Calibrating irrigation on avocado using plant and soil based measurements: Where do we currently stand and what is the way forward?

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ABSTRACT

The aim of this three year project was to optimise irrigation management on avocado, using plant and soil-based measurements. DFM probes and tensiometers were used to measure soil water content. Graphs obtained from the DFM probes showed the water withdrawal patterns from the soil by the roots. The rate of water withdrawal correlated significantly with evapotranspiration (r^2 = 0.6353) and was also related to phenological stage. A good indication of the water needs of avocado trees was therefore obtained, but the water requirements in terms of amounts still need to be determined for the different production areas. Midday stem xylem water potential was used as a plant stress indicator. Midday stem xylem water potential norms, indicating the onset of plant stress, had to be determined first. It was shown that the onset of plant stress occurred at a midday stem xylem water potential value of approximately -0.5 MPa. This norm was further used to test the current soil based recommendations for irrigation scheduling. The preliminary results for this aspect showed that soil can be dried out more than recommended, but the exact point still needs to be determined during the current season.

INTRODUCTION

It is well known that water stress, both from over- or under-irrigation, results in an adverse effect on plant health and productivity. Avocado is especially sensitive to both under- and over-irrigation. Under-irrigation was shown to cause stunted growth, reduced biomass of feeder roots, smaller leaves, reduced yields and poor postharvest ripening and storage quality of fruit (Bower, 1984; Van Eyk, 1994; Chartzoulakis *et al*., 2002; Kruger & Magwaza, 2012; Kruger *et al*., 2013). On the other hand, over-irrigation and excessively wet conditions (prolonged conditions with soil being saturated with water) enhances the incidence of *Phytophthora* root rot infection and feeder root death due to oxygen starvation, as they need oxygen for proper functioning and respiration (Sterne *et al*., 1977; Schaffer, 2006). Over-irrigation further results in water wastage, which in the light of stricter water legislation and increasing water prices cannot be afforded.

In order to ensure optimal irrigation practices and production, the above aspects have to be taken into consideration. However, irrigation can only be optimally applied if the water requirements of the trees are known. Currently, in South Africa, irrigation recommendations for avocado are based on soil properties and monitoring soil water content (Kruger, 2011). The problem with this is that soil-based measurements only give an indirect indication of the water needs of the plant (Lahav & Whiley, 2002) and it is therefore assumed that the correct amount of water is applied. The existing water status of the plant is still unknown and there is therefore still a possibility that under- or over-irrigation can take place.

Plant-based measurements or indicators offer the most direct way of obtaining information about the water status of plants (Winer, 2003). One such an indicator is midday stem xylem water potential. Xylem water potential refers to the tension or differential pressure created in the xylem by transpiration. Midday stem xylem water potential was shown in many crops to be a highly reliable indicator of plant water status and in many crops also correlated highly with fruit size and quality, as well as stomatal conduc-

tance and photosynthesis (Naor, 2000). However, under South African conditions, stem xylem water potential norms have not yet been established for avocado. But it is important to note that measuring plant parameters holds some practical challenges. It requires expensive equipment, trained technicians, it is time consuming and labour intensive. It would therefore be more practical if plant parameters can be used to calibrate or refine current soil based recommendations. This will provide norms to growers in which case they will still use soil based norms for irrigation scheduling, which is easy to measure, but knowing the water status of the plant as well.

The aim of this three year irrigation project was 1) to gain a better understanding into the physiology of the avocado plant, and to establish midday stem xylem water potential norms indicating onset of plant stress, and 2) to use the midday stem xylem water potential norms determined in 1) to test the currently recommended soil-based norms.

