Soil Monitoring, Irrigation Scheduling and Vegetable Production

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Executive Summary

The results of a study into the factors affecting the adoption of drip irrigation, soil moisture monitoring and soil testing in the irrigated vegetable industry are presented in this report. Nearly twenty growers were interviewed from three regions in the Murray Darling Basin. These were the Murrumbidgee Irrigation Area in New South Wales, Murray Bridge in South Australia, and central and northern Victoria. The crops covered in the interviews were tomatoes, both processing and fresh market, onions, melons and carrots.

We found that the crucial factors driving the choice of irrigation system for vegetable production were soil type and topography. There is a strong association between soil type and the rate with which bacterial and fungal diseases build up in the soil. The rapid rate of build up of diseases in highly permeable and impermeable soils means that vegetables from the same family cannot be cropped in successive seasons on these soils. Consequently, growers must follow lengthy crop rotations. This renders drip irrigation prohibitively expensive for vegetable production in many areas. In other areas furrow irrigation was impractical because of the undulating topography.

Growers did not raise the availability of irrigation water, a need to save time or labour, or crop yield per se as important factors in their choice of an irrigation system. Optimising crop quality was a factor in the choice of irrigation system for growers of fresh tomatoes.

Our results indicate that vegetable growers can be classified into three segments in on the basis of their location and the type of vegetable the produce. One segment consists of growers on heavy, impermeable clay soils that use furrow irrigation. These growers lease new land each year or follow lengthy rotations to overcome problems with soil borne disease. This renders drip irrigation too expensive to be practical. These growers are mostly located in the Murrumbidgee Irrigation Area.

The second segment consists of growers on light, highly permeable, sandy soils that use spray irrigation. These growers are located around Murray Bridge in South Australia and Swan Hill in Victoria. Spray irrigation also allows these growers to manage problems with sandblasting, erosion and heat.

The third segment consists of fresh tomato growers and growers around Shepparton in Victoria and parts of the Murrumbidgee Irrigation Area on moderately permeable soils, especially where the topography is undulating, that use drip irrigation. The rate of build up of disease in these soils is slower. This allows growers to produce two or three vegetable crops in successively seasons on the same ground. This means drip irrigation becomes viable.

Given that vegetable growers can be classified into one of three segments on the basis of location and crop type we believe there strategies and priorities for research and extension can be formulated without the need for a large scale, quantitative survey.

Many growers felt there were no long-term benefits to be had from using soil moisture monitoring equipment. Those growers who used soil moisture monitoring did so to establish an irrigation program when irrigating a new lease or, on larger properties, as a means of occasionally checking their irrigation management was adequate.

Most growers undertook soil testing on a reasonably regular basis. As a rule, growers commissioned soil tests for new leases and to assist them with resolving problems in particular blocks. Salinity was not an issue for any of the growers we interviewed.

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All errors and omissions remain the responsibility of the authors.

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Soil Monitoring, Irrigation Scheduling and Vegetable Production

Introduction

The sustainability of the irrigated vegetable industry in the Murray Darling Basin has been a matter of increasing concern over the last few years, especially with regard to the management of water resources. In response to these concerns a number of Best Management Practices and associated benchmarks have been identified for the irrigation of fresh and processing tomatoes, onions, melons and carrots (Hickey et al 2001). Our objective in this study was to identify the factors that influence the adoption of irrigation technologies and management practices in the irrigated vegetable industries. This knowledge will be used to develop research and extension strategies to facilitate the adoption of the recommended practices and benchmarks.

In this report we present the results of the first stage of the study in which we identified the factors affecting the adoption of drip irrigation, soil moisture monitoring and soil testing for fresh and processing tomatoes, onions, melons and carrots. The research and extension strategies, which will be developed in the next stage of the study, will be the subject of a subsequent report.

In the first part of this report we outline the theory and background to the research approach used in the study. In the second part of the report we describe the factors that influence the adoption of irrigation systems. We then present our findings with respect to the adoption of soil moisture monitoring and soil testing.

Adoption and involvement

The decision by a producer to adopt a new technology can be likened to the decision by a consumer to buy a new product. Consumer behaviour theory suggests that, in situations that matter to the consumer, the consumer is a motivated and discriminating purchaser. The consumer actively seeks information on, and systematically learns about, the product of interest. Failure to purchase is generally attributed to a mismatch between the needs of the consumer and the benefits the product offers.

The effort consumers invest in making decisions to purchase (or adopt) products, and the type of processes they follow in making those decisions, depends on how important the product is to them. In consumer behaviour theory, the term 'involvement' is used to describe and measure the importance of the product to the consumer (Kapferer and Laurent 1985, 1986).

Low involvement purchasing occurs with products that are unimportant to the purchaser (Assael 1998). Usually, low involvement products are inexpensive and bought frequently. Many household goods such as groceries, laundry products and basic toiletries are low involvement products. The purchase process is characterised by passive learning and product evaluation after purchase. Generally, people spend as little time and effort as possible on purchasing low involvement products.

High involvement purchasing occurs with products that are important to the purchaser. Usually, such products are expensive, bought infrequently, are risky or are highly expressive of self-identity (Assael 1998). Homes, cars, and clothes are often high involvement products. The purchase process is characterised by active learning and products are evaluated prior to purchase. Generally, people invest a great deal of time and effort in purchasing high involvement products.

We believe the adoption of a new farming practice is, usually, a highly involving issue for farmers and decisions about adopting a new practice tend to have the characteristics of high involvement purchases for two reasons. First, most innovative practices are likely to have substantial impacts on farmers' incomes and, in many

instances, their lifestyle. Second, the integration of a new practice into an existing farming system generally requires careful planning and management.

This view of the adoption of new practices as a form of high involvement purchasing has a number of implications. First, it implies that farmers are likely to devote a substantial amount of time and energy to evaluating new practices prior to adoption. Sometimes the adoption process can extend over several years (Kaine and Niall 1999). Second, this view implies farmers are unlikely to retain apparently outdated or inefficient practices simply on the grounds of ignorance, tradition or conservatism. Third, this view implies that the decision not to adopt a new practice will be founded on a reasoned argument. Consequently, attempts to promote adoption that do not address these arguments are unlikely to be successful. Fourth, the notion that farmers can be permanently classified into adopter categories (Rogers 1962) according to their propensity to innovate is not consistent with this perspective.

This view of adoption as a form of high involvement purchasing treats all farmers as potential innovators. This potential is given expression when a farmer is prompted by the discovery of a need to actively seek information about new practices to satisfy that need.

Adoption and context

Consumers purchase products to satisfy their needs. Since the needs of consumers vary, one product usually will not meet the needs of all consumers. Consequently, products with different characteristics are required to satisfy the needs of different consumers.

Differences in consumers' needs arise for a variety of reasons, one of the most important being the usage situation or context in which the product is consumed (Assael 1998). For example, the uses for paper towels have been classified into heavy duty (cleaning ovens, washing windows and cars), light duty (wiping hands, counters and dishes) and decorative (placemats, napkins). Clearly, paper towels with different

characteristics are needed for each of these situations. Consequently, consumers will employ different criteria to choose between brands of towels depending on the usage situation they are purchasing for.

Differences in farmers' needs also arise for a variety of reasons, again one of the most important being the usage situation. In the case of farming, the usage situation is defined by the farming context. This is the mix of practices and resources used on the farm that influence the benefits and costs of adopting the innovation (Kaine and Lees 1994).

Rogers and Shoemaker (1971) identified five factors that influence the rate of adoption of innovations. These were:

- Relative advantage, which is the degree to which a new product is perceived to be superior to existing substitutes.
- Compatibility, which is the degree to which a new product is consistent with needs, attitudes and past experience.
- Simplicity, which is the ease with which a new product can be understood and used.
- Observability, which is the ease with which a new product can be seen.
- Trialability, which is the degree to which a new product can be tested or sampled before adoption.

In terms of the adoption of agricultural innovations, relative advantage and compatibility are usually strongly related since the benefits of adopting a new practice depend heavily on the ease with which it can be integrated into the existing mix of practices and techniques used in the farm enterprise. In effect, the resources and mix of practices and techniques used in a farm enterprise, the farm context, describe the agricultural equivalent of the consumers' usage situation.

Extension and market segmentation

The objective in this study is to identify the key factors influencing the adoption of micro irrigation, soil moisture monitoring and soil testing for the tomato, onion, melon and carrot industries. As described earlier, the key factors that influence adoption are determined by the nature of the farm context. This means that differences in farm context across enterprises will give rise to differences among enterprises in the key factors that influence adoption. Consequently, enterprises can be classified into groups or segments based on the similarities and differences in their farm contexts. In other words, different market segments for an agricultural practice can be described by identifying key differences in usage situations, that is, key differences in farm contexts.

Where there are relatively few differences in farm contexts, agricultural enterprises can be classified into a small number of segments. The difference in these segments then provides the basis for developing targeted research and extension programs (Kaine and Lees 1994, Kaine, Lees and Sandall 1994, Kaine and Niall 1999, Kaine and Niall 2000). In these circumstances knowledge of the nature of segments and information on their size is needed to set priorities for resource allocation and to formulate strategies. This means quantitative information on the segment sizes and relationships is required.

Where there are only one or two differences in farm contexts then enterprises can be classified into one or two segments. In this situation strategies can be formulated and priorities determined based on knowledge of the nature of segments and limited information on their size. In this situation quantitative information on the segment sizes and relationships is usually unnecessary.

Where there are many differences in farm contexts then many, relatively small segments are present. In other words, the market is fragmented. In this case, identifying and quantifying segments is problematic because each segment is too small to justify the targeting of research and extension resources. Instead, research activities need to be directed toward overcoming the source of fragmentation.

Key factors in the adoption of irrigation systems

To date we have investigated the adoption of irrigation systems in a number of industries including dairying, stone and pome fruit and grape growing (Kaine and Bewsell 2000a, Kaine and Bewsell 2001a, Kaine and Bewsell 2000b and Kaine and Bewsell 2001b). This work has revealed that the key factors that affect the adoption of irrigation systems can be grouped into the five categories described below.

