AGRICULTURAL WATER USE

Growing more with less – helping pecan farmers flourish

Research is underway to quantify the water use and water efficiency of mature pecan trees grown in local conditions and establish the effect of water stress on irrigated orchards. The Water Wheel provides a snapshot of the findings so far. Article by Jorisna Bonthuys.

How much water do mature pecan orchards need to flourish? What happens to the yield and quality of pecan orchards if there is not enough water? How does a pecan tree's water use change with changing environmental conditions and canopy size? And: What is the water use efficiency and water use productivity of pecan trees grown in South Africa?

These are some of the questions being answered in a study currently underway in the Northern Cape. The project is funded by the Water Research Commission (WRC) and the South African Pecan Nut Producers Association (SAPPA) (**WRC Project No. K5/2814/4**). This study is part of ongoing efforts by the WRC to help ensure sustainable water use and agricultural production in key regions.

Dr Nicky Taylor, a researcher in the University of Pretoria's (UP) Department of Plant and Soil Sciences, is the lead researcher involved. She is collaborating with scientists at the Stellenbosch University and the University of KwaZulu-Natal on this project.

Given the added pressures of climate change, population growth and decline in water quality, the need for improved assessments of available water resources and how it is used remain critical. With irrigated agriculture being labelled the largest water user in the country, it is vital to gather accurate data on water used by different irrigated crops.

The demand for research into the water use of horticultural crops, particularly pecan (***Carya illinoinensis)***, has increased in recent years. This is linked to efforts to ensure sustainability in the industry, including in the context of potential water stress in key production areas.

The backdrop of this research is the growing pressure among water users and indications of future pressures on water availability, including for irrigation purposes. Therefore, producers must implement good water management strategies to sustain production and expand the industry. Producers also need to know if and when they can make water savings during a season without a major impact on yield or quality. During droughts, if less water is available local water boards or catchment management agencies are likely to reduce the amount of water allocated to growers.

"Understanding the water needs of the pecan trees is crucial for farmers and efforts to ensure responsible water use in the sector," Taylor points out. "Irrigation systems must also be designed to meet the maximum daily (water) need during warm and dry periods."

Understanding pecan water requirements

South Africa has a long history of pecan production, which has gradually shifted to the west of the country as the industry matured.

The oldest commercial pecan operation in South Africa was established in 1913 outside Nelspruit (now called Mbombela) in Mpumalanga. Since then, pecan orchards have been established in the Northern Cape, KwaZulu-Natal, Mpumalanga, North West, Gauteng, the Free State, the Eastern Cape and the Western Cape.

Most of South Africa's pecan production now resides in the Northern Cape, specifically around Upington, Prieska, Douglas, and Hartswater. More than 90% of all new plantings are also being established in the country's drier western production region. This region has scab-free growing conditions. Pecan scab is a fungal disease, often causing major headaches for producers.

Currently, South Africa is the world's third-largest pecan producer. In 2021, the annual production of pecans was 19 100 tons (compared to 21 377 tons the previous year). Most of the nuts are exported to Europe and the Far East.

Production is booming, and this trend is expected to continue. This has led to many farmers replacing their cash crops with nut trees in certain areas, including the Vaalharts region. But growing pecans requires long-term planning, including from an irrigation perspective. It takes approximately six to eight years for a tree to start producing nuts and around ten years until a farmer can turn a profit. So, while water requirements are quite low when trees are small, these will increase dramatically as trees mature. Therefore, these and other factors should be taken into consideration by producers.

Pecan trees consume large amounts of water compared to other fruit trees and crops. Yet very little is known about the exact water requirements of mature pecan orchards grown under local conditions. (Till now, most of the research on pecan water use has been done in the United States.) Seeing that most pecan orchards are also irrigated, the need exists to measure and estimate pecan water use under local conditions to ensure the best irrigation practices are followed.

Whilst some research on pecan water use was done in Cullinan (Gauteng), knowledge on the water use of pecans in the hotter production regions of South Africa (Upington and Vaalharts regions) is, for instance, almost non-existent. This could mean that the existing irrigation schedules may be resulting in excessive volumes of water irrigated or water stressing of trees, which impacts yields.

By doing measurements in these regions, the scientists can ensure that their water use model is suitable for all the production regions in South Africa.

