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IRRIGATION OF FRUIT TREES AND VINES

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Adoption of sustainable irrigation management practices by stone and pome fruit growers in the Goulburn/Murray Valleys, Australia

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Abstract The management of water resources by orchards in the south-eastern region of Australia is an increasingly important policy issue, especially given the low water allocations and concerns about salinity in recent years. Optimal management for economic and environmental sustainability can be described as best management practice (BMP). A project was developed to run an extension program, which aimed to achieve behavioural change among orchardists through the adoption of irrigation BMPs and benchmarks. The effectiveness of the extension program was evaluated and the drivers for adoption assessed. In the first stage of the project both BMPs and benchmarks were determined for irrigation management. A survey of 200 growers showed no relationship between yield and irrigation system or irrigation volume suggesting that increased yields were not a key driver for adoption of sustainable irrigation practices. Stage two of the project involved undertaking an extension program aimed to facilitate the adoption of BMPs and benchmarks and incorporated a suite of activities to meet the learning needs of a diversity of participants (40 growers). The program was effective in establishing behavioural change for many of the growers involved; however, it was resource intensive requiring significant one-on-one input. Stage three aimed to analyse the key drivers for adoption of sustainable irrigation practices for the whole of the stone and pome fruit industry in south-eastern Australia using market research. The study determined that water use efficiency was not a key driver for adoption of sustainable irrigation practices (micro irrigation and soil moisture monitoring) and adoption was generally not limited by lack of knowledge. Groups of growers were identified where extension programs could be effective by focussing on specific information e.g. redevelopment of orchard. Other groups had no need and/or ability to change unless the external operating environment was to change e.g. regulation, access to pressurised water. The voluntary adoption of more sustainable irrigation practices will probably require extensive resources using one-on-one methodology. The extension program should not focus on the broader social objective of improved water use efficiency but promote other potential benefits (e.g. labour saving, redevelopment of production systems, management flexibility) with targeted messages for specific groups.

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Introduction

Management of water resources is critical for orchardists and the wider community in south-eastern Australia. Optimal management of water for economic and environmental sustainability can be described as best management practices (BMPs). BMPs for orchard irrigation involves many factors, including irrigation scheduling, nutrient management, salinity and water table control, vigour management using deficit irrigation strategies and knowledge of crop development stages (Boland et al. 2001, 2002). BMPs must integrate these factors within the physical and practical constraints of the orchard. Considerable background information is available on BMPs for irrigation that has evolved from many years of research and development in the area of water management (e.g. Oster and Wichelns 2003).

Appropriate tools must also be available to implement improvements in irrigation management and monitor progress. Numerous monitoring programs have been conducted that measure the key benchmarks (indicators) for sustainable irrigation practices and verify their application in the orchard (Boland et al. 1998). This information has formed the basis for extension activities with the aim to encourage growers to adopt better irrigation practices.

Adoption by growers of these BMPs for irrigation requires a greater knowledge by extension professionals of the adoption process including the relevance to general orchard management practice. Adoption has been defined as 'the result of making full use of an innovation as the best course of action available' (Rogers 1983). Adoption theory seeks to explain behavioural change within an individual. In agriculture, the term adoption has been used to define the uptake of agricultural practices and is usually targeted at the farmer or grower. The main objective is to achieve behavioural change to improve farming methods in line with the latest BMPs. A range of extension methodologies can be used to achieve change based on adult learning principles (see Burrows and Boland 2002).

Understanding the process of adoption will facilitate the development of successful extension programs. Exploring the reasons for adoption or non-adoption (drivers) will also enable the implementation of targeted extension strategies (Kaine and Bewsell 2002). Consumer behaviour theory can be used to assess the drivers for adoption of innovations in agriculture. This method relies on market segmentation and has been applied to the adoption of irrigation management in the stone and pome fruit industry (Kaine et al., 2005).

The project and associated extension program described in this paper was intended to facilitate behavioural change in the form of the adoption of sustainable irrigation BMPs and benchmarks. The extension program drew on the current theory associated with adoption and included a range of extension methodologies to meet the individual needs of the growers. Activities included a monitoring program, demonstrations, farm walks, discussion groups and orchard season reports. The effectiveness of these activities is discussed. A market segmentation study was also undertaken as part of the project to more closely assess the drivers for adoption of irrigation technologies and practices. The key findings from this study are presented and the implications for the design of extension programs in horticulture are discussed.

