WATER AND AGRICULTURE

'First' study quantifies water needed to grow avocados in SA

In one of the first studies of its kind in South Africa, researchers, with funding from the Water Research Commission (WRC) and the South African Avocado Growers' Association have succeeded in quantifying water use of avocado orchards growing in the country. The knowledge generated by the study paves the way for this profitable crop to be grown more water efficiently. Matthew Hattingh reports.

Nicky Taylor

Consider that incomparable fruit, the avocado. Botanically it's a berry with a single, large seed. Slice its bumpy, purple-black skin. Split it asunder and behold a thing of beauty, if not a joy forever, to borrow from the poet.

High in fat, and with a subtle, buttery flavour that leans to the savoury, the avo is the key ingredient in dozens of dishes. Avocado ritz would be ***niks***, without it. And, holy moly, don't forget guacamole!

Little wonder more people are eating them. South Africa, as of 2020, has 14 700 ha under avocado orchards, with about 800 ha added each year.

Trouble is, it takes a lot of water to grow one. Some 150-200 litres are needed to produce a single avocado of perhaps 250 g. The counter-argument is that avos are a high-value, high oil-content crop so comparing it with, say apples or oranges, is like comparing, well, apples and pears. Nonetheless, water is scarce in this country, with less to spare for more agriculture in the future.

Avocado trees are evergreen so need water year-round. Most of South Africa's avos are cultivated in the east of the country, particularly in Limpopo and Mpumalanga, but increasingly in cooler sub-tropical regions, including KwaZulu-Natal and further west. So, while summer rainfall provides a big chunk of the tree's needs, in dry spells and drought, irrigation is essential. But it must be done right.

Too little water and fruit will fail to set (transform from flower to fruit) or will drop off the tree and the harvest may be smaller or ripen unevenly. Individual avocados may also be smaller. They may be more likely to suffer from something called diffuse mesocarp discolouration (think brown or grey areas in the yellow part of the avo, especially towards the pointy end), or vascular browning (think stringy, brown bits).

Too much water and the tree's shallow roots rot and death beckons. It's enough to wind up avo lovers across the land, more so given the dearth of research on local avocado irrigation.

The good news is that the South African Avocado Growers' Association and the WRC have published a report examining water use in avocado orchards relative to yield.

The report, titled *Water Use of Avocado Orchards – Volume 1* (**WRC Report No. 2552/1/21**) is said to be one of "very few attempts to quantify water use of avocado orchards" under different conditions, including climatic regions, seasons and stages in the growth cycle.

"This study represents a significant contribution to our understanding of avocado orchard water use," according to its authors, Nicolette Taylor, Evidence Mazhawu, Alistair Clulow, Nico Roets, Stephanie Midgley, Theunis Smit and John Annandale. The team said they had succeeded in partitioning orchard water use into its two components: transpiration and evaporation, a rare achievement. Evaporation is when water changes to vapour on soil or plant surfaces. Transpiration refers to the water lost through the leaves of plants.

The distinction is important because, as the report explains, "transpiration should ideally be maximised in orchards, whilst evaporation should be minimised". It comes down to photosynthesis, the process plants use to turn energy from the sun into chemical energy, stored as sugars and starches. Without transpiration there can be no photosynthesis.

The report was the "first to provide reliable figures for water use efficiency and water use productivity". And its authors hoped it would help growers better design and schedule irrigation, taking into account weather predictions for the week ahead. This would allow optimal irrigation, limiting harvest losses and squeezing out water savings – particularly important during drought when growers must find ways to do more with less.

The findings were also expected to assist with planning and site selection for new orchards and in the issuing of water licences, making the process fairer.

The researchers began their work with a review of local and international journals and growers' association yearbooks and weighed up a number of different models for estimating water use. It was likely, they noted, that less than half of the country's growers schedule irrigation, this despite its well-documented value. But change may be afoot with the "increased focus on sustainable production and water restrictions".

Having identified gaps in the avo-watering body of knowledge, the team selected a number of well-managed orchards where they could do experiments and gather data.

At Everdon Estate near Howick, in KwaZulu-Natal from April 2017 to October 2020, the researchers studied a mature and intermediate orchard, as well one that had yet to bear a commercial crop. They sought to learn how the orchards responded to environmental conditions and gathered plant data, including the extent of the trees' canopies, which have a direct bearing on evapotranspiration. Water-use data was compared with yield and fruit price data in an effort to gauge the efficiency and productivity of water use for the two fruit-bearing orchards.

But KwaZulu-Natal is not a major avocado producing region, so measuring equipment was also set up at a fourth orchard, in Tzaneen, Limpopo. During the research, the team noted:

- The locations and size of the different orchards;
- Soil types;
- Spacing and density of trees and orientation of rows;
- Ages of the trees;
- Type of irrigation and quantities of water delivered;
- Canopy dimensions and cover; and
- The size, quality and quantity of fruit yielded at the different orchards.

To get a better handle on transpiration, the team measured the flow of sap in the stems of trees in the orchards in Howick and in Tzaneen. Total evapotranspiration was established at the three Howick orchards using eddy covariance systems above the tree canopies. Equipment atop masts logged details about the air swirling above the treetops, radiation, the passage of heat and other meteorological data. Canopy and soil temperatures were monitored too. The data gathered was analysed statistically to determine orchard evapotranspiration.

Alistair Clulow

PhD student Evidence Mazhawu digs a hole to insert soil water probes beneath the roots of an avocado tree at the mature orchard in Howick.

Alistair Clulow

Researchers from the University of KwaZulu-Natal prepare probes and logging equipment for the eddy covariance system in the mature orchard in Howick.