MATERIALS AND METHODS

During the past three growing seasons, trials had been carried out in the Nelspruit and Tzaneen areas. The initial trial had been carried out during the 2011/12 season in the Schagen area on 'Hass' avocado trees grafted on 'Bounty' rootstocks. Three different irrigation treatments had been applied (Table 1). During the second season (2012/13) the trial was carried out on the Agricultural Research Council's Institute for Tropical and Subtropical Crops (ARC-ITSC) Nelspruit Research Farm on 'Pinkerton' avocado trees grafted on 'Duke 7' rootstocks. Three different irrigation regimes were applied (Table 1). During the last season (2013/14), the trial was carried out on a commercial farm in the Tzaneen area on 'Hass' avocado trees grafted on 'Duke 7' rootstocks. Four different irrigation regimes or treatments were applied (Table 1).

For each season, DFM probes were installed for each treatment, recording soil water content data at hourly intervals at depths of 100, 200, 300, 400, 600 and 800 mm. During the last season, tensiometers were also installed at depths of 300 and 600 mm as treatments were based on soil matrix potential. Physiological data, which include midday stem xylem water potential, photosynthesis, transpiration and stomatal conductance, were collected on a two weekly basis for the second and third season. During the first season only midday stem xylem water potential data was collected during the onset, middle and end of flowering, rapid fruit growth and fruit maturation. Other data that was collected include fruit set (all seasons), yield (all seasons) and flush vigour (first season). Weather data, which include temperature, humidity, rainfall and evapotranspiration data was obtained from the nearest weather stations.

RESULTS AND DISCUSSION

In this discussion the focus will be on the most important results obtained for the past three seasons. As mentioned, the first aim was to gain a better understanding about the physiology of the avocado tree with specific reference to water use or water relations.

The pattern of water use or withdrawal by the roots of the plant can be seen from the graph obtained from the DFM probes (Fig. 1). From these graphs the rate of water withdrawal can be obtained by determining the slopes of withdrawal on the graphs. Unfortunately, one drawback of using DFM probes is that units used are relative and not exact and the exact amount of water withdrawn is unknown. In order to know the amount of water withdrawn, the probe needs to be calibrated with an instrument of known units, such as a tensiometer.

Nevertheless, water withdrawal rates measured by the DFM probes still give a good indication on water use by the trees throughout the growing season. Figure 2 illustrates the correlation between the rate of water withdrawal and evapotranspiration and it can be seen that there is a strong positive correlation between water withdrawal and evapotranspiration. This was expected, as the rate of transpiration is related to evapotranspiration with the withdrawal of water from the soil being related to transpiration. Water withdrawal is further related to the phenological stage (Fig. 3). It can clearly be seen that there is a tendency of higher water use during certain phenological stages, such as full flowering and rapid

Table 1. Irrigation treatments applied over three seasons for the avocado irrigation trial.

Season	Treatment no.	Treatment
2011/12	1	0.5 x ET
	2	1.0 x ET
	3	1.5 x ET
2012/13	1	30 L/h for 4 hours twice a week
	2	30 L/h for 4 hours once a week
	3	30 L/h for 4 hours once every 2 weeks
2013/14	1	Farm irrigation scheduling
	2	10 – 25 kPa
	3	25 – 35 kPa
	4	35 – 45 kPa

fruit growth. However, the exact water requirements of avocado trees still need to be determined under South African conditions. It should be expected that the water requirement will be dependent on the environment surrounding the tree and it will therefore be important to determine the water requirements for every producing area.

As mentioned, midday stem xylem water potential was found to be a highly reliable indicator of plant stress. However, as stem xylem water potential has never been used on avocado in South Africa, no norms exist as to give an indication on when the plant starts to experience stress. In order to establish such norms, physiological parameters related to water use was selected, which included transpiration rate and stomatal conductance. Usually plants react towards water deficits firstly by stomatal closure (or partial stomatal closure) with a subsequent decrease in transpiration. Figure 4 illustrates the relationship between transpiration rate and midday stem xylem

