AUSTRALIAN AVOCADO IRRIGATION REVIEW 2020 - 2021

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OVERVIEW

This review (also referred to as an 'Advanced Management Workshop') is one of three scheduled as part of the project "Avocado extension and development" (AV17005).

The ultimate purpose of the avocado irrigation review is to improve the efficiency and effectiveness of avocado irrigation in Australia.

The process used was to examine current avocado irrigation practices in Australia, look at emerging trends here and overseas, identify areas where improvements can be made, discuss the information gathered with an expert panel, identify research and extension needs, and establish sound practices and guidelines that can be used to update irrigation guidelines for Australian producers.

The avocado irrigation review consisted of four components:

Part 1: Survey of current avocado practices in Australia

Part 2: Survey of international avocado irrigation trends

Part 3: Avocado irrigation literature review

Part 4: Face-to-face summit of key growers, consultants, extension staff and invited speakers to evaluate the information gathered and identify appropriate practices and research needs.

All information gathered and recommendations listed will be used to guide future research, development and extension of irrigation across the Australian avocado industry.

This document presents the information generated by the review. More information including presentations, webinar recording, and the 71-page literature review can be found on the Avocados Australia Ltd Best Practice Resource in the 'Library' under 'Event Proceedings', '2021 Avocado Irrigation Review'.

PART 1. SUMMARY OF CURRENT AVOCADO IRRIGATION PRACTICES IN AUSTRALIA

INTRODUCTION

The aim of this survey was to get a snapshot of current avocado irrigation practices in Australia and to identify issues in irrigation that producers are facing.

METHOD

In order to get 'quality not quantity' the survey was not sent to all producers. Instead, to cover the range of growers and levels of experience, producers perceived to be at different skill levels were selected from the eight major production regions of Australia and asked to complete the survey. The goal was to get six respondents comprising two 'advanced', two 'experienced' and two 'new' growers from each of the eight regions. Ideally 48 respondents were sought, in reality 37 growers completed the survey as follows. The response was considered to provide a good representation of industry practices.

Table 1. Survey respondents

REGION	ADVANCED	EXPERIENCED	NEW	
North Qld	2	2	2	6
Central Qld	5	-	2	7
South Qld	2	2	1	5
Sunshine Coast	1	-	2	3
NSW	-	2	-	2
Tristate	1	3	-	4
SW Western Australia	2	3	2	7
Perth & northwards	1	-	2	3
	14	12	11	37

RESULTS

Rainfall

- Growers from the Tristate and WA receive most of their rain in winter whilst in the other regions most falls in summer.
- Annual rainfall ranges from 150-250mm amongst Tristate respondents to 800-3000mm on the Sunshine Coast.
- 73% felt that rainfall was changing, in WA 100% of respondents felt it was changing.

Irrigation as a management issue

Irrigation is considered the top management issue for all regions except SW WA where it takes second place after root rot.

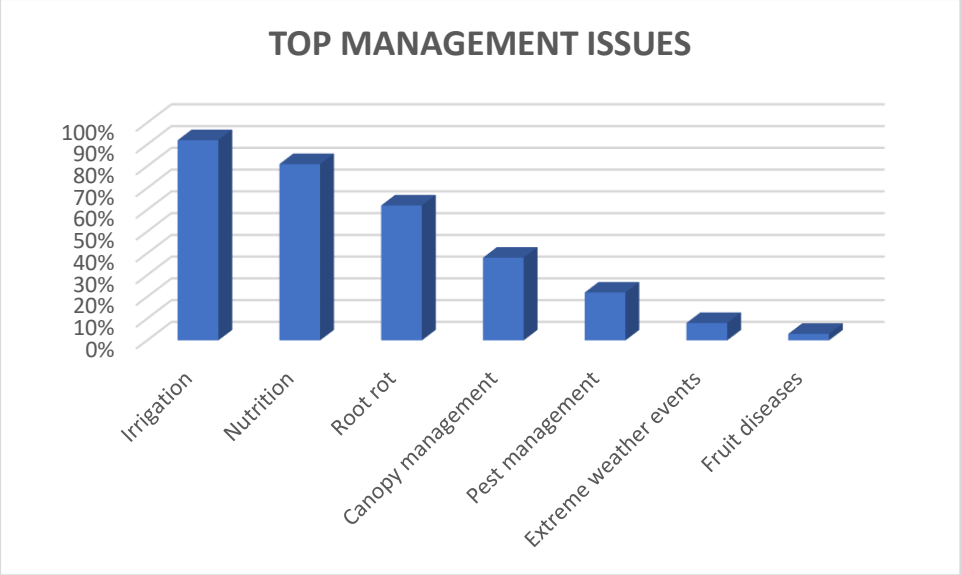

Figure 1. Top management issues

Soil types.

- Sandy loams: 35% of orchards
- Clay loams: 35%
- Sands: 16%
- Clays: 8%
- Loams: 5%

Sources of irrigation water

(note: 46% of growers have more than one source of water)

- Dams 28%
- Irrigation schemes 26%
- Bores 24%
- Creeks 22%

Depth of irrigation in summer

- Growers irrigate down to just 5cm to as deep as 120cm in summer, most irrigate to somewhere between 20cm and 60cm in depth. There is no clear correlation with soil type, but some of the growers on sands tend to irrigate to shallower depths.

Time of day irrigated.

- 35% irrigate during the night only, 16% during the day only and 49% both at night and day.

Irrigation of sick or replant trees

- 76% irrigate sick trees and replants differently from the other trees in the block. Those who don't said that it was too difficult to treat them differently, one said that the soil (a sand) was so well drained that it didn't matter.
- Methods used to irrigate these trees differently include:
    - Installing smaller sprinklers (3)
    - Cutting off water altogether (2)
    - Reducing the number of drippers
    - Reducing the number of sprinklers per tree

Use of consultants or experts

- 46% use the services of a consultant or other expert to assist with irrigation decisions.

Automatic weather stations

- 32% have automatic weather stations.

Water quality

- 27% report issues with irrigation water quality. Every region except NQ and NSW are affected.
- Water conductivity ranges from 350 – 1560 microS/cm (current guideline is to use water with less than 600 microS/cm).
- The worst conductivity was found in the Perth region followed by Central Qld.
- Few growers were able to quote chloride levels, but these ranged from 67 – 210 mg/kg (current guideline is to use water with less than 80 mg/kg chloride).
- The worst areas for chloride were both regions of WA.

Flushing irrigations

- Some growers interpreted this question to mean line flushing rather than flushing the salt out of the soil. Amongst those who understood the intention of this question approximately 32% use irrigations from time to time to flush salts from the root zone.

Readily Available Water (RAW)

(mm water that plant can easily extract from its root zone)

- Few were able to answer this question, but quoted levels ranged from 5 – 18mm. This is a concept not yet in common use.

Infiltration rate

- Only three answered this question. Answers ranged from 1.2 – 25 mm/hour.

Mounds

- 41% of growers have their trees planted on mounds/ridges. All growers in CQ used mounds whilst no respondents from the Tristate (expected) or Sunshine Coast (surprisingly) use them. Apart from the semi-arid region of Tristate, the relatively low % of growers using mounds is surprising given the widespread issue of Phytophthora root rot in Australia.

Mulch

- 86% of growers reported using mulch, this is common across all production regions.

Tree density

- Ranged from 83 – 417 trees/ha.

Fertigation

- 89% of growers use fertigation.

Annual volume of irrigation applied

This ranges from 1.5 (Sunshine Coast) to 18 ML/ha/yr (Perth). Low values corresponded to high rainfall areas, young orchards or limited water supply.

- NQ: 2.5 to 9 ML/ha/yr
- CQ: 4 to 15 ML/ha/yr (young to established trees respectively)
- SQ: 1.5 to 8 ML/ha/yr (most of respondents have very limited water supplies)

- S'shine Coast: 3 ML/ha/yr
- NSW: 8 ML/ha/yr
- Tristate: 10 to 13 ML/ha/yr
- SW WA: 4.3 to 17 ML/ha/yr (young to established trees respectively)
- Perth: 18 ML/ha/yr

Mini-sprinkler or drip irrigation

- 92% currently use mini sprinklers (several are experimenting with or changing to drip)

Number of sprinklers per tree

- One sprinkler per tree: 65%
- Two sprinklers per tree: 32% (using multiple sprinklers give a larger wetted area)
- Three sprinklers per tree: 3%

Sprinkler rates

- Excluding the one orchard that uses Mamkad ball drive sprinklers (260 L/hr) and a newly planted orchard (20 L/hr):
    - individual sprinkler rates averaged between 62 – 123 **37 – 150 L/hr**
    - when multiple sprinklers per tree were considered, the rates of water delivered per tree ranged from 83 – 209 **55 - 300L/hr**, with the highest rates in the Tristate and lowest in SW WA (high density orchard).

Proportion of orchard floor wetted when mini sprinklers are used

- For mature orchards the proportion ranged from 35% to 100%, averaging about 64%.
- The Tristate stands out as having the largest proportion of the orchard floor wetted, averaging 89%, followed by SW WA with 72%. (Some growers in the Tristate like to irrigate the interow to maintain a living grass sward to reduce temperatures in heat waves).

Drip irrigation

- Only three respondents use drip irrigation, however, as the 'Changes being considered' question reveals later, 22% of growers are considering moving to drip irrigation or at least trying it
- Drip lines per tree row ranged from 1 to 3, the former where water is in very short supply.
- Irrigation delivery per tree/hr ranged from 18 – 50 L/hr.
- The trend to use lower rate emitters has not yet been adopted by two of the three users.

Solenoids

- 76% of growers use automatic solenoids for switching irrigation on and off.

Remote controlled irrigation systems

- 46% of growers are able to control their irrigation remotely.

