Quantifying water use of mature pecan orchards in selected irrigation areas of the Northern Cape – research report

NJ Taylor, JG Annandale, W Rossouw, S Kunene, M Zwane, A Human, N Shongwe E Lötze, A Clulow & CS Everson

The pecan water use project, jointly funded by the Water Research Commission and SAPPA (K5/2814//4), is in its second year and we now have a full season of measurements of pecan water use in the Vaalharts region and we have recently instrumented an orchard close to Groblershoop. In addition to water use measurements, we also have two seasons of data on quantifying the impact of water stress at different phenological stages on yield and quality. This report provides a summary of the major findings from the project to date. It should be noted that the water use data is still preliminary as final parameters for the determination of transpiration can only be obtained at the end of the study.

Water use of pecan orchards

The aim of this research is to answer the following questions. How much water do mature 'Wichita' and 'Choctaw' trees use in a day and over the entire growing season in the Vaalharts and Upington regions? How does water use change with changing environmental conditions, canopy size and canopy development? Based on canopy size and local conditions how much water will your trees use in a month and over the season? What is the water use efficiency (kg m^{-3}) and water productivity (R m^{-3}) of pecans?

Where and what are we measuring?

The water use measurements in the Vaalharts region are being conducted on a farm 20 km west of the town of Jan Kempdorp in a 12 year-old mixed cultivar orchard. In this orchard we are measuring transpiration of four 'Wichita' and four 'Choctaw trees (planted 10 x 10 m), together with soil water

content, depth of the water table with a piezometer, soil evaporation, canopy cover, weather variables and total evapotranspiration (Figure 1 and 3). The orchard has recently been changed to full surface irrigation (wetted radius of 6.5 m) using 150 L h^{-1} Mamkad 16 sprinklers (NaanDanJain Irrigation) and a vegetation cover is being established in the work row.

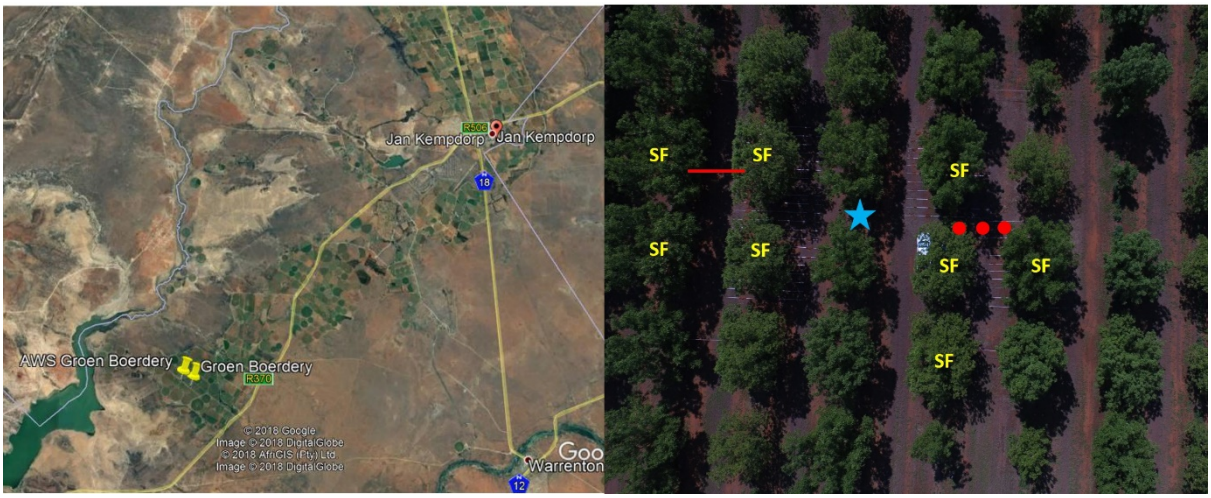

Figure 1 Location of the study site in the Vaalharts region and the experimental layout in the mature pecan orchard. SF indicates the trees in which sap flow is measured. The red line indicates where the soil water content of the topsoil is measured. The red dots indicate where soil water content down the profile is measured. The blue star indicates the location of the piezometer for determining the level of the water table.

