Refinement of Guidelines for Avocado Irrigation Management Under Australian Conditions for Different Phenological Stages

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RMCG

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Executive Summary

This project aimed to further scope the requirements for undertaking irrigation research to address the needs of the Australian avocado industry.

Background

Stage 1 of the project involved:

- Consultation with industry to confirm gaps in irrigation management knowledge
- Discussion with research providers to determine capacity in delivery of irrigation research and development

A range of factors relating to irrigation management were identified during this consultation including:

- *There are variable growing conditions across Australia with different climatic regions and soil types*
- *Availability and security of water varies across Australia and will influence the degree of interest in irrigation management in a region*
- *Irrigation monitoring methods used across regions include feel, visual assessment, tensiometers, and C-probes*
- *Irrigation decision-making is based on experience, what fits with orchard management and in some cases quantitative data*
- *Drivers for change include increasing productivity (yield and quality) and lack of water while impediments to change include age, attitudes, risk and lack of funds*
- *Preferred learning approaches include 'learning by doing' and 'learning from others'*
- *Benefit arising from changes to irrigation management need to be demonstrated by increased returns*
- *The relationship between yield and irrigation volume need to be known for each region*
- *There are a number of research questions that require further exploration*

Feedback was provided from the IAC on the Stage 1 report with the recommendation that the project proceed to Stage 2 focusing on the research priorities.

This report (Stage 2) further develops the scope for the delivery of a research/extension project addressing irrigation management for the avocado industry.

Principles for an R, D & E water program were developed from the consultation and included:

Regional Program - The program should be nationally coordinated but regionally owned and be specifically tailored to the needs of local grower groups.

Experimental Sites - The regionalisation of the program should include a focal experimental site(s). This site(s) will be instrumented to ensure that applied research can be undertaken. The site(s) will also be used for field days and farm walks.

Research Issues - All regions need to fully understand their crop water requirements. Other issues for consideration will include salinity, fertigation, drought management and drip irrigation.

Extension Networks - A network of providers should be established incorporating existing extension personnel and other service providers, such as consultants and agronomists.

Proposed Program

The proposed program was designed following discussion with the potential research/extension providers.

Applied Research

The need for irrigation related research is most prevalent in the southern region of Australia where there are severe water shortages and the benefits of irrigation are apparent. For this reason it was considered that the applied research should be undertaken in the Riverland region of South Australia (SARDI) and the South West region of Western Australia (DAFWA).

The key research questions that need to be considered include:

a) How much water is required to maximise avocado yield and quality?

b) When are the critical irrigation times – how is water application matched to plant growth stages?

c) How are environmental impacts of irrigation minimised?

d) How can yield and quality be optimised when the water supply is limited?

e) What are the best irrigation systems under different climatic and soil conditions?

A methodology involving two sites in Southern Australia utilising a range of climatic and soil conditions has been developed. The sites will be established on selected grower's properties and be instrumented to determine water balance and crop responses under different irrigation regimes. Key aspects for monitoring include; tree performance, crop aspects, water balance, solute monitoring, irrigation system performance and water use efficiency.

A detailed budget has not been developed for the research components, as potential providers will undertake this once there is a clear requirement for research in this area. An indicative budget suggests that the total cost would be in the vicinity of $920K for two sites over three years.

There is significant potential to explore possibilities for co-investment by the providers. This co-investment could be in the order of 25-50% involving both cash and in-kind support.

Regional Extension

The extension program has been designed to utilise the experimental sites while focusing on regional issues. The experimental sites would be an integral part of the extension activities undertaken in the regions, with direct use for avocado growers in southern regions. The tools that are utilised, and expertise developed, in these regions could be adapted for the northern regions.

It is proposed that four grower groups are established across Australia. Two groups would be associated with the experimental sites and two others would be formed in northern Australia where there is an identified need for increased irrigation management knowledge.

It is recommended that a coordinator be appointed to identify and develop an irrigation extension network and guide activities across the regions. This would ensure that research results are applied more broadly and that learnings from growers are built into the research program.