Frequency of testing uniformity of irrigation systems

- More than once per year: 27% of growers
- Annually: 40%
- Seldom: 22%
- Never: 11%

No correlation with grower experience levels.

Weather events monitored to help make irrigation decisions

- Rainfall: 92% of growers
- Temperature: 92%
- Evaporation: 57%
- Wind: 57%
- Humidity: 46%

Factors on which irrigation decisions are based

- Soil moisture: 97% of growers
- Tree appearance: 51%
- Stage of growth cycle: 43%
- Evaporation: 35%
- Calendar schedule: 27%
- Dendrometers: 14%

Soil moisture monitoring methods used

- Dig and feel soil: 57% of growers
- Capacitance probes: 51%
- Tensiometers: 41%
- Gypsum blocks: 24%

41% of growers use two of these methods, 14% use three methods and 3% use all four. Thus 58% of growers employ more than one method.

The primary soil moisture monitoring method used when more than one is employed (also see pp 12)

- Capacitance probes: 45% of growers
- Dig and feel soil: 27%
- Tensiometers: 23%
- Gypsum blocks: 5%

Shallow tensiometer reading that triggers irrigation

- Ranged from 5cB (in Perth sands) to 40cB (in a sandy loam in South Qld)
- Most fell within the 15 to 20cB range

How the soil moisture monitoring system is read

- Manually in the field: 53%
- Remotely and automatically: 39%
- Remotely: 8%

How often a soil moisture monitoring station is checked to see if it is still representative of the trees it represents (also see pp 12)

Frequency monitoring sites are checked for uniformity

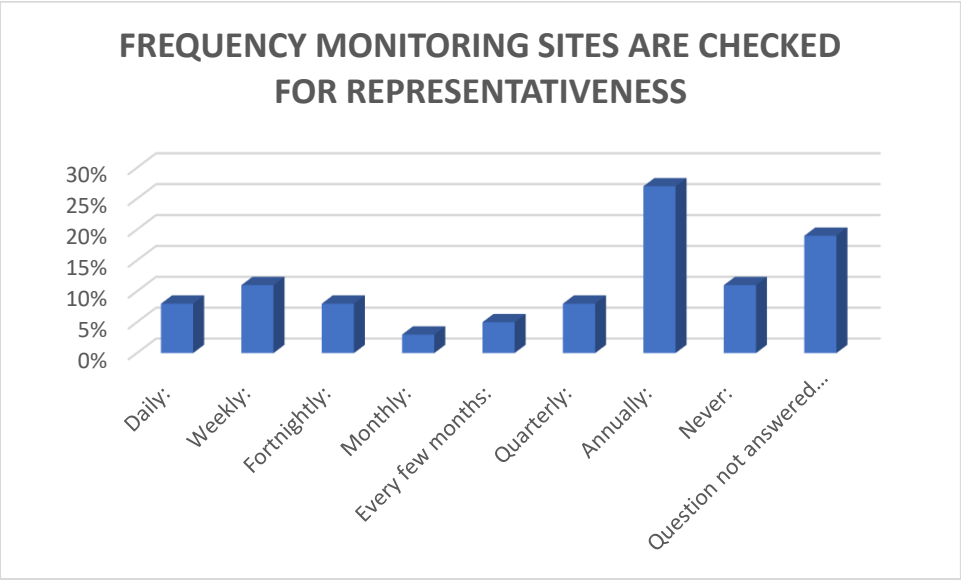

Figure 2. Frequency monitoring sites are checked for representativeness

Number of trees represented by a single soil moisture monitoring station

Ranges between 130 to 15,000 trees per station (the latter in very uniform orchard conditions). Most fell in the range of 300 – 2,000 trees per station.

Use of dendrometers

- Currently used by 4 growers (11% of respondents)

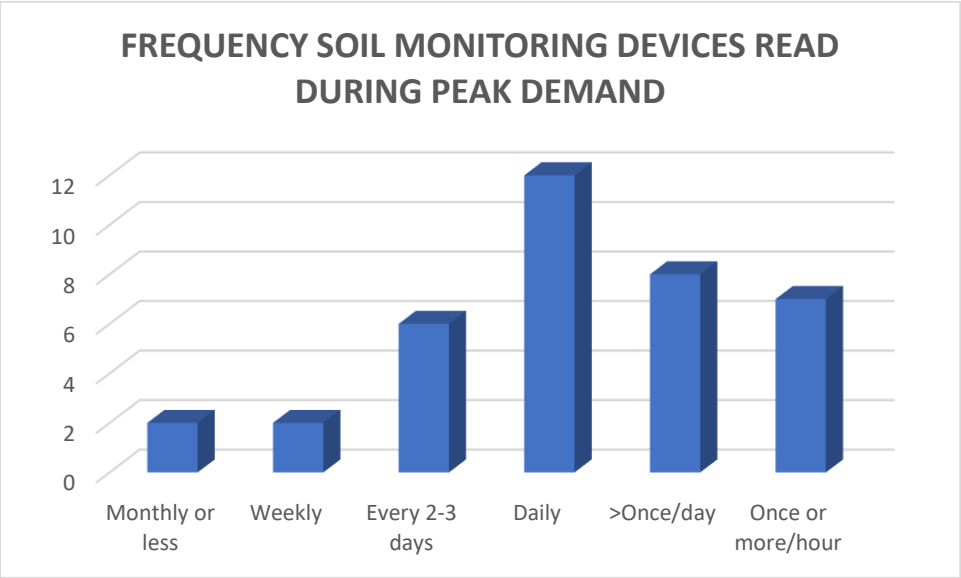

Figure 3. Frequency of reading soil monitoring devices during peak demand

Stage within the growth cycle that growers report extra water is used that is not in proportion to the evaporation rates

During flowering & fruitset x8

At flower initiation x1

At budbreak x1

When fruit is golf ball size x1

Winter: 'more used during winter than other crops' x1

In other words, for example, eight growers report more water being used by the tree during flowering and fruitset than can be explained by a change in evaporation rates.

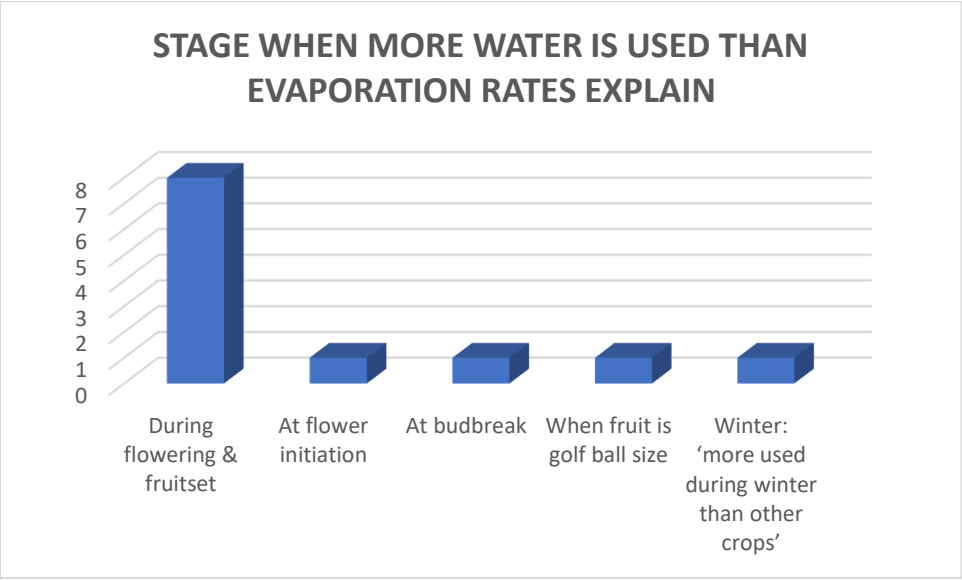

Figure 4. Stage when more water is used than evaporation rates explain.