Methods

Stage 1: irrigation management practices and productivity

A survey (irrigation survey) of 200 fruit growers in four regions in south-eastern Australia (Shepparton East, Ardmona, Cobram and Swan Hill) was conducted in June 1997. The growers in these regions represented approximately 33% of the national stone and pome fruit grower population. The purpose of the survey was to identify the management practices that growers used to irrigate and the effect of these practices on production (e.g. yield and quality) and environmental indicators (e.g. water table depth and soil pH) both within and between districts. The survey involved a face-to-face interview of approximately 2 h duration. Growers were provided with a free soil salinity (EC_e) and pH test of the block being surveyed. This information was sent to the grower in conjunction with a comparison of the average district results for EC_e and pH.

Growers returned a total of 174 surveys. A statistical analysis of these was undertaken to determine the relationships between (a) yield and irrigation system (b) yield and amount of irrigation applied and (c) irrigation system and amount of water applied. These relationships would assist in assessing the potential role of productivity and yield as key drivers for adoption of irrigation technologies and practices.

Stage 2: extension program for BMPs

An extension program was developed to promote the adoption of the defined BMPs and benchmarks. The program involved a variety of strategies including a monitoring program, discussion groups, benchmark analysis and demonstration sites and was constructed in the light of current knowledge of adult learning principles.

Monitoring program

Forty orchard-monitoring sites (in four regions in south-eastern Australia—Ardmona, Shepparton East, Cobram and Swan Hill) were established. The 40 orchard blocks were selected from the initial survey covering the major soil types identified and a cross-section of tree species (peach/nectarine, apple and pear), irrigation method and orchard management. The monitoring program was conducted over two seasons (1997/1998 and 1998/1999) and key sustainability and productivity indicators were monitored.

Grower discussion groups

Meetings were organised for the 40 growers participating in the monitoring program. The meetings focussed on discussion of results and technical issues including irrigation and salinity monitoring techniques, critical growth stages and nutrient application and system maintenance. The grower groups were also used to test and discuss the BMPs and benchmarks.

Benchmarking

A report was prepared at the end of the season based on the monitoring results (1997/1998 and 1998/1999). This report presented the growers results and compared these with the district range, average and 25 and 75 percentiles. The benchmarking information was used for a number of purposes:

- The information allowed the grower to measure their own performance and to monitor the effect of change in management practices.
- The results were used at grower meetings to generate discussion and create an environment of inquiry.
- The information enabled growers to compare their performance against others.

Demonstration sites

Two sites were established on commercial properties to demonstrate irrigation management practices to control vegetative vigour using regulated deficit irrigation (RDI) on Golden Queen peaches and Packham pears. The trials were conducted for two seasons (1997/1998 and 1998/1999).

Impact of extension program

To determine the change in management practices over the period of the monitoring program, a follow-up survey was designed and distributed in January 2000 to the 40 growers involved. This survey concentrated on the general orchard and irrigation management practices such as monitoring and irrigation scheduling methods.

Stage 3: market research

Despite the success of stages 1 and 2 with measured change in practice of the 40 growers, it was recognised that this approach required significant resources and focussed on a relatively small group of growers in the industry. Stage 3 was designed to develop a greater understanding of the drivers for adoption of improved irrigation practices among the broader grower community.

There were two phases involved in gaining an understanding of the needs of growers in relation to irrigation management. For a detailed outline of these stages see Boland et al. (2001) and Kaine et al. (2005).

In the first phase of the market research, in-depth personal interviews were conducted with approximately 30 growers to identify the key factors influencing the adoption of irrigation technologies and practices.

For the second phase, the information gathered during the interviews was used to develop a mail survey to quantify the frequency of the key factors that influence adoption of the irrigation practices and to classify growers into market segments with respect to those practices.