The estimated budget for the extension program for the three years is $280K. In some of the identified regions there is already an existing extension program and established grower groups. In these cases there may be an opportunity to seek co-investment.

1 Background

Production of avocados occurs across diverse regions of Australia. In particular, water resource availability varies significantly, with declining resources in some regions and plentiful supplies in others.

The industry identified a lack of information on how to manage water under limited and drought conditions. This recognition triggered the development of the *Guidelines For Managing Under Limited Water Supply – Avocados,* with growers being encouraged to consider irrigation management in the context of different climatic conditions and water resource availability.

The process for development of the guidelines included an assessment of the available international literature and key knowledge gaps associated with water management in the avocado industry. The major issue identified as requiring research was to understand tree water requirements at different growth stages under Australian conditions.

The guidelines use best estimates of crop water requirements, adopting an international standard (FA056 – Crop Evapotranspiration). They focus on water requirements during non-limiting and limiting conditions, and include information on:

- Purpose of guidelines
- Critical growth stages
- Irrigation requirements – non-limiting and limiting conditions
- Drought management strategies
- References and further information

The guidelines were published in 2007 and are available at www.horticulture.com.au/water (grower resources).

The FAO56 publication (http://www.fao.org/docrep/X0490E/X0490E00.htm) used in the development of the guidelines is an internationally accepted methodology for calculating crop water requirements under non-limiting conditions. For Australian purposes, this methodology is an excellent starting point. The suitability of this calculation to Australian conditions does however warrant testing.

A paper was therefore prepared describing the Irrigation Research and Development needs for the avocado industry. The paper highlighted that water requirements for avocados in Australia under limited and non-limited conditions is a major gap in our knowledge.

It was recommended that the avocado industry consider investment in a research project to determine the water requirements during different phenological stages and when yield is most sensitive to water stress. Previous research would suggest that avocados are sensitive to water stress throughout the growing season. However, when faced with inevitable water shortages, when is limited water best used to maximise yields? In addition, are we confident that we are not applying excess water during the season? Are the water requirements based on FAO56 applicable to Australian conditions?

2 Objectives and Outputs

The project aimed to determine the scope for improving and refining guidelines for avocado irrigation management under Australian conditions for different phenological stages.

As a first step, the project identified the requirements for undertaking irrigation research to address the needs of the Australian avocado industry. The second stage involved the development of a research proposal outlining the scope of research and development/extension delivery methods (RD&E).

The key outputs from the project were:

Stage 1: A report summarising the consultation with industry and research providers, highlighting information gaps and the feasibility of undertaking the work was completed and presented to the Industry Advisory Committee.

Stage 2: The Industry Advisory Committee provided feedback on the proposed approach. This information was considered in discussions with potential research providers and has shaped the design of a research/development program to meet the needs of the industry. This Stage 2 report provides a recommended research/development approach for the delivery of improved water management, with irrigation tailored to plant water requirements.

3 Summary of Stage 1

3.1 Consultation with Growers and Research Providers

Extensive consultation was undertaken with growers and research/extension personnel in Stage 1. The approach taken and a list of contacts is provided in Appendix 1.

The consultation process involved discussion with six leading growers/industry personnel to gain an understanding of the issues and information gaps related to efficient irrigation water use for optimum production. The interviews focused on:

- Farming context and management
- Decision making and risk management and
- Resources – natural and business related

An understanding of water industry needs was also obtained from a questionnaire which was sent to key avocado research and development personnel, located in the major avocado growing regions across Australia. The survey focused on:

- Previous irrigation research and development
- Current activities related to research, development and extension
- Application of existing irrigation guidelines
- Methods to increase knowledge and adoption of improved irrigation management
- Potential providers of future irrigation research, development and extension

3.2 Findings

The key issues identified from the consultation are summarised in Table 3-1 with more detailed descriptions available in Appendix 1.

