Adoption of Integrated Fruit Production:

A Qualitative Study

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April 2003

Acknowledgements

We would especially like to thank David Williams (Victorian DPI) for his encouragement and support in developing, promoting and backing this project. We would like to thank both Dave and Jo Vigliaturo (Victorian DPI) for their help in organising and conducting interviews and for contributing to the discussion and interpretation of results.

We would like to thank Peter Nimmo (Queensland DPI), Jeremy Bright (NSW Agriculture), Paul James (Rural Solutions, South Australia), Tony Portman and Bruce Radys (Department of Agriculture WA) and Penny Domeney (DPIWE, Tasmania) for their help organising interviews with growers in each state and assisting us when we visited.

We would also like to thank Chris Linehan for his contribution to our interviews with growers and Kylie Elston for organising David.

We are deeply indebted to all the fruit growers who gave up their time to talk to us and share their experiences.

Executive Summary

In this project we identified the factors which influence apple growers' propensity to adopt pest and disease management practices, irrigation practices, whole farm planning and orchard record keeping in order to assess the likelihood that growers will adopt an IFP program. These factors were identified through a series of personal interviews with 40 apple growers, and 20 consultants, research and extension personnel from apple producing regions across Australia.

Key findings – pest and disease management

We found that growers from different regions had to contend with different pest and disease problems. In most regions, codling moth, light brown apple moth and dimpling bug are the major pests and black spot is the key disease.

Our interviews with growers revealed that the particular combinations of pest and disease management practices they use are determined primarily by their orchard circumstances, not their attitudes towards sustainability and the environment. The key factors that were identified by growers as influencing their adoption of pest and disease management practices were:

- The climate and topography of the orchard;
- The isolation of the orchard;
- The crop types in the region;
- The chemical and biological options available for managing pests and diseases; and
- The effectiveness of those options.

One of the principal themes to emerge from the interviews was the role of resistance to chemicals in triggering widespread changes in pest and disease management.

As a result of the decline in broad spectrum chemical use that has accompanied the use of control measures such as growth regulators and mating disruption, secondary pests were identified as an increasingly important problem for growers in all regions. Unfortunately, broad spectrum chemicals are the only means of controlling many secondary pests at present. Hence, the emergence of secondary pests as serious economic pests threatens the future of integrated pest management.

Key findings – irrigation management

A variety of irrigation systems are used. Most apple growers used some form of pressure irrigation such as micro jets or drip irrigation as these suit the soil types or topography in the orchard. Growers have adopted these systems in order to reduce the amount of water used in the orchard; to reduce the time and labour required to manage irrigation in the orchard; to better co-ordinate orchard activities such as irrigation and harvesting; or because the orchard has been redeveloped to a high density planting design which only suit micro-jet or drip irrigation. We found growers in most areas in Australia had the flexibility to respond to soil moisture monitoring as they were able to irrigate on demand.

Key findings – Whole farm planning, quality assurance and record keeping

With respect to whole farm planning we found that growers in Shepparton had invested in an accredited whole farm plan primarily to obtain access to grants when they redeveloped a flood irrigated property to pressurised irrigation or installed a groundwater pump. Whole Farm Plans designed by an accredited planner were not perceived as being particularly useful.

In relation to quality assurance we found that growers have observed that they can supply fruit to domestic and some export markets without participating in a quality assurance scheme, provided they can supply spray diaries. Hence, growers' experience is that participation in quality assurance programs does not result in exclusive access to markets. Consequently, growers are suspicious of any claims that a new program, such as Integrated Fruit Production, is likely to make in terms of creating exclusive access to markets.

Generally speaking given adequate irrigation and fertiliser management, growers indicated that fruit yield and quality is most sensitive to pest and disease management. In growers' experience, pest and disease management is far more complex and difficult than are irrigation and fertiliser management. Consequently, growers' believe their management of pests and diseases can benefit more from an understanding of past management actions than can their management of irrigation or fertiliser. This suggests that record keeping is quite valuable in terms of pest and disease management but of limited value in terms of fertiliser and irrigation management.

Integrated Fruit Production

In our view, given the information we obtained, growers' participation in an Integrated Fruit Production program is likely to be limited in the present circumstances. We believe there is little opportunity to promote the adoption of an Integrated Fruit Production program through extension as there is no evidence to suggest that growers are particularly misinformed about, or are unable to properly evaluate, the benefits of such a program. Interest among fruit growers in participating in an Integrated Fruit Production program will remain low until the threat of exclusion from markets because of non-participation becomes a reality.

Until that time arrives we believe there is the opportunity to:

- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate variation in pest and disease management practices within and between regions
- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate variation in pest and disease management practices in response to the emergence of new pest and disease pressures and control technologies
- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate differences in irrigation management practices within and between regions
- Design record keeping systems that are appropriately tailored in terms of meaningful detail for fruit growing and fruit packing, particularly for pest and disease management
- Develop program materials to assist fruit growers to implement Integrated Fruit Production when the need arises
- Develop biological and ‘soft’ chemical procedures for controlling secondary pests.

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1. Introduction

1.1 Background

Integrated Fruit Production (IFP) is a system for producing fruit that emphasises a holistic systems approach with a focus on environmentally friendly practices. The concept of IFP originated in Europe in the fifties however formal guidelines for IFP have only been formulated in the last ten years (Vannoppen, Verbeke *et al.* 2002). These guidelines were based on regulations for Integrated Pest Management (IPM) which were introduced in the European Union in the seventies and eighties to limit the use of pesticides and other chemicals (Sansavini 1997). Other countries, for example Africa, New Zealand, Argentina and the United States, have adopted the principles of IFP and used the European Union guidelines as a basis for developing programs appropriate to their local conditions (Sansavini 1997).

The apple industry in Australia has focused on developing IFP as a national program that emphasises crop production and environmental issues. The program that has been proposed incorporates whole farm planning, selection of scion/rootstock combinations, integrated pest management, irrigation and fertiliser management, crop management, quality assurance, food safety, and occupational health and safety. IFP is intended to encourage better integration of these areas, an increased understanding of the interactions occurring in the orchard, and an understanding of the impact of these on crop quality (Williams, Harrison et al. 2000).

The Australian apple industry is keen to encourage IFP because of a desire to operate in an economically and environmentally sustainable way, and because key export markets are beginning to expect or demand that apples be produced using an IFP system (Williams, Harrison et al. 2000). The European and United Kingdom markets are requiring growers demonstrate that they are growing their crops in a way that is safe for the environment, consumers, farm workers and the general community. Given the recent food safety issues in these countries, there is increasing pressure on agricultural producers and processors to document management practices to ensure traceability and accountability. Some have predicted that Asian markets, which tend to follow the lead of the European markets, will also eventually require growers supplying these markets to have some form of IFP accreditation (Williams 2002).

The indications are that IFP accreditation is increasingly likely to be used by retailers in overseas markets as a criterion for differentiating preferred suppliers. Hence, IFP accreditation will eventually become a prerequisite for access to the European and other overseas markets. Consequently, there is a need to for the Australian apple industry to develop strategies and options to meet this eventuality. Our aim in this study is to identify the key factors that will influence the adoption of IFP by fruit growers and to use that knowledge to assist the industry to develop research and extension programs to promote IFP.

In principle, IFP encompasses all aspects of orchard management and fruit handling and storage. However, from an environmental and food safety perspective pest and disease management, irrigation management, whole farm planning and the documentation of management decisions and actions are probably the most important areas of concern. Consequently, these four areas were chosen as the focus for our study.

In the remainder of this chapter we describe the literature on the adoption of IFP programs and the literature on the adoption of pest and disease management in particular. We also briefly review the literature on the adoption of irrigation management and whole farm planning. We then outline the theoretical foundation of our approach to understanding adoption behaviour. We end the chapter with a description of the research methods we used in this study.

1.2 Adoption of Integrated Fruit Production

IFP programs have been instituted in Europe, South Africa, New Zealand and Argentina and demonstration projects have been established in the United States, Chile, Canada and Brazil (Agnolin, Ioriatti *et al.* 2000); (McKenna, Roche *et al.* 1998); (Niederholzer, Seavert *et al.* 1998); (Yuri 2001); (Smith, O' Flaherty *et al.* 2000); (Donadio, Muller *et al.* 2000). To date there are relatively few studies of the adoption of IFP.

(Candolfi-Vasconcelos, Lombard *et al.* 2000) describes an IFP program for wine grapes in Oregon. The region is free of major arthropod pests and downy mildew and enjoys a reputation as pioneer in environmental protection. It appears likely in this instance that growers have adopted IFP as a means of building on these advantages. Agnolin *et al.* (2000) describes an IFP program for apple growers in the Trentino region of Italy. Apple production in the region is characterised by part-time, small scale production and marketing through producer co-operatives. Agnolin *et al.* (2000) attribute the adoption of IFP to a perceived need to respond to consumer concerns over food safety, a desire to safeguard the environment, and a need to improve the viability of fruit growers in the region by improving product quality.

(McKenna, Roche *et al.* 1998) found that apple growers in New Zealand were adopting IFP primarily to reduce costs and maintain market access rather than because they believed IFP offered a more sustainable approach to apple production. (Fairweather, Campbell *et al.* 1999) also found that economic motivations were important in the adoption of IFP by New Zealand grape growers. However, they did suggest that other factors such as having a personal philosophy that emphasised the importance of sustainability and minimising chemical use also played a role in growers’ decisions to adopt IFP.

These studies suggest that, in the absence of economic benefits, few fruit growers adopt IFP purely on the basis that it provides them with a philosophically attractive model for sustainable fruit production. On balance, it seems economic advantage is the primary motivation for fruit growers to adopt IFP.

Although there are few studies on the adoption of IFP programs *per se*, there is a substantial literature on the adoption of certain components of IFP programs, in particular with regard to the management of pests and diseases. We report on this literature in the following sections.

1.3 Adoption of integrated pest management

Integrated Fruit Production programs have been promoted as a comprehensive framework for encouraging environmentally responsible and sustainable fruit production. In practice it seems that chemical use in the management of pests and disease has been the key priority in the design of these programs. For example, although the IFP program described by Agnolin *et al.* (2000) has guidelines covering choice of variety, pruning systems, irrigation, nutrition harvest time and farm records the success of the program is evaluated entirely in terms of numbers of pesticide, fungicide and acaricide sprays applied, the use of selective chemicals and mating disruption, the use of biological controls, and the incidence of chemical residues. The central importance of chemical use in the design of European IFP programs is also reflected in EUREPGAP (2001).

Although (Batchelor, Walker *et al.* 1997), (McKenna, Le Heron *et al.* 2001) and (McKenna, Roche *et al.* 1998) state that the apple industry in New Zealand introduced an IFP program to demonstrate its commitment to sustainable management practices McKenna *et al.* (1998) argue that the main objective of the program was to ensure that fruit growers used a “more selective and less damaging spray regime”. The importance of chemical use in IFP programs is also reflected in programs instituted in other horticultural and viticultural industries such as the New Zealand wine and kiwifruit industries (Campbell, Fairweather et al. 1997; Fairweather, Campbell et al. 1999).

The adoption of pest and disease management techniques, especially integrated pest management, has been the subject of numerous studies. These studies have investigated the adoption of practices such as monitoring of pests and disease, the use of population thresholds to determine spray regimes, monitoring and use of beneficial insects to control pests, the use of selective chemicals, the use of growth regulators and the use of mating disruption techniques. Unfortunately, there is little consistency in the findings of these studies (see table one).

For example, a number of studies have concentrated on identifying relationships between pest and disease practices and the characteristics of growers and their enterprises. Higher levels of formal education have been positively associated with the adoption of practices such as monitoring of pest levels, use of selective chemicals and encouragement of beneficial insects among growers of pears in California and potato growers in Ohio (Chaves and Riley 2001; Ridgley and Brush 1992; Waller, Hoy *et al.* 1998). However, Grieshop *et al.* (1988) did not find a relationship between education and adoption of IPM among tomato growers in the United States, while Chaves and Riley (2001) found that the significance of the role of education varied among coffee growers in Columbia depending on mix of practices they analysed.

Similar inconsistencies are present in studies into relationship between choice of pest and disease management techniques and farm size. Shennan *et al.* (2001) found a relationship between choice of pest and disease management techniques and farm size for vegetable and fruit growers in California. However, Chaves and Riley (2001) in their analysis of pest management practices among Colombian coffee berry growers found a relationship between farm size and adoption for some combinations of practices but not for other combinations of practices. In contrast, Grieshop *et al.* (1988), Ridgley and Brush (1992) and Waller *et al.* (1998) did not find a relationship between farm size and adoption of IPM among tomato growers, pear growers, or potato growers in the United States respectively.

Finally, Fernandez-Cornejo *et al.* (1994) obtained mixed results when investigating the impact of risk aversion on the adoption of IPM among vegetable growers in the United States.

A number of studies have described the complexity of pest and disease management and have attributed the rapid spread of integrated pest management techniques in Asian and African countries in particular to novel approaches to grower education and extension. (Grieshop, Zalom *et al.* 1988) highlighted the complexity of IPM techniques as a key obstacle to adoption of IPM among tomato growers in California. Escalada and Heong (1993) attributed the slow spread of IPM techniques among rice farmers in the Philippines to a lack of knowledge among growers and concluded that farmer field schools would accelerate adoption by providing growers with the opportunity for experiential learning of IPM skills.

Both Jeger (2000) and Kogan (1998) conclude that the success of the farm field schools in southeast Asia had little to do with a new or novel approach to extension. Instead they provide evidence to suggest the apparent achievements of farmer field schools in promoting changes in the management of rice pests are due to the banning of widely used broad spectrum insecticides. For example, in Indonesia, 57 broad spectrum organophosphate, pyrethroid and chlorinated hydrocarbon insecticides were banned by presidential decree (Kogan 1998). The only option for rice growers under these circumstances was to adopt IPM strategies and gain an understanding of the pest and disease cycles through the farmer field schools. Jeger (2000) also cites the case of wheat production in the United Kingdom which has been free of pest or disease crises. He argues that there is a low level of awareness of IPM amongst wheat producers because current approaches to pest and disease management remain successful. Consequently there is no incentive to develop IPM strategies for this industry.