Times growers consider critical to irrigate

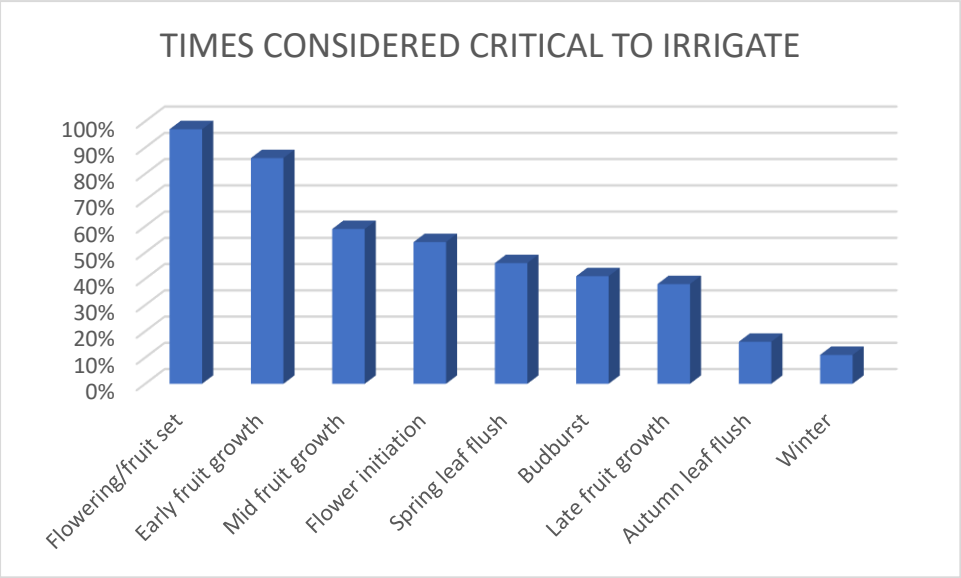

Figure 5. Times considered critical to irrigate

Irrigation management challenges

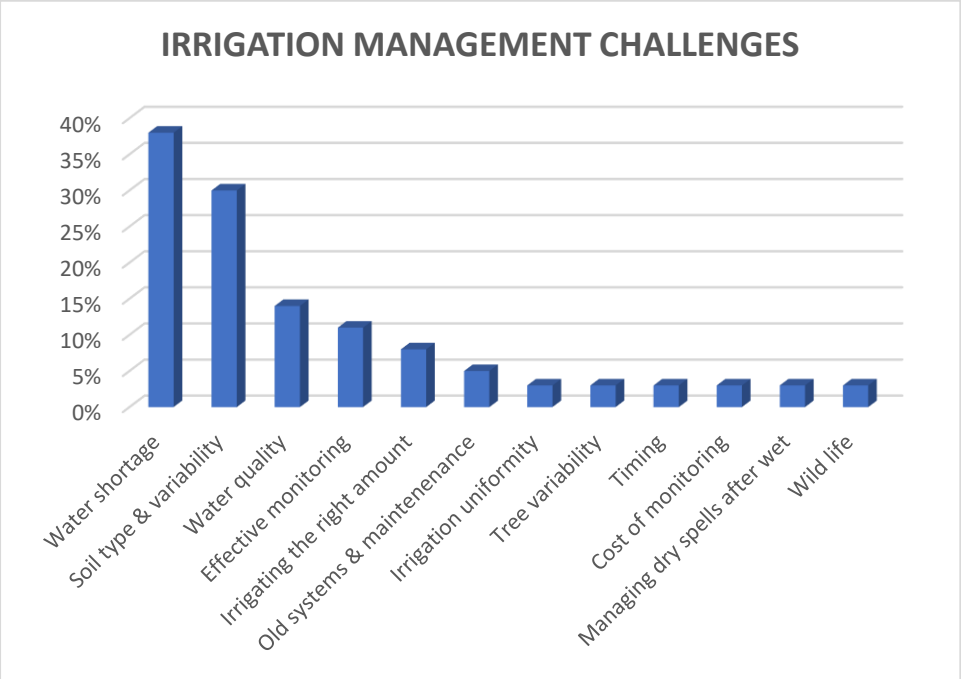

Figure 6. Irrigation management challenges

Information, training, research, resource or technology that would lead to better irrigation decisions

- 11 votes: Soil moisture monitoring – better value, training, automation
- 7: Find out the most important stage(s) of growth cycle that trees need water
- 3: Better ways of monitoring tree
- 3: Use of remote sensing for sensing moisture status
- 3: Managing water quality especially chloride
- 3: Refill points of different soils
- 2: Information exchange and training
- 1: Movement of water and nutrients in tree
- 1: Subsurface drippers
- 1: Better water supply e.g. govt schemes
- 1: Better evaporation forecasts
- 1: Overcoming over irrigation
- 1: Affordable consultants for smaller growers

Things you need to get right to irrigate effectively

- 13 votes: Scheduling application rates & intervals
- 10: Monitoring sites: well sited, monitored frequently (up to 3/times/day in peak period) & interpreted correctly
- 9: Timing for water and nutrient uptake
- 8: Good coverage of root zone, uniform distribution over wetted pattern

- 7: Checking sprinklers, system maintenance
- 5: Account for different soil types
- 5: Monitor weather, calculate evapotranspiration (evaporation & crop factor for stage)
- 4: System capacity
- 3: Suitable irrigation system design
- 2: Sufficient water for trees and salt flushing
- 2: Balancing soil moisture and soil aeration
- 1: Hand check soil moisture
- 1: Avoid tree stress
- 1: Responsible use of water resource
- 1: Automation

Changes being considered

- 8 votes (22% of respondents): Trialling or moving to a drip system (one of them plans to install a dual drip/mini-sprinkler system)
- 5: More automation (of monitoring and/or irrigation), one planning for an automated fail-safe system. Another grower plans to introduce 'more technology'.
- 5: Planning to instal more monitoring devices (soil and plant) and paying more attention to the information they provide.
- 1: Overhead misting system for cooling
- 1: Install a booster pump
- 1: 'Using what we've got better'

IRRIGATION PHILOSOPHY

NQ

Advanced growers

- Irrigate often and wet up in advance of the critical times or before dry weather conditions.
- We were irrigating on demand but are re-looking at our whole irrigation scheduling.

Experienced growers

- Always get the timing right.
- Maintain the system. Auger soil. Irrigate often in small amounts while still maintaining uniformity.

New growers

- Irrigation is the number one priority.
- What it needs when it needs it.

CQ

Advanced growers

- Irrigation is the most important job on the farm... schedule water to soil type and apply what is needed when it is needed.
- Listen to the trees, listen to the soil. Watch the weather. Slow down the water to slightly stress the trees in winter to switch them over to a reproductive state, watch over the flowering fruit set stage, plenty of water then. The rest of the year is small amounts often and the weekly deep water.

- To keep the tree as happy as you can with moisture and grow as many roots as you can.
- Working towards accurate irrigation & fertigation.

New growers

- Use the auger and look for yourself.
- Maintain optimum moisture for the season.

SQ
Advanced growers

- Keep topsoil moist.
- Keep soil water tension between 10 and 30 cB (30cm tensiometer) from panicle emergence to the 2nd fruit drop in December, and between 10 and 40cB the rest of the year. Try to keep the 60 cm tensiometer between 10 and 50 cB throughout the year.

Experienced growers

- Monitor & irrigate accordingly.

New grower

- Water is my greatest limitation; more water means more yield; I water whenever possible but maintain heavy inspections on bore water depth; I try to target the equivalent rainfall of 25 mm per week.

SC
Advanced grower

- Keep the orchard moist, not over wet.

New growers

- Wish it would rain more. Work with what we got. Mulch. Tall grass in summer to reduce soil evaporation and over all tree temperature.
- Supplement rainfall because limited water supply especially in drought

NSW
Experienced grower

- Regular irrigation - enough to wet root zone.

Tristate
Advanced grower

- Do our best to meet the tree demands.

Experienced growers

- Keep trees healthy and stress free.
- Don't hold back.
- Try and provide enough water to keep the trees happy to give max production.

SW WA
Advanced growers

- Get out in the field, don't rely on your phone to tell you when to water, make it a priority, don't water the same time each day as they don't require the same each day and simple methods are best.
- Irrigate to crop demand which is based off calculated evapotranspiration and crop factors. Monitor moisture probes (tensiometers and capacitance) regularly and feel the dirt regularly during peak irrigation periods.

Experienced growers

- Provide the best growing conditions for the trees combined with responsible use of the water resource.
- Unless it has rained, don't postpone or delay a scheduled irrigation cycle - the rain may not happen; get soil moisture levels topped right up before a hot/dry weather event (its too difficult to play catch-up); and finally, try to get it right.
- Don't get caught out by forgetting to check the monitoring devices.

New growers

- Check pipes and sprinklers every time.
- To run an efficient irrigation system which is based on the plant's needs, weather & soil conditions that avoids unnecessary overwatering and wastage of this commodity

Perth WA
Experienced grower

- Maximise water use efficiency in terms of productivity

New growers

- Correct balance on a weekly basis.
- Monitor daily in summer.

Other comments

- Benchmarking of water use by region would be useful to help improve overall industry yield
- Good irrigation = good fruit quality
- Government interest & support for water security for agriculture.
- To a great extent, irrigation design and scheduling should fit the soil water quality and climate (drip vs micro-sprinkler) of the farm. There is no one rule for all situations.
- Managing water in high rainfall area is only challenging in extended dry periods.
- Keep trees healthy and stress free.
- Provide enough water to keep the trees happy to give maximum production
- Meet tree demands
- Don't hold back.
- Mulch is a great buffer/blanket that can help iron out climatic effects on soil moisture levels.
- There is still an enormous amount of understanding to be done in terms of watering to climate and the ratio of water use by tree.

DIFFERENCES BETWEEN ADVANCED, EXPERIENCED AND NEW GROWERS

There were few standout differences between the three different grower experience levels. The following are those where some contrasts were apparent.

Use of consultants

71% of 'Advanced' growers use a consultant or irrigation expert, whilst only 33% of 'Experienced' growers and 27% of 'New' growers use them. This is interesting because despite their greater knowledge and experience, it suggests that 'Advanced' growers consider it worthwhile to seek further advice and expertise on the subject of irrigation.

Basis for making irrigation decisions

In this question growers were asked to identify which of the following are used to make irrigation decisions: calendar schedule, soil moisture monitoring, stage of growth cycle, evaporation, tree appearance, and dendrometers.

On average, 'Advanced' growers used 2.5 different items, 'Experienced' growers 3.1 and 'New' growers 2.

Different soil moisture monitoring devices used

There is equal use of tensiometers across growers at all levels. The highest proportion of capacitance probe use and lowest use of gypsum block devices is amongst 'Advanced' growers.

	Advanced growers	Experienced growers	New growers
Tensiometer	26%	25%	24%
Capacitance probe	37%	25%	18%
Gypsum block (e.g. G dot)	7%	25%	12%
Dig & feel soil	30%	25%	47%

Frequency of reading soil moisture monitoring devices

In general, 'Advanced' growers tend to read devices more frequently.

Frequency of observations	Advanced growers	Experienced growers	New growers
At least daily	79%	58%	82%
Several times per day	57%	17%	45%
At least hourly	29%	17%	9%

2020 FOLLOW UP WITH GROWERS WHO CONTRIBUTED TO 2013 IRRIGATION STUDY

The 2013 study "The Irrigation Practices of Five Australian Avocado Growers" can be found in the Best Practice Resource under Library/Education Material/What the good irrigators do. Or simply type 'What the good irrigators do' in the Search box.

Renmark, Tristate (Mediterranean climate subject to heat waves, sandy loam)

- More reliance on stored soil moisture now than in 2013, i.e. less reliance on the "hand-to-mouth" approach from day time irrigation with drip irrigation.
- Typically, now starts irrigating at 2am and by 7am the soil is at field capacity. Even so during a heatwave he can't keep up in the middle of the day (but has overhead cooling sprinklers).
- Feels that fertigation with drip irrigation is very effective.