Table 3-1 Key issues identified during consultation

Issue	Comments
Growers and industry	
Variable growing conditions	Production is spread over a wide range of climatic regions and soil types.
Water infrastructure	Sprinkler systems commonly used with water supplied from on farm storage, bores and direct access to waterways.
Irrigation monitoring	Variability in methods of soil moisture monitoring (C-probes, tensiometers and checking moisture visually or by feel). Plant based methods to monitor stress not used. Monitoring systems provide rewards in fruit size and quality and avoid water and nutrient losses.
Irrigation decision-making	Scheduling based on monitoring but also 'experience' and/or what is believed to be sufficient. Water management generally not a high priority.
Information materials	Generally aware of publications on irrigation management, including the recently published guidelines. Need simple, easy to understand materials. Use advisors, manufacturers and positive attitude towards grower groups.
Drivers for change	Key drivers for water management are economic factors (marketable yields and good fruit size) and lack of water. Need to be more precise in water management.
Learning approach	Best way of showing 'what works' is an action oriented learning approach with grower groups and on-farm demonstrations of issues selected by growers.
Demonstrating benefits	Link between good water management and profitability is not well understood and requires monitoring of different water regimes.
Impediments for change	Impediments include industry ethnographic, landholder age, tradition, training level, attitudes as well as a lack of funds to upgrade old irrigation systems.
Research and extension personnel	
Benefits of irrigation	Benefits of irrigation are not evident in all regions. Needs to be clear demonstration of greater returns through investment in water.
Relationship between yield and irrigation volume	Considerable uncertainty for all regions as to the optimum volume of water to apply. Regional trials for optimum irrigation volumes need to be undertaken integrating theory with local grower knowledge and soil moisture monitoring.
Availability and security of water	Availability and security of water across Australia varies enormously. The scarcity of water will generally determine the degree of interest exhibited by the growers. Focus should be in regions where there is a high need.
Impacts of low water applications	Need to understand the on-going impacts of drought and low water allocations in some regions and determine the consequences of severe drought management actions on crop yields in the medium term.
Salinity and fertigation	Impacts of poor quality saline water are of interest in some regions. An opportunity exists to focus on precise application of nutrients through fertigation.
Extension	A significant amount of information currently available needs to be extended to growers in each of the regions. Activities should focus on irrigation scheduling, system performance, fertigation, understanding soils, soil moisture monitoring and economic benefits of irrigation.
Regionalisation	Irrigation research and extension programs need to be regionalised (targeted).
Capacity to deliver	A number of organisations that have previously undertaken irrigation research and/or extension are interested in progressing further RD&E activities related to water management.

4 R, D & E Program (Stage 2)

4.1 Principles of the Program Derived from Consultation

Water is an increasingly scarce and/or unreliable resource. This, along with the opportunity to return higher marketable yields from improved water management has resulted in a renewed interest in irrigation management in some regions. The specific issues of interest vary from region to region, highlighting that a water management program needs to be designed that meet the needs of each of the regions.

A reasonable information base is currently available to avocado growers and their advisers. However, a major concern is the need for the information to be tested and applied at a regional level to determine its relevance and applicability.

Following discussion with industry leaders and research and extension personnel a number of principles for an avocado water management program were proposed. These are presented in Table 4.1.

Table 4-1 Principles for R,D&E water program

Principle	Description
Regional Program	The program should be nationally coordinated but regionally owned and be specifically tailored to the needs of local grower groups.
Experimental Sites	The regionalisation of the program should include a focal experimental site(s). This site(s) will be instrumented to ensure that applied research can be undertaken. The site(s) will also be used for field days and farm walks. It is expected that the researchers and growers will work together to determine applied trials to be conducted at the site(s) that are relevant to the region. The site(s) will be used to demonstrate benefits of particular management and the expected costs associated with implementation.
Research Issues	It is expected that all regions need to more fully understand their crop water requirements. This would be a key focus for the demonstration site(s) and would involve determination of crop water requirements based broadly on the guidelines with adaptation based on soil moisture monitoring, observation, experience and production. Other issues for consideration at a regional level will include salinity, fertigation, drought management and drip irrigation.
Extension Networks	A network of providers will be established incorporating existing extension personnel and other service providers, such as consultants and agronomists. This network will be kept informed of research outcomes and involved in the irrigation extension activities determined by local grower groups. A range of material will be developed at a regional level including information resources (web and print), case studies and newsletters.

