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Adoption of Integrated Fruit Production: A Quantitative Study

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1. Executive Summary

In this project we sought to determine the likelihood that apple growers would adopt an Integrated Fruit Production program by identifying the factors which would influence growers' propensity to adopt key components of such a program. These components were pest and disease management practices, irrigation practices, whole farm planning and record keeping. The factors influencing adoption of these components were identified and evaluated through a series of personal interviews with apple growers and consultants, research and extension personnel from apple producing regions across Australia and a national mail survey of apple growers.

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 were the major pests and black spot was the key disease.

Our interviews with growers revealed that the particular combinations of pest and disease management practices they used were 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 of the region and topography of the orchard;
- The isolation of the orchard relative to other orchards;
- 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 were used apple growers. Most used some form of pressure irrigation such as micro jets or drip irrigation as these suit the soil types or topography of their 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 coordinate orchard activities such as irrigation and harvesting;
- Or because the orchard had been redeveloped to a high density planting design which only suits micro-jet or drip irrigation.

We found growers in most areas in Australia were able to irrigate on demand and so had the capability to adopt quantitative techniques for monitoring soil moisture.

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

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. Generally, apple growers did not view whole farm planning as a key management tool.

In relation to quality assurance growers have discovered 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 guarantee exclusive access to markets. Consequently, growers are suspicious of any claims that a new program, such as IFP, 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 was most sensitive to pest and disease management. In growers' experience, pest and disease management was far more complex and difficult than irrigation and fertiliser management. Consequently, growers' believed their management of pests and diseases could benefit more from an understanding of past management actions than could their management of irrigation or fertiliser. This suggests that record keeping is quite valuable in terms of pest and disease management but of more limited value in terms of fertiliser and irrigation management.

Key findings – integrated fruit production

In our view, given the information we obtained, growers' participation in an IFP program is likely to be limited in the present circumstances. We believe there is little opportunity to promote the adoption of an IFP 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 IFP 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 IFP program that is sufficiently flexible to accommodate variation in pest and disease management practices within and between regions
- Design an IFP 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 IFP 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 IFP when the need arises
- Develop biological and 'soft' chemical procedures for controlling secondary pests.

Key findings – adoption of new technologies

We found that demographic and psychographic characteristics such as age, education and innovativeness had little, if any, influence on their adoption of pest and disease management techniques, irrigation systems, soil moisture monitoring, record keeping and quality assurance. The key to understanding their adoption of these technologies and practices was to understand the way in which the contextual factors of apple growers' businesses influenced the benefits to be had from adopting new practices and technologies.

2. Introduction

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).

In this study we investigated the factors likely to influence the adoption of IFP by apple growers in Australia by identifying the factors that have influenced the adoption of key components of an IFP program. These key components were pest and disease management, irrigation management and participation in quality assurance programs. The study involved a combination of qualitative and quantitative research. The results of the qualitative research were presented in Kaine and Bewsell (2003). In this report we present the results of the quantitative research and integrate these results with the results obtained in the earlier qualitative research.

2.1 Background

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 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 this 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.

2.2 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 on the adoption of IFP.

(Candolfi-Vasconcelos, Lombard *et al.* 2000) describe 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.

2.3 Adoption of integrated pest management

IFP 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 was 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 IPM, 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.

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 (Ridgley and Brush 1992; Waller, Hoy et al. 1998; Chaves and Riley 2001). 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 IPM 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) concluded 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 provided evidence to suggest the apparent achievements of farmer field schools in promoting changes in the management of rice pests were 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 argued 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).

In conclusion, there was 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.

2.4 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 was 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 were 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 were 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; 2002) reached similar conclusions in regard to the adoption of irrigation technologies in the viticulture and vegetable industries.

2.5 Adoption of record keeping

A key feature of IFP 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).

2.6 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.