Now:

- 3 dripper lines per row, 0.7 L/hr drippers every 500mm.
- 20 drippers per tree = 14 L/tree/hr.
- The system now applies 0.55mm/hr whereas the earlier system delivered 1.1mm/hr.
- This system delivering half the rate per tree than 7 years ago – this allows the system to be left on all day if necessary.
- Previously he used to turn it on and off several times per day but every time it was turned off the lines would drain out into the low spots creating areas that were over-wet.
- Typically has the irrigation running 12 hours per day, in a heat wave it would be 14 hrs per day plus the overhead cooling system which he says with drip irrigation you can't afford to go without.
- Since each tree is delivered water from 20 emitters if one blocks up, it is not serious, whereas if he had one sprinkler per tree and it blocked up or got damaged the tree wouldn't get any water.
- He still wouldn't recommend drip irrigation to a lot of growers. Requires a higher level of management and there's less margin for error.
- Still tries to keep soil at field capacity in the top 20 to 30cm in summer.
- Most of the feeder roots are in the top 30cm but on a hot day the capacitance probes show that water is being extracted from as deep as 800mm. This is because with his mounds and sandy soil he has 800 – 1000mm of soil that the roots are able to penetrate.
- Running it continuously gets away from a lot of the line drainage that can occur every time you switch it off which can create wet spots.
- Strong on the need for mounds for drainage purposes.
- Necessary to lift the drip lines above the mulch several times per year to prevent roots growing into emitters.
- About 33% of orchard floor wetted
- Visiting the field and inspecting with a spade is very important.
- Now has one capacitance probe site per hectare which works out to be one probe per valve. Because he has a probe per valve, he can also use the probes as a check to see whether each block is receiving irrigation when it should.
- Also, sources (from BOM) max temperature, humidity and wind for the day – gives him an approximate measure of the Vapour Pressure Deficit (VPD).
- Need research on the benefits of increasing humidity during flowering (has overhead sprinkler system for heat waves).

North Queensland (low summer rainfall, very sandy soil)

- Currently reviewing all Full and Refill points.

- You can't "set and forget" with respect to Full Pts, Refill Pts, siting of sensor etc - they change over time e.g. as a result of mulching practices they have significantly raised soil OM level with the result that the soil holds more moisture – this alters how they irrigate.
- But fruit size has decreased in recent years and still getting ringneck in spite of diligent watering. Discussed the need for air in root zone as well as moisture.
- Main moisture extraction zone is between 10 and 20 cm.
- Trialling drip irrigation but no good for prevention of frost damage.
- In addition to capacitance probes has a few G-dots so that staff can notice when passing and report any issues.

OTHER INPUT

Childers, CQ grower

Raised the issue about the difficulty in knowing where to site the soil moisture sensing device.

Finds vast difference in the readings when the probe position is moved. E.g. from almost mid-way between trees in the row to 1m out from the tree trunk towards the interow.

Mentioned that those who used dendrometers this past season got poor fruit size.

Neil Lantzke, WA DPIRD, Perth area

On the subject of soil moisture monitoring, most of what is available for other fruit crops will be directly relevant to avocados, the main differences are:

- Because of the shallow root depth, the top sensor should be at 10 cm and the second at 20 cm (not 15 cm and 30 cm).
- Because of avocado's lack of drought tolerance, the refill points will be higher (%VWC) than for other fruit crops.
- I would also think that because of root disease issues the soil should not be kept close to saturation.

The range of soil moisture contents will be narrower than for a crop such as mangoes which are both drought and waterlogging tolerant. Even more reason to monitor soil moisture in avocados.

We (DPIRD) are currently working to test the accuracy and reliability of different equipment and to develop soil moisture monitoring guidelines for a range of fruit crops in Carnarvon.

Growers would rather take direct measurements of plant moisture stress, but in my limited experience, the equipment is not robust and reliable enough for farmers to use.

Graeme Thomas, GLT consulting

It is very clear that the conditions of the Australian growers is very different to the rest of the world and we probably need to address things differently.

When considered we have:

- With the exception of Riverland, and Perth Metro, high phytophthora challenge
- With the exception of North Qld, Central NSW and S Qld, high chloride irrigation water
- All areas generally have a root stock that has poor chloride tolerances and nil to little pc tolerance.
- Nearly all are seedling rootstocks

I have always maintained there are 3 basic management practises that need to be addressed first if you are to be successful in growing avocados.

1. Maintain root health
2. Maintain exact soil moisture
3. Fertilize to the crop load

I have found that growers who closely address these 3 categories will have long term yield averages that are double the Australian average. Eg WA grower with 2 major pruning events in the last 10 years is currently averaging 19.25 t / Ha

I would suggest that growers are letting the trees get too dry between irrigations.

It is also clear that more education is needed in the management of high chloride water – flushing, nitrate fertiliser application, irrigation frequency etc.

The review by Liz is really good and needs to be distributed to all growers. I would look at a grower-friendly summary to get their interest with the review then available to get all the background mentioned in the summary.

One point in the review, is that an avocado is not evergreen, it is a wintergreen tree. The differences is the leaf of an evergreen leaf will live for up to 8 years whereas a wintergreen leaf only lives for 13 months (or less). This is particularly important when we are looking at the managing chloride toxicity.

ACKNOWLEDGEMENTS
The project team would like to sincerely thank the 37 growers who gave their time to complete the survey and to those that contributed to the other input. The information has provided the project team and the industry valuable insights into the current practices and issues amongst avocado irrigators in Australia. It will be used to provide direction for developing and promoting advances in avocado irrigation in Australia.

PART 2. SUMMARY OF INTERNATIONAL AVOCADO IRRIGATION TRENDS

Thirteen collaborative avocado experts from around the world kindly agreed to participate in this survey; five from California (four growers and one extension officer), two from Chile (both consultants), two from Israel (one extension officer and one consultant), one from New Zealand (a research manager), two from South Africa (both technical managers with large corporate producers), and one from Spain (a researcher). The aim was to find out trends in avocado producing countries outside of Australia in order to learn from others, identify common issues and identify where potential advances can possibly be made. This information will be shared with the Australian industry and international collaborators and will hopefully be useful to all.

A wealth of information was gathered; however, the information needs to be considered in the context of the growing conditions of the region being reported. Generally, where there was more than respondent from one country, conditions were quite similar but there were differences in the environments of the two South African contributors.

Commonalities across all countries

In all countries surveyed irrigation is becoming a higher agronomic priority, reasons given are better yield and fruit size, more effective nutrition, and improved Phytophthora root rot management.

The biggest challenge across the board is the shortage of water.

Most countries believe that climate change is real and is generally resulting in drier and hotter conditions with more extreme weather events, especially heat waves.

CALIFORNIA

There were five respondents from California made up of one extension officer and four growers.

The climate is Mediterranean with rainfall ranging from 230 to 500mm/year, poorly distributed.

Soils range from sandy loams to clay loams with depth ranging from less than 30cm to more than 100cm.

100% of orchards are irrigated and 95% are fertigated. Phytophthora root rot is regarded by two respondents as a serious issue, one as a moderate issue and two as a minor issue. 5 to 33% of orchards are planted on mounds.

Irrigation water is very expensive, around AUD 1,000/ML (assuming an exchange rate of AUD 1.29 to US 1).

Water quality

Water quality is an issue; chloride content varies from 40 to over 150ppm. Measures taken to manage this issue are leaching irrigations, some chemistry, keeping soils wetter than would be necessary without salts, use of Dusa® and Toro Canyon root stocks, reverse osmosis, mounds, drip irrigation, humates, calcium sources, and changes in fertilisation methods and types.

Frequency of leaching is variable and ranges from every irrigation up to every fifth irrigation, monthly and six to eight times during the growing season. The frequency is determined by the calendar, evapotranspiration (ETO), weather, soil and leaf tests, water quality and quantity available, rootstock, lysimeter and convenience.

One grower uses a leaf chloride over 0.25 to 0.35% as a trigger to leach, two others said that as leaf analysis is only done once per year it is not useful to determine leaching needs.

Current irrigation systems & practices
There has been a general trend towards more frequent light irrigations.

Annual irrigation volumes range from 6 - 12 ML/ha.

The period regarded as the most important to maintain optimum soil moisture is the entire cycle excluding autumn leaf flush and wintertime.

Mini sprinklers are the most commonly used system. Most growers use one sprinkler per tree delivering between 40 and 60 L/tree/hour; one uses 150 L/hr. Another grower uses two sprinklers per tree delivering 58 L/tree/hour. Two growers also use some drip irrigation. Configurations reported are two lines with emitters every 46 to 60 cm each delivering 1.6 or 4 L/emitter giving a total delivery rate per tree of 28 and 53 L/tree/hour respectively.

Two of the five respondents reported using overhead irrigation for the purpose of cooling the canopy. The range of soil depth growers aim to keep moist varies from 20 to 100cm. Irrigation is applied during the day and night. If a heat wave is forecast all growers will pre-irrigate deeper.

Monitoring devices
Most growers don't have weather stations on the farm.

Growers make irrigation decisions based on the calendar, ETO data supplied by the State or water company, physical examination of the soil using augers/spades. More recently, growers have been adopting tensiometers, capacitance probes and gypsum blocks, driven by the high cost of water.

Where tensiometers are used, the trigger point to irrigate ranges from 20 to 40 cb depending on the time of year and stage of the phenological cycle.

Monitoring by devices is done remotely and automatically from continuously, to daily, to every four days. Where soil moisture is determined manually this is typically performed every two to three days.

Measures taken to make up for the fact that relatively tiny volumes of soil are measured by devices include using more than one method, physically examining the soil (with auger or spade), using the information from different areas, and observing the tree condition.