4.2 Proposed Program

Feedback on the above principles was provided by the IAC. The IAC were keen to ensure that the approach focused on gaining greater knowledge around irrigation management in addition to extending existing information.

Following discussion with the potential research/extension providers the following program was designed accommodating the feedback from the industry and incorporating the practical limitations of the research/extension providers.

4.2.1 Applied Research

The need for irrigation related research is most prevalent in the southern region of Australia where there are severe water shortages and the benefits of irrigation are apparent. For this reason it was considered that the applied research should be undertaken in the Riverland region of South Australia and the South West region of Western Australia.

The providers would be:

- South Australian Research & Development Institute. Key contact - Jim Cox (Principal Scientist Water Resources & Irrigated Crops)
- Department of Agriculture and Food WA. Key contact - Alec McCarthy (Horticulturist, Bunbury District Office)

Knowledge Generation

Research undertaken to date has highlighted a need to understand the relationship between water application and avocado yield and quality. Information generated both internationally and in Australia is inconclusive as to the optimum amount of water to apply to maximise yield and ultimately profitability. For this reason it is important for industry to undertake applied research to generate knowledge at a regional level, as to how much water to apply and when.

Decreasing availability of water in a number of regions will drive the need to understand how to optimise the application of limited water supply, and the recovery of orchards from drought.

Other issues that require greater depth of understanding relate to:

- Fertigation techniques and timing/amount of nutrient applications
- Salinity and sodicity management
- Advantages/disadvantages of different irrigation systems

Research Questions

The key research questions that need to be considered are:

- *How much water is required to maximise avocado yield and quality?*
- *When are the critical irrigation times – how is water application matched to plant growth stages?*
- *How often should I irrigate and how long should I run the system?*
- *How are environmental impacts of irrigation minimised?*
- *How do I optimise yield and quality when water supply is limited?*
- *What management practices will assist under drought conditions and what can be done during recovery?*
- *What are the best irrigation systems under different climatic and soil conditions?*
- *How do I manage fertigation?*
- *How do I manage salinity and sodicity issues?*

Methodology

The applied research will involve two key sites in Southern Australia. These sites provide a range of climatic and soil conditions. The sites are:

Riverland (South Australia) – sandy soils, high evaporative demand and irrigation requirement, salinity potentially an issue

Pemberton/Manjimup (South West Western Australia) – clay loam soils, moderate evaporative demand and irrigation requirement, potential to explore fertigation

Both sites would involve the establishment of a field experiment on a selected growers property. The site would be instrumented to determine the water balance and crop response. Key aspects for monitoring are described in Table 4.2.

Table 4-2 Description of key parameters and monitoring program

Parameter	Monitoring
Tree performance	Tree growth, crop yield (total), fruit size (range of sizes) and packout
Crop aspects	Root distribution, plant water stress
Water balance	Soil moisture in root profile, deep drainage, evaporation, estimated crop water use
Solute monitoring	Movement of salts and nutrients, soil salinity, leaf salinity
Irrigation system performance	Assessment of system efficiency
Water use efficiency	Estimation of efficiency of volume of irrigation applied and the value of production
Tools	A component of the monitoring will include the use of a range of tools for irrigation scheduling including C-probes, Full stops, tensiometers, Enviroscan and Solute samplers. The management and benefit of these tools will be demonstrated during the extension program.

Budget

A detailed budget has not been developed for the research components. The potential providers will undertake this once there is a clear requirement for research in this area.

The indicative budgets have been developed based on similar research approaches but in no way indicate a commitment by the providers for delivery of research within these budgets. The level of funding would require a degree of negotiation.

Ballpark figures have therefore been provided for each site as described in the following table (Table 4.3). It is recommended that the research be undertaken for three years.