Soils and topography

Different irrigation systems suit different soil types and topography. Flood irrigation is not an option, for example, on undulating country or highly permeable soils. Spray irrigation or drip irrigation better suit these circumstances.

To illustrate, in the dairy industry we found that laser graded flood irrigation suited the soil types and topography in the Northern Irrigation Region of Victoria (Kaine and Bewsell 2000a). In contrast, we found that spray irrigation was more suitable than flood irrigation on farms with light sandy soils and undulating topography in the Macalister Irrigation District in Gippsland (Kaine and Bewsell 2001a).

The grape industry in Sunraysia provides another example. Furrow irrigation was the original method that was used to irrigate vineyards even though the soils are relatively permeable. To counter the problem of permeability grapes were grown in small blocks of short rows. In recent years growers have been redeveloping their vineyards to longer rows in order to use mechanical harvesting and pruning techniques. This means furrow irrigation is no longer an option and growers have shifted spray or micro-irrigation techniques (Kaine and Bewsell 2001b).

Saving water

In areas where water is a limiting resource producers are likely to adopt micro-irrigation techniques to maximise production from their limited water supplies. This is the case for stone and pome fruit growers in Tumut and Batlow districts of New South Wales (Kaine and Bewsell 2000b).

Saving time

A key factor for many producers in their choice of irrigation system is the need to save time. For some growers this may simply amounts to reducing the amount of time they need to devote to the task of irrigating. For others, the need to save time encompasses both a need to reduce the amount of time they spend irrigating, need to save time undertaking other activities such as harvesting and spraying, and a need to increase their flexibility in the timing of these activities.

For example, the need to save time spent irrigating was particularly apparent in the dairy industry (Kaine and Bewsell 2000a). Many dairy farms originally consisted of numerous narrow, short irrigation bays with small outlets. Consequently, farmers were spending many hours, often at night, changing irrigation bays and checking on the irrigation generally. Laser grading allowed farmers to consolidate many small bays into a few large bays thereby dramatically reducing the amount of time that needed to be spent irrigating (Kaine and Bewsell 2000a).

Growers in the stone and pome fruit industry have redeveloped their orchards and adopted micro-irrigation in order to save time irrigating, harvesting and spraying, and to increase their flexibility in the timing of these activities (Kaine and Bewsell 2000b). Redevelopment involves planting trees more densely in longer rows using trellising techniques. This enables harvesting to be mechanised saving time and money. Redevelopment requires the adoption of micro-irrigation, as closer planting layouts are not suited to furrow irrigation. Since the orchard floor remains dry with micro-irrigation systems growers are able to irrigate, harvest and spray concurrently with these systems. Hence, their flexibility in timing these activities is enhanced (Kaine and Bewsell 2000b).

Crop quality

Crop quality can also be a factor in the choice of irrigation system. For example, we found in interviews with grape growers that, for some growers, a need to improve the

quality of the grapes they grew was a key reason in their decision to adopt a pressurised irrigation system (Kaine and Bewsell 2001b).

Crop yield

A growers decision to adopt an irrigation system can also be influenced by the potential the system offers to lift their yields. For example, we found growers of table grapes had adopted micro-irrigation to reduce problems with disease and pests in the grape canopy, thereby increasing yields (Kaine and Bewsell 2001b).

In conclusion, the choice of irrigation system depends on biophysical characteristics such as soils and topography and the availability and quality of irrigation water. The choice of irrigation system is also influenced by enterprise characteristics such as the supply and demand for labour. Finally, the choice of irrigation systems may also be influenced by considerations such as crop quality and yield.

The adoption of irrigation systems in vegetable production

To identify the factors that influence the adoption of irrigation systems for tomatoes, both fresh and processing, onions, melons and carrots we interviewed vegetable growers in three regions. These regions were the Murray Bridge region of South Australia, the Murrumbidgee Irrigation District centred on Griffith in New South Wales, and the Northern Irrigation Region centred on Shepparton in Victoria. The interviews are reported in Appendix A.

Our interviews with growers revealed that soil type is the fundamental factor influencing growers' choice of irrigation system in each of the three regions. This is because the rate of build up of soil borne disease differs across varies across soil types. The rate of build up is greatest in soils that are highly permeable (light sands) and soils that are impermeable (heavy clays). Growers with these soils are unable to grow successive crops of vegetables from the same scientific family and must follow a crop rotation. The rate of build up appears lowest in soils of moderate permeability. Growers with moderately permeable soils are able to grow vegetables from the same family for two and sometimes three successive seasons.

The results of the interviews in each region are summarised below.

Murrumbidgee Irrigation Area, New South Wales

The growers we interviewed in the Murrumbidgee Irrigation Area grew either carrots, onions, melons or tomatoes, or a mix of these vegetables.

Soil type and topography

All of the growers we spoke to in the Murrumbidgee Irrigation Area had experienced problems with soil borne diseases. Soil borne diseases build up rapidly over a season in the relatively impermeable clay soils in this region, especially to the south and east of Griffith. Consequently, growers cannot plant vegetables from the same scientific family in successive seasons.

Growers had two different approaches to coping with the problem of soil borne diseases. Growers that grew vegetables on their own property used furrow irrigation and followed a four, five or six year rotation. The growers indicated that drip irrigation was too expensive because the need to rotate crops meant they were unable to generate sufficient revenue to cover the cost of installing drip lines. Drip would become a viable option if two or three crops could be grown in successive seasons on the same land. Growers were experimenting with a range of crops to identify rotations that would maximise income.

Growers that grew vegetables on leased land simply shifted to a new site each season. These growers also used furrow irrigation as drip irrigation is simply too expensive to install for one season.

The opposite is true for growers located in the Hillston area to the north and west of Griffith, and along the Murray River, with more permeable soils and undulating ground. Growers are trialing continuous cropping of tomatoes or melons over two to three years in these areas. The results to date have been favourable. Growers have produced two or even three crops from the same ground in successive seasons without experiencing any decline in yields or significant build up of disease in the soil. On these soils drip irrigation is a more attractive option than furrow irrigation.

Saving water

None of the growers we spoke to in the Murrumbidgee Irrigation Area reported that they had experienced any problems in obtaining sufficient water for vegetable production.

Saving time

Growers in the Murrumbidgee Irrigation Area had a considerable labour force at their disposal for planting, weeding, spraying and harvesting. Consequently, none of the growers indicated that time or labour was a factor in their choice of irrigation system.

Crop quality

Some of the growers we interviewed were experimenting with drip irrigation in an effort to improve crop quality so as to sell into particular high return markets. For

example, one grower who was planning to produce export quality melons had been experiencing problems with stains and discolouration. In an attempt to overcome these problems, this grower was trialing drip irrigation in a block of honeydew melons.

Crop yield

None of the growers we interviewed indicated that crop yield per se was a factor in their choice of irrigation system because of the over-riding impact on yield of the relationship between soil type and disease.

In our view, it is highly unlikely that vegetable growers in the Murrumbidgee Irrigation Area are not adopting drip irrigation systems because of a lack of knowledge or skills. Several vegetable growers we interviewed were growing grapes using drip irrigation and were using soil moisture monitoring to schedule irrigations in their vineyards. Yet, at the same time, these growers were continuing to use furrow irrigation on their vegetable crops and were relying on their experience to schedule irrigations on these crops.

These growers believed installing drip irrigation in their vineyards was worthwhile because they could obtain significantly higher returns from their grapes by precisely controlling grape quality and yield. They believed a similar investment in their vegetable enterprise could not be justified because of the need to rotate vegetable crops to control diseases in the soil.

In conclusion, soil type and topography is the fundamental factor governing the choice of irrigation system for vegetable growers in the Murrumbidgee Irrigation Area district. More permeable soils in undulating country favour drip or pressurised irrigation systems, while for furrow irrigation is more effective on impermeable, heavier soils. In short, the need to rotate vegetable crops to alleviate problems with the build up of disease in heavier, more impermeable soils means that furrow irrigation is more attractive than drip irrigation furrow in much of the Murrumbidgee Irrigation Area.

Murray Bridge, South Australia, and Swan Hill, Victoria

We interviewed onion growers in the Murray Bridge region of South Australia, together with carrot and melon growers in the Swan Hill district of Victoria. Once again soil type was the key factor influencing the choice of irrigation system in these areas. The area around both Murray Bridge and Swan Hill is undulating country with light, highly permeable, sandy soils. Sprinkler irrigation is the predominant irrigation system in these areas. Sprinklers come in various forms – either fixed, portable or centre pivots.

Soil type and topography

The growers around Murray Bridge and Swan Hill indicated that sprinkler irrigation is the only feasible irrigation systems given their soil types and topography. Furrow irrigation is impractical because the soil is highly permeable and the country is undulating. Drip irrigation is not feasible because there is no capacity with this type of irrigation to protect vegetable crops from sandblasting. Sprinkler irrigation systems are effective in undulating topography and on permeable soils. Most importantly, they can also be used to provide protection to crops from sandblasting by wetting the soil around the crop and reducing soil movement. Growers indicated they also used other management strategies such as windbreaks and planting into stubble to alleviate problems with erosion and sand blasting.

Saving water

None of the growers we interviewed had problems obtaining adequate supplies of irrigation water.

Saving time

None of the growers we interviewed indicated that time or labour was a factor in their choice of irrigation system. However, some of the growers we spoke to around Murray Bridge had used timers to automate their pump and sprinkler system to reduce the time they spent irrigating.

Crop quality

Some of the growers we interviewed had experienced problems with crop quality when water application was uneven because of high winds or because of excessive heat.

The ability to control the uniformity of water application on windy days was a factor in growers' decision as to which type of spray system they installed. For example, wind affects the evenness with which water distributed with fixed and portable spray systems creating wet and dry spots in crops. This is a problem for growers in both Murray Bridge and Swan Hill. From interviews with these growers it was clear that this is less of a problem with centre pivot systems. Some growers indicated they often irrigated at night to alleviate this problem.