2.6.1 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 1.1: Consumer purchase behaviour

	High involvement purchase decision	*Low involvement purchase decision*
Decision making (More effort)	Complex decision making (e.g. cars) • High motivation to search for information • High effort into learning and discovery • Evaluation both prior to and after purchase	Variety seeking (e.g. snack foods) • Low motivation to search for information • Some effort into learning and discovery • Evaluation after purchase
Habit (Less effort)	Brand loyalty (e.g. 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 (e.g. laundry detergent) • No motivation to search for information • No effort put into learning and discovery • Evaluation after purchase

2.6.2 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 the 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.

2.6.3 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 their 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.

2.7 Research methods

In this project we were 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 they 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. Convergent interviewing is unstructured in terms of 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. In total 40 apple growers were interviewed throughout Australia and a detailed report on the findings is contained in Kaine and Bewsell (2003).

The results of the interviews were used to design a mail questionnaire which was 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. The questionnaire was piloted with growers in each state. The questionnaire was mailed, together with a cover letter and reply paid envelope, to all apple growers listed by the Australian Apple and Pear Association.

2.8 Report outline

In chapter two we report on the response rates and representativeness of the survey sample and provide general results with regard to grower demographics and orchard characteristics. In chapter three we report on 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 four and the factors that influence whole farm planning and documentation of orchard decision-making and actions are described in chapter five. Chapter six contains a discussion of the implications of our results.

3. General Results

In this chapter we report on the response rates and representativeness of the survey sample and provide general results with regard to grower demographics and orchard characteristics such as orchard areas, irrigation systems, apple varieties grown, and markets supplied.

3.1 Sampling and response rates

The questionnaire was distributed to growers in New South Wales, Victoria, South Australia, Queensland, Tasmania and Western Australia in November 2003 with a reminder posted four weeks later. A total of 1313 questionnaires were mailed. Of these 278 were completed and returned by growers. Some 243 questionnaires or reminder notes were returned by respondents who were no longer growing apples or whose questionnaires were incorrectly addressed. On the basis of this data we estimated that the response rate to the survey was between 26 and 28 per cent. Discussions with extension staff indicated that they believed we had consistently obtained a response rate of approximately 30 per cent in each state.

3.2 Demographics and enterprise characteristics

For the sample as a whole the average orchard area was 24.2 hectares, ranging from a minimum of 0.2 hectares to a maximum of 555 hectares. There were no statistically significant differences among the states in the average area of orchards. There were, however, significant differences among the states in the use of irrigation systems (see Table 2.1). Relatively speaking, a high proportion of orchards in South Australia and were irrigated using micro-jets or mini sprinklers while a high proportion of orchards in Queensland and Tasmania were watered using drip irrigation. Notably, only a trivial proportion of orchards in the sample were watered using furrow or bay irrigation.

The average age of the growers in the sample was 52, ranging from a minimum of 29 to a maximum of 80. Some 34 per cent of respondents had primary or some secondary schooling, 29 per cent had completed secondary school, 14 per cent had completed a course at a TAFE, technical or agricultural college and 23 per cent had attended University.

Approximately 63 per cent of respondents relied on their orchard for more than 85 per cent of their net income. Only 21 per cent of respondents earned less than 50 per cent of their net income from their orchards. Some five per cent of respondents had full-time employment off-farm and a further five per cent had regular off-farm employment. Most respondents, 54 per cent, considered themselves debt free or nearly so. Only 22 per cent indicated they their equity in their orchards was less than 70 per cent.

Only six per cent of the sample participated in a benchmarking program.

There were no statistically significant differences among the states in regard to age or education of growers, their dependence on their orchards for income, their equity, or the proportion with off-farm employment.

There were significant differences between the states with regard to the types of fruit crops grown in conjunction with apples (see table 2.2)[1]. In New South Wales, Victoria and Queensland the majority of growers grew one or two other tree crops in addition to apples. In Tasmania and South Australia most growers only grew one other tree crop in addition to apples, if any. Most growers in Western Australia grew three or more tree crops in addition to apples.