Table 4-3 Budget for undertaking applied irrigation research on one experimental site

	Year 1	Year 2	Year 3
Establishment, instrumentation	40	10	10
Monitoring	120	120	110
Field Days/Activities	10	20	20
Total ($)	**170**	**150**	**140**

Total costs for each experimental site would be in the vicinity of $460K. For two sites this figure would approach $920K for three years.

Co-investment

There is significant potential to explore possibilities for co-investment by the providers. This co-investment could be in the order of 25-50% involving both cash and in-kind support. Leverage opportunities would need to be discussed with each provider.

4.2.2 Regional Extension

Experimental Sites

The experimental sites would be an integral part of the extension activities undertaken in the regions with direct use for avocado growers in southern regions. The tools that are utilised and expertise developed in these regions could be adapted for the northern regions.

Grower Groups/Farm Walks

It is proposed that four groups are established across Australia. Two groups would be associated with the experimental sites and two others would be formed in Northern Australia where there is an identified need for increased irrigation management knowledge.

The four grower groups would be based around the following regions:

- South West (Western Australia)
- Riverland (South Australia)
- Northern Coast (New South Wales)
- Queensland

The two southern groups would utilise the monitoring results and tools to assess and improve their own performance. These groups would have irrigation/nutrition as a core focus but would relate this information to tree performance and avocado quality.

The two northern groups would likely have irrigation as one of a number of issues of interest. These groups could test the findings from experiments conducted in the southern region by undertaking on-farm trials or adopting some of the tools. It is likely that irrigation knowledge will not be a priority for these groups but would be incorporated into existing extension activities relating to other production issues.

Extension Network

It is recommended that a coordinator be appointed to identify and develop an irrigation extension network and guide activities across the regions. This would ensure that research results are applied more broadly and that learnings from growers are built into the research program.

The extension network would include broad based avocado extension personnel and other service providers with irrigation specific expertise eg scheduling consultants, irrigation designers and fertiliser representatives.

Information Materials

Additional information materials should be developed based on the research undertaken and also the specific needs of the regional groups. These materials may include case studies, guidelines, benchmarking data and 'how to' documents.

A newsletter will also be established for the network.

Budget and Leverage

The estimated budget for the extension component is described in Table 4.4.

Table 4-4 Budget for regional extension program

	Year 1	Year 2	Year 3
Facilitation of grower groups/farm walks/activities (4 groups)	30	50	60
Coordination of extension network	30	30	30
Information Materials	10	20	20
Total ($)	**70**	**100**	**110**

The total budget for the three years for the extension program is $280K. In some of the identified regions there is already an existing extension program and established grower groups. In these cases there may be an opportunity to seek co-investment from State governments. There are also likely to be efficiency gains achieved by using established groups. The budget for facilitation may therefore be substantially less but will require negotiation on a state by state basis.

The role of coordination will be critical in ensuring a transfer of knowledge between regions and across Australia.

References

A selection of publications for industry is listed below:

1. Guidelines for managing under limited water supplies: Avocados. A resource developed for the avocado industry focused on understanding crop water requirements and improving water management under non-limiting and limiting water supply conditions.

   http://www.horticulture.com.au/delivering_know-how/Environment/Water/Grower_Resources.asp

2. Water Budgeting Guidelines - avocado (PIRSA FactSheet 09/06)

3. Seasonal & Weekly Water Budgeting Tools (PIRSA Spreadsheets)

   http://www.samdbnrm.sa.gov.au/BoardProjects/IrrigationManagement/tabid/345/language/en-US/Default.aspx

4. Avocado Irrigation Budget Worksheet (PIRSA FactSheet) - custom irrigation budget to calculate how to apply a fixed volume of water on a weekly basis using volume (kL) of water available, irrigation depth (mm), weekly ETc.

   http://www.pir.sa.gov.au/pirsa/more/factsheets/fact_sheets/horticulture/water_budgeting_guidelines/water_budgeting_guidelines_-_avocado