Excessive heat can also create problems with crop quality. For example, growers in Murray Bridge indicated that onions are vulnerable to sunburn in the weeks leading up to harvest. Sprinklers provide a means to reduce temperatures in the crop and prevent sunburn from occurring. Permanent and solid set (portable) sprinklers are ideal for this situation as growers can use these systems to irrigate for a short period in the morning of a hot day. This prevents disease problems but provides the crop with extra moisture in the soil. Centre pivots are not as effective in controlling heat as these systems can take six hours or more to irrigate a crop.

Crop yield

All of the growers we spoke to indicated crop yields were satisfactory under sprinkler irrigation.

To summarise, the key factor in growers' choice of irrigation systems in the Murray Bridge and Swan Hill regions is soil type and topography. Drip irrigation is less attractive than spray irrigation on the light, sandy soils and undulating ground in these regions.

Victoria

There is a mix of growing conditions and irrigation systems in Victoria. We included our interviews with growers in the Swan Hill region of Victoria in our discussions of interviews with growers in South Australia as the growing conditions in these two regions are quite similar. Both these regions have light, highly permeable sandy soils and undulating country. The other Victorian growers we interviewed were producing fresh market or processing tomatoes and were based around Shepparton. We found that like growers in the Murrumbidgee Irrigation District and in South Australia, soil type was a key factor in the choice of irrigation system for Victorian growers.

Soil type and topography

The build up of disease in soils meant that most growers around Shepparton had to move to new ground every year. The need to move each year was forcing growers to look further afield for new ground. Some tomato growers had been forced to adopt drip irrigation as they had moved into undulating country where furrow irrigation is not possible.

Saving water

None of the growers we spoke to in Victoria had experienced problems obtaining supplies of irrigation water although water allocations have been below average for a number of years. They indicated that they had no difficulties purchasing extra water.

Saving time

For most growers, time and labour was not a factor in their choice of irrigation system. Many of the growers we interviewed indicated that one person on the property was dedicated to doing the irrigating. However, the fresh market tomato growers we interviewed did cite timely harvesting as one reason for adopting drip irrigation as this type of irrigation allows growers to irrigate and harvest concurrently.

Crop quality

Fresh market tomato growers raised crop quality as a key factor in their adoption of drip irrigation. Compared to furrow irrigation, drip irrigation ensures a cleaner crop

and provides the flexibility to irrigate while harvesting. This allows growers to optimise crop quality by harvesting eight or more times in a season.

Crop yield

Some growers indicated they had experienced higher yields for processing tomatoes by using drip irrigation. However this was observation was not made by all growers and appeared to be associated with differences in location.

To summarise, drip irrigation is a viable alternative to furrow irrigation on the moderately permeable soils around Shepparton. Fresh tomato growers prefer drip irrigation because of the capacity this system provides for them to optimise crop quality. However, problems with soil borne disease does mean that both fresh and processing tomato growers are forced to regularly shift to new ground, or follow some form of crop rotation.

Conclusion

The key factor influencing vegetable growers' choice of irrigation system is soil type and topography. In the heavier, relatively impermeable soils in the Murrumbidgee Irrigation Area growers have found that soil borne diseases rapidly develop into a serious problem. Their response has been to either lease new land each season or to follow a crop rotation. In these circumstances furrow irrigation is a more attractive than drip irrigation. However, on the lighter, more permeable soils in some districts in the Murrumbidgee Irrigation Area the build up of disease in the soil is slower and two or three crops can be grown successively on the same ground. In this case drip irrigation is an attractive investment.

Growers around Murray Bridge in South Australia and Swan Hill in Victoria have found the highly permeable, sandy soils and undulating topography in these areas favours the adoption of sprinkler irrigation. Sprinkler irrigation gives growers the capacity to manage problems with sandblasting, erosion and heat.

Fresh tomato growers around Shepparton in Victoria have found that although disease build up in their moderately permeable soils means they need to lease new ground each year, drip irrigation is an attractive investment because it provides growers with the capacity to optimise crop quality. With regard to processing tomatoes, the choice between furrow and drip irrigation is largely determined by soil type and topography.

Our results indicate that, with the exception of fresh tomatoes, soil type and topography determine the type of irrigation system that is used in vegetable production. This suggests vegetable growers can be classified into three segments in on the basis of their location and the type of vegetable the produce. One segment consists of growers on heavy, impermeable clay soils that use furrow irrigation. The second segment consists of growers on light, highly permeable, sandy soils that use spray irrigation. The third segment consists of fresh tomato growers and growers on moderately permeable soils, especially where the topography is undulating, that use drip irrigation.

Given that vegetable growers can be classified into one of three segments on the basis of location and crop type we believe there strategies and priorities for research and extension can be formulated without the need for a large scale, quantitative survey.

Scheduling and soil moisture monitoring

In our interviews with vegetable growers we discovered that most growers did not believe that soil moisture monitoring equipment would provide them with any valuable additional information in the long term even though most did have some experience with monitoring equipment. Although all the growers we interviewed agreed that vegetable crops are particularly sensitive to the timing of irrigations, they believed they had acquired through experience the irrigation management skills that are needed to control crop quality and quantity.

Those growers who were using soil moisture monitoring equipment were using the equipment either to familiarise themselves with cropping a new lease, to address a problem in a particular block, or as a means of checking their irrigation management was working adequately.

Growers raised a number of problems with soil moisture monitoring equipment. First, the number of probes that need to be installed in a block, and their arrangement across the block, depends on the variation in soil types within the block. If the soil profile is relatively uniform then the soil moisture across the block can be predicted using only a small number of probes. Consequently, soil moisture monitoring will be relatively inexpensive to install and taking soil moisture readings will be a simple task. However, irrigation management is relatively straightforward in these circumstances.

On the other hand, if the soil profile is quite diverse then a large number of probes is required to predict soil moisture in different parts of the block. Consequently, soil moisture monitoring will be relatively expensive to install and taking soil moisture readings will be a time consuming task.

The need to follow a crop rotation or to move leases also creates a problem with monitoring equipment as it then becomes necessary to move the equipment each season.

As a final point, monitoring equipment may be employed as part of an automated irrigation system. However, none of the growers we interviewed had automated their systems in this way. Several growers raised the possibility of doing so in the future but did not see that this type of automation offered any benefits at present. The growers felt sufficient savings were available in terms of time and labour by using timers to automate irrigation systems.

Soil testing

Most growers in all three regions tested their soils on a regular basis and used the information to help develop a fertiliser program for the crop. The information from the test would also indicate whether lime or gypsum might be required. Most growers were testing to ensure their fertiliser program was adequate. Growers also commissioned tests when they experienced a problem with a block, or if they thought a problem might develop.

As a rule, growers commissioned a soil test when they moved to a new lease. Some growers did not test a new lease if detailed fertiliser records had been kept.

None of the growers we interviewed had a problem with salinity. Although information on salinity was generally included in the test results, most growers felt it was not particularly relevant or useful to them as they avoided planting in areas where they thought there might be a problem with salinity.

Conclusion

Interviews with growers revealed that the crucial factors driving the choice of irrigation system for vegetable production were soil type and topography. There is a strong association between soil type and the rate with which bacterial and fungal diseases build up in the soil. Based on our interviews with growers it appears that the

rate of disease build up in the soil is fastest in highly permeable and impermeable soils, and slowest in moderately permeable soils. The rapid rate of build up of disease in highly permeable and impermeable soils means that vegetables from the same family cannot be cropped in successive seasons. Consequently, growers must follow lengthy crop rotations. This renders drip irrigation prohibitively expensive for vegetable production in many areas. In some areas with an undulating topography furrow irrigation is impractical and growers use pressurised irrigation systems.

The availability of irrigation water or a need to save time or labour were not raised by growers as factors in their choice of irrigation system. Growers did not mention crop yield per se as a factor in deciding on an irrigation system. Considerations of yield did, of course, underlie their observations on the association between soil type and disease. Optimising crop quality was a factor in the choice of irrigation system for growers of fresh tomatoes.

Our results indicate that vegetable growers can be classified into three segments in on the basis of their location and the type of vegetable the produce. One segment consists of growers on heavy, impermeable clay soils that use furrow irrigation. These growers lease new land each year or follow lengthy rotations to overcome problems with soil borne disease. This renders drip irrigation too expensive to be practical. These growers are mostly located in the Murrumbidgee Irrigation Area.

The second segment consists of growers on light, highly permeable, sandy soils that use spray irrigation. These growers are located around Murray Bridge in South Australia and Swan Hill in Victoria. Spray irrigation also allows these growers to manage problems with sandblasting, erosion and heat.

The third segment consists of fresh tomato growers and growers around Shepparton in Victoria and parts of the Murrumbidgee Irrigation Area on moderately permeable soils, especially where the topography is undulating, that use drip irrigation. The rate of build up of disease in these soils is slower. This allows growers to produce two or three vegetable crops in successively seasons on the same ground. This means drip irrigation becomes viable.

Given that vegetable growers can be classified into one of three segments on the basis of location and crop type we believe there strategies and priorities for research and extension can be formulated without the need for a large scale, quantitative survey.

Many growers felt there were no long-term benefits to be had from using soil moisture monitoring equipment. Those growers who used soil moisture monitoring did so to establish an irrigation program when irrigating a new lease or, on larger properties, as a means of occasionally checking their irrigation management was adequate.

Most growers undertook soil testing on a reasonably regular basis. As a rule, growers commissioned soil tests for new leases and to assist them with resolving problems in particular blocks. Salinity was not an issue for any of the growers we interviewed.

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Appendix A

Grower interviews

Murrumbidgee Irrigation Area New South Wales

1. Joe, Hanwood MIA

Joe and his two brothers runs a large property growing vegetables, citrus, vines and rice. They primarily grow melons as part of a rotation with wheat and rice. They grow the melons on six feet beds, irrigated with siphons from open channels. On the vines they have converted to drip irrigation because of the water saving – they can then use the water on other parts of the farm, and because it gives them more flexibility.

Joe uses a C-probe in the vines but wouldn't put it in the vegetables because of the rotations. They were involved in some trial work using soil moisture monitoring on the melons but didn't go ahead with it for this reason.