Assessing the representativeness of the sample is a difficult task as little national data is available on the demographic characteristics of apple growers, or on the financial and physical characteristics of apple orchards. The age and education distribution of respondents in our sample is broadly consistent with those obtained in other studies (e.g. ABS 2003).

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[1] χ^2=61.4 p=0.00.

Table 2.1: Irrigation systems in each state

(Average proportion of orchard area irrigated by system)

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania
Furrow/bay channels*	0	5.3	0	0	0	0
Furrow/bay pipe and risers	1.7	2.4	0	0	0	1.0
Under tree knocker sprinklers	3.4	3.5	0	8.4	0.8	10.9
Overhead sprinklers*	2.6	0.6	0	2.1	0.8	9.6
Drip or trickle*	41.7	39.8	100.0	11.8	41.7	65.4
Micro jets or mini sprinklers*	41.9	46.1	0	67.8	52.1	5.9
Average orchard area (hectares)	20.0	14.8	40.0	11.1	16.1	31.8

* denotes statistically significant differences in proportions across states (p<0.05)

Table 2.2: Fruit crops grown with apples in each state

(% of growers in each state)

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania
Pears*	29.3	65.6	50.0	37.5	63.6	25.0
Nectarines*	27.6	22.2	33.3	7.5	56.8	0
Peaches*	34.5	38.9	58.3	10.0	52.3	7.1
Cherries*	39.7	18.9	0	35.0	18.2	28.6
Plums*	20.7	34.4	50.0	10.0	72.7	7.1
Apricots*	8.6	30.0	0	5.0	34.1	3.6

* denotes statistically significant differences in proportions across states (p<0.05)

3.3 Markets for apples

In figure 2.1 the proportions of apple growers in each state supplying the domestic fresh fruit, domestic juice and export fruit markets are shown. A higher proportion of apple growers in Western Australia and Tasmania supplied export markets compared to growers in the other states.

In figure 2.2 the relative shares of each state in the domestic fresh, domestic juice and export market, as measured by proportion of respondents, is shown. Apple growers in Victoria and New South Wales were the main suppliers of domestic fresh fruit and juicing apples while the export market was supplied mostly by Victorian, Tasmanian and West Australian growers.

In table 2.3 the proportion of exporting growers supplying each export market is reported for each state. Growers in different states export to distinctly different markets with a high proportion of growers in Victoria, South and Western Australia supplying the United Kingdom. In table 2.4 the relative size of each state in the different export markets is presented. Tasmanian and Western Australian growers are notable for being the major suppliers to Asian markets.

In figures 2.3 through 2.5 the varieties of apples grown in each state are presented. Apart from Gala, the proportions of orchards growing each variety are significantly different among the states. Briefly:

- The majority of New South Wales growers had Gala, Fuji, Red Delicious and Granny Smith varieties.
- The majority of Victorian growers had Gala, Fuji, Pink Ladies, Golden Delicious and Granny Smith varieties.
- The majority of Queensland growers had Gala, Fuji, Red Delicious, Pink Ladies and Granny Smith varieties.
- The majority of South Australian growers had Gala, Fuji, Red Delicious, Pink Ladies, Sundowner, Golden Delicious and Granny Smith varieties.
- The majority of West Australian growers had Gala, Fuji, Pink Ladies, Sundowner and Granny Smith varieties.
- The majority of Tasmanian growers had Gala, Fuji, Red Delicious, Pink Ladies, Sundowner and Golden Delicious varieties.