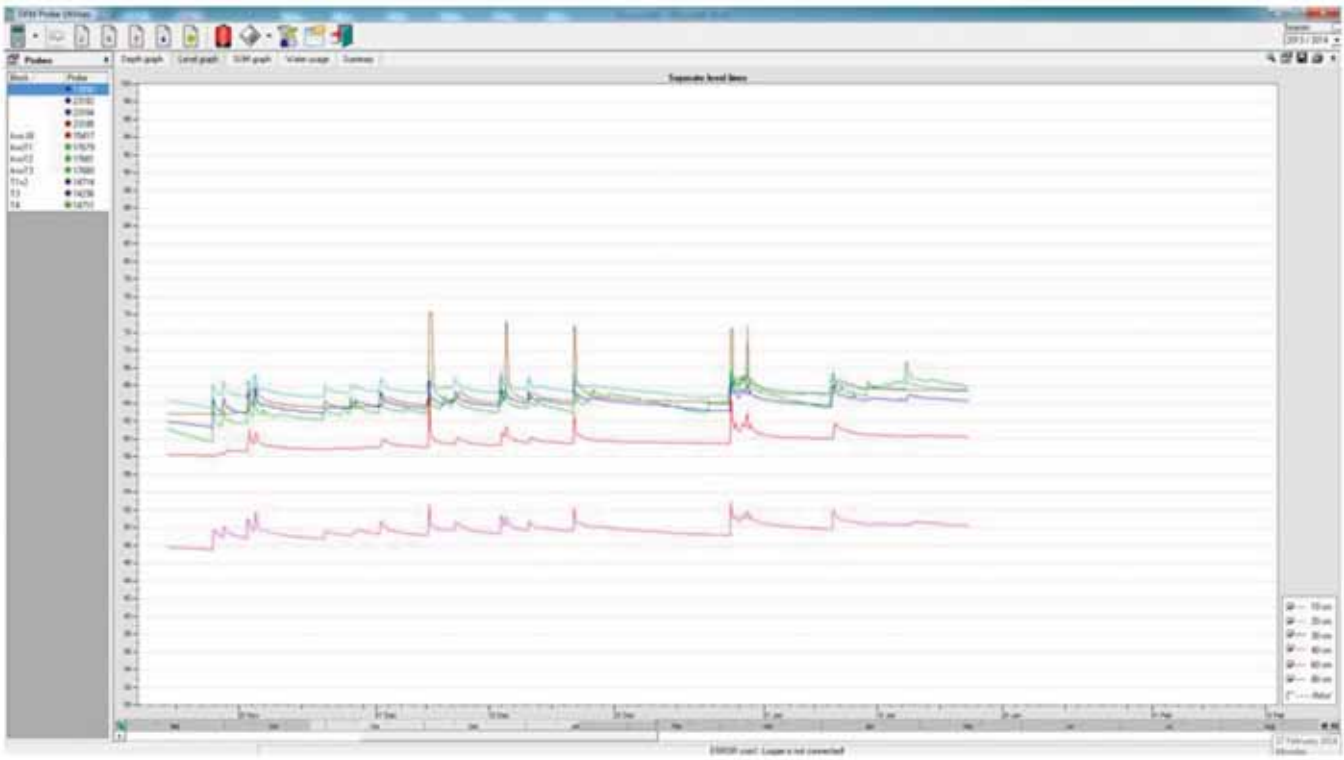

Figure 1. Soil moisture graphs obtained from DFM probes.