Joe obtains a pH test on the soil before planting the melon beds so he can draft a fertiliser regime. He has done a full soil survey under the vines but doesn't think it would be worthwhile on the melons.

2. Francis, Griffith MIA

Francis runs a large property just out of Griffith. He grows carrots, onions, rice, wheat and corn in rotation. He furrow irrigates the carrots, onions and corn. A few years ago he bought a centre pivot to convert from furrow irrigation. However he found it was the worst way of irrigating his vegetables. The soil type he grows on is medium to heavy and the pivot kept on getting bogged. He spent more time trying to make sure the pivot was irrigating properly than he would have furrow irrigating. He went back to siphons from furrows because he didn't need the extra headaches!

He doesn't use soil moisture monitoring as he is experienced in working out irrigation programs.

He soil tests for fertiliser before planting vegetables. He checks particularly for residual fertiliser so he doesn't over fertiliser with the following vegetable crop. He doesn't have any salinity problems.

3. John, Whitton MIA

John runs a large property out of Whitton growing processing tomatoes, corn, rice and grapes. He furrow irrigates his vegetable crops as he can only get one crop before having to move to new ground. This doesn't make putting a drip irrigation system in very viable. The soil type he is growing on is medium to heavy and suits furrow irrigation. However his partner in the business who also growing processing tomatoes has found drip is an excellent system on the lighter soils out towards Hillston.

John uses a consultant to help him schedule his irrigations. The consultant uses a neutron probe and also gives a visual appraisal of the crop. John knows the consultant has experience in managing tomatoes so knows the information he gets given will be of use. He uses the information as a check to make sure everything is under control.

John used to soil test every paddock every year, but it got very repetitive. Now he incorporates the stubble from the previous crop into the soil before planting a vegetable crop. He has also started using chook manure to help improve the soil.

John has several on farm storages, as well as a recycling dam. He also has a groundwater pump.

4. Scott and Ashley, Darlington Point MIA

Scott and Ashley manage a large corporate property near Darlington Point. They grow onions and carrots, as well as vines and olives. They furrow irrigate the vegetables and olives, but the grapes are under drip irrigation. They don't believe it is worth putting in drip for the vegetables because they can only crop onions once every five years. To continuously crop they would need to fumigate the soil each season. They are happy with the crops they get under furrow.

They use Adcon soil moisture monitoring equipment to schedule irrigations, but only on the grapes. Initially they did a soil survey with soil pits over the whole property and then used this information to pick out sites for the probe in each block of grapes. Scott also checks soil moisture with a shovel and auger.

They soil test for fertiliser and don't have any salinity problems.

5. Warren, Yoolgali MIA

Warren grows approximately 240 acres of melons on leased land just out of Griffith. Although most of the crop is under furrow irrigation he has a small trial investigating drip irrigation. He is trying drip to see if he is able to grow a "clean" honeydew melon. If these melons are dirty or stained it means they are not up to export quality. He has tried black plastic and laser grading but it

is a hassle to put down and pull up. Disposal is also hard. He hopes the drip works because there doesn't seem to be any other options.

Warren does not use soil moisture monitoring. He uses experience together with the shovel to work out his irrigation regime.

Warren does not soil test leased ground. He checks with the owner to see what fertiliser has been put on it and works out his fertiliser program from there.

6. Peter, Whitton MIA

Peter leases a large vegetable growing property out of Griffith, growing both melons and tomatoes. He used grow vegetables on a property the other side of Griffith where the soil type was heavier – the grey clay soil. However he had a lot of problems with rain at harvest which sometimes meant he lost crops because he wasn't able to get on the ground to harvest it. He moved to an area with lighter soil types (red clay loams) where rainfall at harvest was less of a problem. Peter says, "On these soils you can get an inch of rain today and pick tomorrow." With these soil types drip becomes much more viable. Now Peter grows melons and tomatoes under drip with plastic. He has to use the plastic to get the quality melons he needs. He isn't happy having to use the plastic but the system did not work as well without it. He is also finding that he can get two and possibly three crops from a paddock under drip by rotating melons and tomatoes. He is planting the third crop (melons) this year and will see how it goes.

Peter uses an EnviroSCAN along with a shovel and experience to schedule his irrigations.

He soil tests once a year for fertiliser, and follows up with sap tests during the season.

Murray Bridge South Australia and Swan Hill Victoria

7. Tom, Murray Bridge SA

Tom grows onions and potatoes on two properties in South Australia. He has 1000 ha all up, but not all of it irrigated at one time as he rotates the crops around the farm. He has three types of irrigation systems. They are – permanent sprinklers (ie sprinklers on posts), semi permanent aluminium lines and a centre pivot. Tom cannot furrow irrigate because of the soil types and topography. He has a mix of systems because not all his ground is suitable for pivots as it's important to have similar soil types under the pivot. With the permanent sprinklers or aluminium lines he is able to vary the jet size to adjust the water application so the soil type isn't as much of an issue. He does

have problems with uneveness under his sprinklers if it's windy though. Under centre pivots evaporation is more of a problem as it takes about 6 hours to move around a crop.

Tom has tensiometers in all his crops. He has tried the EnviroSCAN® but it was expensive to shift all the time with the crop rotations. He is currently investigating a radio controlled system so he would be able to download from his office, but is happy with the tensiometers for the moment.

He soil tests blocks for nutrients. Salinity is part of this test but he doesn't have a salinity problem. There are a couple of areas he has to watch, but generally it's the amount of salinity that comes in the irrigation water that he needs to check.

Tom has looked at underground drip irrigation in New Mexico. However he believes he couldn't go to drip because of the sandblasting problem in the area. He needs to wet the soil around the crop so it doesn't move when it gets windy. Tom says they have been moving towards a more biological approach with pest and disease management. He has been very happy with the results of this and feels because there has been les disease build-up they may be able to shorten the rotations depending on how things go.

8. David, Murray Bridge SA

David grows onions, potatoes and lettuce in a rotation on his property in South Australia. This year he has 280 acres under irrigation. Lettuce is grown on old blocks to help break the disease cycle. He has a 15 to 20 acre block under permanent sprinklers, solid sets for the rest of the home block and centre pivots that cover 75 acres at a time. The permanent sprinklers are very old and so aren't particularly efficient. They try not to use that block unless necessary for this reason. This year they have – in order to grow the amount of onions needed. The solid sets are moveable sprinklers. They are shifted around the home farm as needed. There are some problems with unevenness because of the strong winds they get. You can see the patterns in the crops and areas where there is more disease problems because more water went on that part of the crop. However the solid sets provide a means of cooling down the crop in very hot weather as they can be turned on for 20 minutes at the start of a hot day. This can make a huge difference to the amount of sunburn and heat damage in a crop.

David can't use pivots on the home farm because he needs open ground with a similar soil type for the pivots. Instead the pivot is on a new block, recently purchased. They chose a centre pivot as opposed to permanent sprinklers because it costs approximately $150 per acre for a pivot compared to $2,500 per acre for permanent sprinklers. The pivot is controlled by a computer system, giving the flexibility of being able to speed up or slow down if there are different soil types around the paddock. They have chosen a small pivot as David doesn't believe you can control soil loss on bare ground under a 75 acre pivot. They sow bare ground (ie the recently harvested part of the pivot

David has tried drip irrigation but found the wetting pattern did not allow him to keep enough water up to the crop.

They use both an EnviroSCAN® and tensiometers. The EnviroSCAN® is set up to send data via a telemetry system/radio frequency so information ca be downloaded at the computer. They use the tensiometers in patches that aren't wetting up properly or other problem areas. They've had the EnviroSCAN® for 10 years now and David says they can usually predict what it will say! The major lesson they learnt after putting in the EnviroSCAN® was that rainfall in summer does not go far. David says it's worth having the equipment to check the soil moisture so they can see how quickly the soil is drying out after rain and ensure they are not pushing water past the roots as well. They can also keep on top of the water use when the onions start bulbing. At this stage they use lots of water. They rely heavily on controlling the water applied to determine the size of the onions and crop amount.

David soil tests every year for nutrients. Salinity is part of this test but they've had no problems with salt. Generally it's the water quality that's a problem, although he's seen the river water quality improve over the last 5 years.

9. Jenny and Allan, Murray Bridge SA

Jenny and Allan grow 112 acres of onions around Murray Bridge in South Australia. They use centre pivots to irrigate most of their crop, with the remainder under shift line. The shift line is used in areas they are unable to get a pivot into or if they are growing a small amount of one variety and need to have it on a different irrigation schedule. They have some flexibility with the pivots as they can isolate one quarter of a pivot and have a different irrigation schedule, but this increases spraying and harvesting inefficiencies. They generally only crop once in an area before moving on to new ground. They tried drip irrigation on a small patch associated with a pivot where they were getting too much run off. They found however that the cost of setting up the system for only one year was too high. They are very happy with the performance of the pivots as they have less wind problems than other sprinklers, as long as they are scheduled well.

They use tensiometers for soil moisture monitoring as a check that the irrigations are going well. Again there are problems using soil moisture monitoring equipment as it must be moved every year. Jenny usually reads and checks the tensiometers while Allan checks the soil moisture with a shovel. Allan had tried to use tensiometers previously but had problems with the crop. The number they were told to water at was too high and so the crop dried out too much. Now they use a lower figure and it seems to be working better.

Jenny and Allan soil test on some patches either because a consultant has recommended it, they are worried about the nutrient level or because the fertiliser company offered to carry out the tests. But they know the soil and what fertiliser is required. The fertiliser is generally constant, however what is

not constant is the disease problems across the blocks. This is of more concern than salinity as salinity is not a problem for them. They are up quite high (on top of a cliff) so the drainage is good.

When they move onto new ground they need to clear it of rocks. It's best to have a centre pivot set up for a block in the preparation phase as you can wet the soil to help with the rock clean up or grow a cover crop (or for green manure) prior to planting onions. At the moment they are looking to buy another centre pivot so they can do this as they can't afford not to have a spare. If the preparation isn't right the crop suffers.

They irrigate at the end of the season, not because the onions need the water but because they want to try and reduce the heat in the paddock so the onions don't get sunburnt. They wouldn't be able to use drip for this!