In order to determine water use in one of the hottest production regions in South Africa, a second 17 year old orchard was instrumented for the determination of water use in the Groblershoop region. The farm is 40 km north of Groblershoop and is situated next to the Orange River (Figure 2 and 3). The set-up is very similar to the orchard in the Vaalharts region. Trees are irrigated by means of two drip lines, with 0.6 m in between drippers and a delivery rate of 3.5 L h^{-1} (approximately 116 L h^{-1} $tree^{-1}$). Typically, irrigation takes place every second night during the peak of the season. The inter-row is kept clean through chemical weed control.

Figure 2: Location of the study site in the Groblershoop region and the experimental layout in the mature pecan orchard. SF indicates the trees in which sap flow is measured. The yellow rectangle indicates where the soil water content of the topsoil is measured. The yellow dots indicate where soil water content down the profile is measured. The blue dot indicates the location of the piezometer for determining the level of the water table.

Figure 3: Sap flow system used to determine transpiration of the pecan trees and Eddy covariance system used to estimate evapotranspiration of the orchard.

What have we found so far?

The weather at Vaalharts during the trial was fairly typical for the region, although rainfall for the 2018/2019 season was 363 mm, which is lower than the mean annual rainfall of 430 mm (Figure 4). The average temperature was 19.6 ^{o}C, maximum temperature was 40.3 ^{o}C and the minimum was -4 ^{o}C. There were 76 days when the maximum temperature was above 36 ^{o}C and 27 days when the minimum temperature fell below 0 ^{o}C. Total reference evapotranspiration (ET_o) for the season (September to June) was 1570 mm.