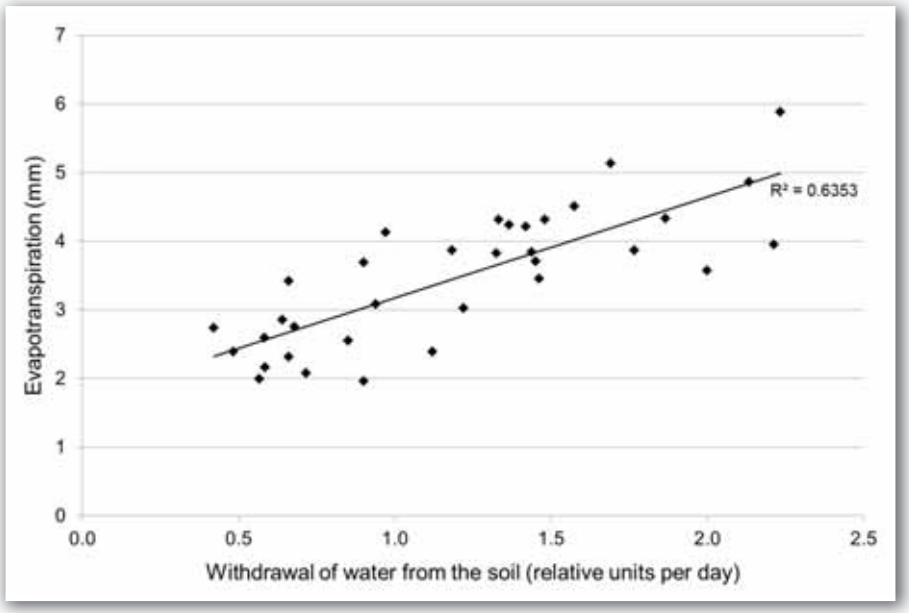

Figure 2. The relationship between evapotranspiration and water withdrawal from the soil by avocado trees.

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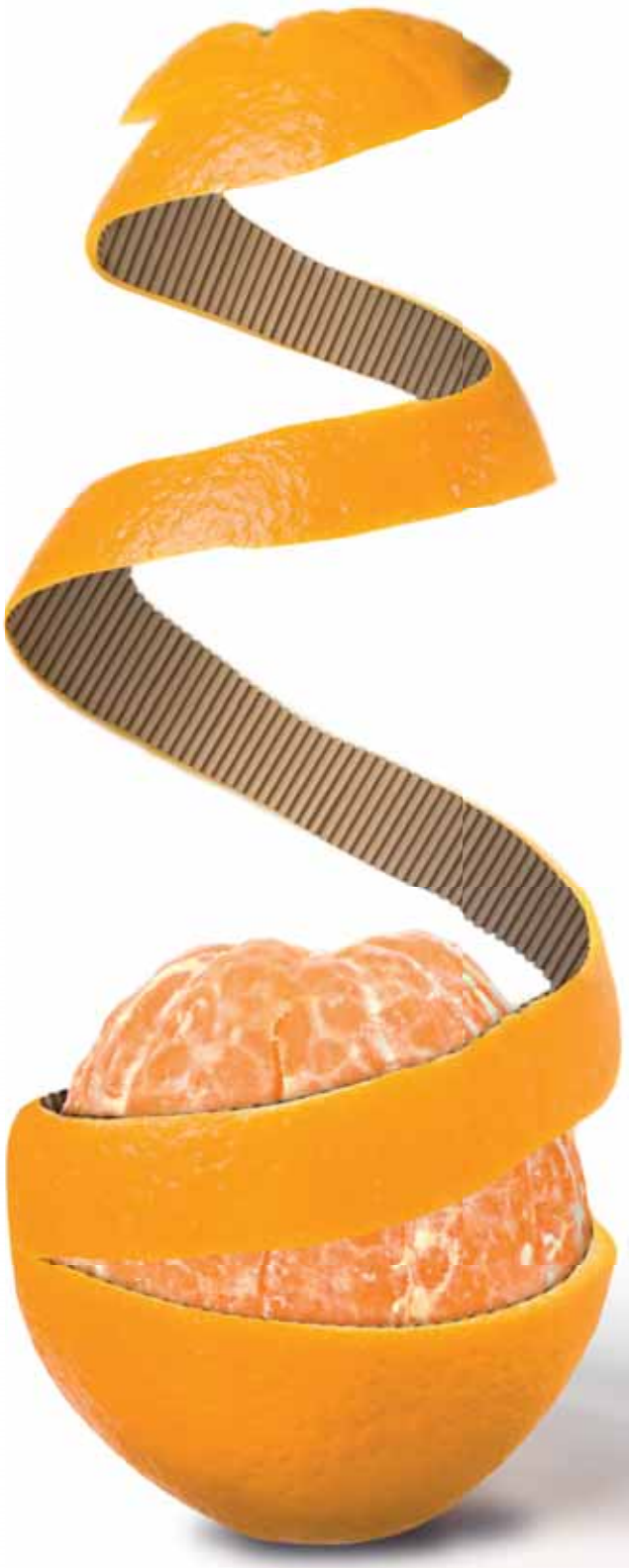