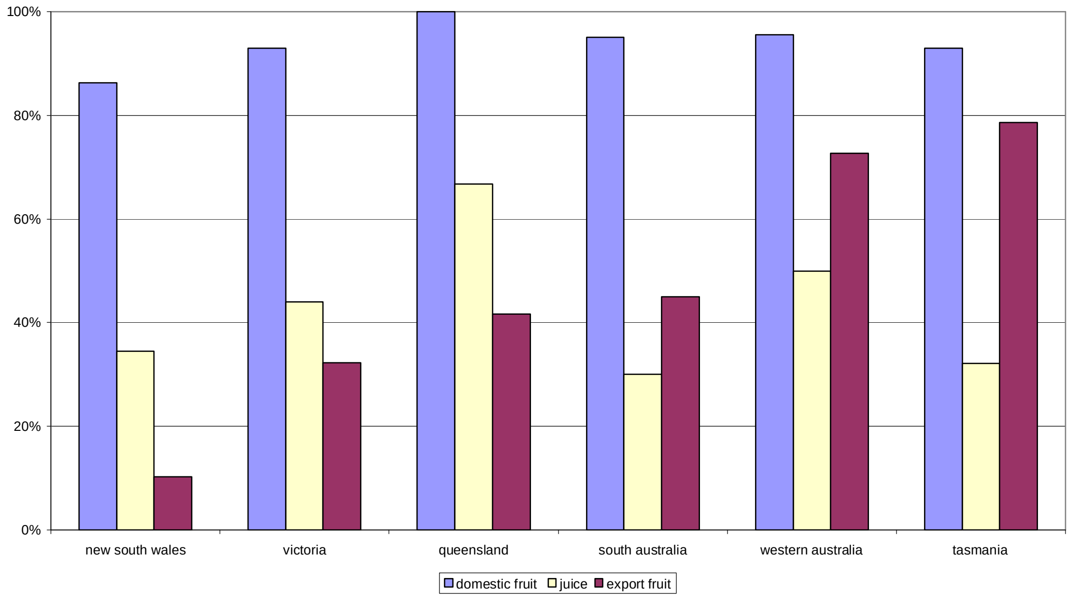

Figure 2.1: Fresh, juice and export market shares for apples by state

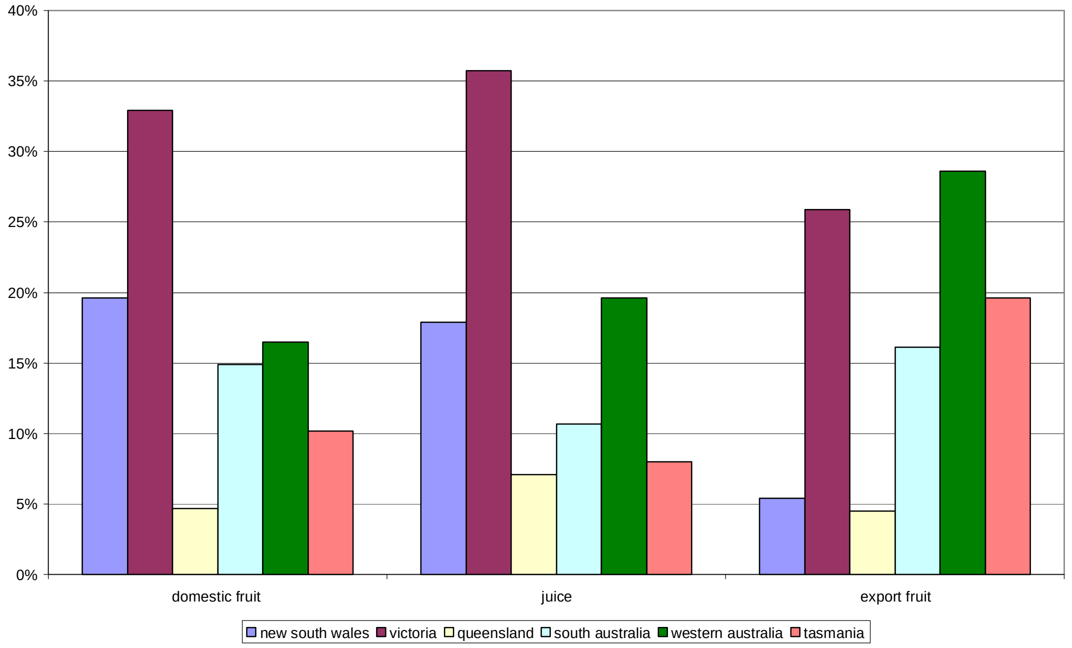

Figure 2.2: state shares in fresh, juice and export markets for apples

Table 2.3: Export markets as a proportion of exporters in each state

(%)