A few growers are using satellite images, and a few are using Phytech dendrometers. The technology needs to be robust, easy to use and inexpensive if it is to be adopted.

Between 1 and 10% of growers are using software to amalgamate information from different sources to help with irrigation decisions.

Improving efficiency of water delivery
A wide range of answers ranging from 'very few', to 50% and 'most' are reported to clean their irrigation lines, and it is reported to be done from every second month to annually. Sulphuric acid, phosphoric acid, and N-phuric (urea and sulphuric acid, used on alkaline soils) are being used for this purpose.

Between 25 and 80% of growers are trying to improve the root environment and this is being done with the use of mulch, humic acid and carbon-based products.

Recent changes and the future

The biggest changes seen in avocado irrigation over the past 5 to 10 years include the fact that many growers have gone out of business due to high water costs which has gone up 10% a year for 10 years, and is now about AUD 1,000/ML. This has also impinged on the frequency of leaching irrigations. Other changes include greater use of ridges in combination with drippers and shorter but more frequent irrigations. There has also been more automation and more growers applying irrigation in anticipation of heat waves.

Expected changes in the next 5 – 10 years are that many will go out of business if water prices keep going up, more adoption of monitoring and better monitoring, more low flow/low pressure (dripper) irrigation, centralization of controls and fertigation, applying less water more often, and more automation.

The biggest challenge is the cost of water which is also declining in quality. Other challenges are drought and sudden heat waves.

Suggested research: can we irrigate the trees directly e.g. using an 'intra-venous' system instead of having to use the roots for water transfer? Cost efficient ways to improve water quality. Tailoring irrigation scheduling by soil type, cultivar and rootstock for each different region. One respondent said we know what to do we just need to achieve greater adoption of best practice.

Information required is chemistry that helps leach salts, grove specific information, on farm visits and one-on-one evaluations.

Factors considered critical in order to irrigate effectively are ETO information, correct understanding and utilization of resources available to help schedule irrigations, timing and quantity of water, and grower education.

One respondent stated that irrigation is just one of many things a grower does which include managing weeds, insects, disease, labour, regulations etc. - it has to rise to top of priorities to get attention.

CHILE

Our two respondents are both consultants.

The growing area in Chile has a Mediterranean and semi-desert climate with quite cold winters. Avocados are generally grown on hill slopes (to avoid frost) in two different environments - coastal areas that have cooler but less variable temperatures (influenced by the cold Humboldt ocean current) and inland valleys which are drier and experience more extreme temperatures (hot and cold). Annual rainfall is poorly distributed and ranges from 150mm (inland valleys) to 300mm (coastal areas). The climate is reported becoming drier with up to 70% less rain.

The predominant soil type is clay loam and typical soil depth is from 30 to 100cm. 90 to 100% of trees are planted on mounds. 100% of orchards are irrigated and use fertigation. Phytophthora root rot is regarded as a minor issue.

Water quality

Water quality is an issue, chloride levels range from 20 to 80ppm.

Measures used to manage the poor water quality are monthly soil analysis, a leaching program, modifying irrigation frequency and using quality fertilizers.

Leaching is typically conducted once per month (using three times the regular volume of irrigation) over the five months of summer.

Leaching decisions are based on soil analysis (when chloride exceeds 2 meq/L), the soil moisture level and the calendar.

One respondent states that using leaf analysis to trigger leaching is always too late. The other respondent uses a leaf chloride level of 0.4% to trigger flushing.

Current irrigation systems & practices
There has been a trend towards more frequent, light irrigations.

Annual irrigation volumes range from 8 - 12 ML/ha.

The period regarded as the most important to maintain optimum soil moisture is for the entire crop cycle although one respondent does not regard winter as being quite as critical.

Both mini sprinklers and drip are used. A mini-sprinkler system typically uses one sprinkler per tree delivering 20 to 35 L/hr. Drip systems typically consist of three lines, the centre one on the sunny side of the trunk but never next to it, the other two placed 40 cm on either side of the central one. Some growers are changing to drip systems, and some are changing to mini sprinkler. Overhead irrigation is not used to cool the canopy. Growers aim to keep the top 45 to 80cm of soil moist and apply irrigation during the day and night.

Monitoring devices
Growers have weather stations on site to help with irrigation decisions.

Growers use a combination of devices that include tensiometers, capacitance probes, excavating soil pits to examine soil moisture as well as root health and growth, use of ETO derived from weather station data and dendrometers on trees. All devices are regarded as being important. Capacitance probes are the most popular and allow continuous monitoring and the ability to evaluate water dynamics in the soil. Tensiometers are losing favour.

Monitoring is done remotely and automatically every 15 minutes to hourly.

One respondent reported that dendrometers can detect trunk size changes as little as 5 to 30 microns and are used to determine plant stress levels and daily growth rates which is combined with soil monitoring data to adjust irrigation timing, the number of pulse irrigations, and avoid plant stress. The other respondent reports that trunk measurement using dendrometers was tried several years ago but was a failure.

ETO is used to forecast irrigation needs for the next week.

Measures taken to make up for the fact that relatively tiny volumes of soil are measured by devices include ensuring that representative trees are used, digging soil pits, and using devices as indicators, not as 'gospel'. One respondent always uses three sensors per irrigation block.

One uses satellite, the other doesn't but all information from soil, tree and weather station goes to a central dashboard. 50 to 70% of growers are using software in this way to amalgamate information from different sources to help with irrigation decisions.

70% of growers are able to remotely view data from monitoring devices and control irrigation.

Improving efficiency of water delivery
All growers clean irrigation lines, this is considered a basic requirement. It is done with citric acid, chlorine dioxide, chlorine and /or phosphoric acid. Chlorine is used fortnightly or monthly and phosphoric acid is used every 2 months.

Between 10% to 80% of growers are reported to be trying to improve the root environment by using compost, mycorrhizae, humic acid and other organic matter.

Recent changes and the future
The biggest changes seen over the past 5 to 10 years have been better design of irrigation systems, better control of irrigation and soil moisture, and better maintenance of irrigation systems.

Expected changes in the next 5 – 10 years include improvements to valve design to allow more pulses per day, and better satellite and/or drone tools.

The biggest challenge is the shortage and quality of water.

One respondent believes that better execution and extension of existing knowledge is required instead of more research. The other believes that better sensors are required to make sure all trees receive the same amount of water, and that we need more reliable drone and/or satellite tools.

Good sensor readings and interpretation, a homogeneous irrigation system, and well-maintained systems with a uniformity coefficient of above 95% are considered critical in order to irrigate effectively.

ISRAEL
Two respondents, one an extension officer with the Israeli department of agriculture and the other a consultant.

Israel has a Mediterranean climate (hot dry summers, cool wet winters) and experiences heat waves. Rain falls predominantly in winter, is fairly well distributed through winter and ranges from 650mm per year near the coast to 400mm in inland valleys. Both contributors feel that the climate is becoming hotter with more extreme weather events. Soils are clay loams and range from 60 to more than 100cm in depth, some trees are planted on mounds. 100% of orchards are irrigated and fertigated. Phytophthora root rot is absent or a minor issue.

Water quality
Water quality is a major issue with chloride levels over 150ppm. Measures being taken to manage this problem are the use of tolerant rootstocks and regular leaching.

Leaching varies from every 2 - 4 weeks, to twice during summer and at the start of winter rains.

Soil analysis & experience of the grower determines the frequency of flushing. Leaf analysis is not used for this purpose because when leaf chloride levels increase the damage is already there.

Current irrigation systems & practices
Irrigation frequency varies from 2-3 pulses per day, to daily, to every 2-3 days. It depends on soil type, ETO and other factors.

Annual irrigation volumes range from 6.5 - 8.5 ML/ha in coastal areas to 8 - 12 ML/ha inland.

The period regarded as the most important to maintain optimum soil moisture is the entire cycle although one respondent does not include flower initiation or winter as critical.

The main type of irrigation is drip. Typically, it consists of two lines, a dripper interval of 30-40 cm and emitter rates between 1.2 - 1.6 L/hr. This configuration delivers 26 to 32 L/tree/hr. The recent trend is towards emitter rates lower than 1 L/hr. One respondent reports the use of overhead irrigation for cooling purposes. Growers aim to keep the top 40cm of soil moist and will irrigate deeper if a heat wave is predicted. Irrigation is applied by day or night.

Monitoring devices

Growers have weather stations on site to help with irrigation decisions.

The main devices used to make irrigation decisions are tensiometers, augers/spades to physically examine soil moisture, ETO calculated by the Penman equation, and dendrometers. Dendrometers are reported to be better for spring and autumn, whilst tensiometers are best for summer.

One respondent gave the following irrigation trigger points for tensiometers: heavy soils 15-18cB in summer and 30cB in winter, light soils: 10-15cB. The other gave the range as 25 - 35cB.

Monitoring is done remotely and automatically from hourly to daily.

To make up for the fact that relatively tiny volumes of soil are measured by devices, the number of monitoring sites is increased, and to use Phytech technology.

Dendrometers on tree trunks are widely used. Continual monitoring is practiced, and the 'winning combination is the use of soil monitoring and tree monitoring together'. Dendrometers are useful for providing additional information for making decisions.

75 to 90% of growers can view soil moisture and control irrigation remotely. 75 to 90% of growers are also adopting software systems that bring together information from several sources.

Improving efficiency of water delivery

95 to 100% of growers clean their irrigation lines. Frequency depends on the quality of the water. The majority clean once a year, some twice a year. The most common product used is phosphoric acid, although some chlorine is used.

About 20% of growers are using measures including application of compost and humic acid to improve the root environment.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years are better monitoring and the understanding that irrigation is the most important issue.

Expected changes in the next 5 – 10 years are less fresh water available, better quality recycled water (because more desalinated water will be available), a greater number of monitoring sites, and adjustment of irrigation protocols specific for each block.