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water potential. A significant negative correlation was obtained, indicating that increasing tension in the xylem (increasing negative stem xylem water potential values) resulted in decreased transpiration. But it is important to note that at a certain tension there is a sudden decrease in both transpiration rate and stomatal conductance (Fig. 4). This is a typical stress reaction towards water deficit giving rise to partial stomatal closure to prevent any further excessive moisture loss through transpiration. For avocado, the specific tension at which this stress response occurred in this experiment was at approximately -0.5 MPa. This will be considered an established norm from now on and will be used when soil-based recommendations are tested and calibrated.

Midday stem xylem water potential was measured on very hot sunny days. Hot sunny days were chosen, as trees are more likely to stress during hot

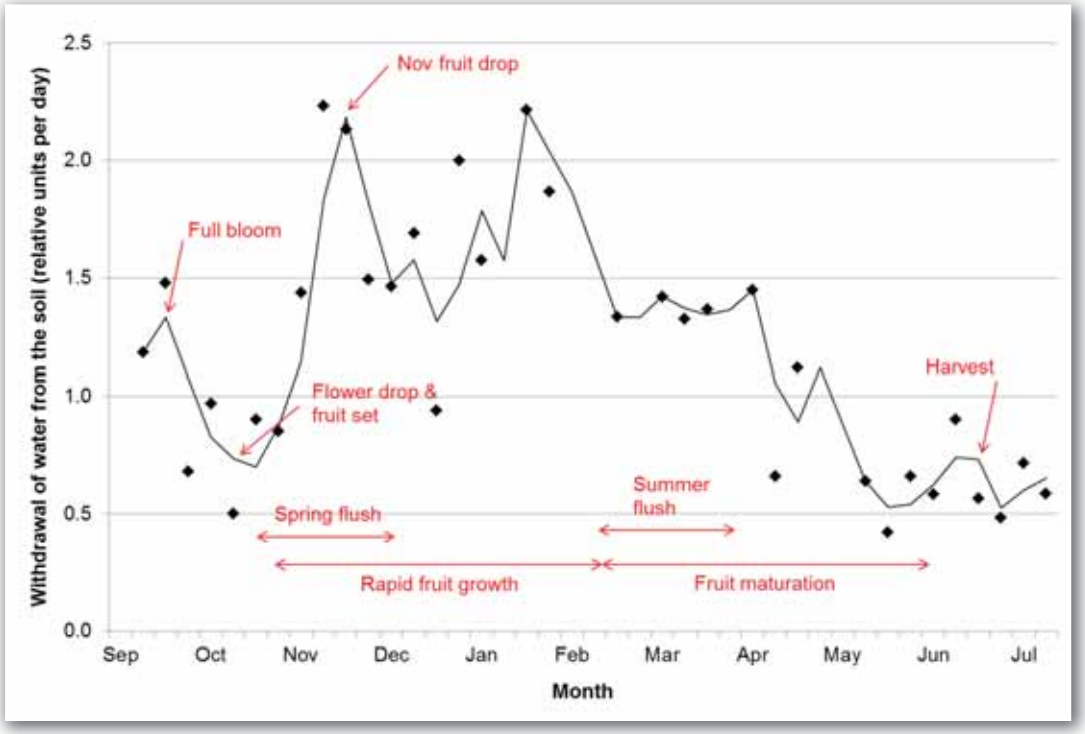

Figure 3. The relationship between phenological stage and water withdrawal from the soil by avocado trees.