Following piloting, the questionnaire was distributed to all fruit growers in the south-eastern Australia districts [Shepparton East, Ardmona, Cobram, Swan Hill (Victoria) and Tumut, Batlow (New South Wales)]. The population of growers in these districts is approximately 780 (650 in Victoria and 130 in New South Wales). The questionnaires were mailed in May 2000 with a reminder posted 4 weeks later. The study and survey were also publicised through the local print media and industry newsletters. Forty-four questionnaires were returned with incorrect addresses or from people who were not fruit growers giving an effective mail out of 736 questionnaires. A total of 251 questionnaires were returned 10 weeks after the initial mailing representing a response rate of 34%.

The segmentation analysis was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987), which is specifically designed for use with dichotomous data. The algorithm works by placing all respondents in one segment and then dividing respondents into successively smaller and smaller segments depending on their characteristics. Following common practice a 'scree' test was used to determine the number of segments present in the sample (Aldenderfer and Blashfield 1984).

Results

Stage 1: irrigation management practices and productivity

Management

The irrigation survey demonstrated a wide range of practices in irrigation with little objective assessment of irrigation requirements. Over the four districts the irrigation systems adopted were as follows: flood 30%, knocker sprinklers 11%, micro irrigation 36% and drip 23%. Differences in irrigation systems were observed between districts with micro irrigation predominant in Shepparton East, Cobram and Ardmona and drip the preferred option in Swan Hill (Table 1).

Irrigation scheduling decisions in Shepparton East, Ardmona and Swan Hill were almost exclusively based on experience (>95%) while in Cobram this was only 76%. A significant proportion of growers used tensiometers to help schedule irrigation in Cobram and Swan Hill (19 and 28%, respectively). In all four districts more than 25% of growers used a shovel or auger to help schedule while alternative soil moisture monitoring equipment was rarely adopted (Table 1).

The provision of drainage (either tile drainage or a groundwater pump) is often important for irrigation and salinity management. The provision of different types of

Table 1 Irrigation survey (1997)—irrigation system, irrigation scheduling practices, general irrigation and orchard management practices deployed in each district

	Irrigation district			
	Cobram (%)	Swan hill (%)	Shepparton east (%)	Ardmona (%)
Irrigation system				
Flood	0	32	44	19
Knocker sprinkler	45	0	51	29
Micro irrigation	55	6	2	49
Drip	0	62	3	3
Irrigation scheduling practice				
Check emitter flow	0	26	21	6
Schedule irrigation by:				
Calender	0	8	7	0
Shovel/auger	43	26	30	32
Experience	76	95	95	97
Evaporation (E_{pan})	5	3	2	3
Evapotranspiration (ET)	5	3	0	0
Tensiometer	19	28	11	6
Irrigation and orchard management practice				
Tile drainage	0	87	5	0
Groundwater pump	67	1	26	32
Leaf analysis	76	49	61	61
Measure soil salinity	14	8	67	58
Measure soil acidity	62	28	74	81
Monitor water table	19	13	41	16
Monitor water table salinity	14	5	39	10

drainage reflects the hydrological and soil characteristics of the districts (Table 1). Monitoring of leaf nutrition is an important part of fertiliser management and it appears that the majority of growers use leaf analysis as an indicator of fertiliser requirements (Table 1). Measurement of soil salinity and acidity is frequently conducted by commercial companies. The difference in measurement between districts may be a result of education programs on specific topics in these regions (Table 1). Monitoring of the water table and salinity also reflects the predominant problems in the different districts (Table 1).

The survey highlighted the wide range in irrigation management practices used by growers in the 1996/97 season. Irrigation scheduling decisions were almost exclusively based on experience with little objective measurement or adoption of soil moisture monitoring equipment. Some growers used tensiometers and a shovel or auger; however, the amount and frequency of irrigation applied varied enormously in all districts. These differences suggested substantial improvements may be possible in irrigation scheduling. Assessment of other orchard management practices related to irrigation demonstrated that growers frequently monitor tree nutrition (leaf analysis) and soil salinity and acidity.

Irrigation and productivity

The relationship between irrigation practices and production was assessed from the 174 surveys returned. The relationships between (a) yield (t/ha) and irrigation system (b) yield (t/ha) and amount of irrigation applied (ML/ha/day) and (c) irrigation system and amount of irrigation applied (ML/ha/day) are presented.