The biggest challenges (and those that need to be researched) are how to irrigate during spring, selecting the correct volumes and intervals, and the optimum emitter rates for drippers.

Further development of dendrometer systems is seen as the key to making better irrigation decisions.

Factors considered critical in order to irrigate effectively are close monitoring of the soil and tree, and to know how much air the root system needs in spring after the winter rains.

NEW ZEALAND

The region reported on was Far North of the North Island where avocado farming is relatively new, and conditions are sandier, warmer and drier and therefore irrigation more necessary than the more traditional growing region of the Bay of Plenty which is wetter and cooler with richer soils.

In the Far North, the average annual rainfall is 1300 mm (average for 2000-2019) and is well distributed with slightly more in winter. No drastic changes in climate are evident.

In the natural state the soils are predominantly poorly drained sandy densipan podzol. During orchard development the pan is broken resulting in a free draining sandy soil greater than 100 cm. Most of the trees are planted on mounds, all orchards are irrigated, and most orchards use fertigation to some extent. Phytophthora root rot is a moderate issue.

Water quality

Water quality is not an issue.

Current irrigation systems & practices

Mini sprinklers are the dominant irrigation system and typically consists of one sprinkler per tree. High density plantings use 25 to 40 L/hr sprinklers, conventional plantings use 50 to 90 L/hr sprinklers. Generally, growers try to keep the top 30cm of soil moist. Irrigation predominantly takes place at night. There is a trend for more frequent, light irrigations. Annual application is only about 2 ML/ha/yr. The phenological stages between bud burst through to mid-fruit growth are considered the most important for maintaining optimum soil moisture.

Monitoring devices

Capacitance probes are the most popular soil moisture monitoring device. The reasons given are that they are able to monitor continuously, their data can be accessed remotely, and they require less maintenance than tensiometers. Information is usually accessed daily. Where tensiometers are used, 25cB is the trigger point on the shallow 15 cm probe to start irrigating. Only a few growers control their irrigation systems remotely but the number that are adopting software to amalgamate all available data to facilitate better irrigation systems is growing.

Monitoring the tree itself is restricted to research on sap flow.

Improving efficiency of water delivery

Most growers clean their irrigation lines annually. Phosphoric or sulphuric acid is used.

About half of growers are trying to improve the root environment by using mulch and biological soil amendments such as seaweed and humates.

Recent changes and the future

The biggest change in the past 5 – 10 years is that growers are now placing more trust in soil moisture monitoring devices.

Expected changes in the next 5 – 10 years are the use of more digital sensors and the availability of online data with recommendations.

Research suggested is a better understanding of negative impacts of moisture stress at different stages in the phenology.

Technology that would be useful is a platform that incorporates information from multiple sources such as real-time weather data and forecasts, and soil moisture devices to help with irrigation scheduling.

Accurate soil moisture monitoring is considered critical in order to irrigate effectively.

SOUTH AFRICA

Two respondents, one from a more benign environment near Tzaneen and the other was from a less benign environment near Nelspruit (Mbombela).

Both regions have predominantly summer rainfall which ranges from 900 to 1000mm/year and is generally not well distributed through the year. Soils range from clay in the Tzaneen area to sand in the Nelspruit region. 85 to 95% of orchards are irrigated. Most trees are not fertigated. Phytophthora root rot is a moderate to serious issue.

Water quality

Water quality is not reported as becoming an issue although the orchards at Tzaneen practice longer irrigations every second week to leach salts.

Current irrigation systems & practices

Annual application is between 3 and 4 ML/ha/year. The period between budburst and early fruit growth is considered the most import period to maintain optimum soil moisture.

Irrigation is applied mainly through mini sprinklers. One or two sprinklers are used per tree to deliver between 30 (wetter) to 60 (drier areas) L/tree/hour. A little drip irrigation is used in drier areas, two lines are used per row with emitters 1m apart delivering between 0.7 and 1.6 L/hr/emitter so applying between 6 and 13 L/tree/hr. There is a trend towards more drip irrigation in new plantings especially as water becomes scarcer. Growers try to keep the top 40 to 60 cm of soil moist. Irrigation is applied daily. One area irrigates deeper prior to heat waves.

Monitoring devices

Capacitance probes are the most popular devices because they are considered reliable, efficient, can be placed at different soil depths, save time and enable more precise irrigation management. Soil moisture is read remotely and automatically on a daily basis. However, tensiometers are also used because they give a clear indication of water potential in the soil 'if stress wants to be induced or prevented', 10 - 30cB is used as the irrigation trigger point depending on phenological stage.

To make up for the fact that devices, more than one type of moisture monitoring device, monitor relatively tiny volumes of soil is used and the number of monitoring sites is increased.

One of the respondents notes that remote monitoring technology is becoming increasingly popular. Dendrometers are uncommon and are viewed by some as a research tool. They could be more effective if definite stress points within the phenology cycle could be identified. They need to be practical and easy to use for a grower, but they could provide more sensitive control during critical phenological stages.

80% of growers can view soil moisture status via a mobile device but only 5 - 20% can control the irrigation remotely.

Improving efficiency of water delivery

Only 10% of growers clean their irrigation lines.

Most growers try to improve the root environment. They use mulch, especially during establishment, organic fertilisers and additives. “Sustainability” is reported as a growing trend.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years are better soil moisture monitoring, use of fertigation and more efficient irrigation systems e.g. drip.

Changes expected in the next 5 to 10 years include closer monitoring of soil moisture, logging data to simultaneously reduce orchard water use, more use of drip irrigation as water resources become scarcer, and automation to reduce costs.

Research suggested includes establishing crop factors suitable for different stages in phenology, and developing a drip irrigation design to suit different soil types. One respondent pointed out that we still don't know how much water avocado uses (and at different stages in the phenology).

Information that would help with better irrigation decisions include comparing results of monitoring both the tree and the soil, probes at different depths to read soil moisture and EC simultaneously and instantaneously, and accurate irrigation prediction models.

Factors considered critical in order to irrigate effectively are a good understanding of soil type and tree requirements (for different canopy sizes and phenological periods), truly understanding your soil type, monitoring soil moisture as much and as often as possible, and proper soil preparation (coupled with mounding) before planting to limit the effects of compaction etc. that are often unseen.

SPAIN

Our respondent is a researcher based near Malaga.

Spain has a Mediterranean climate with an annual rainfall of about 485mm that is poorly distributed. More extreme weather events are reported as occurring together with milder winters.

The predominant soil type is clay loam and typical soil depth is 60 to 100cm. 50% of trees are planted on mounds. 100% of orchards are irrigated and 80% use fertigation. Phytophthora root rot is regarded as a moderate issue.

Water quality

Water quality is an issue, and the common chloride level is between 120-150ppm.

More tolerant rootstocks are the main measure to deal with this.

Current irrigation systems & practices

There has been a trend towards more frequent light irrigations.

Annual irrigation volume averages 6 ML/ha.

The period regarded as the most important to maintain optimum soil moisture is the entire cycle except for flower initiation and winter.

The main type of irrigation is drip. Typically, it consists of three lines, a dripper interval of 30 cm and emitter rates of 4 L/hr. This delivers between 160 to 213 L/tree/hr.

The recent trend is towards more drip irrigation. Overhead irrigation is used for cooling purposes. Growers aim to keep the top 40cm of soil moist and will irrigate deeper if a heat wave is predicted. The preferred time to irrigate is during the day

Monitoring devices
Growers have weather stations on site to help with irrigation decisions.

The main device used to make irrigation decisions is tensiometers which are regarded as easy to manage. The irrigation trigger points are between 20 - 30cB. Tensiometers are read every three days in the field.

The main measure taken to make up for the fact that relatively tiny volumes of soil are measured by devices is to increase the number of monitoring sites.

Dendrometers and sap flow meters are starting to be used but at this stage only for experimentation, monitoring the tree is regarded as being key in addition to soil monitoring. This will allow optimisation of irrigation applications specific to smaller groups of trees. It is believed that satellite imagery will become increasingly useful.

Only about 5% of growers view soil moisture and control irrigation remotely. As yet, no growers are using software to amalgamate information from different sources to help with irrigation decisions.

Improving efficiency of water delivery
80% of growers clean their irrigation lines about once a year using phosphoric acid.

About 50% of growers are trying to improve the root environment and this is being done with the use of mulch.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years is the change from mini sprinklers to drip irrigation.

Expected changes in the next 5 – 10 years are increasing use of drip ('low flow') irrigation and more use of satellite images.

The biggest challenge is the shortage of water.

Genetic research is needed to develop drought tolerant rootstocks.

The availability of appropriate and easy to use sensors is needed to measure soil and tree water status.

Factors considered critical in order to irrigate effectively are greater use of weather forecasts together with data from probes.

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PART 3: AVOCADO IRRIGATION LITERATURE REVIEW

Please refer to the 71 page "Avocado Irrigation Literature Review" 2020 booklet by Liz Singh for the full report (available on the Best Practice Resource). This review studied in detail 89 scientific papers relating to avocado irrigation. A summary of key points is presented below.

LITERATURE REVIEW SUMMARY

Irrigating Australian avocado orchards appropriately is a duty of care to ensure environmental sustainability, while effective irrigation is essential to maximise tree health, fruit yield and quality. Both are important to ensure long-term business and industry viability.

When reviewing irrigation practice consider the following points:

• Irrigation scheduling is specific to individual orchards and is reliant on irrigation infrastructure and system type, soil type, rootstock / scion selection, cropping levels, tree size, environmental conditions, and monitoring equipment, etc. The operator can only control the time interval between irrigation events and the water volume applied. The effectiveness of irrigation scheduling and improving best practice will develop from understanding tree water relations specifically physiological and phenological in real orchard time.