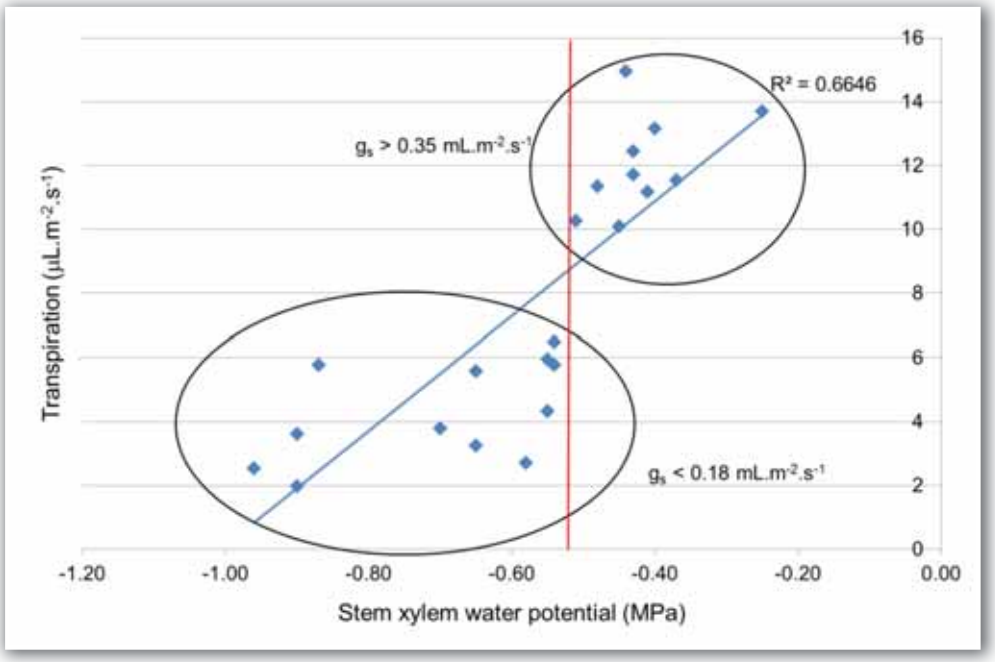

Figure 4. Correlation between transpiration rate and midday stem xylem water potential for 'Hass' avocado trees (the circled areas indicate the sudden decrease in transpiration rate and stomatal conductance, while the red line illustrates the stem xylem water potential value of approximately -0.5 MPa at which the sudden decrease occurred).

days, especially during the middle of the day, compared to cool moist days. If at these extreme conditions trees do not stress, they will definitely not stress when temperatures are lower and conditions are more favourable. In most cases when data collection was carried out, the soil was close to the refill point (the point where 50% of the easily available water is removed) (Fig. 5). Unfortunately, due to regular and sometimes high rainfall, the soil could not be dried out to values lower than refill point. When considering midday stem xylem water potential under conditions of high temperatures, it can be seen that in most cases trees have not shown symptoms of stress (Fig. 6). It is therefore possible to dry out the soil more before plant stress starts to occur. However, the soil matrix potential value at which the plant starts to show stress symptoms still need to be determined.