5. Fact sheets and information for irrigated horticulture covering water use efficiency, irrigation in drought conditions, salinity management for a range of tree crops (Almonds, Citrus, Grapes, Pistachios, Olives, Pomefruit, Stonefruit)

   http://www.pir.sa.gov.au/pirsa/drought/irrigation__and__water_management/irrigated_crop_information

6. 'AVOMAN' an Australian initiative that provides growers with management tools and information for improving orchard productivity and fruit quality by the Department of Primary Industries and Fisheries, Queensland, funded and supported by the following organisations: DPI&F Queensland Australian Avocado Growers' Federation Horticultural Research & Development Corporation NSW Department of Primary Industries Agriculture. AVOMAN addresses the four priority areas of root rot, irrigation, nutrition and anthracnose. http://www2.dpi.qld.gov.au/avoman/

7. Lahav E and D Kalmar (1983) Determination of the irrigation regimen for an avocado plantation in spring and autumn Australian Journal of Agricultural Research 34(6) 717 - 724 Full text doi:10.1071/AR9830717 © CSIRO 1983 - R&D publication

   http://www.publish.csiro.au/paper/AR9830717

8. Irrigation requirements of avocado, Department of Agriculture, and Food WA Farmnote 42/1988 [Reviewed July 2005] - provides a simple method for calculation water requirements of avocados and information on Construction, location and use of an evaporimeter. http://www.agric.wa.gov.au/

9. Californian irrigation calculator on-line. http://www.avocado.org/growers/irrigcalc.php

10. Waterwise on the Farm - A multi-stakeholder industry initiative developed and delivered in WA by both the Department of Agriculture and Food and Perth Region NRM proving an good example and outline of irrigation training. http://www.perthregionnrm.com/default.aspx?MenuID=96

11. Waterwise on the Farm – A user pays training course offered in NSW for landholders, farm managers, consultants and rural retailers to improve irrigation system performance and water use efficiency.

    http://www.dpi.nsw.gov.au/agriculture/profarm/courses/agricultural-resource-management/waterwise-on-farm

12. Turner D. W. et al. (2002) Managing Irrigation for yield and fruit quality in avocado. Bib ID 1676306, ISBN 0734103948 Horticulture Australia Limited Project number AV96005", Completion date: 30 September 2001.

Appendix 1 - Consultation Methodology

A1 Growers

Consultation with growers was conducted via semi-structured interviews. Apart from identifying gaps in industry knowledge, the interviews were also useful to gain an understanding of how growers would like to progress their knowledge and improve irrigation efficiency in their avocado plantations. This is important for tailoring the scope in Stage 2 for further research and extension activities.

The following individuals were consulted to confirm knowledge gaps in irrigation management.

Table A1.1 Growers/Organisations

Contact Name	Organisation	Region
Alan Blight	Avowest	Western Australia
Nick Hobbs	Chinoola Orchards	South Australia
Graeme Thomas	Graeme Thomas Horticultural Services	Queensland
Lachlan Donovan	Donovan Family Investment	Queensland
Daryl Boardman	Sunnyspot Packhouse	Queensland
Sam and Kylie Collins	Blushing Acres Pty Ltd	Queensland

A1.1 Survey Content

The following questions formed the basis for interviews. The major aim was to establish the degree of understanding of issues related to efficient irrigation water use for optimum production (marketable yield at certain input costs).

Environment and management

f) Farming Context - location, local climate, soil type, soil management, varieties, tree age(s)

g) Water Management - source(s), water quality, water storage, type of irrigation system, nozzles etc. (why chosen), fertigation, systems water delivery per hectare, hours running time

h) Monitoring - is water use per hectare monitored? Is soil moisture monitored? Yield per hectare / tree

Decision making and risk management

i) How are start up and finish of irrigation cycles determined; which methods are used to assess/calculate irrigation requirements?

j) How are decisions on irrigation timing and amounts made under low water supply conditions? Are decisions ever made based on returns per megalitre water?

k) How are crop management or soil management changed to mitigate effects of low water supply (pruning, thinning, mulching etc.)?