10. Craig, Murray Bridge SA

Craig grows 100 acres of onions in South Australia, near Murray Bridge. He has approximately half under pivots and half under permanent irrigation. He says you need larger patches of similar soil for the pivots. He doesn't find the pivots are necessarily better as they are not quite as manageable as permanent sprinklers. However the pivots are more flexible and are less affected by wind. He doesn't believe drip would be very useful for growing onions. They need the overhead irrigation to wash off the downy mildew and so they can put fertiliser through the water.

Craig uses the EnviroSCAN® as a check on the irrigations. They've used this for eight to nine years. When they first started with the soil moisture monitoring they realised they needed to put on a bit more water. Now they use more water than before, however more efficiently. Craig uses it as a guide now to check how far the nitrogen has been flushed.

They soil test all the time for nutrients, and this test covers salt. They have no salinity problem.

11. Jeff, Mannum SA

Jeff runs a medium size onion growing property near Mannum in South Australia. He also grows sweet corn and a few pumpkins. The property is all under overhead permanent irrigation (sprinklers), although they are starting to move into centre pivots. Jeff says they have stayed with the sprinklers because of the sweet corn. They plant four to five acres every week so that the harvesting is staggered. However this means it's easier to irrigate using the sprinklers because the irrigation for each block can be properly tailored to the stage the crop is at. With the new pivots they are going to small pivots, 50 or 32 acres, rather than the usual 75 acres. This means they will still be able to irrigate specific sweet corn blocks but will be able to expand the area of corn

they grow. Jeff pumps directly from the river so is able to water when he needs to, although they generally try to water at night to take advantage of the reduced power costs.

Jeff uses Agrilink® probes to monitor soil moisture. They had previously been using tensiometers to check irrigations. However Jeff is very happy with the new system. They are changing their irrigation practices and are seeing the results in a more even crop. In particular they are finding that they need to increase the amount of water they were putting on at the start of bulbing (for onions) and decrease the amount of water they were putting on when bulbing stops when the crop doesn't need as much water. This is very clear on the graphs from the probes and Jeff says the results are good. They use shorter probes than for other crops (only 50 cm long, rather than 1 m). This is much more suitable for vegetable crops.

They use a computer program to run the sprinklers. Unlike most computer systems this means they don't have to run blocks in sequence which gives greater flexibility. They are also able to set the system to the minute. This means they are able to put the water on for 20 minute bursts for example if they want to cool down blocks in the middle of summer.

Jeff soil tests every onion block before planting. They are working with agronomists to fine tune their fertiliser application. However they don't have any salt problems at present.

12. Len, Swan Hill Victoria

Len grows carrots, onions and broccoli in rotation on 230 acres near Swan Hill. He irrigates with fixed sprays because he says "they are the only way to grow vegies properly". For the crops he grows and the soil types he has he knows drip would not work. He would have sandblasting problems, use more water to try and keep up with the crop demand and increase his pumping costs. He is happy with the crops he gets with the sprinklers.

Len doesn't use soil moisture monitoring. He checks the soil moisture with a shovel when he is out in the crop. He says "you have to look anyway" and doesn't believe that soil moisture monitoring equipment would give him any more information than he currently gets. He is able to set up the sprinklers using a computer program and irrigates at night to take advantage of the lower power costs.

Len soils test some of the time but is confident he knows his ground and what it needs. He would soil test blocks where he thinks there may be a problem.

Len gets frustrated that a lot of advice offered to vegetable growers is not suitable for his situation and is often given by people with no growing experience.

13. Paul, Swan Hill Victoria

Paul grows onions, broccoli and pumpkins on approximately 100 acres near Swan Hill. Onions are a summer crop, while the broccoli is grown in winter. He irrigates it all with fixed overhead sprays, a system he inherited from his Dad. The system has been in for 25 years and he finds it the best way to irrigate vegetables in this area. He says, "It's by far the best way." Over the years he has decreased the spacings of the sprinklers in order to reduce dry spots in windy conditions.

Paul has tried soil moisture monitoring in the past but there was no benefit. It told him what he already knew. It was an extra expense so he decided he didn't need to use it.

He soil tests occasionally but he finds it doesn't tell him anything knew as he knows his ground. He hasn't had any problems with salt but he has a couple of leaky pipes and about 4 acres got a bit wet. He thinks he may have to drain this area which he thinks will fix the problem.

Victoria

14. Brett, Colbinabbin Victoria

Brett and his brothers run a 200 ha processing tomato property near Colbinabbin. They furrow irrigate their crop from channels with siphons. Although it is a lot of work it is Brett's job to concentrate on the irrigation, while his brothers focus on other parts of the business. They are happy with the crop they get from furrow irrigating so see no reason to change at present. If they decided to change the way they irrigated they would install drip irrigation. Sprinklers would not work because tomatoes don't like wet leaves all the time. With drip, although there is less work during the season, it takes a lot more time to set up at the start. They would have to weigh up the benefits of this set up time as well the cost of changing blocks most years. They find it's not usually possible grow two crops on the same soil. Generally they would move two thirds of the plantings to new ground, and leave one third in the same place as last year. Occasionally they might try for a third year but the disease risk is high.

They grow on a mix of "ordinary" red soil and "good" grey soil. The property is set up so they can catch drainage water and store it in a series of dams. This also means they are able to fill dams from the channel so they are able to water when they want to.

Brett doesn't use soil moisture monitoring. He uses a shovel to check the soil and in that way tries to make sure that he "knows how it's going". He says "you stick those things [soil moisture monitoring equipment] in one place but

conditions vary in the paddock so you only get a limited picture". The furrow irrigation gets good results as long as he waters frequently.

They soil test every block before planting to get an idea how much phosphorus and trace elements are needed. They have no salinity problem. They also have tried sap testing last year and applied some foliar sprays based on that information. However they didn't really see a large improvement in the crop and so probably won't try again this year.

Brett estimates he uses between 6 and 7 ML/ha per season. Definitely no more than 7 ML/ha, a figure he uses to budget on and work out if he needs to buy temporary water. They irrigate wheat as well so not all the water goes to the tomatoes. Brett says this makes it a bit hard to be more precise about how much goes onto the tomatoes.

15. Richard, Rochester Victoria

Richard runs a large 520 acre processing tomato farm near Rochester. Ninety per cent of the tomatoes are irrigated using sub surface drip. The drip is allowing them to expand onto land they wouldn't be able to furrow irrigate. Richard says they have increased their yield by 50 per cent with drip and it's much easier to manage. They use slightly less water per acre, and even less per tonne of fruit produced. The drip allows them to apply fertiliser through the lines and prevent leaching of either fertiliser or water below the rootzone. Richard also finds there are fewer weeds to deal with as the top of the bed is dry. Weeding can only be done manually and so it expensive (to employ labour) and time consuming.

Richard still has a bit of furrow left. This is in an area that is very low lying. The soil is excellent but there is the risk of flooding. Richard doesn't want to risk losing not just a crop but an expensive drip system as well, so they furrow irrigate. He says it reminds them why they converted the rest of the area to drip!

Richard plants transplants on much of the ground. He able to do this with the drip irrigation, and it uses less water. They are short of water this year so this is important. If they direct seed they have to keep the ground moist for a week, using a lot of water. It's possible to do this with flood but not with drip. The transplants, being about 6 inches high, also have a head start on any weeds.

Generally Richard is able to grow three crops in a row (as compared to one on furrow). Then they would leave the ground for three to four years.

Richard has occasionally used tensiometers and Netafim data loggers. The data loggers don't give you a reading of how much water is in the soil, instead it's the graphs that give you the most information. How steep the lines are tells you how much water the plant is using and whether it is stressed. They can also check to make sure there is no water going beneath the rootzone. The shovel is also an important tool. Richard usually decides at the start of a

season whether it's worth putting probes in a block. It will depend on the soils.

Soil testing is carried out before planting for nutrients. They have no salinity problems.

16. Tom, Undera Victoria

Tom and Paula grow processing tomatoes, maize and chickpeas on a property just out of Undera. All these crops are grown under drip irrigation. Tom waters every day via a computer program set up in the office. He has a standing water order that ensures he is able to irrigate whenever he needs to. Tom and Paula crop tomatoes for one year before putting in grain crops. These repair the ground and allow a disease break, ensuring they get good tomato yields. Tom runs a four year rotation to ensure he gets good tomato yields. He finds that the redder/lighter soils tend to build up disease quicker than heavier soils.

Tom buries the drip tape about 20 cm. He bought tape that was designed to last two years. However this tape has been in the ground for six years with no sign of damage to date. He believes selection of tape is very important as insects and animals could damage it. He has had problems with mice in the past, after a maize crop.

Tom and Paula don't use any soil moisture monitoring. It would not provide any extra information for them. Tom uses tensiometers as a check in the orchard but doesn't see the need in the vegetables or grain crops. If he did decide to use monitoring equipment he would invest in some that was downloadable to the computer via telemetry for example. Tom uses the evaporation figures and weather information to decide on a schedule.

17. Ken, Murchison Victoria

Ken is a large fresh tomato grower near Murchison. The entire crop is under trickle (drip) irrigation. They have used drip for the last 14 to 15 years. They have found it's the best way to get even growth, good use of water and enables them to grow in areas where it's not suitable for flood irrigation. For example on undulating ground.

Ken tried soil moisture monitoring last year. He found that it matched what he was already doing and so doesn't see the need to keep using the equipment. He will keep doing what he has been doing. Ken plans on moving to new ground every two years so it would be an additional expense to move the equipment as well.

Ken soil tests every year before planting, looking particularly at pH and lime and gypsum requirements. He doesn't have a salt problem as he doesn't grow in traditional irrigation areas.

18. Phillip, Harston Victoria

Phillip grows approximately 300 acres of fresh market tomatoes around Harston. The entire crop is drip irrigated. Phillip has been using drip irrigation for 14 years and has found it to be very cost efficient. He is able to produce high quality tomatoes using drip irrigation, and saves a lot of time. He only needs one person to run the irrigation now. This person is also able to look after the spraying. Drip irrigation gives great deal of managerial flexibility. Phillip also uses black plastic mulch. This helps prevent flooding as the water runs off the plastic and drains quickly.