Meters linked to data loggers tracked how much water was used for irrigation, when and for how long. To better understand what happens to avocado trees and their fruit when they are deprived of water, a fifth orchard was selected for monitoring at the Agriculture Research Council Tropical and Subtropical Crops experimental farm in Nelspruit.

Over two seasons, trees were water stressed at different fruit development stages. Irrigation through a micro-sprinkler system was withdrawn during four growth stages: flowering; fruit set; fruit growth; and fruit maturation. To exclude rainfall from the experiment, the researchers put plastic sheets beneath the trees.

They stuck moisture probes into the ground at different depths near the roots. These measured soil matric potential. This is the relative availability of water held in the soil that the tree can suck up and use. The team restricted irrigation, drying the soil to a specific, carefully determined pressure level.
They marked flower clusters on the experimental tree and recorded the number of fruit each produced. New shoots were measured, leaf sizes recorded and the number of fruit that fell were counted daily. Fruitlets were examined in the lab to learn why they dropped.

Mature fruit were harvested and samples drawn and weighed. However, complications arose at this stage. "Unfortunately, a large number of fruit were stolen during the Covid-19 lockdown during 2020 and yield data for the 2019/20 season had to be estimated," the report noted.

During cold storage, fruit were weighed regularly and the moisture loss noted. After ripening, the fruit were examined for fungal decay and other disorders, including those kill-joys we encountered earlier, vascular browning and diffuse mesocarp discoloration. "Even though these postharvest physiological disorders develop during cold storage, pre-harvest stress conditions are strongly linked to their occurrence," said the authors.

Then it was time to crunch the numbers and compare the various experimental treatments.

So what were the results and the conclusions? Orchard transpiration was found to be largely dependent on canopy size. In young orchards with little shade it mostly consisted of evaporation from soil and transpiration from grass between tree rows. Mulches and reducing the area of surfaces wet by irrigation were recommended to save water.

How hot and dry it got made all the difference and changing weather caused transpiration and evapotranspiration to vary greatly from day to day. "Understanding the water balance in these orchards could go a long way to making water savings, especially during very dry years when water quotas are reduced," noted the authors.

Transpiration was found to be driven largely by solar radiation and vapour pressure deficit (a measure of humidity related to air pressure). However, transpiration did not always increase in step with vapour pressure deficit. It might track changes in humidity closely when vapour pressure deficit is quite low, but transpiration reaches a plateau passed a certain threshold and won't increase further, even if the vapour pressure deficit continues to rise. This suggested transpiration was at times limited by supply – the "rate at which the tree is able to transport water from the roots to the leaves". The authors advised this be taken into account when estimating water use with the crop coefficient approach, a demand-limited model.

The report evaluated three models. First, a crop coefficient approach. Here, a reference evapotranspiration value (estimated from weather station data and representing water use of a hypothetical, well-watered short grass surface) is multiplied by a coefficient calculated for the crop being studied (avocados) to calculate the crop's expected water use. But not so fast, put away the champers. Arriving at a coefficient can be a painstaking, experimental business.

To be widely reliable across many orchards and different climatic regions, a coefficient may need to take into account a host of parameters – seasons, growing stages, temperature, vapour pressure deficit and canopy density, for example. The researchers looked at some of these, noting the extent to which transpiration was over- or underestimated as parameters were tweaked.

They concluded the coefficient approach, while "still not sufficiently accurate to provide accurate estimates across all avocado orchards… represents a significant improvement on previously suggested crop coefficients". The model could be used with reasonable confidence for estimating transpiration for planning purposes, said the report.

The second model required reliable estimates of canopy conductance (vapour transfer from tree to atmosphere), as well as weather data. Its use as a predictor proved problematic, particularly when applied across a wide range of orchards.

The third model also sought to predict transpiration directly by using a mathematical approach to assess how transpiration varied with weather data. Transpiration was modelled daily

Vivek Naiken

Researchers (left to right) Ruvekh Singh and Alistair Clulow rig up an eddy covariance systems at the intermediate orchard in Howick.

Alistair Clulow

An eddy covariance system in a new avocado orchard in Howick, that has yet to bear fruit. Orchard transpiration was found to be largely dependent on canopy size. In young orchards with little shade it mostly consisted of evaporation from soil and transpiration from grass between tree rows.

and parameters set in the intermediate orchard in Howick. But, this empirical approach proved a poor traveller. "When these parameters were applied to the other two orchards, transpiration was poorly estimated," said the team. They questioned whether the model could be used for irrigation scheduling, but felt it marked a good start.

All in all, the models were found to be unpromising for day-to-day planning but of value for strategic planning. "This study represents a significant step in the right direction, as there have been no previous reports on modelling of transpiration of avocado orchards. Future modelling exercises should also focus on modelling of soil evaporation."

Orchard-specific information needed to be translated into water use models that could be applied more widely by growers, consultants and the government, said the authors. "Models that are easier to use and provide information for strategic decisions need to be considered, together with those models that provide accurate estimates on shorter time scales for tactical decision making," they said.

What of the water stress experiments? The study confirmed that avocado trees and yields were sensitive to even moderate spells of water deprivation. Growers should be vigilant in monitoring soil water conditions and scheduling irrigation, especially during the fruit set period when rainfall is usually quite low in many summer rainfall regions. Significant fruit drop can occur if trees are stressed at the time, the report said. As rains begin water stress is less likely to occur in orchards, but growers should still carefully monitor soil water and schedule irrigation to prevent the soil from drying out too much.

To download the report, ***Water Use of Avocado Orchards** – Volume 1* (**WRC Report No. 2552/1/21**), Visit: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/2552%20Vol%2012.pdf