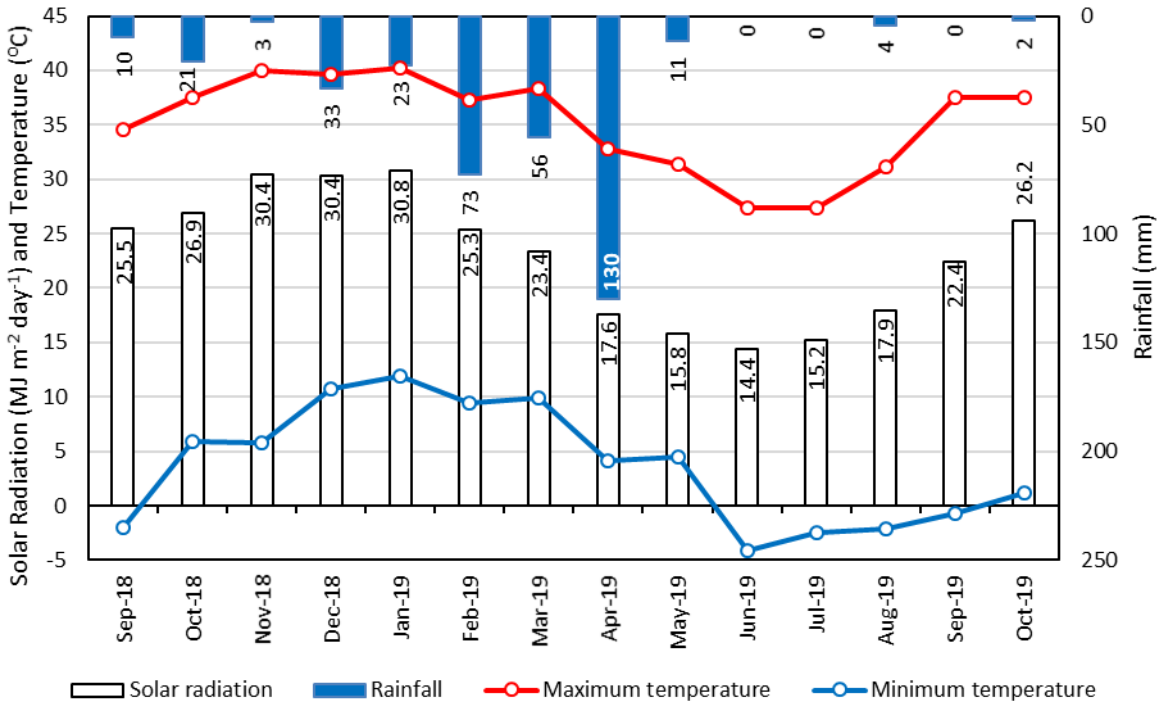

Figure 4: Monthly weather variables for the pecan orchard in the Vaalharts region from September 2018 to October 2019.

Preliminary transpiration data indicated that in the hottest part of the season (December to March) the 'Wichita' trees on average transpired approximately 350 L day^{-1}, whilst the 'Choctaw' trees transpired approximately 400 L day^{-1} (Table 1). Over the season from September to June 'Wichita' trees transpired 887 mm (8870 m^3) and the 'Choctaw' trees transpired 925 mm (9250 m^3). This is only water transpired by the trees and represents the minimum water use by the orchard, as soil evaporation and transpiration by the vegetation in between the tree rows still needs to be taken into account.

Table 1: Summary of preliminary transpiration volumes for 'Wichita' and 'Choctaw' trees in the Vaalharts region for the 2018/19 season

Transpiration*		**Wichita**	**Choctaw**
Average (December to March)	mm day^{-1}	3.56	4.08
	L day^{-1}	356	408
Maximum	mm day^{-1}	4.25	5.08
	L day^{-1}	425	508
Seasonal total (September to June)	mm	887	925
	m^3	8870	9250

* The data still needs to undergo some final checks

The transpiration data, together with yield, can be used to determine water use efficiency (WUE) and water use productivity (WUP) for the 2018/19 season. It should be noted that these are values for a single season, which are based on preliminary transpiration data. A much better understanding of WUE and WUP in pecans will be obtained after three years of measurements in two different orchards, as this take into account the alternate bearing cycle of cultivars and the impact of local climate. WUE derived using transpiration was 0.30 kg m^{-3} for 'Choctaw' trees and 0.51 kg m^{-3} for 'Wichita' trees, whilst WUP varied from R23.11 m^{-3} to R33.37 m^{-3}. It should be noted that these values are impacted by the climate of the region and hotter and drier regions are likely to have lower WUE and WUP values than the cooler regions, due to increased evapotranspiration under hotter and drier conditions.

Table 2: Preliminary water use efficiency (WUE) and water productivity (WUP) for the 'Choctaw' and 'Wichita' trees in an orchard in Vaalharts

	Choctaw	**Wichita**
Total Transpiration (m^3)	9250	8870
Total Dry in Shell Nut Yield (kg ha^{-1})	2800	4550

Total Net Income (R ha^{-1})	R213 850	R296 000
WUE (kg m^{-3}) - In Shell	0.30	0.51
WUP (R m^{-3}) - In Shell	23.11	33.37

The transpiration values for a particular orchard are dependent both on the season and canopy and if we are to estimate water use of pecan orchards in different locations, we need to determine both weather variables and canopy size. Whilst weather variables can be fairly easily measured with an automatic weather station, canopy size is not so easy to determine. This is largely due to different pruning practices and planting densities of different orchards. In order to try and get better estimates of canopy size, at fairly low cost, we have used a drone to take images of the trees from above. These images are then analysed using the *Canopeo* app to determine canopy cover and assessed relative to ground measurements of fractional interception of solar radiation. The app seems to be providing good estimates of canopy size (Figure 5A) and the estimates seem to be related well to transpiration crop coefficients (K_t) on the Hatfield Experimental Farm (Figure 5B).