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania
India	20.0	7.4	20.0	5.6	19.4	72.7
Malaya	60.0	18.5	40.0	27.8	45.2	54.5
Sri Lanka	20.0	3.7	0.0	0.0	9.7	45.5
Singapore	60.0	37.0	60.0	38.9	54.8	40.9
UK	0.0	59.3	20.0	72.2	61.3	18.2
Bangladesh	0.0	0.0	0.0	0.0	9.7	36.4
Taiwan	20.0	22.2	0.0	22.2	35.5	59.1
Other	20.0	14.8	40.0	11.1	16.1	31.8

Table 2.4: state share of each export market

(% of growers exporting to each market)

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania
India	3.7	7.4	3.7	3.7	22.2	59.3
Malaya	7.3	12.2	4.9	12.2	34.1	29.3
Sri Lanka	6.7	6.7	0.0	0.0	20.0	66.7
Singapore	6.1	20.4	6.1	14.3	34.7	18.4
UK	0.0	30.2	1.9	24.5	35.8	7.5
Bangladesh	0.0	0.0	0.0	0.0	27.3	72.7
Taiwan	2.9	17.1	0.0	11.4	31.4	37.1
Other	4.3	17.4	8.7	8.7	21.7	39.1

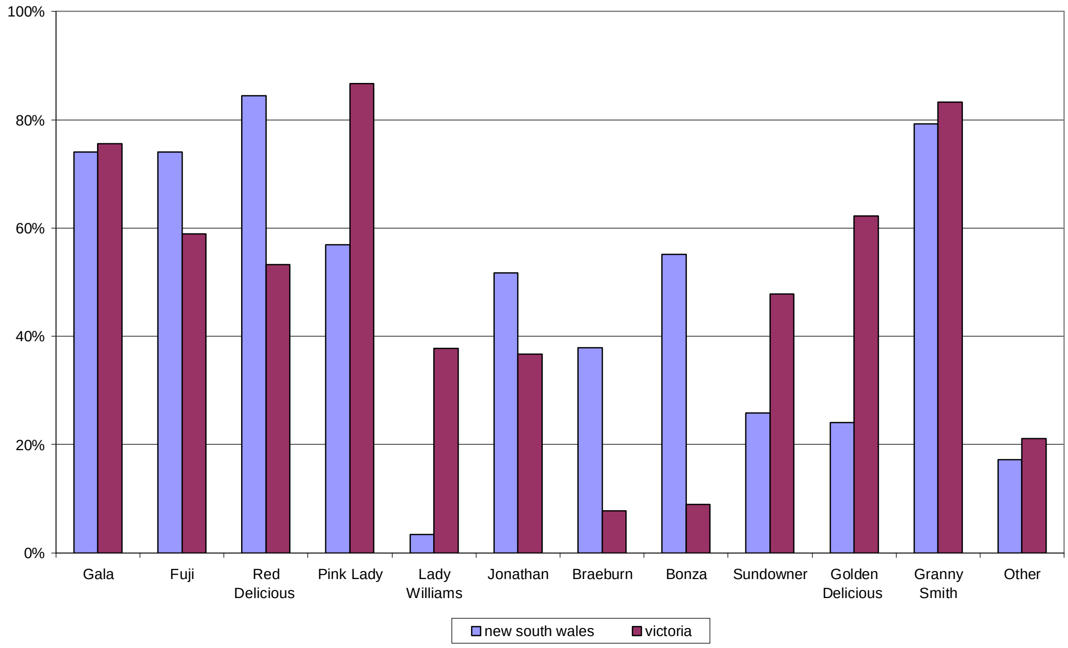

Figure 2.3: Apple varieties grown in New South Wales and Victoria

(% growers in each state)