(Jeger 2000) goes on to explore the differences between rice and vegetable production in Asia and comment on the potential for farmer field schools to promote IPM in vegetables. He argues the potential is limited at present, especially if the industry continues to move towards monoculture systems. Currently vegetable crops are grown in biologically diverse home gardens which provide a buffer against pests and diseases (Jeger 2000).

Table one: Factors reported in the literature as influencing adoption of IPM

Author/ Type of enterprise & location	Age	Education	Experience (or knowledge)	Farm size	Farm ownership	Risk Debt/Asset ratio	Off farm employment	Crop type
(Grieshop, Zalom *et al.* 1988) Processing tomato growers California, USA	0	0	+	0	-			Significant
(Ridgley and Brush 1992) Pear growers California, USA		+		0				Significant
(Fernandez-Cornejo, Beach *et al.* 1994) Vegetable growers USA				+		±		Significant
(Brough, Frank *et al.* 1996) Apple growers Queensland, Australia			-					
(Fernandez-Cornejo 1998) Grape growers USA		+	-	+			-	Significant
(Waller, Hoy *et al.* 1998) Potato growers Ohio, USA	0	+	-	0				
(Shennan, Cecchettini *et al.* 2001) Vegetable and fruit growers California, USA	-	+	0	±	0			0
(Chaves and Riley 2001) Coffee growers Columbia	±	±	±	±				Significant

+ denotes a positive relationship between the factor and adoption of IPM, - denotes a negative relationship between the factor and adoption of IPM, 0 denotes no significant relationship between the factor and adoption of IPM.

In conclusion, there is little reliability in the findings of studies into the adoption of pest and disease management practices. Studies focussing on grower and enterprise characteristics have failed to identify any relationships between variables such as age, education and experience that are consistent across industries and countries. Some authors have argued that a lack of knowledge and skills is the key obstacle to the widespread use of IPM and therefore training and extension is essential. Other authors have argued the popularity of programs such as farmer field schools is primarily attributable to the banning of commonly used pesticides and fungicides. Interestingly, concern for the environment and sustainability was not identified as a key factor in the adoption of pest and disease management techniques in any of the studies we examined.

1.4 Adoption of irrigation practices

The adoption of modern irrigation systems and irrigation scheduling techniques has been studied in a number of countries, including the United States and Israel. Skaggs (2001) investigated the propensity of chilli pepper growers in New Mexico to adopt drip irrigation and found growers who were younger, had larger farms and had a positive attitude toward modern irrigation technology were most likely to adopt drip irrigation. Skaggs (2001) also found that growers were less likely to adopt drip irrigation if they grew other vegetables in addition to chilli peppers.

Lynne *et al.* (1995) related adoption of drip irrigation by strawberry growers in Florida to growers' attitudes towards drip irrigation technology and their perceptions of control over the decision to invest in the technology. They found growers with a positive attitude and a greater degree of perceived control over the decision to invest were more likely to adopt drip irrigation. The importance of growers' commitment to reducing water use in motivating the adoption of drip irrigation is questionable given threats by government agencies to rescind growers' irrigation permits if they did not install drip irrigation.

The diffusion-abandonment process for irrigation technologies in citrus groves was studied in Israel by Dinar and Yaron (1992). They concluded that input and output prices influenced the uptake of modern irrigation systems.

The adoption of irrigation scheduling techniques has been found to depend critically on the type system used to deliver irrigation water to farms. Delivery systems that continuously supply water ('on demand' systems) are necessary to effective use quantitative irrigation scheduling techniques (Goussard 1996). Leib *et al* (2002) found that approximately 18 per cent of producers in Washington state are using 'scientific' irrigation scheduling and that more than half of the acreage being scheduled using such methods were either tree fruit or potatoes. They postulated that these producers are willing to use and pay for scientific irrigation scheduling in order to ensure the quality of their high value crops.

Kaine and Bewsell (2000) found that the adoption of micro irrigation technology in horticulture in Australia, including drip irrigation, depended on a number of factors.

Growers adopted such technologies primarily to save time irrigating, to irrigate areas that were unsuited to flood irrigation (sandy or hilly areas), to improve managerial flexibility in the orchard (e.g. to allow activities like irrigation and harvesting to be conducted simultaneously) and to irrigate orchards that had been redeveloped using closer planting techniques which are unsuited to flood irrigation. Some growers in areas with limited water supplies or problems with high water tables had adopted micro irrigation technology to save water (Kaine and Bewsell 2000). They also found that the adoption of micro irrigation, especially drip irrigation systems, did depend on access to a continuous supply of irrigation water (Kaine and Bewsell 2000).

(Kaine and Bewsell 2000) also found that the adoption of quantitative irrigation scheduling techniques in Australian horticulture depended on access to a continuous supply of irrigation water and on the need to conserve limited water supplies.

In conclusion, previous studies indicate that the adoption of new irrigation technologies and irrigation scheduling techniques is motivated by growers' perceptions of the benefits of these innovations and that these perceptions depend on the specific circumstances of the individual grower in terms of labour and water availability, orchard layout and so on. Kaine and Bewsell (2001) and (2002) reached similar conclusions in regard to the adoption of irrigation technologies in the viticulture and vegetable industries.

1.5 Adoption of record keeping

A key feature of integrated fruit production is the documentation of orchard activities and decision making, especially in relation to management of pest and diseases, irrigation, fertiliser management and fruit production and fruit packing. This documentation is intended to provide a means of tracing product flow to resolve food safety concerns, to provide evidence of acting in an environmentally responsible manner, and to assist growers in their decision making.

To date, the only documentation requirements apple growers in Australia have had to comply with pertain to the maintenance of spray diaries. However, many growers have participated in quality assurance schemes of various kinds, each scheme with its particular reporting and auditing requirements. Fruit growers in the Shepparton region have been required to submit certified whole farm plans when seeking financial assistance for redeveloping their orchards.

We were unable to find any literature on the adoption of quality assurance and whole farm planning in horticulture. Much of the literature on whole farm planning concerns efforts to create more effective water flow in extensive farming systems. The Yeoman Keyline System is one example of this literature (Watkins 1999).

1.6 Consumer behaviour as a model of adoption behaviour

The approach we take to understanding the adoption of new agricultural technologies draws on the conceptual foundations of consumer behaviour theory (Assael 1998). This theory proposes that consumers use a variety of decision processes when purchasing products. The type of decision process they actually follow depends partly on the importance of the purchase to the consumer, partly on how routine the purchase decision is and partly on how familiar the consumer is with the products and brands available. In this section we describe the different types of decision processes used by consumers, the circumstances in which they are used, and the implications of these for understanding adoption decisions.

1.6.1 Involvement and purchase decisions

Consumers make purchase decisions in a variety of ways depending on circumstances. The way in which a purchase decision is made is determined by two key factors. These are the level of consumer involvement in the product and the degree of effort the consumer is willing to invest in making a purchase decision (see figure 1). When involvement is high consumers tend to engage in complex decision making process or brand loyalty depending on the degree of effort they invest in the purchase decision. When involvement is low consumers tend to engage in variety seeking behaviour or habit depending on the degree of effort they invest in the purchase decision.

Consumer involvement depends on the importance the purchase is to the consumer. High involvement purchases are purchases that are important to the consumer (Assael 1998). High involvement products are generally expensive, rarely or infrequently purchased and closely tied to self-image and ego. High involvement purchases usually involve some form of risk - financial, social or psychological. Where this is the case the consumer is more likely to devote time and effort to careful consideration of alternatives before making a purchase. Typical high involvement purchases are homes, motor vehicles, white goods, clothing and perfumes.

Low involvement purchases are purchases that are unimportant to the consumer (Assael 1998). These purchases are commonly inexpensive products that are routinely purchased and involve little risk. The consumer is unlikely to devote much, if any, time and effort to consideration of alternatives for low involvement purchases before making a decision. Typical low involvement purchases are groceries, toiletries, and laundry products.

The effort that a consumer is willing to invest in making a purchase decision depends on a number of factors. These include the extent to which the consumer can draw on past experiences to simplify the decision process and the extent to which the consumer is familiar with the product and brand alternatives that are available.

We believe that the adoption of most agricultural innovations represent a form of high involvement purchase for primary producers. Usually the adoption of a new agricultural practice or technique has significant consequences for the future financial performance of the farm enterprise. The new technology or practice must be integrated into the existing mix of technologies, practices and resources that exist on the farm (Crouch 1981; Kaine and Lees 1994). This means, generally speaking, the likely outcomes of adopting a particular technology or practice are difficult to predict as the compatibility of the technology or practice with the existing farm system, and the resulting benefits, depends on a range contextual factors that are specific to the circumstances of each farm enterprise. Consequently, the decision to adopt an agricultural innovation is often financially risky. As such they entail social risks and psychological risks in that the outcomes affect the wellbeing of family members and can influence producers' feelings of achievement and self-fulfilment.

As mentioned earlier, there are two types of decision processes consumers follow when making high involvement purchases depending on the effort they are willing to invest in the decision process (see table two). These are complex decision-making when consumers invest a substantial amount of effort in decision making, and brand loyalty when consumers wish to minimise the effort invested in decision making (Assael 1998). We will now describe these two decision processes in detail.

Table Two: Consumer purchase behaviour

	High involvement purchase decision	*Low involvement purchase decision*
Decision making (More effort)	Complex decision making (eg cars) • High motivation to search for information • High effort into learning and discovery • Evaluation both prior to and after purchase	Variety seeking (eg snack foods) • Low motivation to search for information • Some effort into learning and discovery • Evaluation after purchase
Habit (Less effort)	Brand loyalty (eg athletic shoes) • Less effort into learning and discovery as consumer already has a product they are satisfied with • Evaluation based on experience with the product	Inertia (eg laundry detergent) • No motivation to search for information • No effort put into learning and discovery • Evaluation after purchase

1.6.2 Complex decision making

Consumer behaviour theory suggests that consumers follow a complex decision-making process with high involvement purchases (Assael 1998). Complex decision-making is a systematic, often iterative process in which the consumer learns about the attributes of products and develops a set of purchase criteria for choosing the most suitable product. Complex decision making is facilitated when there is adequate time for extensive information search and processing (Beatty and Smith 1987), adequate information is available on product characteristics and the consumer has the ability to process the available information (Greenleaf and Lehmann 1995).

The benefit or purchase criteria represent the key benefits sought by the consumer and generally reflect their usage situation. In the case of consumer goods the usage situation is often a function of the consumer's past experiences, their lifestyle and their personality (Assael 1998). For example, economy, dependability and safety are key purchase criteria for many consumers with families that are buying motor vehicles that will be used daily to transport family members, especially children. Having settled on a set of purchase criteria for deciding between products, the consumer then evaluates the products against the criteria and makes a choice.

Following purchase the consumer will evaluate the products performance. Satisfactory performance will reinforce the consumer's judgement and promote the chances of repurchase. Dissatisfaction with product performance will lead to reassessment and decrease the likelihood of repurchase. Dissatisfaction will also promote the likelihood of purchasing an alternative product (or brand).

Consumers from different usage situations will employ different purchase criteria to evaluate products because they seek different benefits from a product, while consumers from similar situations will employ similar criteria. Information on the similarities and differences in the key purchase criteria used by consumers can be used to classify consumers into market segments (Assael 1998). This information can also be used to develop and promote a suite of products with characteristics that are tailored to provide the benefits sought by consumers in each particular segment.

In the case of agriculture the purchase criteria that producers use to evaluate new technologies should reflect the key benefits the technology offers given producers' usage situations. In this instance the usage situation is likely to be a function of the farm context into which a new technology must be integrated. Broadly speaking, the farm context is the mix of practices and techniques used on the farm, and the biophysical and financial resources available to the farm business that influence the benefits and costs of adopting an innovation (Crouch 1981; Kaine and Lees 1994). Similarities and differences among farm contexts for an agricultural innovation will translate into similarities and differences in the key purchase criteria that producers will use to evaluate that innovation.

Given that the usage situation for agricultural innovations is defined by farm contexts, differences in farm contexts will result in different market segments for an innovation. Logically, the market for an innovation will be defined by the set of farm contexts for which the innovation generates a net benefit (see (Kaine and Bewsell 1999); (Kaine and Bewsell 2000); (Kaine and Bewsell 2001); (Kaine and Bewsell 2002); (Kaine and Niall 1999); (Kaine and Niall 2001) for examples).

As is the case with consumer goods, knowledge of similarities and differences in the key purchase criteria that will be used by producers to evaluate an innovation can be employed to tailor the innovation to meet the specific needs of producers in a segment and promote the innovation accordingly.

To the degree that the mix of farm practices, technologies and resources that influence the benefits and costs of adopting an innovation are different for different innovations, the purchase criteria used to evaluate innovations will change accordingly. This means purchase criteria are frequently innovation specific and often cannot be generalised across innovations.

Complex decision making can be influenced in two ways (Assael 1998). One is to persuade consumers to change the purchase criteria they use to evaluate products. The other is to change their beliefs about the extent to which products meet their criteria. Both these changes lead to changes in consumers' evaluations of products which, in turn, may cause changes in product choices.

1.6.3 Brand loyalty

When repeated purchasing of a chosen product consistently generates a high degree of satisfaction then complex decision making may be replaced over time by brand loyalty. Brand loyalty is the second approach to purchasing high involvement products. Brand loyalty is more than just habitual purchasing of a brand. It represents a personal commitment to repeatedly purchase a brand on the basis of favourable attitudes towards the brand. In situations where the purchase of a product entails a high level of risk, then brand loyalty may be an effective strategy for reducing risk. Brand loyalty does not equate with habit (Assael 1998).

Brand loyal consumers may change brands for three reasons. Brand loyal consumers may change brands because they experience a change in their needs and the original product does not satisfy match new needs. Brand loyal consumers may also be forced to change brands because of dissatisfaction with the favoured product due to continually poor performance of the product over a period of time. Finally, brand loyal consumers may be induced to change brands because they learn of an alternative which is demonstrably superior.

In the case of agricultural innovations, brand loyal behaviour translates into a personal commitment to the use of an agricultural technology or practice that has been proven through experience to be successful, especially in situations where failure can have serious consequences. This means that producers are likely to be particularly unwilling to change technologies in situations where the failure of a technology can have serious consequences for the farm enterprise and existing technologies and practices have proved to be reliable. In such situations the rate of adoption and diffusion of alternative technologies is likely to be exceedingly low unless a change in circumstances leads to the failure of the traditional technology. The loyalty of producers to traditional technologies and practices in this type of situation is a structured, strategic response to risk. (Kaine and Niall 2001) found that wool producers' approach to sheep breeding and their choice of stud for purchasing rams resembled brand loyal behaviour.