Total yield of each block (t/ha) was assessed for each of the irrigation systems, which were classified as flood (or furrow), sprinkler (knocker), microjet (or mini-sprinkler) and drip. Complete information was gathered from 159 blocks. There was no significant association between yield and irrigation systems for apple ($P=0.18$), peach and nectarine ($P=0.09$) and pear ($P=0.97$). Over all fruit types and after the effects of fruit type were removed, there was no general association between yield and irrigation type ($P=0.43$).

Total yield was obtained from the reports for each block (t/ha) and amount of irrigation water applied was calculated as an average over a fortnight in the peak irrigation season (ML/ha/day). Complete information was available from a total of 113 blocks (12 apple, 2 apricot, 25 nectarine, 30 peach and 44 pear), which were analysed in the four districts (Ardmona, Shepparton East, Cobram and Swan Hill). There was no association between yield and amount of water applied for apple ($P=0.96$), peach ($P=0.35$), nectarine ($P=0.16$) and pear ($P=0.21$) when analysed separately. For all fruit and after the effects of fruit type were removed, there was no association between yields and amount of water applied ($P=0.76$). Yields were therefore independent of irrigation volume.

Irrigation system and amount of irrigation water applied (ML/ha/day) was available from a total of 112 blocks over all districts. The analysis demonstrated that when considering all blocks, significantly more water was applied in flood irrigation than in the other systems ($P<0.05$). There was a strong trend for more water to be applied with sprinkler than drip (Table 2). While more water was applied with flood and sprinkler irrigation there was no difference in yield for the various irrigation systems ($P = 0.43$).

It was not possible to demonstrate an effect of irrigation volume or frequency on yield, despite the large differences in yield among growers (see below). This could be explained by the relatively high water application rates of Table 2 indicating that above a certain threshold, stone and pome fruit are relatively insensitive to irrigation volumes under the environmental and physical conditions of the Goulburn and Murray Valleys. These results highlight the futility of trying to promote efficient water use or changes in irrigation practice under such conditions on the basis of yield benefits alone.

Stage 2: extension program for BMP

Monitoring program

The program involved an initial soil assessment to establish total water holding capacity and root distribution. Sites were monitored for two seasons (1997/1998 and 1998/1999) for soil moisture, water table depth and salinity, tree nutrition, fertiliser movement, soil salinity and pH. Records were maintained of irrigation and fertiliser applications, general management practices and yield and fruit size assessment. Regular feedback of results was provided to the grower. This feedback included soil moisture monitoring via on-site tensiometer charts and interpretation of leaf and soil analysis results. Informal discussion with growers in their orchard was particularly important for the process of understanding methods of monitoring, interpreting results and developing confidence in the program.

Discussion groups

The discussion groups were designed to review monitoring results and discuss technical issues. They included a mix of "classroom" and field sessions. More than ten meetings were conducted with each of the four groups over the two seasons including; review of season results, low water allocation strategies, farm walk of the RDI demonstration sites, review of leaf analysis and fertiliser results, and discussion on RDI and partial rootzone drying (PRD) demonstration sites.

Attendance by growers at the meetings varied across the districts: in Ardmona 80% of growers with monitoring sites attended, Shepparton East: 50%, Swan Hill: 50%, and in Cobram 90% of growers with monitoring sites attended. The discussion groups were an extremely important part of the program resulting in improved understanding of the processes involved in irrigation management and leading to the implementation of better practice by the grower members.

Table 2 Irrigation survey (1997)—number of blocks and mean water applied (ML/ha/day) for irrigation system in the 1996/1997 season

Irrigation system	No. blocks	Calculated water applied ML/ha/day (peak season)
Drip	34	0.056b*
Microjet	54	0.071b
Sprinkler	17	0.101b
Flood	7	0.173a
$LSD_{5\%}$		0.046

*Means with any common superscript are not significantly different ($P = 0.05$)

Benchmarking

Information from the monitoring program was presented in an orchard report. Data was presented in a form for individuals to compare their performance. The information in the orchard reports included:

1. Crop growth stages
2. Soil pit assessment and plan of irrigation run time
3. Soil moisture monitoring—tensiometer chart
4. Water applied
5. Crop factors
6. Fertiliser application and nutrition
7. Soil analysis (EC and pH)
8. Production and size comparison

The growers results were highlighted and compared with the average, range and 25 and 75 percentiles for the district. An example of the benchmark data for Packham pear crops in the Shepparton East and Ardmona districts combined is provided in Table 3 (see Boland et al., 2002 for more information).