Phillip usually crops a piece of ground for two years before leaving it for two to three years in fallow. This gives the soil a chance to dry out and breaks the disease cycle. They begin preparing a paddock up to 12 months before planting – laser grading, bed preparation and gypsum application. They pull up the drip tape each year and install new tape with a new crop. They have found they have to do this otherwise they have problems with drippers blocking up and leaks.

Phillip has an on farm storage so that he is able to irrigate on demand.

Phillip does not use soil moisture monitoring. He judges irrigation demand by plant colour. Tomatoes will show signs of stress quite quickly so he is confident that he is able to pick up any problems. He has to check each field every day for pests, so checking plant colour for moisture is easy.

The only problem he has at present is the disposal of the plastic and drip lines. This is a large problem and doesn't show any signs of getting easier to deal with!

Table 1: Grower case studies scored against the key factors influencing a growers' decision to change their irrigation system

No	Soil	Save water	Quality	Save time	Crop yield	Overall
14	0	0	0	0	0	Furrow
1	0	0	0	0	0	Furrow
2	0	0	0	0	0	Furrow
3	0	0	0	0	0	Furrow
4	0	0	0	0	0	Furrow
7	1	0	0	0	0	Sprinklers
8	1	0	0	0	0	Sprinklers
9	1	0	0	0	0	Sprinklers
10	1	0	0	0	0	Sprinklers
12	1	0	0	0	0	Sprinklers
11	1	0	0	0	0	Sprinklers
13	1	0	0	0	0	Sprinklers
15	1	0	0	0	1	Drip
17	1	0	1	0	0	Drip
18	1	0	1	1	0	Drip
6	1	0	0	0	0	Drip
5	0	0	1	0	0	Trialing drip
16	0	0	0	0	0	Drip, trialing alternative crop rotations

Soil Monitoring, Irrigation Scheduling and Vegetable Production

Second report

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Soil Monitoring, Irrigation Scheduling and Vegetable Production

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5 April 2002

Executive Summary

In this report we used information from a previous qualitative study in the vegetable industry to develop extension strategies for irrigation management of vegetable crops. The study revealed that the crucial factors driving choice of irrigation system for vegetable production were soil types and topography.

We found that soil type influences the build up of soil borne diseases. Growers revealed that light to medium soils had a slower build up of disease than very light or heavy soils. This means crop rotation is critical in order to break the disease cycle. The topography in some areas meant furrow irrigation was not practical, forcing growers to use some form of pressurised irrigation system.

The qualitative study also revealed that many growers' felt there were few benefits to adopting soil moisture monitoring. Those growers who had adopted soil moisture monitoring did so to provide information when irrigating new ground, or as a check on larger properties to ensure the irrigation management was working adequately.

Two focus groups with industry representatives and research and extension staff from NSW and Victoria were organised to review and interpret the results of the market research and to develop draft extension strategies. Validation interviews were then undertaken with growers to confirm that the extension strategies developed were relevant.

Based on the outcomes of the focus groups, the validation interviews and the results of the earlier study we recommend:

- A research strategy is developed to explore options for high return crops to be used in rotation with vegetables.

- A research strategy is developed to understand the build up of soil borne diseases in different soil types.

- A strategy is developed to facilitate the change from furrow to drip or spray irrigation by providing advice and assistance to vegetable growers on the management of these irrigation systems when they are first installed. In developing this strategy the information needs of growers will vary. Growers that are converting to drip or sprinkler systems on heavy soil will have different needs compared to growers that are converting to drip or sprinkler systems on lighter soils.

- That strategies to facilitate the change from furrow to drip or spray irrigation include recommendations to growers to use soil moisture monitoring to help establish irrigation schedules for newly installed drip or sprinkler irrigation systems.

- Long term soil moisture monitoring demonstration sites be established to provide information and assistance to growers in choosing and installing soil moisture monitoring equipment and in interpreting data.

- A strategy is developed to promote the use of soil moisture monitoring as a technique for managing problems such as crop vigour, high water tables and salinity and to assist growers in establishing irrigation schedules when planting vegetables on new blocks.

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All errors and omissions remain the responsibility of the authors.

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Soil Monitoring, Irrigation Scheduling and Vegetable Production

Introduction

In a previous report (Bewsell and Kaine 2002) we described the results from the qualitative study into the adoption of drip irrigation, soil moisture monitoring and soil testing in the vegetable industry. The results from that study were used to develop extension strategies and recommendations for promoting the adoption of drip irrigation, soil moisture monitoring and soil testing. These strategies and recommendations form the subject of this report.

The qualitative study revealed that the crucial factors driving choice of irrigation system for vegetable production were soil types and topography. Soil type influences the rate of build up of soil borne diseases. Diseases build up on a crop over a season. Once the crop is harvested the disease lies dormant in the soil. When a new crop is planted the disease is able to infect the crop. Interviews with growers revealed that light to medium soils had a slower rate of build up of disease than very light or heavy soils. The build up of disease in soils means crop rotations are required in order to break the disease cycle.

We found that in some areas growers had no choice but to use a pressurised irrigation system because the soils were light and sandy or because the terrain was undulating.

We were able to classify vegetable growers into three irrigation system segments based on soil type and topography, and the type of irrigation system they chose. The segments, which are summarised in table 1, were as follows.

- The first segment consisted of growers who use furrow irrigation on heavier soil types. Disease build up is quite rapid in heavy soils and these growers find that moving to new ground each year means investment in drip irrigation is impractical. Most of the growers in this segment come from Griffith, NSW.

- The second segment consisted of growers who use sprinkler irrigation because it allows them to manage soil movement on the very light sandy soils. Most of the growers in this segment come from Murray Bridge in South Australia and Swan Hill in Victoria.
- The third segment consisted of growers who use drip irrigation on light to medium soils. For some growers disease build up is slower and several crops can be grown in succession. Other growers in this segment, for example, fresh market tomato growers, use drip irrigation because of improvements in crop quality even though disease build up means shifting to new ground each year. Most of the growers in this segment come from Victoria.

The results from the qualitative study indicated that the area under furrow irrigation was not likely to change unless alternative crops for rotation could be found or there was an opportunity to grow different quality produce that could only be produced using a pressurised irrigation system. This suggests the rate of adoption of drip or sprinkler irrigation may be influenced through research and extension activities that are focussed on investigating disease build up and crop rotations. The results also suggests that extension activities that promote the benefits of increased water use efficiency that result from using drip or sprinkler irrigation systems are unlikely to be effective in increasing the adoption of drip or sprinkler irrigation.

The qualitative study also revealed that many growers' felt there were few benefits to adopting soil moisture monitoring. Those growers who had adopted soil moisture monitoring did so to provide information when irrigating new ground. Some growers on larger properties used soil moisture monitoring as a check to ensure the irrigation management was working adequately.

Soil testing was undertaken as required and used to develop fertiliser programs. Growers were more likely to soil test new ground and areas they felt could be problematic. Salinity was not an issue for any of the growers we interviewed.

Table 1: Summary of irrigation system segments.

	1	2	3
Type of irrigation system	Furrow	Sprinklers	Drip
Soil type	Heavy	Very light	Light – medium
Rate of disease build up	Fast	Fast	Slower
Main location	NSW	SA	Victoria

Irrigation segments and extension strategies

Two focus groups were used to develop extension strategies and priorities using the information and perspective's gained from the qualitative study and the knowledge and experience of Department and industry staff involved in irrigation extension for vegetable crops. Draft strategies were developed for an extension program using the program logic approach (Mayeske, 1994).

We took the view, in developing extension strategies, that these strategies would need to target growers who were dissatisfied with their irrigation and, as a result, would be likely to be motivated to change their irrigation management. The starting point in the process of formulating extension strategies was identifying the range of problems that could potentially create dissatisfaction on the part of growers with respect to irrigation management.

Following Mayeske's (1994) procedure the problems that could potentially cause dissatisfaction with irrigation management for growers were categorised into problem trees. Solutions to these potential problems were then developed. These problem and solution trees are summarised in appendix A.

A number of issues were identified that could potentially cause dissatisfaction with irrigation management for growers with furrow, sprinkler or drip irrigation. The main focus of the focus group participants was on drip and furrow irrigation as these are the most common types of irrigation systems used in New South Wales and Victoria. Consequently, the problems that were identified in the focus group concern difficulties either in dealing with the necessity for rotations or difficulties in managing drip or furrow irrigation systems in an annual cropping environment. However many of these factors would also be relevant to sprinkler irrigation management. The problems that emerged were classified into the following broad categories:

- High return crop rotations. It is difficult to find alternative crops to include in rotations with vegetables that are not susceptible to the same soil borne diseases.

Some growers are experimenting with alternatives, but there are few options at present.

- Problems managing furrow irrigation. Growers with furrow irrigation experience problems with soil borne diseases that force them to move to new ground each year. They may also use more water than growers with a drip or sprinkler system.
- Problems managing drip irrigation. Growers changing from furrow irrigation may experience problems establishing crops under drip irrigation and when developing new irrigation schedules. Growers with drip irrigation also face problems with soil borne diseases.
- Cheaper, disposable or portable drip irrigation systems. Systems that can be moved to new ground or that are cheap enough to be discarded help growers manage crop rotation requirements.

Given these problems, the participants in the focus group believed that Department extension programs could be promoted to growers by:

- Providing information directed at assisting growers to manage problems with furrow and drip irrigation, including assistance when growers are changing irrigation systems.
- Developing information through research on crop rotations and soil borne diseases.

A final round of interviews with a total of ten growers from New South Wales and Victoria were used to validate the extension strategies.