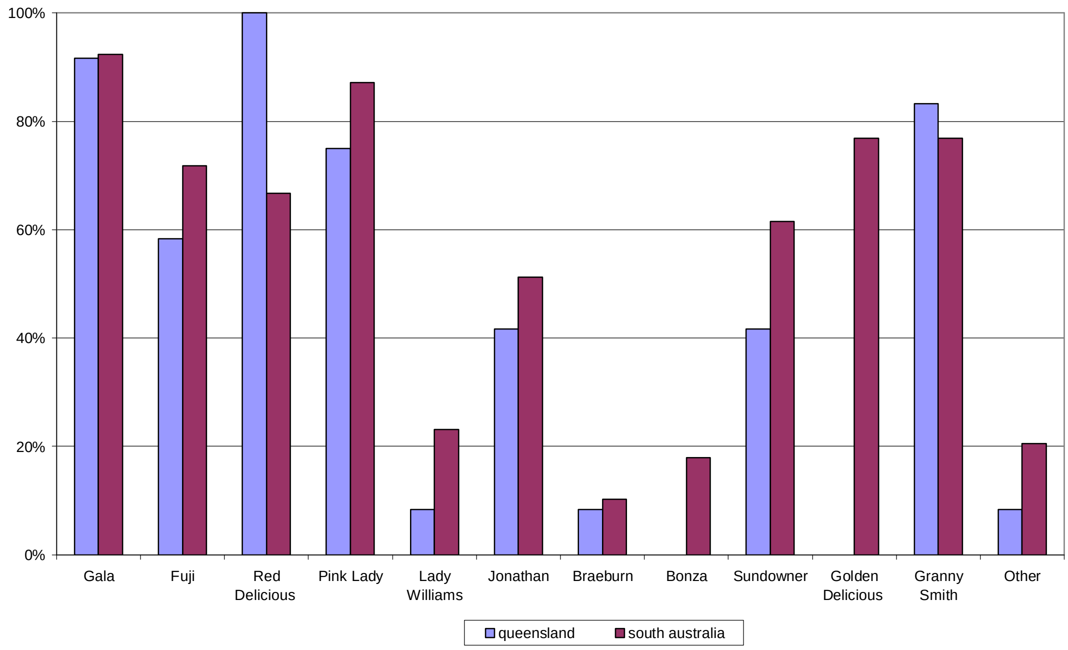

Figure 2.4: Apple varieties grown in Queensland and South Australia

(% growers in each state)