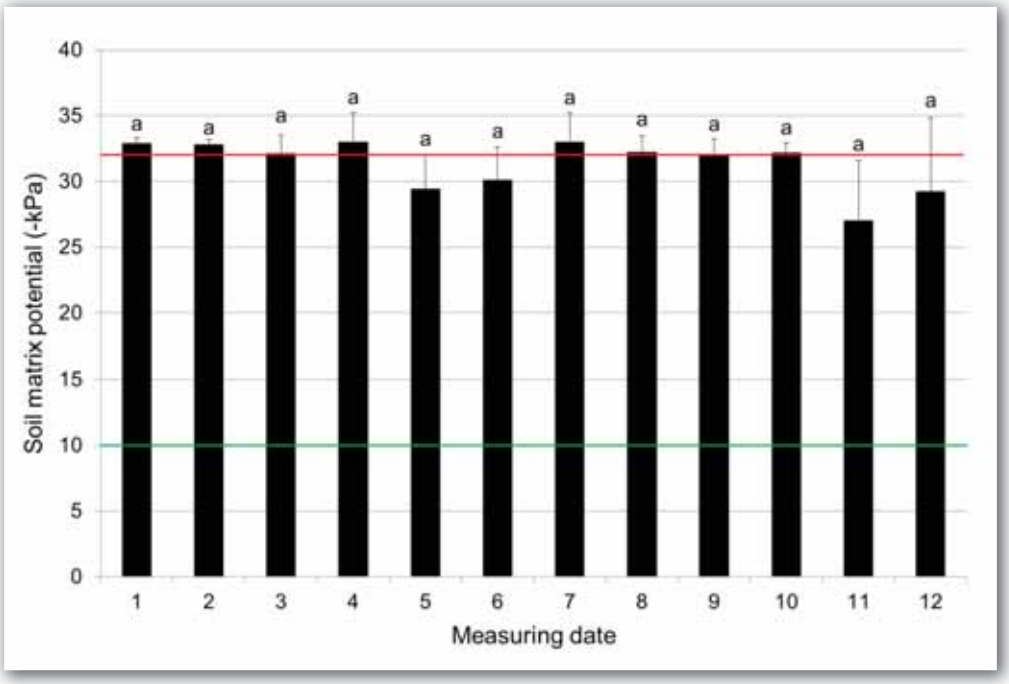

Figure 5. Soil matrix potential at different measuring times at the Tzaneen site (the red line indicates the refill point of the soil [-32 kPa] while the green indicates field water capacity [-10 kPa]).

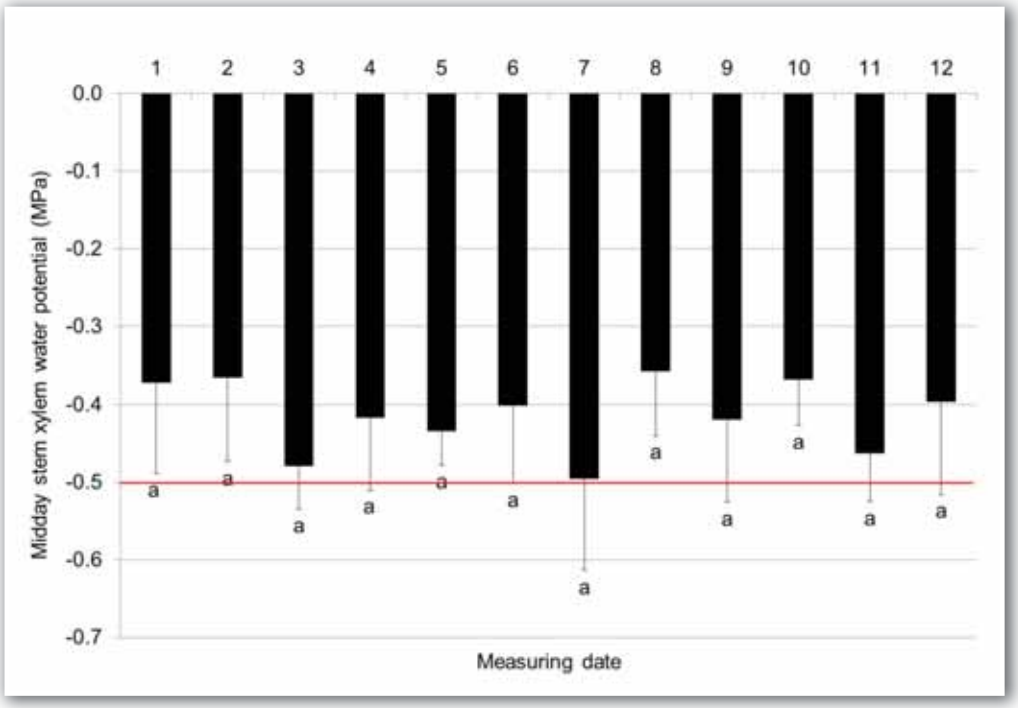

Figure 6. Midday stem xylem water potential values for trees at the Tzaneen site (red line indicates the stem xylem water potential norm of -0.5 MPa determined earlier).