Demonstration sites

The demonstration sites were developed at the request of some growers to gain a greater understanding of RDI. The sites were successful in demonstrating the operation and advantages of RDI, and were used as a resource to show the technique to other growers. Growers comments in relation to these demonstration sites included; "seeing is believing" and "growers are more likely to adopt if they see the practice on another grower's property".

Impact of extension program

The survey was sent to 40 growers with a response rate of 70%. The main practices that were compared over the period of the project were changes in scheduling irrigation and monitoring of the plant, soil and water table. Given the limited number of participants results are combined for all districts.

Table 3 Monitoring program—benchmark data for canning pears (Packham) in the Shepparton East and Ardmona districts over two seasons (15 sites) (1997/1998 and 1998/1999)

	Range		Mean		Highest 25%		Lowest 25%	
Irrigation								
Rootzone depth (cm)	35–95		70		85		55	
Available water (mm) (8–40 kPa)	17–50		36		46		29	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
Seasonal water applied (ML/ha)	4.5–7.5	2.2–10.3	6.0	5.2	6.9	6.4	5.1	3.6
Production								
Total yield (t/ha)	11–79	13–81	40	40	48	56	24	23
Average fruit size (mm)	65–87	64–75	74	70	76	73	70	64
Water use efficiency (t/ML)	1.5–13.7	2.2–16.7	7.6	8.6	13.5	12.9	3.1	4.4
Plant and soil fertility								
Leaf nitrogen (%)	1.2–2.0	2.5–3.2	1.9	2.6	2.0	2.9	1.8	2.6
Soil ECe (dS/m) (0–25 cm)	0.5–3.4	0.43–2.1	0.8	0.96	1.0	1.18	0.8	0.48
Soil pH ($CaCl_2$) (0–25 cm)	4.6–7.1	4.4–6.2	5.3	5.3	6.5	6.2	5.5	4.63

The greatest change over the period was the use of tensiometers to schedule irrigation (68% by the end of the program). A small proportion of growers had also adopted evaporation or evapotranspiration for scheduling. More growers were undertaking leaf analysis and there was a large increase in growers monitoring water table depth and salinity (Table 4).

Stage 3: understanding adoption in the broader grower industry

Phase 1

During interviews with fruit growers it was determined that the installation of micro irrigation was a major factor affecting the use of objective monitoring of soil moisture for irrigation scheduling. Only fruit growers with micro irrigation and immediate access to water (i.e. are able to irrigate on demand) were able to take full advantage of monitoring to schedule irrigations. Consequently, factors that influence the adoption of micro irrigation were the focus in this stage of the project. Growers adopted micro irrigation to either save water to manage a salinity or water table problem, to save labour and time, or to increase control over the timing or application of watering. Some growers adopted micro irrigation to save water because of limited supplies. Growers who had installed micro irrigation were unlikely to adopt monitoring unless it was demonstrated to be more accurate than their experience and easy to use.

Table 4 Change in irrigation scheduling practices, general irrigation and orchard management practices of 40 growers involved in monitoring program

	Growers involved in monitoring program	
	1997 (%)	2000 (%)
Irrigation scheduling practice		
Check emitter flow	36	46
Schedule irrigation by:		
Calendar	4	25
Shovel/auger	32	50
Experience	89	82
Evaporation (E_{pan})	0	7
Evapotranspiration (ET)	4	7
Tensiometer	36	68
Consultant	21	21‘
Irrigation and orchard management practice		
Leaf analysis	68	89
Measure soil salinity	50	36
Measure soil acidity	68	57
Monitor water table	43	75
Monitor water table salinity	29	43

Most growers were in a position to use soil moisture monitoring (such as tensiometers) to assist them in deciding when to commence the irrigation season. Most growers were also able to use monitoring to assist them in optimising their irrigation management in terms of irrigation frequency and run-times. However, as a general rule, growers were too constrained by access to water, the cost of power and the scheduling of other farm activities to use monitoring to directly schedule irrigations during the season. Only growers who had access to permanently available water were in a position to use monitoring to schedule irrigations throughout the season.