In conclusion, consumer behaviour theory suggests that consumers are motivated and discriminating purchasers of high involvement products who actively seek information on, and systematically learn about, products that are relevant to their needs. The application of this theory suggests that producers are likely to be motivated and discriminating purchasers of new technologies who actively seek information on, and systematically learn about, innovations that are highly relevant to their needs. In circumstances where the failure of an innovation can have serious consequences for the farm enterprise, and existing technologies and practices have proved to be reliable, producers will resist the introduction of an innovation. This behaviour resembles brand loyalty and is a rational, strategic response to risk.

1.7 Research methods

In this project we are seeking to identify the factors which influence apple growers propensity to adopt pest and disease management practices, irrigation practices, whole farm planning and orchard record keeping in order to assess the likelihood of that growers will adopt an IFP program. To identify these factors we followed a convergent interview process (Dick 1998). This involved personal interviews with growers, consultants and research and extension personnel from apple producing regions across Australia.[1] Convergent interviewing is unstructured in terms the content of the interview. The interviewer employs laddering techniques (Grunert and Grunert 1995) to systematically explore the reasoning underlying the decisions and actions of the interviewee. The power of this interview process lies in identifying common and complementary patterns of reasoning among interviewees.

Initially a brainstorming session involving research and extension staff with the Victorian Department of Primary Industries was conducted to identify fruit growers in Victoria to interview. Care was taken to include growers, with a mix of educational, age and cultural background operating both large and small scale enterprises. Fifteen fruit growers from the Shepparton region, the Yarra Valley and the Mornington Peninsula were interviewed.

In other states the IFP contact for that state identified fruit growers to be interviewed. In each case the contact was asked to identify a sample of growers with a mix of educational, age and cultural background operating both large and small scale enterprises. The number of growers interviewed in each state is reported in table three.

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[1] The results of these interviews will be used to design a mail questionnaire which will be used to collect quantitative data on the factors which influence apple growers' propensity to adopt pest and disease management practices, irrigation practices, whole farm planning and orchard record keeping.

1.8 Report outline

In chapter two we describe the factors that influence the adoption of pest and disease management practices. We then report on the factors that influence the adoption of irrigation management practices in chapter three and the factors that influence whole farm planning and documentation of orchard decision-making and actions are described in chapter four. Chapter five contains a discussion of the implications of our results.

Table Three: Apple grower interviews by state

State	***No. of interviews***
Victoria	15
Queensland	3
New South Wales	3
South Australia	7
Western Australia	6
Tasmania	6
TOTAL	40

2. Pest and disease management

2.1 Introduction

In our interviews we found that growers from different regions had to contend with different pest and disease problems. The key pests in each region are outlined in table four. Black Spot and Powdery Mildew are the two major diseases of apples in Australia. Western Australia is unique in being free of both codling moth and black spot.

One of the principal themes to emerge from the interviews was the role of crises in triggering changes in pest and disease management. Growers revealed that the failure of miticides in the late eighties and early nineties was the key factor prompting changes in pest control during that period. The rapid build-up in resistance to miticides forced fruit growers to try alternative methods of mite control, namely the use of predator mites. However the effectiveness of predator mites was undermined by their susceptibility to the broad spectrum pesticides used for control of codling moth. With the emergence of mating disruption as a successful substitute for pesticide control of codling moth there was a dramatic improvement in the effectiveness of predator mites for controlling pest mites. Many of the growers we interviewed cited this sequence of events as the key to their adoption of IPM techniques.

As a result of the decline in broad spectrum chemical use and the greater dependence on IPM techniques secondary pests were increasingly becoming an issue for growers in all regions. They expressed concern that for some secondary pests there is no alternative but to spray with a broad spectrum pesticide thereby upsetting the balance they were striving for in terms of predators of mites. For example:

> *John and Cathy run an orchard in the Yarra Valley in Victoria, growing stone and pome fruit. John says that using IPM is a bit like trying to follow a family tree. It depends on what branch you chose as to where you end up. There are always consequences to the decisions you make about pest and disease management and you can sometimes box yourself into a corner where the only way forward is to "nuke everything". John also used the analogy of a Nintendo® game – the aim with IPM is to get to the highest level, except that sometimes you lose and you have to go back to the beginning!*

This view was echoed by a grower from Tasmania:

> *Jack and his father Dom own 12 hectares of apples just out of Glendevie. Jack is finding that the cost of IPM compared to conventionally grown fruit seems to be about the same. However secondary pests are emerging that are threatening their IPM strategy, and defeating the purpose of IPM. This battle with secondary pests can make IPM almost impossible. For example, Jack has had to go back to using Lorsban® [Chlorpyrifos] if the monitoring results indicate a spray is needed for his secondary pests. Although he believes this is*

Table Four: Key pests of apples in Australia

Southern Victoria	Codling moth Light Brown Apple Moth (light brown apple moth) Mites Apple Dimpling Bug Woolly aphid
Northern Victoria	Codling moth Oriental Fruit Moth (OFM) Mites Apple dimpling bug
Queensland	Codling moth Mites Apple dimpling bug Western Flower Thrips Queensland fruit fly Woolly aphid
New South Wales	Codling moth Apple dimpling bug Mites Light Brown Apple Moth Woolly aphid
South Australia	Codling moth Light Brown Apple Moth Mites Apple dimpling bug Weevils Woolly aphid
Western Australia	Mites Light Brown Apple Moth Weevils Apple dimpling bug Mediterranean Fruit Fly
Tasmania	Light Brown Apple Moth Woolly aphid Mites Codling moth Weevils

not sustainable in the long term, it is the most cost effective option available to him at present. He knows that the environment is important, but the bottom line is more important.

Our interviews with growers revealed that the particular combinations of pest and disease management practices they use are determined primarily by their circumstances, not their attitudes towards sustainability and the environment. The key factors that were identified by growers as influencing their adoption of pest and disease management practices were the climate and topography of the orchard, the isolation of orchard, the crop types in the region, the chemical and biological options available for managing pests and diseases, the effectiveness of those options.

- The climate largely dictates the type and intensity of pest and disease pressures in an orchard. For example, black spot is a particularly serious problem in Tasmania because of the relatively wet conditions experienced in that region. The particular mix of pests and diseases present in an orchard, and the intensity with which they are present, can limit the control options available to growers.
- The topography of the orchard can create micro climates which will have an impact on the pests and diseases present and the efficacy of some control options.
- Orchard isolation refers to the physical distance between orchards in an area. For example, many orchards in Stanthorpe and the Yarra Valley are geographically distant from each other creating a natural barrier against the movement of pests and disease between properties. This appears to result in considerably lower pest pressures on some orchards compared to others in the same region.
- The mix of tree crops in an area can also contribute to pest and disease pressures. For example in Shepparton there is a concentration of stone and pome fruit. The presence of stone fruit, which is particularly susceptible to oriental fruit moth, in the region adds to the population of this pest in the region. Similarly, the co-occurrence of stone fruit and pear crops with apples adds to the codling moth population in the region.

While climate, topography, orchard isolation and crop mix determine the type and intensity of pest and disease pressures growers' experience, their management of these pressures is determined by chemical and biological options available for managing pests and diseases, the effectiveness of those options.

- For many apple pests the only control options available are broad spectrum chemicals. For example, selective chemicals or biological controls have not been developed for most secondary pests such as weevils. Chemical eradicants are not available, or are of limited effectiveness, for some diseases of apples forcing growers to cover spray protectants.
- Market requirements are also a major factor influencing the options available to growers for managing pests and diseases. Growers supplying fresh market fruit often cannot tolerate the same level of damage, especially cosmetic damage, to fruit as growers supplying fruit for processing. In addition, growers supplying fruit for export must conform to residue limits for those markets.
- Finally, a key factor prompting growers to change management options is the development among pests of resistance to chemicals

In the following sections we describe the factors influencing growers' management of individual pests and diseases. Before commencing those descriptions there are some observations regarding pest and disease monitoring that worth considering.

IPM researchers and extension officers all agreed that establishing a detailed monitoring program is a key part of successfully using IPM (see Rapley *et al.* (2000) for example). Ideally, decisions to spray pests should be made on the basis of population thresholds predicted from the results of monitoring. In our interviews with growers we identified two distinct approaches to monitoring. The first approach we termed predictive monitoring. The purpose of this monitoring corresponded with that described by IPM researchers and extension personnel. This monitoring was undertaken to provide growers with information that will enable them to decide what actions to take, if any, in their pest and disease management program.

The second approach to monitoring we termed evaluative monitoring. The purpose of this monitoring is to provide growers with information on how well their pest and disease program is performing and to anticipate any problems. Growers who have a program of calendar spraying to control codling moth, for example, may use evaluative monitoring to ensure their program is working satisfactorily.

2.2 Pests

In the following sections we describe the different methods growers use to manage each of the major pests of apples. We also tentatively classify growers into segments in terms of these methods and describe the factors influencing their choice of management method.

2.2.1 Codling moth

Codling moth can be controlled with broad spectrum chemicals (for example Chlorpyrifos, Parathion Methyl or Azinphos Methyl), with "soft" chemicals such as growth regulators (for example, Mimic®) and by using pheromones to cause disruption to moth mating (Isomates). The preferred IPM strategy would be to use either a soft chemical program or mating disruption to control codling moth, supported by monitoring and the use of the degree day model to predict moth flights. Soft chemicals and mating disruption have been used successfully in all states where the moth is present except in areas where there is high pest pressure.

The development of mating disruption was a significant step in the control of codling moth in particular and for IPM for apple production generally. Mating disruption allowed growers to reduce their use of, or even eliminate, broad spectrum chemicals. This created the opportunity to use IPM methods to control other pests. The most significant of these was in control of pest mites. Codling moth mating disruption helped growers build up a population of predator mites to control pest mites, instead of having to rely on miticides (see section 2.2.2 Mites).

Based on the information we gathered from the interviews we classified growers into four segments with respect to management of codling moth. The segments are outlined in figure one and table five. The first segment consists of growers for whom codling moth is not a problem. Growers in Western Australia are the major group in this segment as this state is free of codling moth.

The second segment consists of growers who are controlling relatively small codling moth populations by strategically spraying two or three times a season. They use the day degree model and monitoring of moth populations in the orchard to decide when to spray. The pest pressures in these orchards are too low to justify the expense of using of mating disruption. These growers will generally be using a program of 'softer' chemicals though some may use broad spectrum chemicals.

The third segment consists of growers who use mating disruption as the basis for control of codling moth. We believe these growers face moderate but severe pressure from codling moth. These growers will only use chemicals to spray small areas of high infestation, or 'hot spots', in the orchard.

The fourth segment consists of growers who follow a calendar spray program. These growers may use monitoring to evaluate the effectiveness of their spray program but, generally speaking, will not use the monitoring to change the timing of sprays unless they encounter an infestation problem. We expect that most growers in this segment are located in the Shepparton region of northern Victoria.

Bob is a grower from the second segment.

> *Bob has 15 hectares of apples in Uraidla in South Australia. He sees codling moth as a major pest but not a major problem. He sprays on the trap count and usually only sprays about three times in a season. It's fairly cool so the moth doesn't get a chance to develop. Bob tried mating disruption but he found it was far too costly compared to the cost of using chemicals like Gusathion® [Azinphos Methyl] or Penncap® [Parathion Methyl].*

George, a grower from the third segment, uses mating disruption to control codling moth.

> *George has a stone and pome fruit orchard near Stanthorpe in Queensland. He tried isomates (mating disruption) to control codling moth and cut down on the chemicals he was using as he was experiencing a lot of problems with pest mites. The predator mites were being knocked around by the harsh chemicals so to help him build up the predator mites he trialled isomates. The first season he used both the isomates and a chemical program. The pest pressure came straight down and now he just uses the isomates and is very happy with the results. He doesn't have a problem with mites now and doesn't have to struggle with ineffective miticide sprays.*

Nick is an example of a grower from segment four using a calendar based spray program to control codling moth.

> *Nick and his brothers run a large orchard near Tatura in Victoria. Nick uses a calendar based spraying program to control codling moth. He tries to avoid using Gusathion® [Azinphos Methyl], except if it is early in the season, instead relying on Folidol® [Parathion Methyl]. This spray program works in*

Table Five: Summary of segments for codling moth

	Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Codling moth present	No	Yes	Yes	Yes
Moderate population pressure		No	Yes	No
High population pressure				Yes

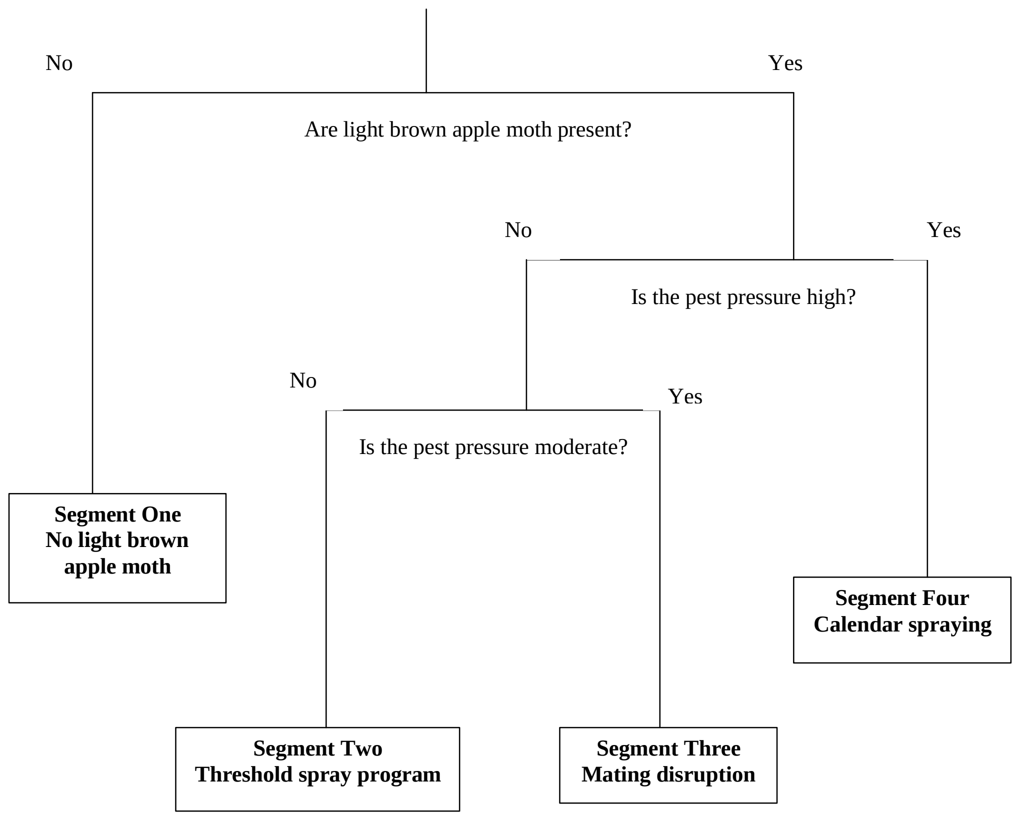

Figure One: Typology of segments for codling moth control *well with the calcium sprays they need to improve the storage life of apples. The isomates cost $450 per hectare and the Folidol® [Parathion Methyl] program only $120 per hectare. At the moment they don't have a problem with mites so Nick is very happy with the program. Nick has a consultant that comes in every week to monitor pests and predators. The consultant would pick up any problems.*

2.2.2 Mites

Pest mites can be controlled chemically with miticides or biologically using predator mites. There is widespread resistance to many miticides across Australia and growers are encouraged, if using miticides, to limit the number of applications per season and alternate chemicals from different groups.