Taylor and her collaborators want to determine the actual water use or evapotranspiration of pecan orchards and the factors that drive water loss (including weather conditions and the strategies trees use to combat water loss). Evapotranspiration is the sum of the water lost through plant transpiration and soil and plant evaporation from the surface to the atmosphere. Transpiration refers to the evaporation of water from stomata (the tiny pores found in the epidermis of leaves, stems and other plant organs). This natural evaporative 'cooling system' reduces the temperature of the trees and allows gases such as carbon dioxide, water vapour and oxygen to diffuse into and out of the trees, which is critical for photosynthesis. The scientists focus on two popular cultivars called 'Wichita' and 'Choctaw'.

Photo supplied

Aerial view of the 18-year-old mixed cultivar pecan orchard on the banks of the Orange River between Groblershoop and Grootdrink. Both transpiration and evapotranspiration measurements are conducted in this orchard.

Photo supplied

The infrared gas analyser and 3D sonic anemometer which forms part of an eddy covariance system. These instruments aid in the determination of water vapour and CO_2 fluxes, which when combined with other measurements can be used to estimate evapotranspiration.

By quantifying water use and yield, they want to establish how many kilograms of nuts are produced per cubic meter of water used in an orchard (defined as water use efficiency). Also, if the quality of the nuts and the price per kilogram are considered, it is possible to determine how much money was earned per cubic meter of water used (defined as water use productivity). "Hopefully, these values will assist growers with a benchmark for achieving optimal water use efficiency," Taylor says. "It will also allow growers to determine how to maximise income with their water allocation."

The team also considers how water stress at different phenological stages (flowering and nut set, nut sizing, nut filling and hardening and shuck split) impacts pecans' yield and quality. This work is being undertaken in Pretoria, on the University of Pretoria's Experimental Farm (Innovation Africa@UP), to ensure good control over the irrigation treatments.

Closing knowledge gaps

The researchers now have three full seasons of measurements of pecan water use in the Vaalharts region and two full seasons of measurements in an orchard close to Groblershoop. They have also finished four seasons of water stress treatments in the orchard on the experimental farm. There will now be one last season of monitoring in all three locations.

To gather water use information, they use different techniques, including quantifying the transpiration of pecan trees using sap flow systems (the heat pulse velocity sap flux density technique) and evapotranspiration with micrometeorological methods. Using sap flow systems involves placing sensors into tree stems and then measuring water flow in plant tissue or xylem, using a short pulse of heat as a tracer.

The experimental set-up includes an automatic weather station erected at each study site, which measures rainfall, solar radiation, temperature and relative humidity, wind speed, and wind direction. In addition, soil water content within the root profile is tracked. Irrigation volumes are determined to assess any possible water stress within the orchards.

Tree physiological measurements (stomatal conductance and leaf water potential) help to assess plant stress. The researchers also consider canopy size to determine the relationship between canopy cover (leaf area) and water use.

In the water stress trial, irrigation for the control is scheduled by assessing changes in soil water content and predawn leaf water potentials (an indication of plant water status). The stress level in each treatment is determined in the same way.

In the 202/21 season, the team started a trial to determine if remote sensing, using a multispectral and thermal camera mounted on a drone, could be used to detect pecan tree stress.

As expected, transpiration and evapotranspiration in the Vaalharts and Groblershoop regions follow a seasonal pattern, with the highest values recorded in summer and the lowest in winter. This reflects the varying weather conditions at the different study sites and that pecan trees are deciduous (meaning they lose their leaves in winter).

Seasonal evapotranspiration (1 September to 30 June) in Vaalharts was 1245 mm for the 2019/20 season and 1103 mm for the following season. During the same season, evapotranspiration in the Groblershoop orchard (1245 mm) was 150 mm higher than in the Vaalharts orchard. This data reflects the slightly hotter conditions in Groblershoop and the slightly bigger trees in this orchard.

Although pecans are considered to use more water than most other fruit tree crops, these values are fairly comparable to evapotranspiration measurements in apple and avocado orchards (both use approximately 1000 mm) in South Africa.

Taylor says this could reflect the big differences in planting densities between the orchards. Planting density in the apple orchards studied varied between 1250 and 1667 trees per hectare, whilst in the avocado orchard, it was 357 trees per hectare. In pecans, it is only 100 trees per hectare. So although individual pecans may use more water than most other fruit trees, water use is not proportionally higher when scaled to a hectare, she says.

