range, it implies that trees were well watered and not stressed. However, during rapid fruit growth, trees experienced mild water stress with xylem water potential values being lower than -0.5 MPa (Figure 1). This implies that water supply to trees was insufficient during the rapid fruit growth period. In addition, daily temperatures were also higher during the rapid fruit growth period than during full flowering, which resulted in higher evapotranspiration and therefore a higher demand for irrigation water during rapid fruit growth. It is critical that sufficient water is supplied to trees just before and during the rapid fruit growth period. Insufficient irrigation with subsequent water stress just before the rapid fruit growth stage will result in enhanced fruit drop during the November fruit drop period (Lovatt, 1990). Water stress during rapid fruit growth will have a negative effect on fruit size, thus resulting in smaller fruit, as cellular expansion is associated with water uptake, while water deficits also suppress the expression of genes that regulate cellular expansion (Bray, 2004).

Daily trends in water potential also differed between the two phenological stages. During full bloom when trees were well watered, water potential tended to decrease as the day progressed (Figure 2), most probably as a result of water loss through transpiration. During the rapid fruit growth period when trees experienced stress, the water potential increased as the day progressed (Figure 2), most probably as a result of stomatal closure due to stress already experienced early in the day with subsequent recovery of the water status of the tree.

Wetting patterns between the baseline treatments showed similar trends, although there were differences in relative soil moisture between the treatments (Figure 3). As expected, the relative soil moisture increased as the volume of water applied increased (Figure 3). However, it appears as if the differences observed between the treatments were too little to obtain differences between treatments in stem xylem water potential. It is further evident that the soil dried out relatively quickly in the root zone of the trees after irrigation or rainfall (Figure 3). This is because the soil on the trial site is mainly a sandy soil (74% sand, 3% silt and 23% clay), which has a relative low water holding capacity. Drying of the soil in the root zone will result in moisture tension and plant stress. Irrigation should therefore be applied in more regular intervals to avoid soil from drying out in the root zone with subsequent water deficits for the tree.

Spring flush growth was significantly more for the control than for the 20 L/h treatment

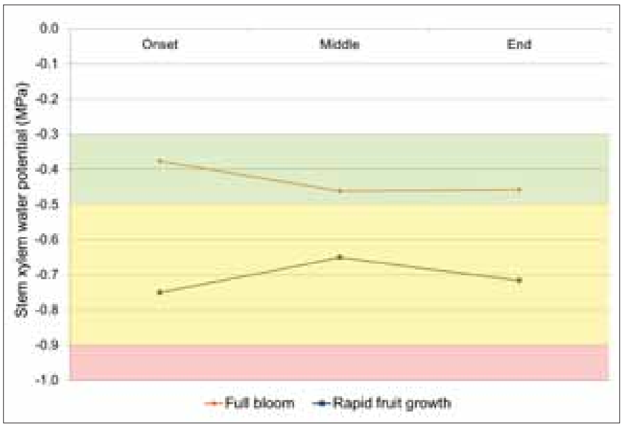

Figure 1. Stem xylem water potential trends during flowering and rapid fruit growth for 'Hass' avocado trees in the Schagen area during the 2011/12 season (green area indicates non-stress range, yellow area indicates moderate stress range and the red area severe stress range of stem xylem water potential).

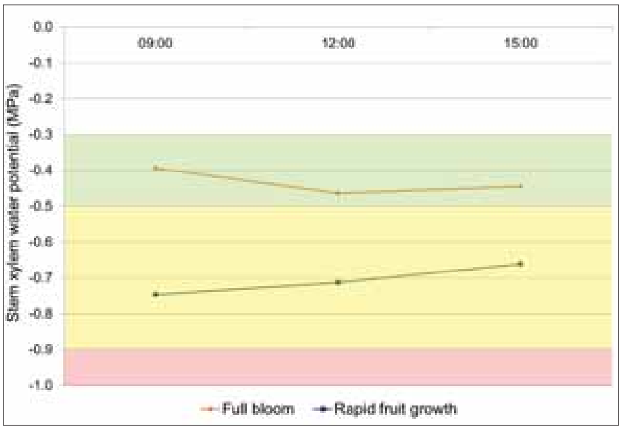

Figure 2. Daily stem xylem water potential trends during flowering and rapid fruit growth for 'Hass' avocado trees in the Schagen area during the 2011/12 season (green area indicates non-stress range, yellow area indicates moderate stress range and the red area severe stress range of stem xylem water potential).