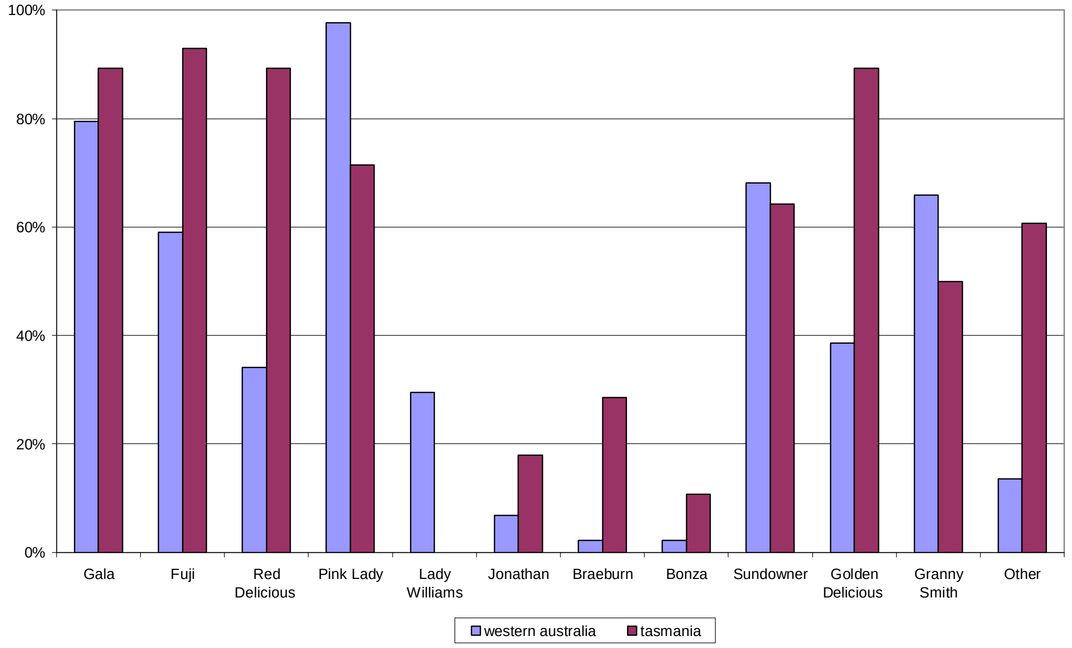

Figure 2.5: Apple varieties grown in West Australia and Tasmania

(% growers in each state)

4. Pest and disease management

In this chapter we report on the incidence of apple pests and diseases and the methods growers used to manage them. We classify growers into segments based on the techniques they used to manage pests and diseases and identify relationships between segment membership and contextual factors such as the severity of pest pressure and orchard size. In the final section of the chapter the relationships between segment membership and demographic factors such as the age, education and innovativeness of growers are explored.

4.1 Incidence of pests and diseases of apples

In our interviews with apple growers we discovered growers from different regions had to contend with different pest and disease problems. The proportion of growers in each state that reported they experienced major problems controlling the different pests and diseases of apples are shown in tables 3.1 to 3.14.

The differences in the proportions were statistically significant except in the case of looper[2]. Generally speaking, the differences in the proportions were consistent with the expectations of extension staff in each state. The key results were that codling moth, apple dimpling bug and woolly aphid were the most common serious pests and that black spot was the most common serious disease. Relatively speaking, apple growers in New South Wales, Victoria and South Australia had to contend with similar combinations of pests and diseases. Growers in Queensland, Tasmania and Western Australia had to contend with uniquely different combinations of pests and diseases.

[2] Codling moth χ^2=164.3 p=0.00, light brown apple moth χ^2=31.3 p=0.00, pest mites χ^2=26.2 p=0.00, apple dimpling bug χ^2=29.7 p=0.00, plague thrips χ^2=76.0 p=0.00, weevils χ^2=49.7 p=0.00, woolly aphid χ^2=31.5 p=0.00, oriental fruit moth χ^2=60.7 p=0.00, western flower thrips χ^2=108.9 p=0.00, fruit fly χ^2=58.9 p=0.00, looper χ^2=8.2 p=0.61, heliothis χ^2=18.9 p=0.04, black spot χ^2=102.6 p=0.04, powdery mildew χ^2=26.6 p=0.00.