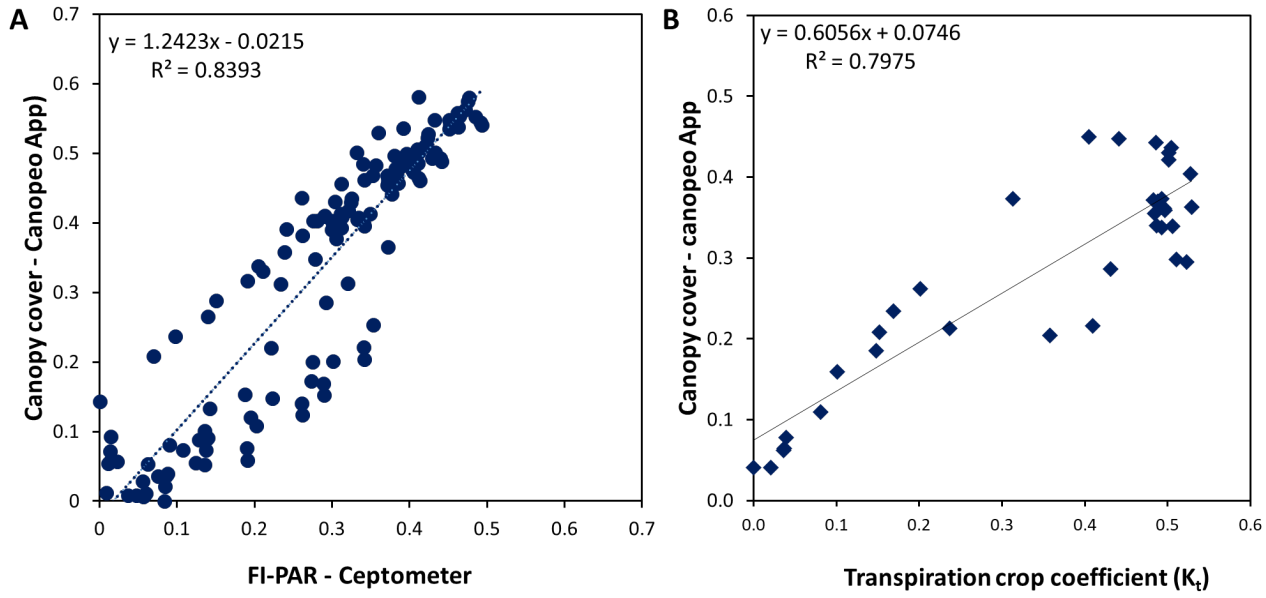

Figure 5: The assessment of the *Canopeo* app to A) determine the canopy cover of pecan orchards and B) the relationship with transpiration crop coefficients (K_t)

This first season of data will soon be used to test crop coefficient models developed for an orchard in Cullinan. This will allow us more predictive capability in terms of water use for a wide range of orchards across South Africa. In addition, it will be tested in the hotter Groblershoop region.

The impact of water stress at different phenological stages on yield and quality of pecans

Where and what are we measuring?

We have managed to complete two full season of measurements of the water stress trial being conducted on the University of Pretoria's Hatfield Experimental Farm. A mild water stress was implemented at four phenological stages, which were flowering and nut set, nut sizing, nut filling and shuck dehiscence. Each treatment is replicated four times on 'Wichita' trees planted 10 m x 10 m. These treatments were compared to a well-watered control, with irrigation scheduled by monitoring soil water content and pre-dawn and midday leaf water potentials. Yield from each replicate is determined after each season, together with a number of quality parameters.

What have we found?

Results from the first two years of measurements showed that yield was reduced when stress was induced during flowering and nut set and nut filling, but there was no significant effect on yield during nut sizing or shuck dehiscence (Figure 6). The reduction in yield during flowering and nut set was as a result of a reduction in nut number, whilst the reduction in yield during nut filling was as a result of poorly filled nuts, as there was an increase in pops and wafers during this stage. Although yield was not reduced when stress was imposed during nut sizing in the 2018/19 season, there was a significant reduction in nut size, compared to the control. This has an impact on income earned as seen in Table 3. There was a reduction in income during most phenological stages, but the reduction was particularly noticeable during the flowering and nut set and nut filling stages. Avoiding water stress during these stages is therefore critical to maximise yield and quality and therefore income. Some water savings may be possible during nut sizing and nut dehiscence, but it is not without risk and a possible reduction in income due to either a reduction in nut size or more stick tights.