In Victoria, NSW, Queensland, South Australia and Tasmania pest mites are generally well controlled by predator mites. Many growers we interviewed from these states indicated they had not had a mite problem for several years. For example:

> *Nick and his brothers run a large orchard near Tatura in Victoria. Generally Nick believes there is not a lot of mite pressure in the district. "We used to use more miticides", but since isomates (mating disruption) came into the district the number of miticide sprays have decreased. Predator mites were introduced 15 years ago [in the late 1980s], but they are rarely seen in the orchard. Nick believes some growers in the area still have mite problems because they use a Gusathion® [Azinphos Methyl] based program which knocks the predator mites around. Nick will only use Gusathion® [Azinphos Methyl] early in the season for this reason.*

Problems can occur with pest mite control when growers are forced to spray a chemical known to be detrimental to predator mites to solve another pest problem. For example:

> *James runs an orchard in East Shepparton growing stone and pome fruit. James has not had a mite problem for seven years. He puts this down to the softer chemicals he is using to control codling moth. He uses a Penncap® [Parathion Methyl] based calendar program. Penncap® [Parathion Methyl] does not persist in the environment for very long so has less effect on the predator mites. This year, because he has introduced bees into the orchard for flowering, he has to go in with Mavrik® [Tau Fluvalinate] to control apple dimpling bug. This chemical is tough on predator mites so he will have to watch his trees in order to make sure he doesn't get a mite problem.*

Most growers we interviewed in Western Australia had an occasional problem with pest mites in particular areas in the orchard, such as alongside a dirt track. For example:

> *Frank has a large orchard near Manjimup in Western Australia. He grows apples, peaches, avocados and nuts. He has had very few problems with mites, as his miticide program is working well. He alternates between two miticides to avoid resistance problems, Omite® [Propargite] and Vertimec® [Abermectin]. Generally the only places he sees mites are along dusty roads.*

Based on this information we divided growers into two segments based on their control of pest mites (see figure two and table six). The first segment consists of growers who rely on the predator mite population to control pest mites and who rarely, if ever, use a miticide. These growers rely on methods to control pests such as codling and light brown apple moth that do not harm predator mites such as mating disruption, growth regulators and 'soft' chemicals.

From segment one:

> *William runs a 350 acre orchard near Stanthorpe in Queensland. He is slowly moving to using isomates on all his apple blocks to control codling moth. He tried isomates in the early 90's because he had a problem with European red mites. The sprays he was using to control codling moth killed the predator mites and the miticides weren't working as well. Moving to isomates has meant he has not had to spray for red mites.*

The second segment consists of growers who routinely use miticides to control pest mites because, as a rule, they employ a persistent, broad spectrum chemical that is harmful to predator mites to control some pests. For example:

> *Matt runs a 280 acre orchard near Manjimup. Matt finds that the mite problem on his orchard is variable. He knows he has to be careful. If he uses Gusathion® [Azinphos Methyl] for weevil control he will have a problem with mites. However the weevils are a big problem, especially if they get into the trees.*

Also, from segment two:

> *Tom and Ed are managing a 16 acre apple orchard near Donnybrook. They have a program of miticides to control pest mites. This season they used Vertimec® [Abermectin] and they have not had a problem with mites.*

2.2.3 Light brown apple moth

Light brown apple moth can controlled with broad spectrum chemicals, "soft" chemicals designed to target light brown apple moth, or by using pheromones to cause mating disruption. Although light brown apple moth is a significant pest in Tasmania it is less of a problem in other states.

We classified growers into four segments for managing light brown apple moth. The segments are similar to those we identified for codling moth and are outlined in table seven and figure three. The first segment consists of growers who did not have a problem with light brown apple moth as the moth populations are extremely low or nonexistent.

The second segment consists of growers who use trap monitoring and chemical sprays to manage low populations of light brown apple moth. These growers use monitoring and moth growth forecasting to decide when and if to spray. They will generally be following a program using softer chemicals such as growth regulators. Some may use

Table Six: Summary of the segments for pest mites

	Segment 1	*Segment 2*
Are broad spectrum chemicals used to control pests	No	Yes

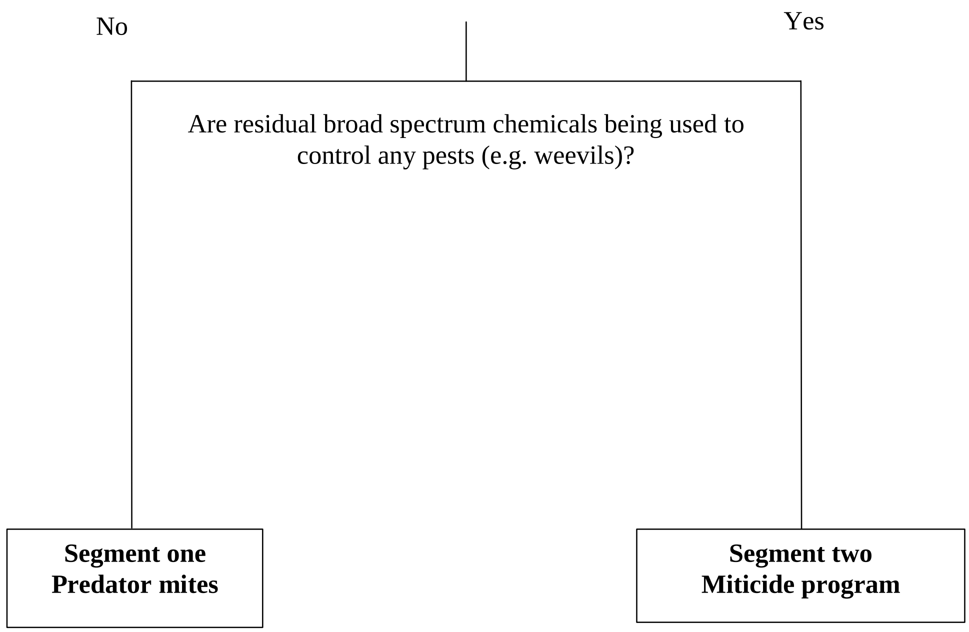

Figure Two: Typology of segments for pest mites

Table Seven: Summary of segments for light brown apple moth

	Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Light brown apple moth present	No	Yes	Yes	Yes
Moderate population pressure		No	Yes	No
High population pressure				Yes

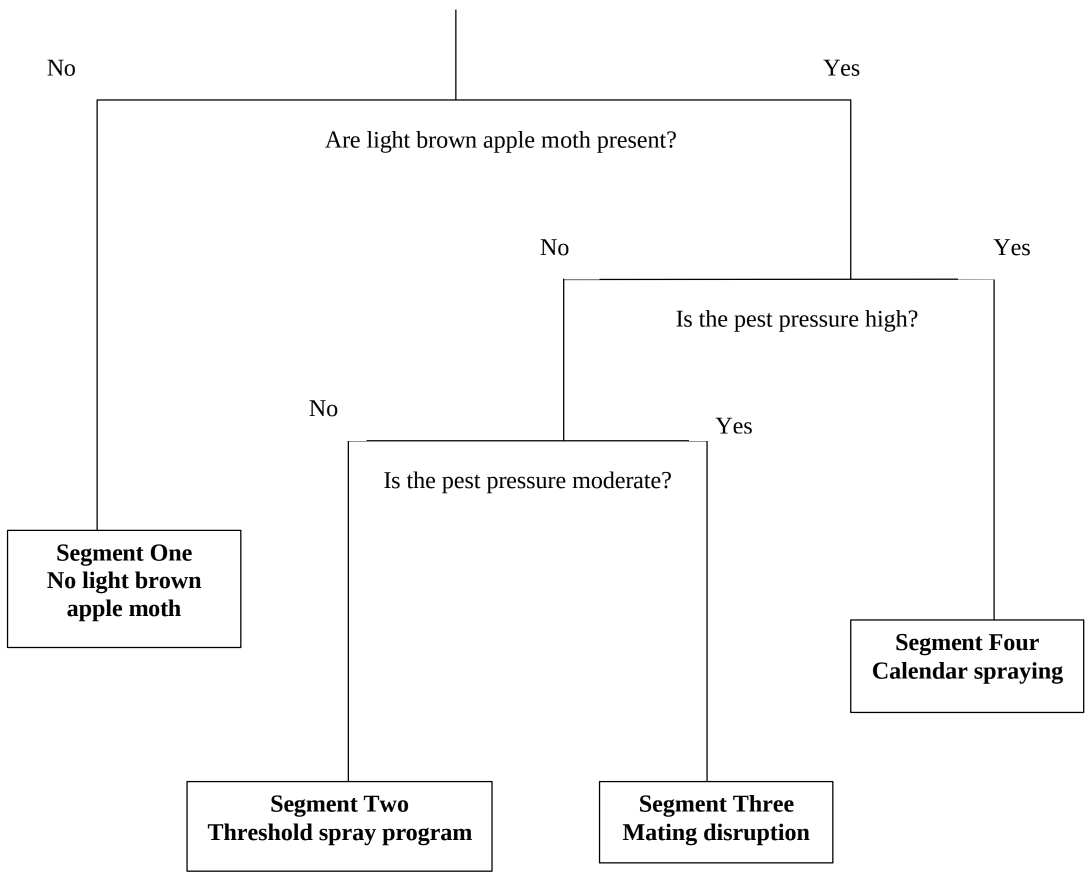

Figure Three: Typology of segments for light brown apple moth control broad spectrum chemicals but the timing of spraying will be based on monitoring information and they will only spray when target thresholds are reached.

The third segment consists of growers who use mating disruption as the basis for control of light brown apple moth. These growers have moderate light brown apple moth pressure. These growers may use chemical sprays if the pest population rises to levels that render disruption ineffective or in particular infestation 'hot spots' in the orchard.

The fourth segment consists of growers who use a calendar spray program and routinely spray to control light brown apple moth.

Jack is representative of growers in the second segment:

> *Jack and his father Dom own 12 hectares of apples just out of Glendevie in Tasmania. Light brown apple moth is a problem and Jack uses one Mimic® [Tebufenozide] spray a year, based on the degree day model. He doesn't use isomates, but monitors with traps to see how it's going. Jack says the pressure in their area is quite low.*

Sam is an example of a grower from the third segment:

> *Sam runs an apple orchard near Grove in Tasmania. The major pest problem he has is light brown apple moth. He stopped blanket spraying of chemicals in 1994 and tried using isomates to control light brown apple moth. Sam was part of a trial of this technology and was so impressed with the results he decided to continue with it. Sam believed it was a good idea to reduce chemical spraying and it allows him to make use of predators in the orchard to control other pests.*

From segment four:

> *Frank grows apples, peaches, avocados and nuts on his orchard near the town of Manjimup. Frank follows a routine of spraying insecticide and fungicide every two weeks for most of the season. He uses Gusathion® [Azinphos Methyl] or Lorsban® [Chlopryiphos] for light brown apple moth.*

2.2.4 Apple dimpling bug

Apple dimpling bug can be controlled with broad spectrum chemicals, during flowering when the bug is active. Apple dimpling bug was a pest in all states except for Tasmania. Many of the growers we interviewed routinely sprayed to prevent apple dimpling bug damage. For example:

> *James runs an orchard in East Shepparton growing stone and pome fruit. James says that apple dimpling bug can be a problem. Even if you are monitoring the orchard closely it can be hard to find. If you find one bug – then you have a problem. James has a preventive program of spraying to ensure apple dimpling bug is controlled.*

And in Queensland:

William runs a 350 acre orchard near Stanthorpe in Queensland. William always applies an early Lorsban® [Chlorpyrifos] to control apple dimpling bug.

We classified growers into three segments based on the information collected in interviews (see figure four and table eight). The first segment consists of growers whose orchards are free of apple dimpling bug. Most growers in this segment are located in Tasmania. The second segment consists of growers who can tolerate some damage to fruit from dimpling bug and who routinely monitor for apple dimpling bug and spray if a population threshold is reached. The third segment consists of growers who cannot tolerate any damage from dimpling bug and follow a preventive program of cover spraying.

The difference in the behaviour of growers in the second and third segments may also be because growers in the second segment may have experienced much lower levels of dimpling bug infestation, and slower rates of population expansion, than growers in the third segment.

From the second segment:

Joy and Duncan grow apples and stone fruit on a small property near Donnybrook. Joy monitors for apple dimpling bug and if she finds any she sprays with [Endosulfan]. The weather generally determines if apple dimpling bug is present as it comes in on the easterly winds. Joy has been caught out once but maintains her monitoring system.

A grower from the third segment:

Julian and Natalie run a stone and pome fruit orchard out of Donnybrook in Western Australia. To control apple dimpling bug Julian uses Mavrik® [Tau Fluvalinate]. He sprays one side of the tree one week and the other side of the tree the following week. He always sprays for apple dimpling bug because he exports his fruit and they need to be just right. He found the monitoring didn't work – the fruit was already too badly damaged by the time you saw the bugs.