CONCLUSION AND FURTHER RESEARCH

From the results of this three year's study, a better understanding of water use by avocado trees were obtained. Water use is strongly influenced by evapotranspiration and the water needs at specific phenological stages. Water requirements will have to be determined for the different avocado producing areas. Midday stem xylem water potential norms, indicating the onset of plant stress, were determined and these norms were used to test current soil-based recommendations. Even though further research on this aspect is critical, there is already an indication that irrigation does not necessarily have to commence when 50% of the easily available water is removed from the soil, as currently recommended, and that the soil can be allowed to get drier. However, soil norms need to be tested in different soil types and the easiest and fastest way to do this is to carry out trials with potted avocado trees. Trials with potted trees in a controlled environment also make it possible to determine the water requirements under various climatic conditions, therefore allowing making correlations to the climate at various production areas, which then can be confirmed by field trials. Once these norms have been established and calibrated, guidelines will be made available to producers on irrigation scheduling using the calibrated norms.

ACKNOWLEDGEMENTS

Funding from the South African Avocado Growers' Association and the National Research Foundation (THRIP) is acknowledged. The authors would further like to thank Dr. Anton Hough and Dr. Andre Ernst for making their orchards available for this research and assisting researchers.

LITERATURE CITED

BOWER, J.P. 1984. Effect of fruit water stress and irrigation regime in the ripening of stored avocado fruit, cultivar Fuerte. *South African Avocado Growers' Association Yearbook* 7: 55-56.

CHARTZOULAKIS, K., PATAKAS, A., KOFIDIS, G., BOSABALIDIS, A. & NASTOU, A. 2002. Water stress affects leaf anatomy, gas exchange, water relations and growth of two avocado cultivars. *Scientia Horticulturae* 95: 39-50.

KRUGER, F.J. & MAGWAZA, L.S. 2012. Does orchard soil moisture content at the time of harvest influence the post-storage ripening pattern of 'Hass' avocado fruit? *South African Avocado Growers' Association Yearbook* 35: 47-53.

KRUGER, F.J., ROETS, N.J.R., VOLSCHENK, O., PIETERSE, P. & NZANZA, B. 2013. Further observations on the effect that rainfall, irrigation and fertiliser practices have on the ripening of avocado fruit. *South African Avocado Growers' Association Yearbook* 36: 9-16.

KRUGER, J.A. 2011. Irrigation. In: The cultivation of avocado, 2nd revised edition. De Villiers, E.A. & Joubert, P.H. (eds.). Agricultural Research Council – Institute for Tropical and Subtropical Crops, Nelspruit, RSA, pp. 134-141.

LAHAV, E. & WHILEY, A.W. 2002. Irrigation and mineral nutrition. In: The avocado botany, production and uses. Whiley, A.W., Schaffer, B. & Wolstenholme, B.N. (eds.). CAB International, Wallingford, UK., pp. 259-297.

NAOR, A. 2000. Midday stem xylem water potential as a plant water stress indicator for irrigation scheduling in fruit trees. *Acta Horticulturae* 537: 447-454.

SCHAFFER, B. 2006. Effects of soil oxygen deficiency on avocado (*Persea americana* Mill.) trees. Seminario International: Manejo del Riego y Suelo en el Cultivo del Palto La Cruz, Chile 27 to 28 September 2006, pp 1-11.

STERNE, R.E., ZENTMYER, G.A. & KAUFMANN, M.R. 1977. The effect of matric potential of soil on *Phytophthora* root disease of *Persea indica*. *Phytopathology* 67: 1491-1494.

VAN EYK, J.H. 1994. Die effek van verskillende besproeiingsregimes op opbrengs en vruggrootte in Hass avokado's. Voorlopige resultate. *South African Avocado Growers' Association Yearbook* 17: 88-90.

WINER, L. 2003. Comparison of optimal and deficient irrigation of avocado by phytomonitoring. *www.avocadosource/papers/israeli/winerleo2003.pdf*