Phase 2

The second phase of the process identified key segments for the use of specific irrigation systems. Application of the ‘scree’ test indicated five segments were present in the sample. Five segments were formed describing growers’ situations with respect to their irrigation system (Table 5). Growers were classified into three segments for soil moisture monitoring on the basis of their type of irrigation system and whether they could irrigate on

Table 5 Characteristics of the five market segments for irrigation systems and the three market segments for soil moisture monitoring in the stone and pome fruit industry (after Kaine et al., 2005)

	Market—irrigation systems				
	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Percentage of respondents	24	25	9	16	26
Replanting orchard	Yes	No	No	Yes	No
Under time pressure or need to increase management flexibility	Yes	Yes	No	No	No
Problems with water scarcity, water tables or salinity	No	No	Yes	No	No
	Market—soil moisture monitoring				
	Segment 1	Segment 2	Segment 3		
Percentage of respondents	42	32	26		
Water on demand	Yes	No	No		
Micro irrigation installed	Yes	Yes	No		

demand (Table 5). A detailed description of the grower segments and their situations is given in Kaine et al. (2005).

Discussion

The aim of the project was to achieve behavioural change, in the form of the adoption of sustainable irrigation BMPs and benchmarks, among a relatively small group of fruit growers. The project was undertaken in three key stages from which a number of key learnings were determined and which influenced the design of subsequent stages (Fig. 1).

The first stage of the project was to establish the irrigation BMPs and benchmarks based on current practices and determine the relationship between sustainable irrigation practices and productivity.

Fig. 1 Adoption drivers and key learnings for each of the three stages

Stage	Drivers for Adoption	Key Learnings
Stage 1 – Irrigation management practices and productivity	- Productivity not related to irrigation system or volume - Soil moisture monitoring based on experience	- Improved water use efficiency is a policy objective not one for individual growers - Can not promote sustainable irrigation on productivity basis
Stage 2 – Extension Program for Best Management Practices	- Range of reasons for growers to self select and be involved - Suite of activities to meet diversity of learning styles - Effective at promoting behavioural change	- Resource intensive program for minimal change – requires one-on-one - Relatively small number - Messages not targeted - On-farm validation on BMPs and benchmarkes critical
Stage 3 – Market research	- Water use efficiency is not a driver - Micro irrigation – time/labour, redevelopment, management flexibility - Soil Moisture Monitoring – problem solving, large orchards, dwarf rootstocks	- Extension needs to focus on segments where we can have impact - Target message based on farm context - Policy, regulation, infrastructure changes may be required

The irrigation survey showed that even though there was a very wide range of yields among growers (see Table 3), there was no relationship between yield and irrigation system or irrigation volume for the stone and pome fruit industry. This would suggest that yields are independent of irrigation volume indicating that more than the full water requirements are applied in most orchards (Boland et al. 2001). It also shows that increasing yields were not a key driver among these growers for adopting improved water use efficiency.

The survey also showed that while more water is applied per hectare with flood and sprinkler irrigation systems than with micro or drip there is no demonstrated influence on yield for the various irrigation systems (Boland et al. 2001). This indicates that yield improvement cannot be presented to these growers as a driver for the adoption of improved irrigation systems. It was shown that growers use little objective assessment for soil moisture monitoring basing their decisions more on experience. More technical soil moisture monitoring was generally used when irrigators were changing systems or experiencing problems with salinity or high water tables.

Stage two of the project, the extension program, was developed to facilitate the adoption of BMPs and benchmarks to promote sustainable irrigation practices. This stage incorporated our knowledge of drivers for adoption and assumed that growers wanted to improve their irrigation management practices as they had volunteered for involvement in the program. Growers' reasons for becoming involved in the program varied but included: (a) problems with salinity and water tables, (b) development of high-density orchards, (c) environmental considerations and, (d) interest in continuous improvement/best practice programs.