2.2.5 Woolly aphid

Woolly aphid can be controlled with broad spectrum chemicals and with *Aphelinus Mali*, a wasp that parasitises the aphid. In interviews with growers we discovered woolly aphid was becoming a serious pest problem in many States because of the reduced use of broad spectrum chemicals. Growers in Tasmania were particularly concerned that they were losing control of woolly aphid by following an IPM program.

Table Eight: Summary of segments for dimpling bug

	Segment 1	*Segment 2*	*Segment 3*
Dimpling bug present	No	Yes	Yes
Damage to fruit must be prevented		No	Yes

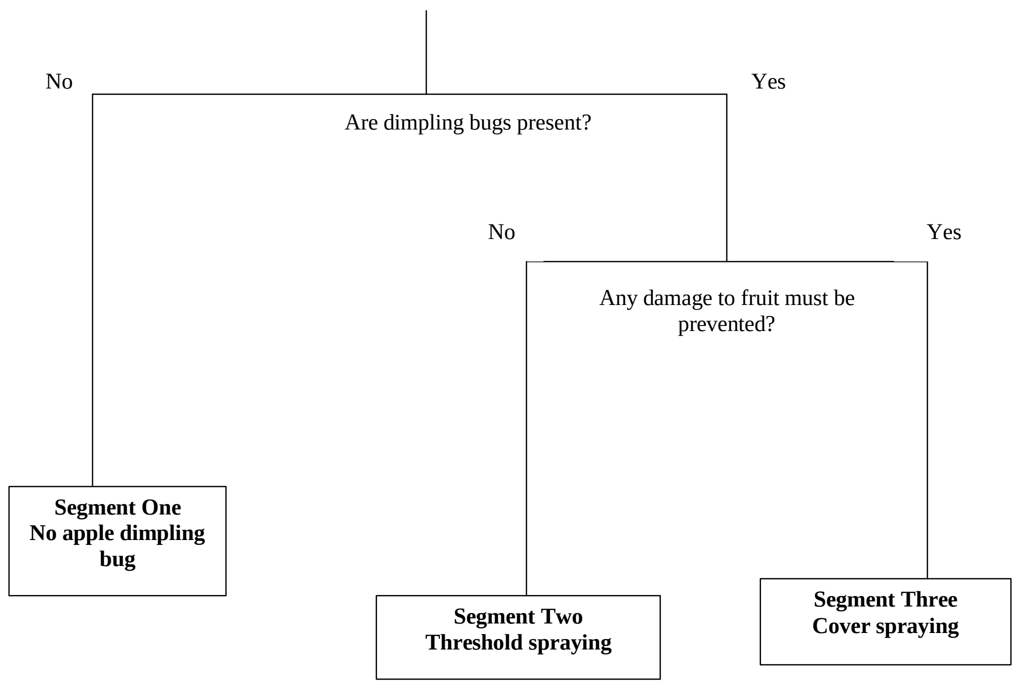

Figure Four: Typology of segments for dimpling bug

For example:

Adam manages 160 hectares of apples near Geeveston, Tasmania. His biggest fear is seeing a woolly aphid become a problem. Adam has been using Endolsulfan® [Endosulfan] together with oil over winter to try and keep on top of the problem. Adam is also adding in a spray of liquid Lorsban® [Parathion Methyl] early in the season to help with woolly aphid control. He is seeing quite good results with this approach, however he knows this is not an IPM friendly approach. He says this is annoying as he has to balance the need to hit the pest on the head early with the need to let the parasitic wasp have a chance to get woolly aphid under control. He would like to see an IPM friendly woolly aphid spray.

While Adam has heard good results from the use of Confidor® [Imidacloprid], he is not sure if he could use it as some of the apples produced are exported to Japan (He is not sure if MRL's have been established for Confidor® [Imidacloprid]).

Growers in other areas are also observing the reappearance of woolly aphid. For example:

Mal has 62 acres of apples just out of Orange in NSW. He is seeing a bit of woolly aphid just before harvest and is going back to using a preventive spray earlier in the season to clean it up. Mal believes he is seeing more woolly aphid because he is using Penncap® [Parathion Methyl] which does not persist for very long in the environment.

We did not classify growers into segments in terms of management of woolly aphid as this pest has been controlled partly through the use of parasitic wasps and partly through the spraying of broad spectrum chemicals for other pests. However, the reappearance of woolly aphid as an economic pest is requiring some growers to use preventative sprays.

2.2.6 Weevils

Many growers we interviewed indicated that, until recently, weevils have not been a major pest in apples. However as the use of broad spectrum chemicals declines growers are seeing a rise in the weevil population. For example:

Bob has 15 hectares of apples in Uraidla in South Australia. Fuller's rose weevil is a pest that Bob knows has been around for years. However since he has stopped spraying [Melathion] he has seen the weevil population rise. He has considered a few options. Bob knows that if he ends up butt spraying with a synthetic pyrethroid to control them he will need to use Vertimec® [Abamectin] to control the mite flares because the synthetic pyrethroid will kill the predator mites and anything else that is over-wintering on the ground.

And:

Julian and Natalie run a stone and pome fruit orchard out of Donnybrook in Western Australia. Weevils are their main pest problem. Although Julian *knows roughly what time of year they will appear, if he sees one in the orchard he will spray. He uses Dominex® [Alpha-cypermethrin] as a butt spray to help control the weevils. Usually two sprays will do but he will sometimes need three. Julian says they were not a problem in the early days but they have become more of a problem in the last 10 years.*

We did not classify growers into segments with respect to management of weevils as this pest can only be controlled using broad spectrum butt sprays.

2.2.7 Oriental fruit moth

Oriental Fruit Moth is widely recognised as a significant pest of stone fruit. However in northern Victoria, which has a mix of stone and pome fruit in close proximity, growers have also seen oriental fruit moth damage on pome fruit. Oriental fruit moth can be controlled with broad spectrum chemicals, or by releasing pheromones to cause mating disruption. For example:

Brad runs a large orchard in Ardmona in Victoria. His major pest problem is oriental fruit moth. He says it comes out of the stone fruit and into the pome fruit. He is using isomates to control the population and is part of a group trialling Wide Area Mating Disruption in the district.

We found that many growers were using a mating disruption program for control of oriental fruit moth. However many of the same growers had a calendar based spray program for controlling codling moth. For example:

Nick and his brothers run a large orchard near Tatura in Victoria. Nick uses isomates to control oriental fruit moth in the orchard, but has a calendar based program to control codling moth. He has had problems with oriental fruit moth resistance to Gusathion® [Azinphos Methyl] in the past. He had to try and keep ahead so shifted to the isomates. Nick says the major difference with the apples compared to stone fruit is that stone fruit do not require nutrient sprays. Apples need regular calcium spraying to improve storage life.

This leading us to conclude that a grower's approach to managing pests depends more on their specific circumstances (such as the intensity of pest pressure in their orchard) and less on their attitudes towards integrated pest management in particular and sustainability in general.

We did not classify growers into segments with respect to management of oriental fruit moth as this pest is usually controlled in pome fruit by mating disruption.

2.2.8 Fruit fly

There are two Fruit Fly species that are pests in Australia. The Mediterranean fruit fly in Western Australia and the Queensland fruit fly in Queensland. Fruit fly can be controlled by baiting or with cover sprays. For many growers cover sprays for other pests also provided a means of controlling fruit fly. This situation is changing however with the adoption of ‘softer’ methods for managing codling moth such as mating disruption. For example in Queensland:

> *George has a stone and pome fruit orchard near Stanthorpe in Queensland. The flip side of being able to control codling moth without Gusathion® [Azinphos Methyl] is that George now thinks he might get a problem with fruit fly, as the Gusathion® [Azinphos Methyl] was helping to suppress it. He believes he will have to start a program of bait spraying for fruit fly now.*

2.2.9 Other pests

Other pest problems that were discussed during the interviews were Western Flower Thrips, Looper and Scale. Looper and scale were minor pest problems for growers and were relatively easy to control. Western Flower Thrips have recently become a problem in Stanthorpe in Queensland. However the growers we interviewed seemed confident they would be able to manage this pest.

2.3 Diseases

In the following sections we describe the different methods growers use to manage the major diseases of apples – black spot or apple scab and powdery mildew. We also tentatively classify growers into segments in terms of these methods and describe the factors influencing their choice of management method.

2.3.1 Black spot

Black spot, also known as apple scab, is a significant disease problem for all states with the exception of Western Australia. It is controlled with a program of protectant fungicide cover sprays with the addition of systemic fungicides (i.e. eradicant sprays) as needed. Systemic fungicides are absorbed into the plant and kill the fungus. Protectant or cover sprays act on the plant surface to prevent germination of the fungal spores. Growers are also being encouraged to undertake cultural practices such as mulching leaves at the end of the season to reduce the disease pressure for the following year.

Using the information gathered from interviews we divided growers into three segments (see table nine and figure five). The first segment consists primarily of growers from Western Australia who are free of black spot. The second segment consists of growers who have a control program for black spot based on monitoring of weather conditions. These growers rely on forecasts of infection periods based on weather information. Key factors in the success implementation of this approach to black spot control are access to reliable forecasts of infection periods, reliable access to the orchard within the infection period, and the labour and machinery capacity to spray the orchard within an appropriate time frame.

The third segment consists of growers who have a cover spray program for black spot. Many of the growers in this segment do not feel that have a viable alternative to routinely spraying, given that most are located in areas with high disease pressure or are in areas where actual infection periods do not correlate well with forecast infection periods. The segments are outlined in figure six and table seven.

From the second segment:

> *Bob has 15 hectares of apples in Uraidla in South Australia. For black spot Bob puts on a protectant plus a DMI [demethylation inhibitor] early in the season, then after thinning he sprays on black spot warnings. He has one of the weather stations that form the black spot warning system on his property so he is very confident about the information. Bob says it takes the guesswork out of it. As insurance Bob says he may add a protectant fungicide into a codling moth spray if he hasn't sprayed for black spot for a while. He also mulches the leaf litter at the end of the season.*

Table Nine: Summary of the segments for black spot

	Segment 1	***Segment 2***	***Segment 3***
Black spot present	No	Yes	Yes
Predictable infection period and capacity to respond		No	Yes

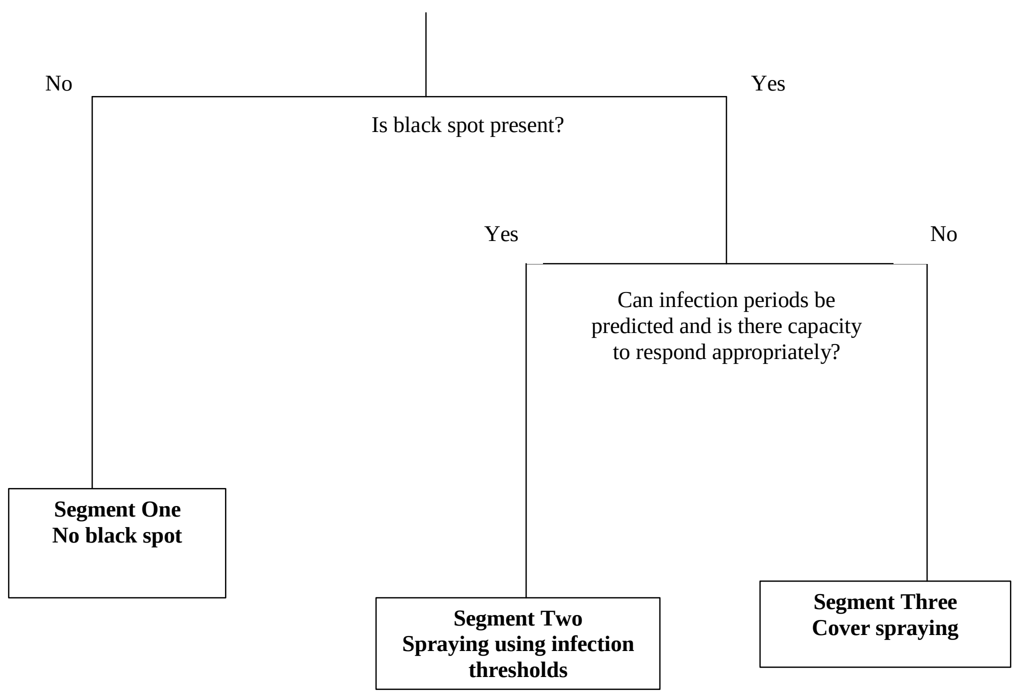

Figure Five: Typology of segments for black spot

From segment three:

> *Mal has 62 acres of apples just out of Orange in NSW. Black spot is the major disease problem in the orchard. Mal has a program of protectant fungicides, applied every two weeks from September to November.*

From a grower in Tasmania, also in segment three:

> *Euan and his brothers run 60 hectares of orchard at Huonville in Tasmania. Black spot is their major disease problem, exacerbated by the changeable weather. Like most growers in the area, Euan avoids this by regular spraying to prevent back spot. He got caught once with bad weather and couldn't get into the orchard for a week. Then he found he had a huge problem with black spot.*

There was some concern about resistance in black spot to fungicides. The Department of Primary Industries at Stanthorpe in Queensland is leading an apple breeding program to find a commercial apple variety that is black spot resistant. A grower from Orange expressed his concern about the issue and outlined his approach:

> *Jeff and Jacinta run an apple orchard near Orange in NSW. Black spot is the major disease they have in the orchard. They have been using a protectant program, however Jeff is concerned about resistance problems [in the commonly used fungicides]. Jeff gets information on black spot from the weather station system so he is moving more towards an eradicant program. He has also started cleaning up the orchard at the end of the season to reduce the amount of disease in the orchard for the following year.*

2.3.2 Powdery mildew

Powdery mildew is a disease problem in all apple growing regions, although generally less severe than black spot. Powdery mildew is controlled with protectant fungicide cover sprays over flowering. Growers are also encouraged to remove infected material. Some of the fungicides available cover both powdery mildew and black spot.

Some of the growers we interviewed used early cover sprays for powdery mildew control. For example:

> *Phil and his brother run a large orchard with 60 acres of apples near Shepparton in Victoria. Their orchard is relatively isolated so they don't tend to have the same pest and disease pressure that other growers in the district have to deal with. Their major disease problem is powdery mildew. Phil applies cover sprays early in the season which he finds is enough to deal with the problem.*

Other growers had a program for the whole season.