• Tree physiological processes change with situations of excess or deficit water; or environmental conditions (e.g. stomatal closure). A roll-on effect directly follows limiting the tree's ability to access nutrients or produce carbohydrates which impacts tree health and production (fruit number, size and quality). Scheduling irrigating to limit a negative change in physiological processes could benefit orchard production.

• Tree phenology changes the volumes of water required by the tree. Irrigation scheduling should be closely linked to the monitoring of tree phenology.

• Calculating water productivity can highlight the opportunities for water savings, differences in water-use between avocado varieties / rootstocks and benchmark individual and industry annual water use.

• Maximising root system growth and health could provide continued function during competition for resources (leaf flushes / fruit growth) and times of water stress. Monitoring root growth regularly by digging holes will provide a timeline for root flushes in your orchard.

• Irrigation during flowering is important to support fruit set and to replace water lost through the increased surface area created by the flowers themselves. Monitoring tree water use during this time is important to meet tree water requirements.

• More information is required to understand the role of water and irrigation scheduling (interval and volume) pre-flowering to support fruit set during flowering and beyond.

• Fruit growth and development is closely linked to the water status of the tree. Water availability is particularly important during the first fruit growth phase for final fruit size. Irrigation interval will impact the final yield results.

• Avocados require an aerobic root environment for maximum growth and production. This environment is flooded each time an irrigation event occurs. While both water and oxygen are important for production, irrigation scheduling that maximises oxygen in the rootzone may benefit orchard production.

• Soil nutrients are not available to the tree without water. Therefore, irrigation and fertigation are linked and informed decisions on how to feed and water trees should be made together not separately, for effective use of resources. Given the relatively new inclusion of fertigation to some orchards, this may require modifications made to the existing irrigation system or totally new infrastructure.

• Salt is becoming a major long-term production issue for some avocado growers. With no easy solution available, growers are encouraged to investigate salt tolerant rootstocks now and start planning for a variety of scenarios.

• *Phytophthora cinnamomi* and avocados both require aerobic environments making them well suited companions. While Phytophthora root rot does not require free water for infection, the use of irrigation is making it easy for the pathogen to travel to the host and spread within the orchard. Flooding in the presence of *Phytophthora cinnamomi* negatively impacts tree health greater than the two factors experienced separately and flooding should be avoided in avocado orchards. More work is required to determine if modifying irrigation intervals or water volumes could reduce Phytophthora root rot activity.

• Irrigation interval and volume will influence the level of soil biological activity.

• Orchard water use efficiency can be improved by using soil or plant-based monitoring equipment; providing information on which to make informed irrigation decisions. As with all equipment - understanding the information recorded, calibration and field monitoring is recommended to ensure the information irrigation decisions are based upon is relevant, accurate and reliable.

• Smartphone apps are allowing data to be only a finger tap away ensuring timely irrigation decisions to meet tree water requirements.

PART 4: IRRIGATION SUMMIT

A face-to-face summit was held to evaluate the information gathered in Parts 1 to 3 of the review and to identify appropriate practice changes and research needed to advance avocado irrigation in Australia. Participants were selected from expressions of interest to provide a good representation of irrigation knowledge and needs across Australia. They included key growers, consultants, extension staff and invited speakers.

IRRIGATION CHALLENGES IN AUSTRALIAN PRODUCTION REGIONS

Common across all regions:

- Water availability and limited allocations
- Deteriorating water quality
- Infrastructure constraints
- Soil variability
- Climate variability
- Design and capacity of old irrigations systems

CQ/SC/SQ

- Lack of education, knowledge and accessing information
- Improving soil quality
- Labour skills and cost

NQ

- Monitoring for decision making
- Water use for optimal outcomes
- Humid, tropical climate
- Large numbers of small to medium growers and lack of knowledge
- Drainage & erosion
- Site selection
- More efficient use of electricity and choice of the most suitable tariff.

Tristate

- Heat waves – stomata closing early
- Low humidity
- Adoption of drip irrigation and its management challenges
- Over irrigation from need to use overhead irrigation for frost control

WHAT WE CAN LEARN FROM INTERNATIONAL IRRIGATION TRENDS

General

- Israelis conduct very good and ongoing irrigation research. Due to their shortage of water, they have adopted drip irrigation and learnt how best to use it.

Site knowledge and soil preparation

- The importance of a thorough soil survey of the site and careful land preparation, including drainage.

Irrigation uniformity and maintenance

- Chileans can get good irrigation uniformity, despite poor soils, by careful and extensive pre-plant land preparation
- Advanced irrigators practice a high standard of irrigation system maintenance which includes cleaning out irrigation lines as standard practice, most commonly with phosphoric acid.

Moisture monitoring and scheduling

- Advanced irrigators are more proactive than reactive in irrigation scheduling and place importance on current and forecasted evapotranspiration.
- As well as frequent referral to soil and plant monitoring tools, advanced irrigators also physically check soil moisture (with a spade or auger), often examining root health at the same time.
- Israelis consider that the 'winning combination' for irrigation scheduling is to monitor both the soil and tree and interpret results together.
- There is strong interest in 'dashboard' software that brings monitoring and weather information together.

Salinity

- Greater use of salt tolerant rootstocks.
- Leaching irrigation practices are tailored to soil texture and the results from analysing soil and/or leaf mineral levels.

Soil aeration

- Awareness of the high oxygen requirement of avocado roots and the challenge this creates in trying to balance soil moisture and oxygen requirements.

KEY POINTS FROM UDI GAFNI'S TALK - 'AVOCADO IRRIGATION IN ISRAEL'

Udi was one of the two keynote speakers at the irrigation summit, he joined via zoom from Israel where he is currently the chief agronomist with Granot, he also consults internationally and has previously worked in the Israeli department of agriculture as an extension officer.

A recording of Udi's presentation is available on the Best Practice Resource.

The notes below are key learnings by the Summit delegates from Udi's presentation.

- The bigger the root system the better (for dealing with high demand)
- Even if you have a small root system, you need to have enough irrigation capacity for high demand – water demand is driven by the size of the canopy

- Drip – apprehension about conversion to drip – but Israelis have learnt to do it
- Israel were forced to make changes – lets follow their example in Australia
- Dealing with saline water
    - Need to collect EC probe data (30cm root zone) for each region
    - Leaching practice is "horses for courses"
- Drip irrigation
    - Matching emitters to soil type, taking into account water quality
    - Use certified irrigation designers (e.g. Irrigation Australia approved)
    - Learn from expertise in other crops
- Irrigation is always evolving; practices need to be re-examined every 3-4 years
- The range of different results from research in different eras was alarming
- Already use 'dashboard' software to integrate monitoring data for scheduling purposes, especially when they have dual systems (under tree & overhead)
- We need to be less insular & look beyond just avocados
- Literature review raised topic of soil aeration as new information. In Israel this is common knowledge
- Traditionally in Australia we water at night & at the weekend for lower tariffs, but power costs are not the only consideration. In Israel they irrigate when the crop needs water which is during day. Daytime irrigation has reduced irregular bearing.
- Drip irrigation requires a higher level of management. Need to predict 2-3 days ahead. Need to be proactive with drip, not reactive.

KEY POINTS FROM MICHAEL FORSTER'S TALK – 'IMPROVING WATER USE EFFICIENCY WITH TECHNOLOGY'

Dr Michael Forster was one of the two keynote speakers at the irrigation summit and attended in person. Michael is a director of Edaphic Scientific and an Adjunct Senior Research Fellow at Griffith University.

The notes below are key learnings by the Summit delegates from Michael's presentation.

- Dendrometers can measure down to 1 micron (one hair strand is 60 microns across).
- Growers like simple guidelines and figures to follow.
- Tensiometers provide a universal value that is applicable across a range of conditions. The development of the digital tensiometer is a significant breakthrough.
- From a panel member who uses dendrometers:
    - Good for picking up problems earlier.

    - Greater insights and therefore confidence.
    - Still likes simplicity.
- From another panel member who uses dendrometers:
    - Don’t use for planning.
    - Helps with irrigation strategy.
    - Interface is easy to use.
- Dendrometers are explaining how fruit drop is related to weather events.
- Sap flow:
    - Sap flow measurements are explaining water use differences between cultivars in macadamias.
    - In a PhD study in macadamias, sap flow gives a better understanding of water relations.
    - Sap flow might stop even when roots are well supplied with water because stomata have closed.
    - Can it be useful for studying the effect of salinity?
    - Concept is good but caution advised for using sap flow meters commercially at this point, and they need to be more robust.
- There was surprise about how high soil water soil tension values are in other crops to trigger irrigation compared to avocados. Avocados have a trigger value of about 14cB (7cB in Perth sands) compared to 58cB in macadamia and 39cB in citrus. Do we need to conduct research to verify the trigger value in avocado?
- We need to develop crop factors for different environments around Australia.
- There is an app available to measure leaf area.
- Physiologically best to base crop factor on leaf area.
- Sap flow readings:
    - Need to know trunk size for understanding water usage.
    - Need to be calibrated on farm (17 calculations).
    - Need to know wood density (wood core dried) & trunk diameter.
- Sap flow meters can be put on petiole, branch, trunk, root. Change position every 3 months. Avoid injection sites.
- Approximately $900 per sap flow sensor. Start with one block to get a feel & understanding for the technology. They can be integrated with other systems.
- Tensiometers are easiest to understand. Other systems need more knowledge.

IRRIGATION RECOMMENDATIONS FOR AUSTRALIAN GROWERS

Work with a combination of professionals (including irrigation consultants, avocado agronomists etc)

Water supply & water quality

- Ascertain volume of water available in good and bad years.
- Limit size of orchard to the number of trees that can be irrigated fully. Avocados can't be half irrigated.
- Conduct water quality analysis and investigate the water quality history.