Few of the growers that were interviewed indicated that they had experienced any major problems managing either drip or furrow irrigation systems. For example a furrow irrigator:

> *Harry grows carrots on a property near Griffith. He furrow irrigates because "in our situation you stick to what works best". Irrigation and proper cultivation is crucial in carrot growing as otherwise the ground packs in too tight and restricts the carrot growth. Harry has to move to new ground every year as well because of the build up of disease. He is satisfied that furrow irrigation works well.*

From a grower with drip irrigation:

> *Tom and his brother grow processing tomatoes just outside Barooga. They grow approximately 45 hectares a year. They have drip irrigation. They went into drip some 18 years ago because their soil types are variable and it was hard to furrow irrigate. They are in marginal tomato country with very sandy to red loam soils. When they put in the drip they got an immediate yield benefit, more than doubling the yield they had been able to achieve on furrow. They have not had any problems managing the irrigation system and are very happy with the results.*

Some growers indicated they had overcome any problems that had arisen within a season or two through trial and error learning and discussions with other growers and with irrigation equipment suppliers. None of these growers indicated that they had experienced any long-term problems with irrigation management and all were satisfied with their current irrigation system and management. For example:

> *Clint manages 222 hectares of processing tomatoes near Echuca. He moves to approximately 60 – 80 hectares of new ground each year. Most of the soil he grows on is a black self mulching clay. Clint converted to drip irrigation 10 years ago because it was easier to manage, it promised yield increases and he could grow crops for four to five years in a row. He didn't have any major problems when he first put the new system in. Clint says managing the drip has become easier over the last few years as more products become available. There are also more growers converting to drip and thus more support offered.*

And:

> *Joseph grows fresh tomatoes on 59 hectares near Ardmona. He has been using trickle [drip] irrigation for eight to ten years. He likes the trickle [drip] irrigation as it improves the quality and yield of the tomatoes by getting the water right to the plant. He's not sure if he has worked out how to use the system "properly" yet, but he is pleased with the results he is getting. He believes there is still room for improvement. This season he is decreasing his block sizes, making the runs shorter and moving the sub mains. He is hoping this will even out the watering as at present the ends of the rows are not getting enough water. The crop should be more even with these changes.*

These responses suggest that there is a limited role for extension programs to facilitate the change from furrow irrigation to drip or sprinkler irrigation systems. Provision of

advice and assistance to growers on the management of these systems when they are first installed could be useful, including recommendations to use soil moisture monitoring to help establish irrigation schedules for newly installed drip and sprinkler irrigation systems.

Soil moisture monitoring segments and extension strategies

The main factor that the focus groups identified that prevented the adoption of soil moisture monitoring was the belief among growers that monitoring offered no benefits to them. Even those growers that had trialed soil moisture monitoring tended to hold this belief. The qualitative study revealed many growers felt that their experience gave them enough information to schedule irrigations effectively, contrary to the views of the focus group participants. Soil moisture monitoring was used by growers' to help irrigate problem areas or to deal with a new block. From the focus groups a problem tree was developed. The problems tree is reported in Appendix B, along with the solution trees that were also developed.

The extension strategy developed to promote soil moisture monitoring was to provide growers with information on the benefits of using soil moisture monitoring through demonstration sites. These sites would provide growers with advice and assistance in siting and calibrating soil moisture monitoring and in utilising monitoring information more effectively. The sites would provide valuable information in unusual circumstances such as dealing with a dry year or a vigorous variety. To this end the sites would need to be managed over several years.

Taken together with the irrigation extension strategies described earlier, extension programs could promote soil moisture monitoring to vegetable growers by:

- Promoting soil moisture monitoring as a technique for developing irrigation schedules for blocks recently converted to drip or sprinkler irrigation.
- Promoting soil moisture monitoring as a technique for developing irrigation schedules for newly developed land (eg leased blocks).

- Promoting soil moisture monitoring as a technique for managing problems with excessive crop vigour, salinity or water tables.
- Providing advice and assistance in siting and calibrating soil moisture monitoring and in utilising monitoring information more effectively.

These extension strategies were validated with the growers that we interviewed to validate the extension strategies for irrigation systems. It became obvious from these interviews that many growers with furrow irrigation did not believe there were any benefits to using soil moisture monitoring. From Harry, for example:

> *Harry grows carrots on a property near Griffith. He furrow irrigates because "in our situation you stick to what works best". Harry doesn't use soil moisture monitoring. He knows you need to be very careful irrigating carrots as too much water in hot weather can be just as detrimental as too little water. He feels his experience is sufficient and so does not need soil moisture monitoring.*

Several furrow irrigators we interviewed had also tried soil moisture monitoring and came to the same conclusions. For example:

> *Paul grows lettuce and melons on a property near Hay. Lettuce is their main crop over winter, and the melons will follow as a summer crop. All up they have approximately 20 to 30 hectares under crop each year. The soil type is a self mulching clay. Paul furrow irrigates. He doesn't use soil moisture monitoring equipment, although he has tried one system. He had some people out demonstrating it a few years ago but it cost a great deal and "was not really worth it". For the lettuce crop, because it grows in winter, he doesn't need to irrigate a great deal anyway.*

Growers with drip irrigation were more likely to view soil moisture monitoring favourably, although several growers had tried but longer used soil moisture monitoring equipment. Growers discontinued their use of soil moisture monitoring for a number of reasons. This included familiarity with their property and a belief the data collected did not provide them with any new information. For example:

> *Tom and his brother grow processing tomatoes just outside Barooga. They grow approximately 45 hectares a year. They have drip irrigation. Tom used soil moisture monitoring and evaporation information for a few years but stopped as he grew confident with the drip irrigation. The variable soil types*

made it hard to site equipment and meant he needed more sites than an average block. Tom is confident the irrigation is going well as he has 18 years experience on the same property!

A sprinkler irrigator expressed similar views on soil moisture monitoring:

Michael runs a 405 hectare property near Yarrawonga. His grows carrots, onions, cabbage, spinach and pumpkins in rotation. The entire property is under permanent sprinklers. Michael has tried soil moisture monitoring but found it very labour intensive. Michael did not have much use for the information. It confirmed that he was already getting it "pretty right".

Responses such as this suggest that it will take some time for extension strategies such as demonstration sites to have an effect on grower attitudes and behaviour.

Some irrigators with drip irrigation systems had found soil moisture monitoring to be a useful way of checking irrigation system performance. For example:

Clint manages 222 hectares of processing tomatoes near Echuca. Clint converted to drip irrigation 10 years ago. Clint uses tensiometers to monitor irrigations. The tensiometers ensure he is "doing the right thing". It took a couple of years to work out what were the appropriate readings for the soil type they were working with. And Clint double checks the readings with the shovel. Clint doesn't use tensiometers in all the blocks, instead he choses a few sites that he believes will give an average picture of the crop. He puts tensiometers in both old and new ground. Clint says that he may eventually move into a different system, perhaps more computerised but the tensiometers suit him at present.

However some growers with drip irrigation found the range of monitoring equipment available confusing, making it difficult to choose a system that suited their situation.

Mac grows processing tomatoes on 50 hectares near Boort. He converted to drip irrigation about 7 years ago. Mac uses tensiometers to monitor soil moisture. He started using them when he first put in drip irrigation, then went away from them for a while. Now he has gone back to them to check how things are going. They are however very labour intensive and only give a "snap shot" in time. Mac is looking at purchasing an automatic radio controlled downloadable system. However he is holding off buying anything until the market settles down a bit. He would like the Department to recommend a brand but he knows this is hard. He believes it would be good to see some testing of different systems across the industry.

Recommendations

Based on the outcomes of the focus groups, the validation interviews and the results of the earlier qualitative study we recommend:

- A research strategy is developed to explore options for high return crops to be used in rotation with vegetables.

- A research strategy is developed to understand the build up of soil borne diseases in different soil types.

- A strategy is developed to facilitate the change from furrow to drip or spray irrigation by providing advice and assistance to vegetable growers on the management of these irrigation systems when they are first installed. In developing this strategy the information needs of growers will vary. Growers that are converting to drip or sprinkler systems on heavy soil will have different needs compared to growers that are converting to drip or sprinkler systems on lighter soils.

- That strategies to facilitate the change from furrow to drip or spray irrigation include recommendations to growers to use soil moisture monitoring to help establish irrigation schedules for newly installed drip or sprinkler irrigation systems.

- Long term soil moisture monitoring demonstration sites be established to provide information and assistance to growers in choosing and installing soil moisture monitoring equipment and in interpreting data.

- A strategy is developed to promote the use of soil moisture monitoring as a technique for managing problems such as crop vigour, high water tables and salinity and to assist growers in establishing irrigation schedules when planting vegetables on new blocks.

Conclusion

The results of this study suggest that efficient water use in vegetable production can be influenced by a variety of extension strategies that will facilitate the adoption of drip or sprinkler irrigation and soil moisture monitoring by vegetable growers. However, it is important to recognise efficient water use is not the key factor influencing growers to change irrigation systems. This means that efforts to promote the adoption of drip or sprinkler irrigation systems or soil moisture monitoring by highlighting gains in water use efficiency are unlikely to be effective.

The crucial factors prompting growers to adopt drip or sprinkler irrigation are soil type and topography. This means the adoption of drip or sprinkler irrigation is largely determined by circumstances beyond the influence of an extension program. Consequently, the role of extension in promoting the adoption of drip or sprinkler irrigation is to facilitate the process of changing systems once circumstances have prompted growers to make the change. Additional research work is required to better understand the severity of disease problems in different soil types. This research would need to investigate the input of alternative crop rotations and the rate of build up of soil borne diseases in different soils.

Some growers were motivated to adopt soil moisture monitoring to assist them in establishing irrigation regimes on new blocks, or as a check on larger properties to ensure the irrigation management was working adequately. We felt there would be some value to promoting soil moisture monitoring equipment as a means of facilitating the change from furrow to drip or sprinkler irrigation. Demonstration sites designed to highlight the value of soil moisture monitoring under different seasonal conditions would also facilitate the adoption of soil moisture monitoring in the longer term. However, we note that most growers interviewed appeared capable of establishing irrigation schedules for newly installed irrigation systems without much difficulty.