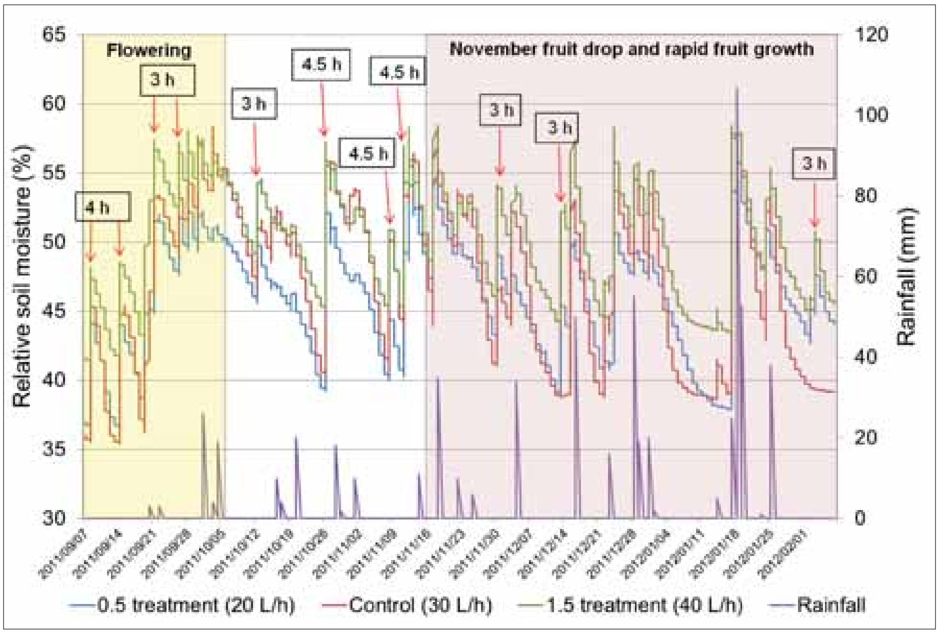

Figure 3. Relative soil moisture content in the tree root zone, rainfall and irrigation intervals for the trial site in the Schagen area during the 2011/12 season (red arrows indicate applied irrigation with the number of hours of applied irrigation in the text boxes).

(Table 1). The 40 L/h treatment did not differ significantly from the other two treatments. In addition, flush length was significantly longer on the eastern side of trees than on the western sides. There were no significant differences between the treatments for fruit set (Table 1). Fruit set on the trial site was relatively low during this season due to hail that occurred during flowering time, which resulted in damage of a large number of flowers. Incidence of *Phytophthora* root rot was relatively high in the samples taken (42 - 83% incidence in roots). However, no visible disease symptoms were observed, possibly because the rootstock is resistant to the disease.

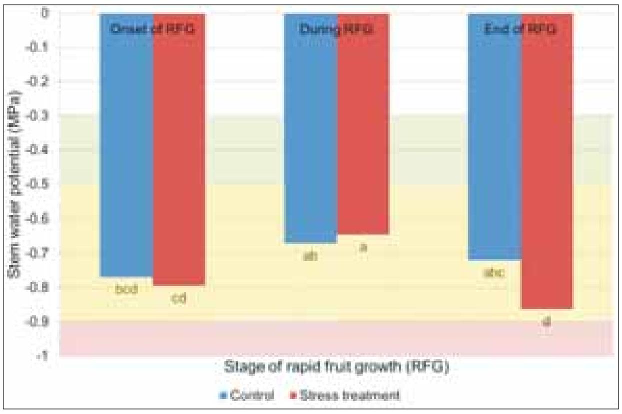

Figure 4: Stem xylem water potential values for 'Hass' avocado trees for stressed and non-stressed treatments in the Schagen area (green area indicates non-stress range, yellow area indicates moderate stress range and the red area severe stress range of xylem water potential).

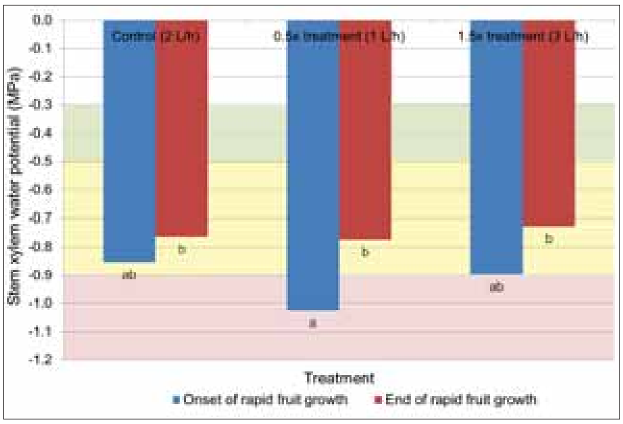

Figure 5. Stem xylem water potential of 'Hass' avocados during the onset and end of rapid fruit growth in the Levubu area (the green area indicates non-stress range, yellow area indicates moderate stress range and the red area severe stress range of xylem water potential).

During the second trial with water stress applied during the rapid fruit growth stage, a treatment effect was only observed at the end of the rapid fruit growth stage (Figure 4). In this case the stem xylem water potential for the stress treatment was significantly lower than for the control at the end of the rapid fruit growth stage. Trees of both the stress treatment and control experienced relatively high levels of stress with water potential measurements ranging between -0.65 and -0.85 MPa (Figure 4). The effect of this treatment on fruit size and yield will be determined later during 2012 at harvesting time.

Trial at Levubu

There were no significant differences in stem xylem water potential between treatments for each stage of rapid fruit growth (Figure 5). At the end of rapid fruit growth, trees were less stressed than during the onset of rapid fruit growth, especially for the 0.5x treatment (1 L/h). However, overall trees were moderately to highly stressed during the rapid fruit growth stage, which could result in a negative effect on fruit retention and size. The effect of stress on fruit size and yield is still to be determined later during the current season.

CONCLUSION

Although a full season's data has not yet been obtained, it was already established in this study that irrigation of avocado orchards is not optimal. This was evident from the xylem stem water potential values showing moderately to relatively heavy stress. It was only during full bloom in the Nelspruit area that trees were well watered. The importance of optimal irrigation during critical phenological stages, *i.e.* full bloom, rapid fruit growth and maturation, has been shown in previous studies. During the next season the focus will be on controlled irrigation, which will attempt in establishing irrigation guidelines to prevent under-irrigation and stress.

ACKNOWLEDGEMENTS

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Table 1. Spring flush growth and fruit set of 'Hass' avocado trees in the Schagen area to which different irrigation treatments were applied.

Treatment	Mean spring flush length (mm)	Mean number of fruit set per tree
0.5x treatment (20 L/h)	14.7 b[#]	29 a
1.0x treatment (30 L/h or control)	17.6 a	28 a
1.5x treatment (40 L/h)	14.9 ab	26 a

[#]Means followed by the same letter in each column do not differ significantly at P≤0.05

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