> *Hans and Victoria have been orcharding for 16 years on a small property near Donnybrook in Western Australia. They grow apples, pears, avocados and plums. Their main disease problem is powdery mildew which is kept under control with three to four lime sulphur sprays each season.*

We did not believe it was worthwhile to classify growers into segments in terms of management of powdery mildew as growers use a preventative spray program to control this disease.

2.5 Conclusion

Growers from different regions had to contend with different pest and disease problems. Codling moth, light brown apple moth and dimpling bug are the major pests and black spot is the key disease in most regions except WA which is free of codling moth and black spot.

Our interviews with growers revealed that the particular combinations of pest and disease management practices they use are determined primarily by their orchard circumstances, not their attitudes towards sustainability and the environment. The key factors that were identified by growers as influencing their adoption of pest and disease management practices were the climate and topography of the orchard, the isolation of orchard, the crop types in the region, the chemical and biological options available for managing pests and diseases, the effectiveness of those options.

Climate, topography, orchard isolation and crop mix determine the type and intensity of pest and disease pressures in an orchard.

- The climate largely dictates the type and intensity of pest and disease pressures in an orchard. The particular mix of pests and diseases present in an orchard, and the intensity with which they are present, can limit the control options available to growers.
- The topography of the orchard can create micro climates which will have an impact on the pests and diseases present and the efficacy of some control options.
- The physical distance between orchards can create a natural barrier against the movement of pests and disease between properties. Orchards that are geographically distant from each other appeared to have considerably lower pest pressures compared to others in the same region that were less isolated.
- The mix of tree crops in an area can also contribute to pest and disease pressures.

Growers' management of pest and disease pressures is determined by chemical and biological options available for managing pests and diseases, the effectiveness of those options.

- For many apple pests the only control options available are broad spectrum chemicals.
- Market requirements such as residue limits and tolerance of cosmetic damage to fruit are also a major factor influencing the options available to growers for managing pests and diseases.

One of the principal themes to emerge from the interviews was the role of resistance to chemicals in triggering widespread changes in pest and disease management. In discussions with growers it emerged the shift to organophosphate chemicals in the seventies resulted from increasing resistance to DDT in pest populations. The failure of failure of miticides in the late eighties and early nineties forced fruit growers to try alternative methods of mite control, namely the use of predator mites. However the effectiveness of predator mites was undermined by their susceptibility to the broad spectrum pesticides used for control of codling moth. With the emergence of mating disruption as a successful substitute for pesticide control of codling moth, there was a dramatic improvement in the effectiveness of predator mites for controlling pest mites.

As a result of the decline in broad spectrum chemical use that has accompanied the use of control measures such as growth regulators and mating disruption secondary pests were identified as increasingly becoming an issue for growers in all regions. Unfortunately, broad spectrum chemical are the only means of controlling many secondary pests. Hence, the emergence of secondary pests as major economic pests represents a key threat to the future of integrated pest management.

3. Irrigation management

3.1 Introduction

The information we gathered during interviews with growers regarding irrigation management was consistent with our previous work (Kaine and Bewsell 1999) and (Kaine and Bewsell 2000). The adoption of new irrigation technologies depended on the benefits these technologies offered the grower.

3.2 Irrigation systems

Irrigation was required in all states for apple production. There was a mix of irrigation systems being used, from flood irrigation through to drip irrigation. Most growers used some form of pressurised irrigation. Growers have adopted pressurised irrigation systems for one or more of the following reasons:

- A need reduce the amount of water used in the orchard;
- A need to reduce the time and labour required to manage irrigation in the orchard;
- A desire to better co-ordinate orchard activities such as irrigation and harvesting;
- The orchard has been redeveloped to a high density planting design (closer plantings), in some cases on dwarfing rootstock, and pressurised irrigation allows growers to control water application.

With this information we divided growers into five segments. These segments are outlined in table ten and figure six. Segment one consists of growers who are flood irrigating. Segment two consists of growers who have installed micro-irrigation because they have redeveloped their orchard to a closer planting design. From segment two:

> *Jack and his father Dom own 12 hectares of apples near Glendevie in Tasmania. The orchard is irrigated with drip irrigation. They are moving towards high density planting so feel there is a need to improve their irrigation in order to get better yields. The irrigation water comes from a farm dam and they always have enough water.*

Segment three consists of growers who installed micro-irrigation because they need to conserve water in the orchard or because the topography or soils in their orchard was not suitable for flood irrigation. These growers are generally relying on good seasonal rainfall to fill on-farm water storages, or may obtained irrigation water from a bore but there are restrictions on how much water can be pumped. These growers need to make the most of their water. For example:

> *Mal has 62 acres of apples just out of Orange in NSW. Mal's orchard is under drip irrigation. He has limited water supplies, even though he has both a dam to catch run off and access to a bore. He generally pumps the bore water into the dam to help him through the season.*

Segment four consists of growers who have converted to micro-irrigation simply to save time irrigating. For example:

> *Harry grows pears and apples on a small orchard in East Shepparton in Victoria. He has a mix of flood and sprinkler irrigation. He finds with the flood irrigation that it is hard to manage his spray program. After flooding he cannot get onto the block for four to five days. If he needs to spray he has to hold off on the irrigating. But that stresses the trees and then he gets mite flares. With sprinklers he has been able to overcome this problem.*

The final segment, segment five, consists of growers that have installed micro-irrigation because they wished to save time irrigating and have redeveloped their orchard to a high density planting design. For example:

> *On his orchard near Manjimup in Western Australia Frank grows apples, peaches, avocados and nuts. He irrigates his orchard with mini sprinklers. Frank used to irrigate with overheads but these blocks had to be pushed out because of apple scab. So when he planted up again he went into mini sprinklers. He gets his water from a local creek, and has never had a water shortage problem.*

Table Ten: An outline of the irrigation system segments

	Segment 1	***Segment 2***	***Segment 3***	***Segment 4***	***Segment 5***
Need to save time irrigating	No	No	No	Yes	Yes
Need to conserve water/topography	No	No	Yes	-	-
Orchard planted to high density design	No	Yes	No	No	Yes

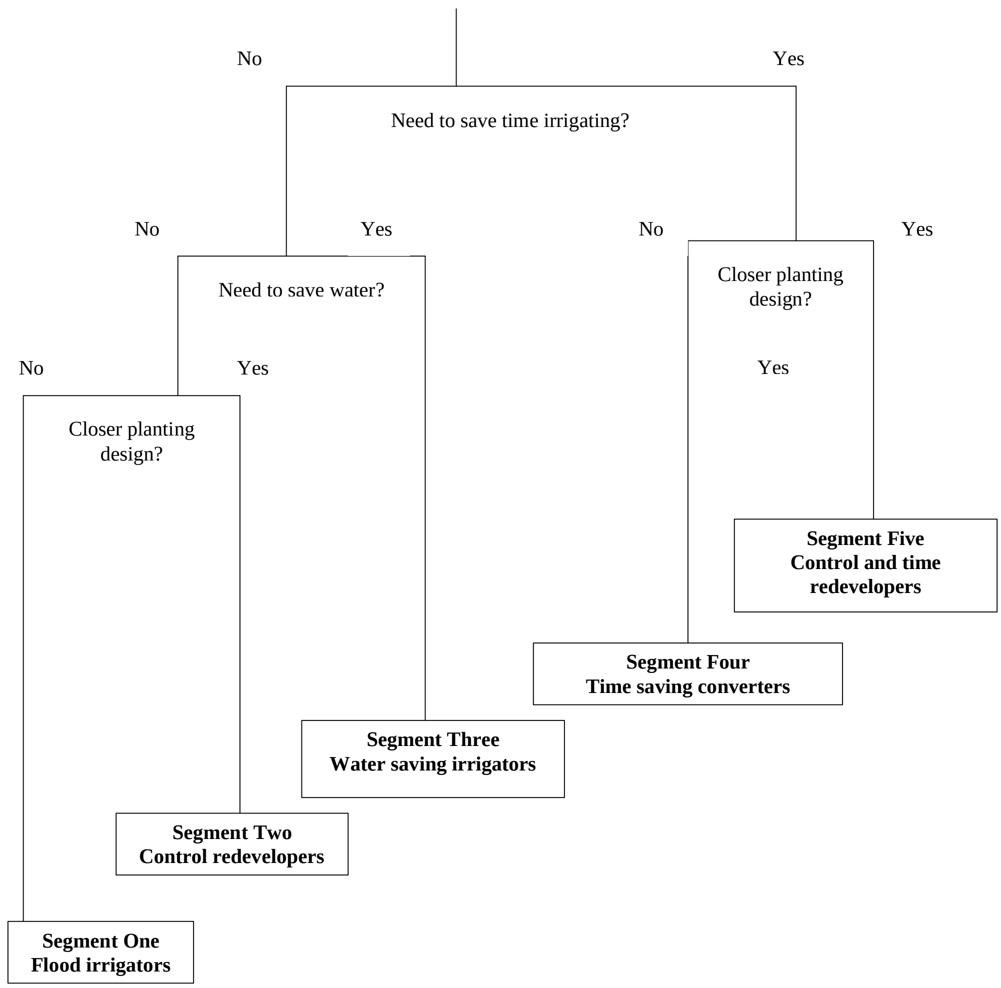

Figure Six: Typology of segments for irrigation

3.3 Soil moisture monitoring

The use of soil moisture monitoring varied among growers. We found that growers with soil moisture monitoring did not necessarily believe that irrigation scheduling using soil moisture monitoring would improve the quality or quantity of fruit produced. Growers indicated they were unlikely to use soil moisture monitoring unless:

- There was a need reduce the amount of water used in the orchard;
- There was a problem in the orchard that the grower believed could be fixed through improving their control over irrigation management, for example, a problem with water logging in a poorly drained section of the orchard;
- There was a need to check the efficacy of irrigations, for example on a large orchard.

Many growers in Shepparton do not have the flexibility, in terms of adjusting the timing of irrigations, to respond effectively to information from soil moisture monitoring. This is because they are unable to irrigate ‘on demand’. Irrigation water is distributed to fruit growers in Shepparton through a system of district channels. Consequently, these growers must order irrigation water up to a week in advance because of constraints imposed by the limited capacity of the channel system and the time taken for water to travel from the headwater storage dams to the irrigation districts. Fruit growers in other areas were able to irrigate on demand because they obtained irrigation water either from bores or from rainfall collected as run-off in on-farm dams. Fruit growers in these circumstances are more likely to have the flexibility to adjust the timing of irrigations in response to information from soil moisture monitoring.

We classified growers into four segments based on the information they supplied in interviews (see table eleven and figure seven). The first segment consists of fruit growers who need to maximise their production per unit of water used in the orchard. Generally, growers in this segment have limited supplies of irrigation water in the form of run-off stored on-farm or ground water. Some growers in this segment may want to expand their orchard and cannot buy extra water. For example:

> ***William runs a 350 acre orchard near Stanthorpe in Queensland. The orchard is under trickle irrigation. The irrigation water comes from farm dams catching run off. He uses a soil moisture monitoring service. He saved a great deal of water and was able to expand the orchard area with the water he had saved.***

Table Eleven: An outline of the soil moisture monitoring segments

	Segment 1	***Segment 2***	***Segment 3***	***Segment 4***
Need to save water	Yes	No	No	No
Problems with water logging or vigour	No	Yes	No	No
Check irrigation effectiveness	No	No	Yes	No

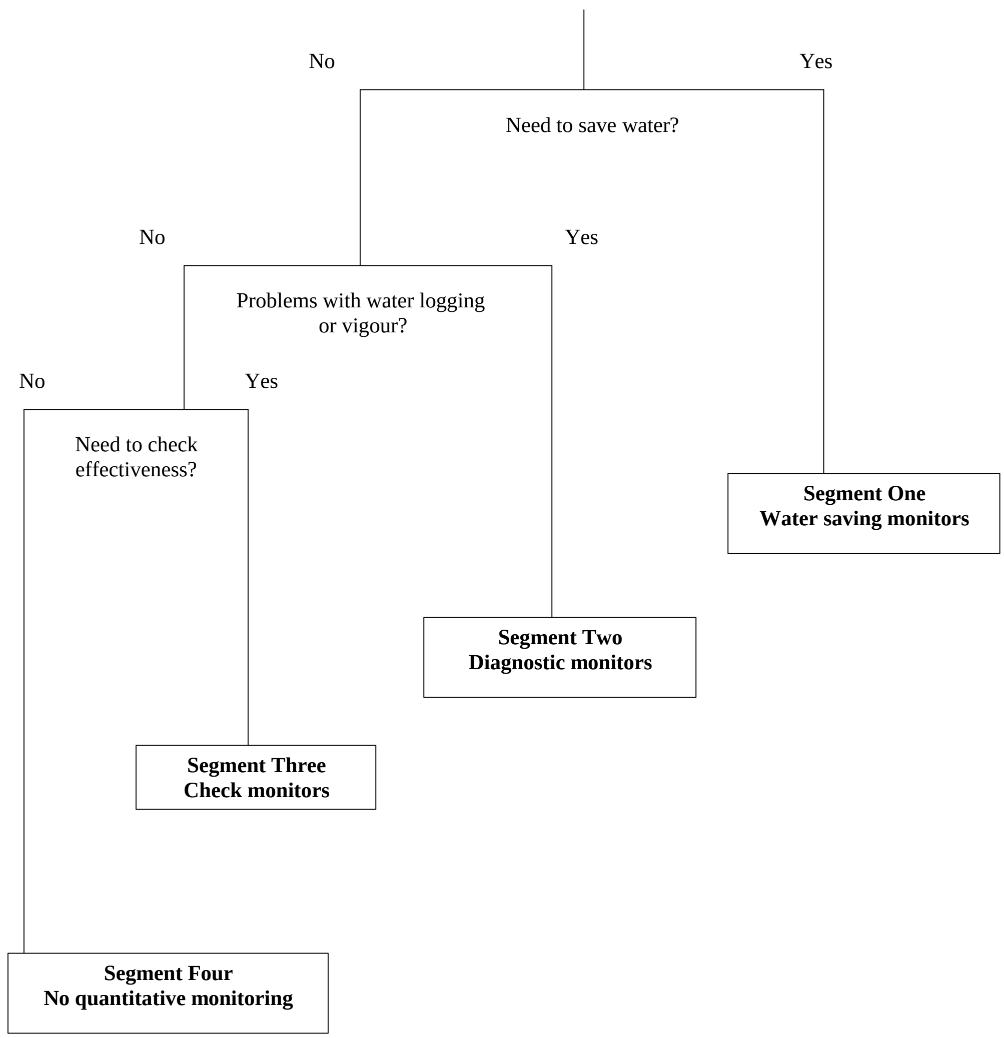

Figure Seven: Typology of segments for soil moisture monitoring

The second segment consists of growers who have a problem in the orchard that they believe they can solve by improving their irrigation management. Growers in this segment may have problems controlling vigour or an area in their orchard which is poorly drained. These growers are hoping to increase fruit production and quality by altering the timing and length of irrigations. For example:

> *Joy and Duncan grow apples and stone fruit on a small property near Donnybrook. The orchard is irrigated with micro jets. Geraldine and Ben chose the micro jets because it allows them to have a grass sward in between the rows, which then allows them to create mulch and because they help keep the orchard cool. They have mounded up their rows because they have some drainage problems on their block. They use Sentek soil moisture monitoring equipment which helps them with the irrigation and with fertigation.*

The third segment consists of growers who need to check the efficacy of irrigations. Often these growers are managing large orchards and want to check the irrigation management.