The program incorporated a suite of activities to meet the adult learning needs of a diversity of participants. Evaluation of the program showed that it was effective in establishing behavioural change for many of the growers involved. The range of extension methodologies used appeared to be effective in promoting adoption of sustainable irrigation practices as evidenced by the evaluation survey. The key learnings from this stage included the fact that the program was resource intensive requiring significant one-on-one input for the establishment of irrigation BMPs and the on-going monitoring of benchmarks. While change was measured (Table 4) this represented a relatively small number of growers from the total community and targeted growers who had already expressed interest in the program for a range of reasons, i.e., the drivers were diverse. As a consequence, the messages conveyed throughout the program may have been relevant only for some individuals. However, it was also apparent that the information on the BMPs and benchmarks required on-farm validation and provided valuable information to diverse stakeholders on realistic targets to achieve. Benchmarking surveys are likely to create awareness and identify scope for change, but are unlikely to result in widespread behavioural change.

What of the wider industry? What are the drivers for change in irrigation management in horticulture? Stage three of the project involved a market segmentation study that aimed to identify the key drivers for adoption of sustainable irrigation practices for the stone and pome fruit industry in south-eastern Australia. The market segmentation work focussed on the grower context to discover the key issues of concern to the individual grower.

Results from the survey indicated that the major forces driving adoption of micro irrigation were:

- Shift to trellis and closer planting techniques
- Need to reduce time spent irrigating
- Need to increase flexibility in managing irrigation, spraying and picking activities in the orchard.

These findings led to the conclusion that the area under flood irrigation would continue to decline as growers redeveloped orchards and demands on grower's time increased, especially in periods when activities such as irrigation, spraying and picking coincide. The findings also indicated that the rate of adoption of micro irrigation could be influenced indirectly through activities that promoted intensification such as trellising and closer planting techniques to growers who are redeveloping their orchards.

It is interesting to note that, as shown in Table 3, there was a wide range of water application rates and yields among growers. However, relationships between yield and applied water were weak indicating that more in-depth investigations will be needed to document the influence of improved irrigation management on commercial yields. In fact, increasing water use efficiency was not identified by most fruit growers as a factor in the adoption of micro irrigation. This is consistent with the findings from the stage one survey on productivity and irrigation management practices.

The preconditions for successfully adopting soil moisture monitoring are the use of micro irrigation and immediate access to irrigation water (water on demand). Growers with flood irrigation derived little benefit from monitoring because they did not have the flexibility necessary to adjust their irrigation scheduling. Growers with micro irrigation who could not water on demand also experienced difficulties with using monitoring to schedule, as they were unable to adjust ordering of irrigation water appropriately.

The survey also indicated that the motivations for adopting soil moisture monitoring were:

- Problems of high water tables, salinity or tree vigour
- Need on larger orchards to check irrigation performance
- Planting of dwarf rootstocks.

Growers with micro irrigation who did not have access to water on demand adopted monitoring either to resolve problems with tree health or tree vigour, or to help determine the timing of the first irrigation of the season. Growers with large orchards who had access to water on demand and used micro irrigation adopted monitoring to check on irrigation performance. As with micro irrigation, increasing water use efficiency was not identified as a factor in the adoption of soil moisture monitoring.

Overall, the study determined that the key drivers for changing irrigation management were not associated with water use efficiency and adoption of innovations in irrigation technology and management were generally not limited by knowledge. There were segments of growers where extension programs could facilitate change by focussing on providing information for a specific issue. Other segments had no need to change and were unlikely to do so unless the policy or external operating environment were to change (e.g. drought). The adoption of more sustainable practices was limited for growers in some segments by the current operating environment (e.g. access to pressurised water).

Summary

Sustainable management of irrigation resources is critical to the viability of the stone and pome fruit industry of south-eastern Australia. Governments have undertaken considerable effort to promote the adoption of BMPs by fruit growers. This paper described a process whereby key drivers for adoption were analysed and their effectiveness evaluated.

In the absence of major changes in water policy and regional irrigation infrastructure, it appears that the voluntary adoption of more sustainable irrigation practices on a large scale would require extensive resources using a one-on-one extension methodology. Irrigation extension programs in horticulture in the regions studied should not focus on the outcome of water use efficiency but should highlight other potential benefits for growers (e.g. labour saving, redevelopment of production systems, marketing) with targeted messages for specific groups.

As extension will probably not achieve rapid behavioural change in irrigation management other non-voluntary mechanisms (e.g. regulation, incentives) may need to be introduced to achieve Government policy in relation to water resource management.

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