Soil properties

- Undertake a thorough grid survey of the soil in order to produce a soil map to understand the site and plan. Set orchard block boundaries according to soil type. Design the irrigation system to suit the situation. The soil survey needs to include:
    - Establish depths and soil texture of each horizon.
    - Water infiltration rates.
    - Readily Available Water (RAW) values (be aware that infiltration rates and RAW can change over time so re-measure every few years).
    - Consider doing an electromagnetic (EM) survey but ensure that it is ground truthed.
- Thorough and careful land preparation is needed to:
    - Achieve good drainage (water must not pond anywhere).
    - Prevent mixing subsoil with topsoil.
    - Establish well-designed mounds, ensure they do not dam water.
- Drainage is critical for avocados and even more important if you also need to flush out salts, so conduct land shaping and install above and below ground drainage where necessary.

Irrigation design

- Use an irrigation specialist certified by Irrigation Australia (source from Home page of www.irrigationaustralia.com.au) to design an irrigation system tailor-made for your situation.
- Consult with experts to select the most economical electricity tariff arrangements but also consider tree water needs e.g. Israeli's have discovered that irrigating during the day (when the tree is using water) reduces irregular bearing.
- Forecast water needs for a year of peak demand and limit size of orchard to the number of trees that can be irrigated fully in a difficult year.
- Determine water requirements in week of peak demand and ensure that the irrigation system and capacity can meet these requirements. Peak demand determines overall design.
- Irrigation design is important to achieve uniform water delivery to each tree across the block.
- The irrigation system needs to cater for local water and climate issues (e.g. frost, heat, water availability, and water quality).

- Undertake ground truthing of specs.
- Salt flushing and fertigation needs must be considered in planning.
- Learn how to better manage poor quality irrigation water – e.g. work out frequency and volumes of leaching irrigations needed.
- Be prepared to review and accept new methods, concepts and technology. Use technology with an open mind.
- Build flexibility into the system to account for future growth, higher or lower application rates and/or tech/practice changes. Design a system that can be built upon.
- Picture selling the block to someone else. Is the design simple, effective and easy to operate?

Irrigation hardware and maintenance

- Establish a maintenance plan with weekly/fortnightly/monthly/6mth and annual tasks. This plan will include:
    - Testing irrigation uniformity at least annually. Aim for a high standard, ensure uniformity and system performance is maintained. *(There is an instructional video in the BPR called "Checking irrigation uniformity in avocado orchards").*
    - Cleaning out irrigation lines at least annually e.g. with phosphoric acid.
    - Filter cleaning.
    - Regular testing of water quality and soil.
    - Re-assessing depth of root zone.
- Don't set and forget. Validate and re-test. Check probes and system performance. Don't rely on a spec sheet.
- Review scheduling and the irrigation system itself periodically to ensure it meets the needs of the orchard e.g. in response to changes in tree size, mulching practices, soil organic matter levels etc.

Moisture monitoring

- Install your own weather station and take daily observations.
- Follow weather forecasts especially evaporation, rainfall, temperature, humidity and wind predictions.
- Integrate information from various sources including stage of tree phenology, soil and plant monitoring tools, weather data and weather forecasts.
- Learn how to be more <u>predictive</u> and less reactive with irrigation needs.
- Better understand how to use and get the most out of moisture monitoring devices - consult an expert and/or seek training.
- It is critical to choose sites for soil moisture monitoring devices that are representative. Careful installation is also essential. Establish multiple sites to achieve adequate

representation and check soil moisture monitoring sites regularly to ensure that they are still representative, relocate if needed.

- As well as checking monitoring tools, also physically inspect soil moisture with auger, spade or pit and monitor root health at same time.
- Establish irrigation trigger point values (tensiometers) or full and refill points (capacitance probes).
- Allocate time and resources to conduct the monitoring and interpretation properly.
- When irrigating also consider soil oxygen levels.
- Regularly research what tech is available, their plusses and minuses and how they work.

Timing

- Maintaining soil moisture through winter is more important than previously thought.
- Match irrigation with demand.
- Better use of current information and knowledge to influence irrigation decisions.

Agronomic aspects to improve irrigation effectiveness

- Improve root health primarily through regular mulching (compost is also good). Higher soil organic matter levels and good root health results in greater water uptake efficiency.
- Determine and monitor depth of root zone as it may change over time.
- Be informed about crop phenology and changes in water demand through crop cycle.
- Plan ahead (4-7 days) but assess daily requirements.
- Network with supplier, consultants and other farmers especially in your region.
- Get a good agronomist.
- Establish an irrigation schedule with assistance from external agronomists and other growers.

LITERATURE REVIEW – IDEAS TO EXPLOIT

- Use of sap flow in irrigation research including plant water use.
- Use of Vapour Pressure Deficit for irrigation scheduling and better understanding water needs.
- Potential of pulse irrigation and its cost benefit.
- The need for 'dashboard' software to integrate different sources of information to assist in making better irrigation decisions.
- Recognition of the need for experts to interpret data.
- The importance of having sufficient soil aeration to match the high oxygen demand of avocado roots.
- A substantial volume of moist soil is still required if drip irrigation is used.
- In hot areas, stomata close early but when this happens it is too late to react, growers need a system to monitor in real time to make more timely decisions.
- Growers need to use evaporation data more extensively.

RECOMMENDATIONS FOR IRRIGATION RELATED RESEARCH IN AUSTRALIA

(listed in approximate order of perceived importance to delegates)

Sap flow research in combination with dendrometers to establish:

- How much water avocado actually uses.
- Crop factors for each stage of the phenology cycle in each region.
- Maximum and minimum water needs for each tree size, age, phenology, variety, rootstock, soil type and region.
- Transpiration ratio/plant-water relations/physiology of water use in Australia
- Water use efficiency (WUE) research.
- Best time of day to irrigate.

Follow development of dendrometers suitable for use in orchards and learn how to use them in an integrated manner with other monitoring tools.

Drip vs sprinkler (in different regions)

- Better understanding of drip to make it work better (different from sprinklers). Design for the crop and conditions including soil type.
- Pros & cons.
- Cost/benefit.
- Case study/other growers experiences.
- Learn from other crops e.g. citrus.
- Converting from mini-sprinkler to drip – is pruning recommended? Run a dual system for the transition? Optimum number of drip lines? The recommended transition process? Best timing and timeframe?

Best practice guidelines for irrigation

- Maintenance.
- Checklist (self-assessment) – see below.
- Standardised terminology/common language - develop an industry protocol so we are all talking the same language. E.g. how we compare irrigation - mm/hr or L/hr? (Perhaps consult with Irrigation Australia on this).
- What tools are available, how to use them and where to site them?

Self-assessment

- App or hard copy for irrigation system/understanding/health check. Best practice audits and advice similar to AHR's fruit quality project? What is your water use, do you REALLY know?
- Growers give themselves scores in efficiency, uniformity, monitoring (moisture levels and system), awareness in soil properties (pH, EC, TDS, L/tree, ML/ha/yr, RAW, infiltration rate), min and max water needs.

Dashboard

- Dashboard that integrates information from different devices and sources and reads back to you in a regional level context with economics/cost-benefit the whole picture approach of what is going on. Collaborate with IT and produce a basic software tool incorporating sap flow, soil moisture, budget lines capacitance for avocado tensiometer regional weather, age, irrigation sensors. Find out what the Israelis are already using.

Irrigation and fertigation masterclasses on best practice

- Make courses available to growers

Rootstock

- Assessment and rootstock breeding, evaluation for salt tolerance, water use efficiency and good production.

Salinity

- Best way of monitoring & managing.
- Better understanding of salinity measurement and management. What are the tree and crop effects under Australian conditions?

Remote sensing technology

- Follow development of remote sensing and how it may be used to pick up water stress and help with irrigation efficiency and scheduling.

Flow rate device

- Measuring sprinkler output without having to use a jug

Overhead evaporative cooling

- How effective is it per region?
- What are the temperatures to use as trigger points?

Environmental impacts

- Effect of humidity on pollen viability, and on stomatal activity.
- Temperature, shade, wind speed, netting.

Drought management

- How far can we push trees and what is the effect med-long term in Australian conditions. Research response to extreme weather events.

Soil aeration needs

- More clarity/research around soil saturation - how much per day can you irrigate for before tree health is affected by poor soil aeration?
- Establish threshold levels for soil oxygen content for avocado in different soil types.
- Establish how to irrigate without unduly impinging on soil oxygen content that will negatively affect avocado trees.

Other ideas raised but not discussed

- Tree height consideration to reduce temp/water usage. How does tree size affect hydraulic resistance? Smaller trees seem to do better.
- The new Great Barrier Reef regulations in relation to the quality (chemical and nutrient content) of water leaving the property through runoff and leaching.
- Looking at highest/good producers and see what they do – “what the good irrigators do”.
- Irrigation study tour. Tour filmed to share with whole industry.

RECOMENDATIONS FOR EXTENSION AND ADOPTION OF BEST IRRIGATION PRACTICE IN AUSTRALIA

(listed in approximate order of perceived importance to delegates)

- Understanding barriers to adoption of technology & the human component.
- Determine what best practice looks like for each region.
- Need to sell best practice and do it with growers on farm.
- Need to change from extension-based training to advertising-based targeting.
- Conduct masterclasses, training, webinars, different topics and focus. Bite sized, include online material, simple clear concise and practical. Using experts in the field but not pushing products. Make it easy and promote strongly. Consider an advertising approach to selling best practice.
- Seek out the best growers in each region and explain what they are doing.
- Use case studies incorporating cost/benefit studies on investment. Cater for the range of farm sizes, from small to large.
- Human factors - why don't people adopt best practice? How do we drive access to best practice information then adoption? A study needs to be done to discover what the barriers are in the avocado industry.
- Practical masterclass – physically show people – get industry base knowledge.
- Educate on Eto, Kc and L/tree.
- Grower education on how to interpret monitoring data.

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