References

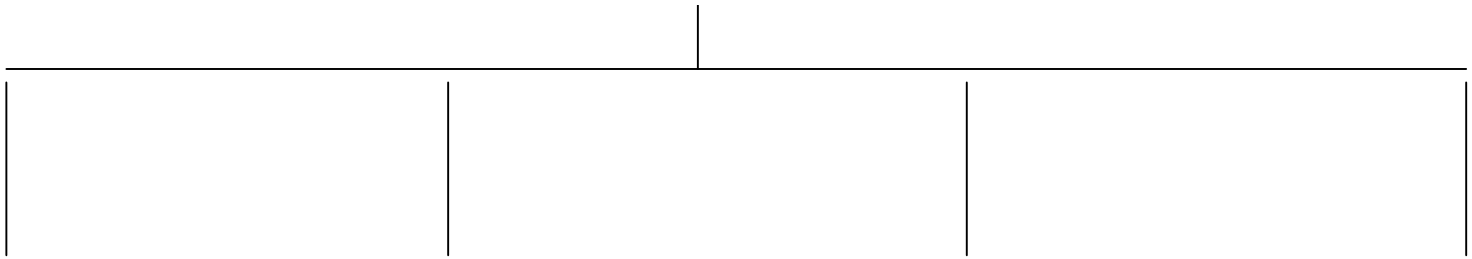
Bewsell, D. and Kaine, G. (2002). Soil Monitoring, Irrigation Scheduling and Vegetable Production. First report. Armidale, N.S.W., School of Marketing and Management, University of New England.

Mayeske, G. W. (1994). *Life Cycle Program Management and Evaluation: An Heuristic Approach*, United States Department of Agriculture Extension Service, Washington.

Appendix A

Irrigation problem tree

Why would a grower be dissatisfied with irrigation performance?



No crop(s) that can be rotated with current vegetable crop

- Need for multiple cropping

Problems with furrow irrigating

- Low WUE
- Build up of soil borne disease

Problems with drip irrigation

- Disposal of tape and plastic
- Build up of soil borne diseases
- Establishment of crops under drip
- Handling the change from furrow to a pressurised irrigation system

Type of systems available

- Need for cheaper or portable or disposable drip irrigation systems
- Consider spray as an alternative to drip irrigation

Solution tree for irrigation problems (1)

No crop(s) that can be rotated with current vegetable crops

- Need for multiple cropping

Research into alternatives

- Other high value crops that complement crops already grown

Growers ' own experiments

- Some growers already trialing alternatives – information from them?

Solution tree for irrigation problems (2)

Problems with furrow irrigation

- Low WUE
- Build up of diseases

Research into understanding soil borne diseases

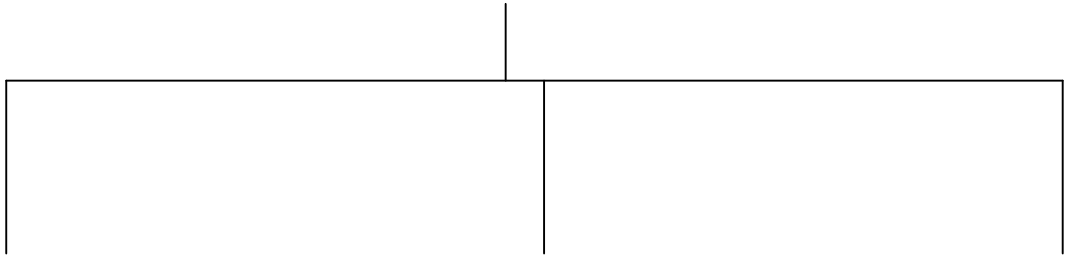
Providing information on managing furrow irrigation

Especially on WUE

Solution trees for irrigation problems (3)

Problems with drip irrigation

- Disposal of tape and plastic
- Build up of soil borne diseases
- Establishment of crops under drip irrigation



Research into alternative disposal methods or other uses

- Providing this information to growers

Providing information on establishing crops under drip irrigation

Research into disease problems

Solution trees for irrigation problems (4)

Type of irrigation systems available

- Need for portable or disposable or cheaper drip irrigation systems
- Spray as an alternative to drip

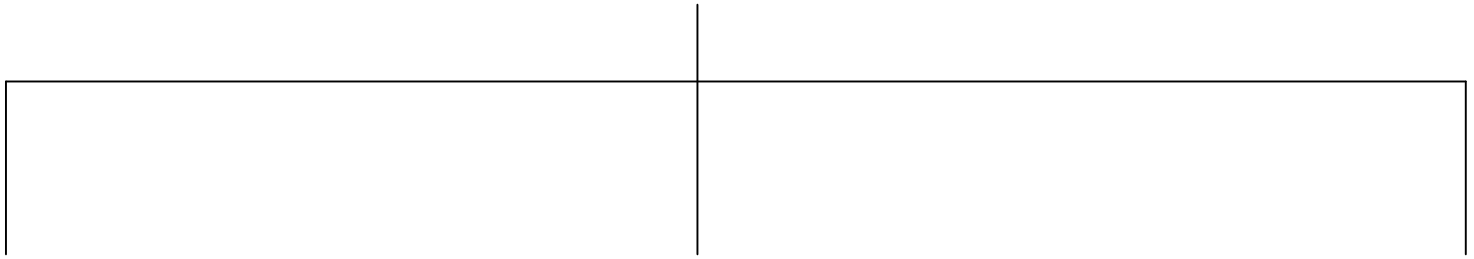
Provide information on different systems (eg. spray irrigation)

Work with suppliers to provide information on different systems

Appendix B

Problem tree for soil moisture monitoring

Why would a grower be dissatisfied with soil moisture monitoring?



Technical problem still not solved:

- New block
- Waterlogging/salinity problem
- New variety too vigorous/not vigorous enough

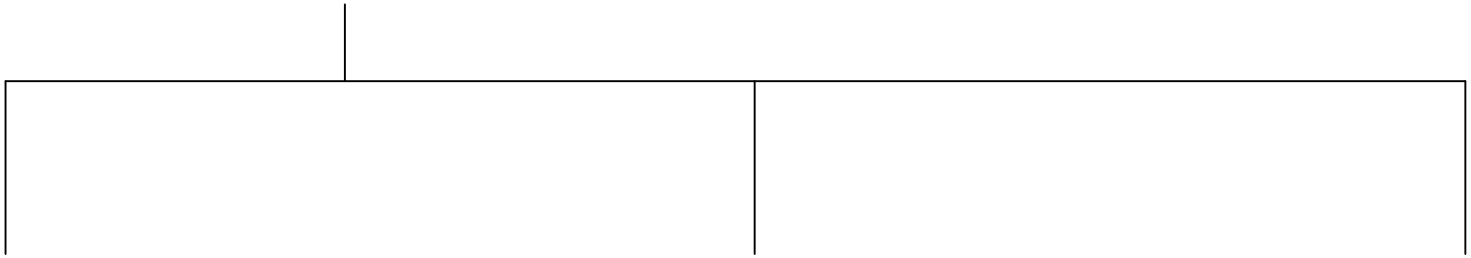
Having to move system each year

Tells grower what they already know - superfluous

Solution tree for soil moisture monitoring (1)

Technical problem still not solved:

- New block
- Waterlogging/salinity problem
- New variety too vigorous/not vigorous enough



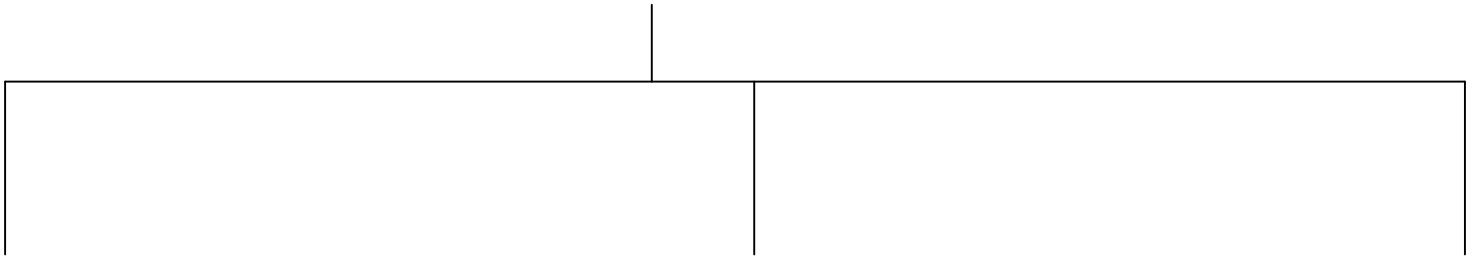
Provide information on technical problems

Provide a monitoring service

Set up demonstration sites to help solve technical problems

Solution tree for soil moisture monitoring (2)

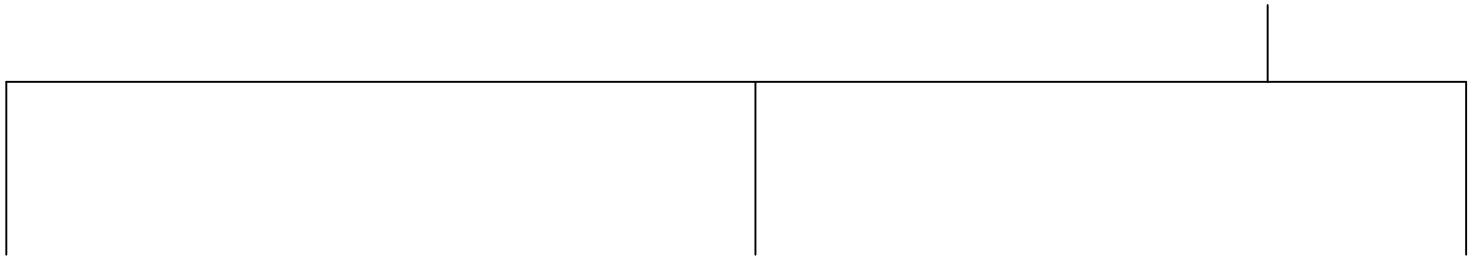
Having to move system each year



Providing information on the "right" system for growers

Solution tree for soil moisture monitoring (3)

Tells grower what they already know - superfluous



Set up a demonstration site to showcase the information that can be gained from soil moisture monitoring