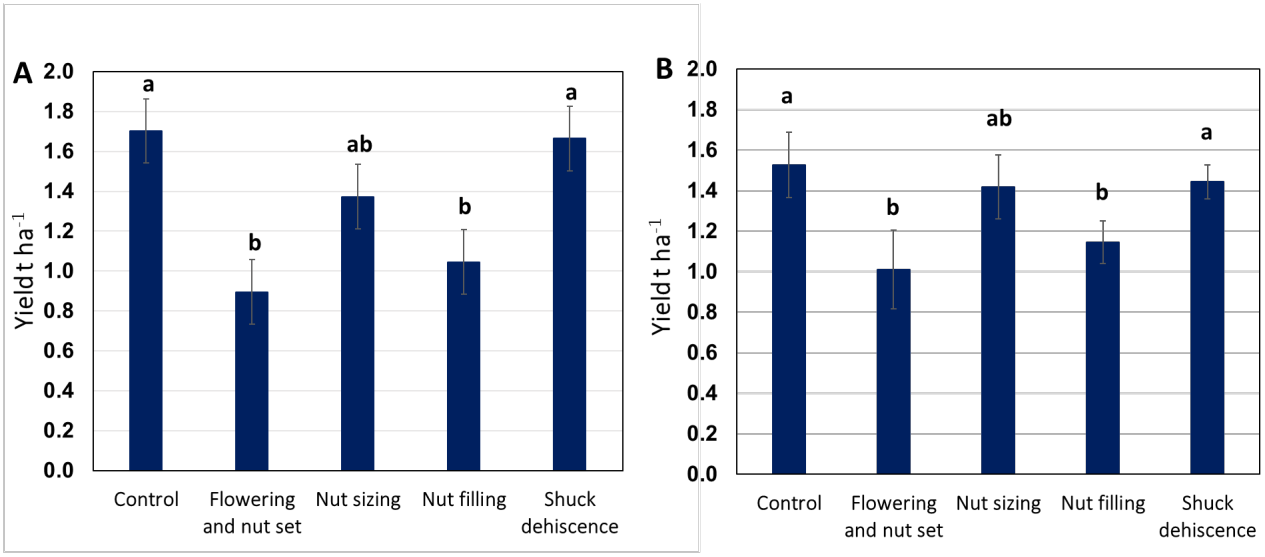

Figure 6: The impact of water stress at different phenological stages on yield in the A) 2017/18 and B) 2018/19 seasons.

Table 3: Potential income earned as a result of stress implemented during different phenological stages

Treatment	**2017/18 Season**	**2018/19 Season**
Control	R109 231.31	R91 609
Flowering and nut set	R56 531.87	R60 396
Nut sizing	R88 292.07	R76 410
Nut filling	R60 434.92	R59 540
Shuck dehiscence	R109 001.34	R86 632

We are currently busy with the third season of measurements, and it will be important to continue for at least another year to fully understand the impact of water stress on yield and quality in an alternate bearing crop and any long term effects of water stress on the trees.

Acknowledgements

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Terminology and units for water use used in this project

When we refer to mm we are referring to the whole area allocated to a tree and not just the wetted area. The conversion of mm to litres (L) therefore depends on the spacing of the trees. For orchards with a 10 x 10 m (100 m^2) spacing this is an easy conversion as 1 mm equals 100 L. However, for a 7 x 10 m planting (70 m2) 1 mm equals 70 L.

1 mm = 10 000 L per hectare or 1 L per m^2

1 mm = 10 m3 per hectare

1 m^3 = 1000 L

1 ML (megalitre) = 1 000 000 L = 1000 m^3