The fourth segment consists of growers who do not use soil moisture monitoring. These growers do not need to save water, do not have a problems with water logging and they believe their irrigation management is resulting in satisfactory yields and fruit quality. Some of these growers may have tried soil moisture monitoring, but found that it did not provide them with any information that justified changing their irrigation scheduling. For example:

> *Terry runs an orchard in Lenswood South Australia. Terry gets his irrigation water from bores, and also has two dams. Eighty per cent of the property has overhead sprinklers. This allows him to cool the orchard later in the season to help improve colour on late varieties, particularly pink lady. This means they can be picked at the right time and so storage isn't a problem. The rest of the orchard is under mini sprinklers. Terry uses a shovel and experience to schedule irrigations in the orchard. He says that In the Adelaide Hills irrigation is not critical because the soil has very good water holding capacity.*

A grower from segment four who has tried soil moisture monitoring:

> *Adam manages 160 hectares of apples near Geeveston, Tasmania. The apples are irrigated with drip irrigation on heavy soils, micro irrigation on sandier soils and overheads where there is the risk of frost. He does not use any form of soil moisture monitoring as he believes that they "tell you what you already know". Adam used tensiometers on a property he managed in Victoria and found they were too time consuming.*

We found that growers who had used soil moisture monitoring often found that they did not need to continue monitor as intensively after a period of time. As George from Stanthorpe Queensland explains:

> *George irrigates with trickle irrigation and monitors with the Diviner 2000®. He used to use tensiometers but is pleased with the Diviner 2000® because you can see further down the soil profile and get a better idea day by day. In the beginning he went out everyday to monitor but has found that he monitors less often as he is getting a feel for it.*

3.4 Conclusion

A variety of irrigation systems were being used, from flood irrigation through to drip irrigation, in apple production. Most fruit growers used some form of pressure irrigation such as micro jets or drip irrigation. Growers have adopted these systems for one or more of the following:

- A need reduce the amount of water used in the orchard;
- A need to reduce the time and labour required to manage irrigation in the orchard;
- A desire to better co-ordinate orchard activities such as irrigation and harvesting;
- The orchard has been redeveloped to a high density planting design (closer plantings), in some cases on dwarfing rootstock, which only suit micro-jet or drip irrigation.

These results are consistent with the findings from our previous work (Kaine and Bewsell 1999) and (Kaine and Bewsell 2000). These results indicate that the adoption of new irrigation technologies depends on the benefits these technologies offered the grower. These benefits differed according to the particular topographical, soil and labour circumstances of individual orchards. This association between the characteristics of a growers orchard and fruit enterprise, the benefits growers seek from their irrigation system and the type of irrigation system they use, is evidence that growers follow a complex decision making process when considering whether to adopt new irrigation technologies.

Generally speaking, we found that growers with soil moisture monitoring did not necessarily believe that irrigation scheduling using soil moisture monitoring would improve the quality or quantity of fruit produced. Growers were most likely to use soil moisture monitoring when there was a need reduce the amount of water used in the orchard or there was a problem in the orchard that the grower believed could be fixed through improving their control over irrigation management.

4. Whole farm planning, quality assurance and record keeping

4.1 Introduction

A key feature of Integrated Fruit Production is the documentation of orchard activities and decision making, especially in relation to management of pest and diseases, irrigation, fertiliser management and fruit production and packing. The documentation of orchard activities and decision making is intended to provide a means of tracing product flow to resolve food safety concerns, to provide evidence of acting in an environmentally responsible manner, and to assist growers in their decision making.

To date, the only documentation requirements apple growers in Australia have had to comply with pertain to the maintenance of spray diaries. However, many growers have participated in quality assurance schemes of various kinds, each scheme with its particular reporting and auditing requirements. Fruit growers in the Shepparton region in particular are also required to submit certified Whole Farm Plans when seeking financial assistance for redeveloping their orchards.

To obtain some insights into growers' likely views on record keeping and documentation as part of Integrated Fruit Production we questioned growers about their experiences with quality assurance schemes, whole farm planning where appropriate, and their sought their views on record keeping and orchard management.

4.2 Whole Farm Planning

Fruit growers did not view whole farm planning as a key management tool. Fruit growers were quite mixed in their views on the value and meaning of whole farm planning. Only growers in Shepparton were familiar with the term 'whole farm planning' and many had obtained a plan when redeveloping their orchards. Growers in Shepparton viewed a whole farm plan primarily as an irrigation design plan. Such plans were obtained by growers to qualify for a subsidy for installing micro-irrigation. Most growers expressed a strong belief that there was little or no benefit to a formal whole farm plan. Growers did not believe that they needed a whole farm plan to assist them in planning the redevelopment of their orchards. For example:

> ***Francis, a grower near Shepparton, got a whole farm plan done when he was converting to micro irrigation. He wanted to get the subsidy but found the plan wasn't very good when it came to installing the irrigation. He ended up doing his own plan when it came time to actually install the irrigation system!***

Growers in fruit growing areas other than Shepparton often had plans of their orchard, outlining the blocks, varieties and irrigation system, but these plans were not certified whole farm plans.

4.3 Quality assurance

There are a number of quality assurance schemes operating in Australia such as the SQF 2000^{CM} Quality Code and the Freshcare Code of Practice. The systems are generally based on safety and quality, although this can differ, depending on the system (McBride 2002).

We soon discovered that the introduction of a discussion on quality assurance into interviews with growers was guaranteed to liven up proceedings. Growers held very strong views on quality assurance, and the impact it has had on them and their businesses. These views ranged from generally favourable among growers who packed fruit through to very unfavourable, especially among growers who did not pack fruit. Generally growers appreciated the need for product flows to be traceable and accountable in terms of food safety. However they questioned whether or not quality assurance schemes were efficient. Many growers could not see any causal link between food safety and the records they were required to keep and the processes they were required to follow.

All growers were aware that random tests to check compliance with Maximum Residue Limits (MRLs) were carried out and some growers were able to relate instances where their fruit had been checked. For example:

> *Terry runs an orchard in Lenswood South Australia, growing fruit for the domestic market. He has a large packing shed that has a HACCP system in place, although it is not accredited. They have been audited by the agent they supply fruit to. Terry keeps chemical records, spraying, dipping and residue testing records. One year there was a problem with the dipping where the chemical concentration got too high. The fruit had been tested for residues and although Ian wasn't over the allowable limit, it was higher than normal. Ian got a call to ask what was happening. Since then he has been extra careful with the dip records and even carries out titrations to ensure that the dip chemicals are at the right levels.*

Many growers we spoke to had tried quality assurance but had found that the process was demanding in terms of time and they felt there were no obvious benefits, particularly if they did not pack fruit. The response from these growers in Western Australia was typical:

> *Hans and Victoria obtained SQF2000 certification when the system was first promoted, however they have been disappointed with the results. They felt it was a lot of work with no return to them. They have discontinued their certification and this has had no effect on their ability to sell their fruit. They don't see the need for a quality assurance system at the moment. They keep spray records which are sufficient for their buyers' requirements.*

A grower in Tasmania took a similar view:

> *Ewen and his brothers run 60 hectares of orchard at Huonville in Tasmania. Roughly half of the apples they produce are sent for export, the rest are sold on the domestic market. They pack their own fruit so have a quality assurance system (SQF 2000), which was forced on them because of the supermarkets in Australia. Ewen says it's really all about traceability. But they [the growers] carry the cost of the quality assurance system but don't get paid enough for their fruit. "A few more dollars per kilo and it would make a huge difference."*

One grower from the Adelaide Hills was blunt in their assessment:

> [Quality assurance is] *a real dog's breakfast. There are too many systems and they're very expensive.*

Based on the information gathered from interviews we classified growers into three segments in terms of their propensity to adopt or comply with quality assurance programs. The segments are outlined in table twelve and figure eight.

The first segment consisted of those growers who did not pack fruit, and therefore felt there was less of a need for quality assurance. A typical example of a grower from segment one is Sam from Grove in Tasmania.

> *Sam is sceptical about the value of quality assurance programs and doesn't have one. "It limits your markets, but it's too much hassle for the amount of apples we grow. It's the same amount of work, no matter what size you are," says Sam. "The bigger orchards can employ a separate person just to do the quality assurance." Sam argues that he has an inbuilt quality assurance system. If you don't do a good job now then you won't be selling any fruit the next year. You have to supply what the market wants or you won't sell fruit. Sam has to forward his spray diary to the packing shed for their records, but that's all the requirements he has.*

Another example is Julian from Manjimup:

> *Julian used to be a fruit packer and so had a quality assurance system in place, but now he no longer packs and just grows for exporters he doesn't have one. He says it got ridiculous the things you were expected to do. And it didn't have much to do with food safety. As long as he meets the residue limits and provides his buyer with a spray diary he can sell his fruit.*

The second segment consists of growers who packed and grew fruit, but sold primarily into the domestic market. These growers were more likely to have a quality assurance system than growers in the first segment, particularly if they were supplying a supermarket.

> *Matt runs a 280 acre orchard near Manjimup in Western Australia. He sells his apples via Sydney mainly and into Coles. He is in the SQF2000 quality assurance scheme. Matt says it is pretty daunting and a waste of time sometimes. It's good for keeping track of chemicals and being able to trace back, however he has always kept chemical records.*

Table Twelve: Segments for quality assurance systems

	Segment 1	*Segment 2*	*Segment 3*
Grower only	Yes	No	No
Grower and packer	No	Yes	Yes
Export market focus	-	No	Yes

Figure Eight: Typology of segments for quality assurance

The third segment consists of growers who grew and packed fruit for both the domestic and export market. These growers were the most likely to have a quality assurance system however the benefits the system offered depended on the export market they were targeting.

Richard runs a 70 hectare orchard growing apples and cherries near Grove in Tasmania. Richard sells both domestically to the supermarkets and also exports. He packs for some of the local growers in the area as well. He has two quality assurance systems, SQF2000 and a supermarket specific system. He says, "It's a necessary evil because supermarkets think it's decreasing their risk..." The export markets for Tasmanian apples though are mainly the Indian sub-continent and Asia. They are not demanding quality assurance systems at this stage.

4.4 Record keeping

In the interviews we sought growers' views on the importance to orchard management of record keeping and documenting decision making about orchard activities. We were particularly interested in identifying which records growers believed were useful to keep from the perspective of managing the yield and quality of fruit they produced.

We discovered that, in the experience of most growers, the records required for quality assurance were not very useful for day to day orchard management. As one grower from South Australia put it:

"*All that documentation really doesn't help manage the orchard*".

This dissatisfaction with quality assurance systems and the types of records that were required was echoed by Frank in Manjimup, Western Australia.

Frank packs both his own and others fruit. He was accredited with SQF2000 but left the scheme two years ago. It was costing too much and there were no financial benefits from it. He has to supply his spray diary anyway. Frank doesn't believe the documentation required helped him manage the orchard and it wasn't helping the workers. "Until he has to do it – he won't be doing it".

From John in the Yarra Valley in Victoria:

The problem with documentation is that it's not entirely practical. For example for the IFP manual [developed by a group of Yarra Valley growers] growers are supposed to count blossom numbers. However by this time growers should have already put out a number of blossom sprays so what is the point?

The only records most growers indicated were particularly useful in terms orchard management were spray records, particularly in relation to their thinning program and yields or pack-outs. Some growers also regularly kept fertiliser records and a few maintained irrigation records. For example Julian, in Manjimup:

Julian finds his spray diary, fertiliser and irrigation records are the most useful records he keeps.

And from Harry in Shepparton:

> *Harry grows pears and apples on an orchard in East Shepparton in Victoria. He grows mainly for the fresh market. The most important records Harry has are his spray diaries. He watches what is happening in the orchard all the time.*

Terry in the Adelaide Hills:

> *Terry runs an orchard in Lenswood South Australia, growing fruit for the domestic market. Terry finds [spray] record keeping crucial, particularly for thinning.*

Similarly:

> *George has a stone and pome fruit orchard near Stanthorpe in Queensland. He packs and stores his own fruit. He supplies the domestic market only. He tracks production and pack out.*

The plea from most growers, articulated by Simon in the Yarra Valley was:

> "*Keep record keeping simple!*"

4.5 Conclusion

The documentation of orchard activities and decision making is a key element of Integrated Fruit Production and quality assurance programs in horticulture generally. This documentation is intended to guarantee market access by providing growers, exporters and retailers with a means of tracing product flow to resolve food safety concerns. This documentation, at least in terms of integrated fruit production, is also evidence that the grower is acting in an environmentally responsible manner. Record keeping is also thought to assist growers in their decision making. Apple growers do not believe these claims.

In relation to market access, growers have observed that they can supply fruit to domestic and (some) exporters and export markets without participating in a quality assurance scheme provided they can supply spray diaries. Hence, their experience is that non-participation does not mean exclusion from markets.

In the absence of a premium for participation, or exclusion for non-participation, then the only benefits to participating in a quality assurance program are the advantages that record keeping offers in terms of orchard management. Unfortunately, most growers believe that, apart from using spray diaries to assist in pest and disease management, there is little or no benefit in keeping records. This can be explained as follows.