The maximum daily transpiration over three seasons for the Wichita trees was 370 litres per tree per day. For the Choctaw trees, the maximum transpiration rate was 425 litres per tree per day.

Typically, transpiration did not increase at the same rate in summer as atmospheric evaporative demand. However, differences in total seasonal transpiration for the two cultivars at the two sites reflected differences in atmospheric evaporative

Photo supplied

The eddy covariance tower in the 15-year-old mixed cultivar pecan orchard outside of Jan Kempdorp, which determines total water use or evapotranspiration of the orchard.

demand and canopy size. Interestingly, the researchers found that when atmospheric evaporative demand is fairly low, transpiration increases steadily as the atmospheric evaporative demand increases.

As it starts getting hotter and drier, transpiration no longer increases at the same rate and begins to plateau. This suggests that as it gets hotter and drier, the transpiration of pecan trees will remain more or less at the same rate.

The trees may not necessarily require a lot more water in the hotter and drier regions. This results from stomata starting to close under these conditions, which limits water loss. Taylor says this finding will be significant to consider in future modelling approaches.

When comparing pecan water use efficiency and water use productivity to other fruit crops, water use efficiency for pecans was generally lower than most other crops, including other oil storing crops such as avocado and macadamia. The researchers attribute this to lower yield and higher water use. In addition, the price per kilogram of pecans is slightly lower than for macadamias. However, pecans compared very favourably when comparing water use productivity (R m^{-3}) with other crops grown in the Vaalharts region. In most instances, it resulted in higher income per unit of water used by the crop.

Taylor says they have a good data set for understanding the impact of water stress on the yield and quality of pecan orchards.

She says it is essential to assess the impact of water stress across a number of seasons due to the alternate bearing nature of pecan trees. This is when trees bear a good crop in one year, referred to as an 'on' year and in the next year, some trees will have a much lower yield, referred to as an 'off' year.

Water stress at various phenological stages decreased yield and/or quality. During the trial, water stress during flowering and nut set generally reduced yield due to an increase in nut drop shortly after nut set.

Whilst yield was not decreased during the nut sizing stage, nut size was generally smaller in this treatment, which would reduce the overall quality of these nuts and, therefore, the price fetched per kilogram. Water stress had the most profound effect on yield and quality when implemented during nut filling. A large percentage of nuts failed to fill properly. These nuts are referred to as 'pops'. In two seasons, water stress during shuck dehiscence resulted in an increased percentage of stick-tights (dry, mature nuts in husks that stay attached to the tree and do not fall naturally).

According to the results, producers should avoid tree water stress as much as possible during flowering, nut set, and nut filling. This includes avoiding prolonged water deficits during this time and no over-irrigation, which causes waterlogging in orchards.

In years where farmers' water allocations are reduced, it may be possible to reduce irrigation during nut sizing and shuck dehiscence to make water savings without significantly impacting yield and quality.

Photo supplied

Sap flow sensors inserted at various depths into the trunk of a 'Choctaw' pecan tree in the orchard outside of Jan Kempdorp. These sensors determine the rate at which sap moves in the xylem and from this the rate of transpiration of a tree can be determined.

"Our understanding of the water use of pecan orchards and their response to water stress is improving," Taylor indicates. "In the next year, we should be able to produce a more robust water use model which applies to a wider range of growing regions in the country."

During the last year of the project, the focus will be on improving canopy size measurements at remote study sites. This will involve efforts to refine the parameters of a radiation interception model for pecan orchards. In addition, the team wants to improve their understanding of the physiological control transpiration by the trees and continue using remote sensing to detect the onset of water stress in the trees.

The study continues till March 2023.

Average in shell yield for the different stress treatments in the 2017/18 season, 2018/19, 2019/20 and 2020/21 seasons. Yield was adjusted to 4% moisture content. Treatments with the same letter are not significantly different from each other ($p < 0.05$).

	Yield (t ha^{-1})			
Treatment	2017/18	2018/19	2019/20	2020/21
Control	1.70a	1.53a	2.70a	0.67a
Flowering and nut set	0.89b	1.03b	2.80ab	0.43a
Nut sizing	1.37ab	1.42a	3.22a	0.83a
Nut filling	1.05b	1.16ab	2.24b	0.70a
Shuck dehiscence	1.66a	1.44a	3.09a	0.51a