Resources

l) Which human resources help in making decisions about water management e.g.

▪ Consultants ▪ Researchers ▪ Other growers	▪ Own/staff experience ▪ Other

m) Other information resources used e.g.:

▪ General publications on irrigation (specify if possible) ▪ Avocado industry publications (specify if possible) ▪ Trial data	▪ Field days ▪ Grower experiences ▪ Case studies ▪ Internet

n) What are the main drivers for change? What are the best ways to learn?

▪ Reduction in water availability ▪ Introduction of soil water monitoring devices ▪ Continued need to gain maximum returns per megalitre of water	▪ Evidence from in-house and / or outside trials ▪ Publications, internet, media ▪ Access to knowledgeable and supportive consultants / agronomists ▪ Others

o) Are other growers, consultants and extension officers willing to share information and knowledge?

A1.2 Research/Extension Personnel

An understanding of water industry needs was also gleaned from avocado industry development personnel. This involved an email questionnaire to key contacts representing the major avocado growing regions across Australia.

The following organisations and individuals were consulted to confirm knowledge gaps in irrigation management.

Table A1.2 Research Providers

Contact Name	Organisation
Alec McCarthy	Department Agriculture WA
David Turner	University of WA
Simon Newett	Department of Primary Industries Qld
Tony Whiley	Private Consultant
Mary Hickey/Phil Wilk	Department of Primary Industries NSW
Jim Cox	SARDI

A1.3 Survey Content

The survey was distributed via email and involved the following questions:

Has there been any irrigation R&D conducted since the guidelines were published in 2007? Is any of it still going?

Have the guidelines been used for extension/training purposes?

Do you believe that there is more need for irrigation R&D to refine the guidelines, to ensure they are fulfilling industry needs/are working under Australian conditions?

Do you believe that rather than conducting further R&D, the industry would benefit more from extension and training e.g.:

- Use of the current guidelines and existing irrigation R&D outcomes; include training on water balance calculations.
- Set up demonstration sites in each major region to show growers the range of soil moisture monitoring tools available to them (including e.g. FullStop wetting front detectors or rootzone solution extraction to show water loss if it occurs).
- Conduct training on the relationship between soil management/soil health and soil moisture retention e.g. as part of existing study group activities.
- Help with irrigation system audits or guidelines for audits.
- Relationship between irrigation management and marketable yield/fruit quality.

A2 R, D & E Capacity

It is expected that industry needs will be delivered by existing research providers. This section involves a summary of the needs for irrigation R, D & E and a brief assessment of current research and extension capacity.

A2.1 Determining Water Requirements

Previous research suggests that avocados are sensitive to water stress throughout the growing season. However, when faced with water shortages, growers need to know at which physiological growth stage limited water is best used to maximise marketable yields and returns per megalitre. Excess water may be applied at some stages during the season, which can be saved.

Tree Water Use

In order to determine water requirements it is necessary to measure the amount of water that avocado trees use under varying conditions including; water availability, climate, soil texture and structure, soil management, tree age, rooting depth, variety and irrigation system.

Water use information can be used to describe crop coefficients to schedule irrigation under different conditions. There are a number of direct and indirect research methods that can be adopted to measure tree water use. The methods vary significantly in their accuracy and cost.

The design of a research program to determine water requirements will need to take into consideration:

- Accuracy and costs of the method used

- Number of sites required to cater for different conditions listed above
- Current guidelines based on international literature and the best estimates from FAO56
- Considerable experience within the industry with respect to water requirements

Alternative approaches

The cost of setting up trials that cover all conditions is likely to be prohibitive. An alternative approach may be to use monitoring sites, using grower owned soil moisture monitoring equipment, water use records (ML/ha) and collecting orchard specific information.

A2.2 Extension and Training

Irrigation scheduling is a complex task and appropriate training may be required to enable R&D results to be implemented successfully.

A2.3 Potential Providers

The research providers were also asked if they would be interested in undertaking irrigation research and development for the avocado industry.