Generally speaking, it appears that fruit yield and quality is most sensitive to pest and disease management given adequate irrigation and fertiliser. In addition, pest and disease factors are both more complex and more variable within and between seasons than are fertiliser and irrigation. In other words, fertiliser and irrigation management is reasonably straightforward and undemanding. Pest and disease management is complex and difficult. Consequently, the management of pests and diseases can benefit more from an understanding of past management actions than can the management of irrigation or fertiliser. This suggests that record keeping is quite valuable in terms of pest and disease management but of limited value in terms of fertiliser and irrigation management.

Finally, the experience growers have had with quality assurance programs has made them suspicious of any claims that a new program, such as Integrated Fruit Production, is likely to make in terms of creating exclusive access to markets or improving orchard management and profitability.

5. Discussion and Conclusion

5.1 Introduction

The explanations growers provided for their choices in terms of pest and disease management, irrigation management, and involvement with quality assurance were, in our view, consistent with the complex decision making and brand loyalty. This means that the adoption of innovative practices by fruit growers is prompted by reasoned consideration of risks and benefits of change.

The results of our interviews with growers suggest to us that the benefits to be gained from new horticultural management practices are particularly sensitive to the individual contexts of apple growers. Consequently, differences among growers in the adoption of new practice are primarily determined by differences in the contexts of growers.

5.2 Pest and disease management

Growers' pest and disease management practices depend on the mix and intensity of pests and diseases present in their orchards and the range of control options available to them. The key factors that influence the mix and intensity of pests and diseases present in an orchard are the climate and topography of the orchard, the relative isolation of orchard, the crop types in the region. The key factors that influence the range of control options available to a grower are the set of chemical and biological options available for managing pests and diseases, mediated by the requirements of the markets the grower is supplying, and the effectiveness of those options. In short, climate, topography, isolation and crop mix determine the type and intensity of pest and disease pressures growers' experience. Their management of these pressures is determined by chemical and biological options available for managing pests and diseases, the effectiveness of those options.

The financial performance of an apple operation is particularly sensitive to growers' management of pest and disease pressures. Given the variety in pests and diseases that growers must manage, the potentially disruptive interactions between control options for different pests, and the variability in seasonal conditions within and between years, pest and disease management is particularly risky area of orchard management and mistakes are costly. Consequently, apple growers exhibit behaviour similar to brand loyalty when it comes to changing pest and disease management practices. This means that once growers have discovered a combination of management options that are successful they will not change that combination unless forced to by circumstances such the repeated failure to control pests due to increasing resistance. Alternatively, growers may be forced to change when either favoured control options are withdrawn from sale or are declared unacceptable in markets supplied by the grower.

The experience with resistance to miticides is an example of this process. The rapid build-up in resistance to miticides forced fruit growers to try alternative methods of mite control such as biological control through the use of predator mites. The effectiveness of predator mites was undermined by their susceptibility to the broad spectrum pesticides used for control of codling moth. With the development of mating disruption as a successful substitute for pesticide control of codling moth there was a dramatic improvement in the effectiveness of predator mites for controlling pest mites. Consequently, except in areas where codling moth pressure is particularly high growers have switched from using broad spectrum chemicals and miticides to a combination of mating disruption and biological control.

When growers are forced to change their pest and disease management they exhibit behaviour similar to complex decision making. Growers will actively search for information on alternative control options and, if possible, observe and experiment with alternatives until they find a new combination that best suits their particular situation.

The growing importance of secondary pests threatens the long term sustainability of integrated pest management programs. The prospect of integrated pest management "hitting the wall" as one agronomist put it does not bode well for its future. The concern articulated by growers was that there are not any control options for secondary pests that are consistent with existing integrated pest management programs. Growers' feared that their integrated pest management programs would be compromised if they had to resort to using broad spectrum chemicals to control secondary pests.

Our interview results indicate that it is unlikely that a lack of knowledge, skills or information is preventing growers from adopting 'advanced' pest management approaches such as pest monitoring and mating disruption. For example, we found fruit growers in the Shepparton region were using a conventional spray program to control codling moth while relying on mating disruption to control oriental fruit moth. The decision to use a conventional spray program for controlling codling moth control was not taken lightly. Many of the growers we interviewed had experimented with isomates to control codling moth. They had, however, encountered problems because of the high populations of codling moth in the area. Populations which were especially hard to control because of the large area of mixed orchards in the region. Growers in other regions also reported that mating disruption was only successful when pest pressures were low.

5.3 Irrigation management

Our results with respect to irrigation management were consistent with those reported in Kaine and Bewsell (1999) and (2000).We found that most growers were using pressurised irrigation systems such as micro-jets and drip irrigation. However few growers were using soil moisture monitoring. Growers were using pressurised irrigation systems because they were redeveloping their orchard to high density planting, they wanted to save time and labour irrigating or because water was scarce and they needed to make the most of the water they had. Growers who were using soil moisture monitoring were doing so because they had a problem in a block that they believed could be improved through irrigation management, there was a need to check the efficacy of irrigations or because water was scarce. We found growers in most areas in Australia had the flexibility to respond to soil moisture monitoring as they were able to irrigate on demand.

These results indicate that the adoption of new irrigation technologies depends on the perceived benefits these technologies offered the grower. These perceived benefits differ according to the particular topographical, soil and labour circumstances of individual orchards. That there appears to be a consistent association between the characteristics of a grower's orchard and fruit enterprise, the perceived benefits the grower seeks from their irrigation system and the type of irrigation system they adopt, is evidence that growers follow a systematic reasoning process similar to complex decision making when considering whether to adopt new irrigation technologies.

5.4 Whole farm planning, quality assurance and record keeping

We believe there is evidence that growers also follow a systematic reasoning process similar to complex decision making when considering management practices such as record keeping, membership of quality assurance schemes, and whole farm planning.

From the perspective of orchard management, the benefits of keeping records about a particular domain of fruit production depend on the degree to which the financial performance of the enterprise can be improved by better management of that domain through learning. If the financial performance of the enterprise is highly sensitive to variability in a domain and that domain is difficult to control then there is both an incentive and an opportunity to learn. Consequently, keeping records about management decisions and actions in the domain will be valuable. If the financial performance of the enterprise is insensitive to variability in a domain or a domain is relatively easy to control then there is little incentive or opportunity to learn. In these circumstances there is little value to keeping records about management decisions and actions.

This line of reasoning appears consistent with growers' perceptions of the benefits of keeping records of pest and disease management, irrigation management, and fertiliser management. Growers acknowledged that poor irrigation or fertiliser management could seriously affect their economic performance. However, the growers we interviewed were confident that they had acquired the requisite skills, knowledge and techniques in managing irrigation and fertiliser to avoid making management decisions in these domains that would result in economic losses. In short, growers believed these domains were relatively easy to manage and so the potential to improve financial performance by using irrigation and fertiliser records as a learning tool was limited.

Growers also acknowledged that poor management of pests and diseases could seriously affect their economic performance. While the growers we interviewed were confident that they had good skills, knowledge and techniques in managing pests and diseases they were not confident that they had enough knowledge and control to always avoid serious economic losses in this domain. In short, growers believed the pest and disease domain was complex, unpredictable and difficult to manage and so there was considerable potential to improve financial performance by using spray records as a learning tool.

Growers' views on record keeping influenced their perceptions of the benefits of participating in quality assurance schemes. Given that most growers believed there was little practical value to keeping irrigation and fertiliser records, and that spray diaries were a legal requirement in any case, most growers were sceptical of the practical benefits, in terms of production management, claimed for the level of record keeping required by quality assurance programs. Consequently, the benefits to growers of participating in quality assurance programs are that such programs might be instrumental in maintaining access to markets, or they may attract market premiums. Growers have become sceptical of these claims as well because, in their experience, access to markets has remained open to participants and non-participant alike and market premiums have failed to materialise.

Growers who were involvement in fruit packing and exporting were more likely to have a favourable attitude towards quality assurance programs, partly because they could appreciate the importance of food safety in fruit handling, and partly because claims about the role of quality assurance in maintaining access to export markets were more likely to accord with their experience.

With respect to whole farm planning we found that growers in Shepparton had invested in an accredited whole farm plan primarily to obtain access to grants when they redeveloped a flood irrigated property to pressurised irrigation or installed a groundwater pump. Whole Farm Plans designed by an accredited planner were not perceived as being particularly useful even in facilitating the design of an irrigation layout because an irrigation equipment supplier can provide an irrigation design as part of their installation package.

5.5 Comparisons with past studies

In our review of previous studies into pest and disease management we concluded there is little consistency in the findings of studies into the adoption of pest and disease management practices. Some authors had argued that a lack of knowledge and skills was the key obstacle to the widespread use of integrated pest management and therefore training and extension is essential. Other authors have argued the popularity of programs such as farmer field schools is primarily attributable to the banning of commonly used pesticides and fungicides. Concern for the environment and sustainability had not been identified as a key factor in the adoption of pest and disease management techniques in any of the studies we examined.

The inconsistency in the findings of previous studies is understandable if our characterisation of growers' decision making about pest and disease management as resembling a combination of complex decision making and brand loyalty is appropriate.

We have found that the particular combination of pest and disease management techniques a grower employs largely depend the mix and intensity of pests and diseases present in their orchards and the range of control options available to them. In short, climate, topography, orchard isolation and crop mix determine the type and intensity of pest and disease pressures growers' experience. Their management of these pressures is determined by the mix of chemical and biological options available for managing pests and diseases, and the effectiveness of those options. These findings imply that growers follow a deliberate and systematic process of learning about, experimenting with, and evaluating management options within the particular context of their orchards (given the constraints imposed by the realities of commercial production). That is, growers follow a decision process that resembles complex decision making when establishing a pest and disease management regime.

We also found that once growers have discovered a combination of management options that is successful they will not change that combination unless forced to by circumstances because the perceived risk of failure is high. Circumstances which would force growers to change their pest and disease management include the repeated failure to control pests due to increasing resistance, the emergence of a new pest which cannot be controlled without disrupting the control of other pests, the withdrawal from sale of a key management option or use of an option is declared unacceptable in export market. This finding implies that growers exhibit behaviour that resembles brand loyalty once they have established a pest and disease management regime.

Our findings mean that the particular combination of pest and disease management practices that best suit an orchard will depend on the particular circumstances of that orchard. Consequently, efforts to construct an index or scale of integrated pest management use are misguided (unless all orchards are the same and all integrated pest management practices are suitable). Our findings also suggest there is no reason to expect a consistent relationship between pest and disease management and orchard size, farm income, operator education and experience. Unless, of course, a particular management technique exhibits scale economies or requires a formal education qualification to implement. We did not discover any indication that this was the case.

Our findings also suggest that Jeger (2000) and Kogan (1998) are correct in attributing the interest in farmer field schools in pest management to the withdrawal of key chemicals from use. The withdrawal of key chemicals forced producers to search for alternative management strategies. This does not mean that education and extension does not play an important role in integrated pest management. Clearly, farmer field schools are a popular element in the conduct of that search. Rather, it is important not to confuse the factors that are motivating change with the factors motivating participation in a change program.

5.6 Prospects for Integrated fruit production

Our results indicate that a fruit grower's decision to adopt a new technology or management practice depends on their perceptions of the benefits of that technology or practice. Our results also indicate that these perceptions are based on deliberate and systematic evaluation of technologies and practices in terms of salient characteristics of the production context of the individual fruit grower. The key to promoting the adoption of an Integrated Fruit Production program depends then on identifying the circumstances in which fruit growers will reach a favourable evaluation of such a program. In other words, under what circumstances will fruit growers form the judgement that participation in an Integrated Fruit Production program will generate significant practical benefits?

Currently, the practical benefits to participating in an Integrated Fruit Production program appear rather limited. Membership of such a program will not generate obvious advantages in terms of the management of fruit production nor does it create exclusive rights to supply fruit to particular markets, especially the domestic market which is the major market for most growers.

Growers experience with quality assurance programs has left a legacy of cynism about the rewards of participating in assurance programs. Until experience demonstrates that non-participation does mean permanent exclusion from markets that cynism will remain.

The attractiveness to growers of an Integrated Fruit Production program is further diminished by a perception among growers that such a program would add to the burden of record keeping and expense just for recognising current practice. There was a strong sense among growers that they were already doing much of what would be required under an Integrated Fruit Production program, especially given the likely emphasis in such a program on Integrated Pest Management. For example:

> *Andy in the Adelaide Hills believes IFP is what a lot of growers are doing already and more should be made of the fact that it's out there. Andy sees it as being mainly driven by isomate use and thinks the pest and disease management aspect of IFP has been really good.*

And Richard in Tasmania:

> *"All we want is to be accredited for what we do already."*

In our view, participation in an Integrated Fruit Production program is likely to be limited in the present circumstances. We believe there is little opportunity to promote the adoption of an Integrated Fruit Production program through extension as there is no evidence to suggest that growers are particularly misinformed about, or are unable to properly evaluate, the benefits of such a program. Interest among fruit growers in participating in an Integrated Fruit Production program will remain low until the threat of exclusion from markets because of non-participation becomes a reality.

Until that time arrives there is the opportunity to:

- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate variation in pest and disease management practices within and between regions

- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate variation in pest and disease management practices in response to the emergence of new pest and disease pressures and control technologies
- Design an Integrated Fruit Production program that is sufficiently flexible to accommodate differences in irrigation management practices within and between regions
- Design record keeping systems that are appropriately tailored in terms of meaningful detail for fruit growing and fruit packing
- Develop program materials to assist fruit growers to implement Integrated Fruit Production
- Develop biological and 'soft' chemical procedures for controlling secondary pests.

5.7 Conclusion

In this project we investigated the factors influencing adoption of pest and disease management, irrigation systems, soil moisture monitoring, whole farm planning, record keeping and quality assurance in the apple industry. We found that the key to understanding adoption of new technologies and practices was to understand the way in which differences in the contextual factors or circumstances of apple growers' influenced the benefits to be had from new practices and technologies.

We believe that there is little incentive at present for apple growers to participate in an Integrated Fruit Production program. We discovered that, based on past experience with quality assurance programs, growers did not believe they would need to participate in such a program to sell their fruit, nor that they would receive a premium should they do so. In the absence of clear market signals verifying the value of assurance programs they appear to have little to offer the typical fruit grower.

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