

Water use of macadamia orchards

Problem

- The availability of water is increasingly threatened by expansions in industry, agriculture, population growth and climate change
- Additional water allocations are not generally available, thus the water available must be used efficiently whilst maximizing productivity

Aims

- To quantify the components of macadamia water use (transpiration (T), evaporation (E) and evapotranspiration (ET))
- To determine the effects of water stress during different phenological stages on yield and quality

During **transpiration**, water is lost from a plant after it has been taken up by the roots and moved upwards through the plant to the evaporating surface in the leaves

Evapotranspiration is the combination of water lost through transpiration and **evaporation** from the land surface

Transpiration, evaporation and evapotranspiration in macadamia orchards

Mature bearing orchard

- ‘Beaumont’
- Schagen Valley, Mpumalanga
- Complete hedgerow had formed
- Canopy cover exceeded 60%
- Tree spacing 8x4
- 1 x 50 l/h micro sprinkler/tree



Intermediate bearing orchard

- ‘Beaumont’
- Schagen Valley, Mpumalanga
- Separate trees
- Canopy cover 40%-60%
- Tree spacing 8x4
- 1 x 50 l/h micro sprinkler/tree

Results - Transpiration

	Mature bearing orchard (2016/17 and 2017/18)	Intermediate bearing orchard (2017/18 and 2018/19)
Total transpiration	316-340 mm/annum	167-195 mm/annum
Lowest daily average transpiration	0.7 mm/day (June)	0.3 mm/day (July)
Highest daily average transpiration	1.1 mm/day (January)	0.7 mm/day (January)
Daily minimum transpiration	0.2 mm/day	0.06 mm/day
Daily maximum	1.47 mm/day	1.26 mm/day
Maximum transpiration rate	47 l/tree/day	40 l/tree/day

- Canopy size is a major determinant of transpiration in macadamias (the larger the tree, the higher the transpiration)
- The leaf area index of the mature orchard was 60% larger than in the intermediate orchard, and transpiration was also approximately 60% larger in the mature bearing orchard

Leaf area index is a measurement of the leaf area per ground area of the canopy and gives an estimation of canopy size

- Transpiration rates were relatively low and indicated that macadamias are conservative water users
- As moisture levels in the air decrease (increased atmospheric demand for water), transpiration increases until a threshold is reached
- Above this threshold, macadamias close their stomata to limit transpiration and a maximum transpiration rate is reached. Macadamias can thus restrict transpiration to make sure the rate of water transport within the tree is not lower than water lost through transpiration as determined by atmospheric evaporative demand
- Continuing irrigation under climatic conditions that result in high evaporative demand has no benefit, and can cause harm if oxygen levels in the soil are depleted due to waterlogging. This is because even though the air gets drier, the closure of stomata prevents transpiration from increasing above a certain threshold.

Results - Evaporation

	Average evaporation (E) (mm/day)	Average evapotranspiration (ET) (mm/day)	% E of ET	Rain (mm)	Irrigation (mm)
10 Sept – 5 Oct 2017	1.21	2.09	58	37	14
1 May – 7 Aug 2018	0.51	1.04	40	23	38

- The daily measurement of transpiration and evapotranspiration allowed for the calculation of evaporation, and included evaporation from the soil, as well as transpiration from understorey vegetation in mature orchards
- Evaporation represented between 40% and 58% of water use, and limiting evaporation will contribute towards conserving water, especially during times when water supply is limited, such as during droughts

Results - How much water is needed to produce a kilogram of macadamias?

	Kernel	NIS
Water use efficiency kg per cubic meter of transpired water	0.69 – 0.72	1.92-1.97
Water use productivity Rand per cubic meter of water transpired	R 117- R118	

- The water use efficiency measured was relatively low, as macadamias store oil, and yield is lower than the other crops which store sugars and have a high water content
- Water use productivity was high due to the high price of macadamias
- An average of 510 litres of water is required to produce a kilogram of macadamias

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

Study orchard

- 14-year-old 'Beaumont' orchard, Schagen Valley, Mpumalanga, 3 seasons
- Irrigation scheduled according to capacitance probe readings
- The area allocated to each tree in the orchard was covered by plastic during the time when the trees were stressed
- Seven water stress treatments were imposed:

No irrigation (rain-fed), half-irrigation scheduled according to a capacitance probe, full irrigation scheduled according to a capacitance probe (two seasons), withholding water during flowering and nut set, withholding water during nut sizing and premature nut drop, withholding water during shell hardening and lastly withholding water during oil accumulation (one season)

Results - Water stress

- A reduction in pre-dawn water potential was observed in the rainfed, half-irrigation and all water-stressed phenological stages when compared to the control (irrigation scheduled according to the capacitance probe)
- The most significant decline in pre-dawn water potential was observed when trees were stressed during flowering and nut set, due to lower rainfall during this stage and fairly high atmospheric evaporative demand
- Irrigation during flowering and nut set is important to limit water stress as rainfall is typically low during this period
- Water stress did not have an impact on yield, as all stress treatments had higher yields compared to the control (irrigation scheduled according to the capacitance probe). This could be due to healthier root systems with lower levels of disease and improved nutrient use efficiency
- No significant differences in total kernel ratio (TKR) were observed between rainfed, half-irrigation and control treatments over two seasons
- Trees stressed during flowering and nut set and shell hardening had lower TKRs (3.35% and 1.12%) compared to the control
- This might be due to a delayed recovery after water stress leading to a reduction in the carbohydrates available during nut sizing and premature nut drop

What does this mean?

- The transpiration rates of macadamias are lower than what is observed in many other fruit tree crops
- Macadamias have strict stomatal control to limit transpiration when there is an imbalance between water supply to the leaves and evaporative demand from the atmosphere
- Evaporation can be high in macadamia orchards, and evapotranspiration is 30-40% higher than transpiration, and this needs to be considered during irrigation scheduling
- The water use efficiency of macadamias is relatively low as they accumulate oils and not sugars and have a low water content relative to many fresh fruit
- Based on this study, macadamias appear to be less sensitive to water stress compared to other crops when looking at yields, but water stress during certain phenological stages can affect quality
- The yield penalties in the control treatments scheduled according to soil water treatments might suggest that scheduling irrigation of an entire orchard with varying soil depths and textures according to a few capacitance probes can lead to overirrigation in certain areas of the orchard. This trial is ongoing