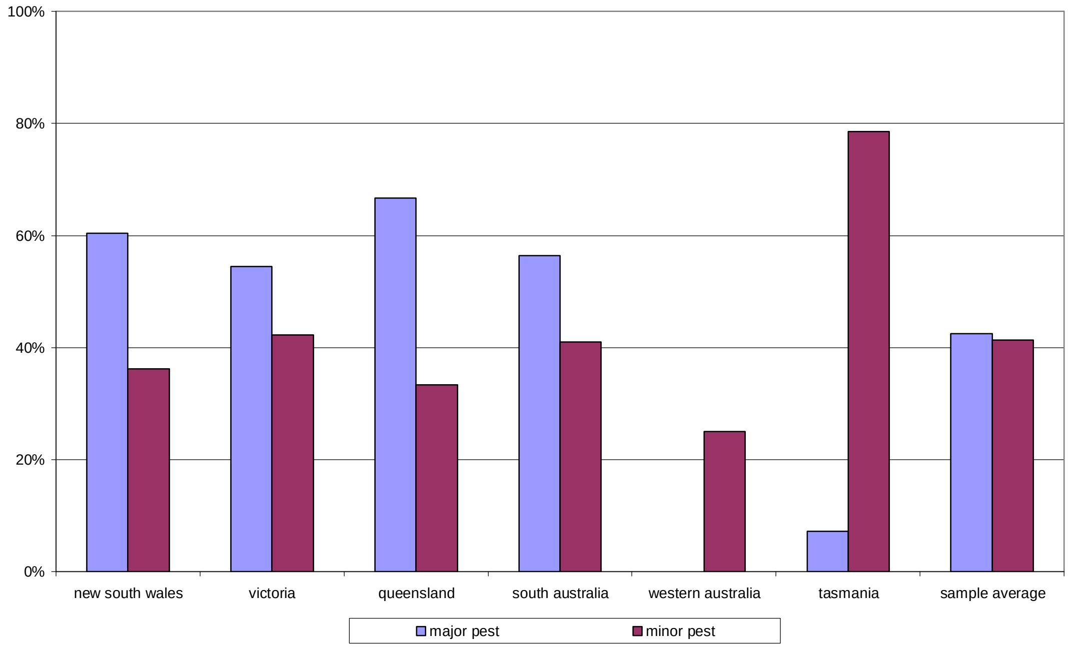

Figure 3.1: Incidence of codling moth by state

(% growers in each state)

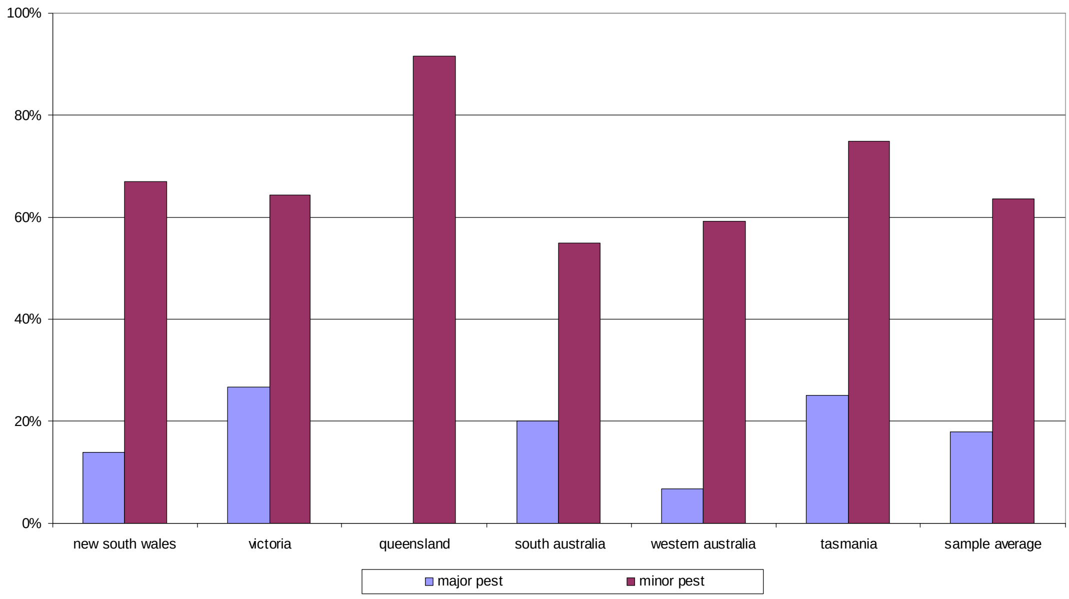

Figure 3.2: Incidence of light brown apple moth by state

(% growers in each state)

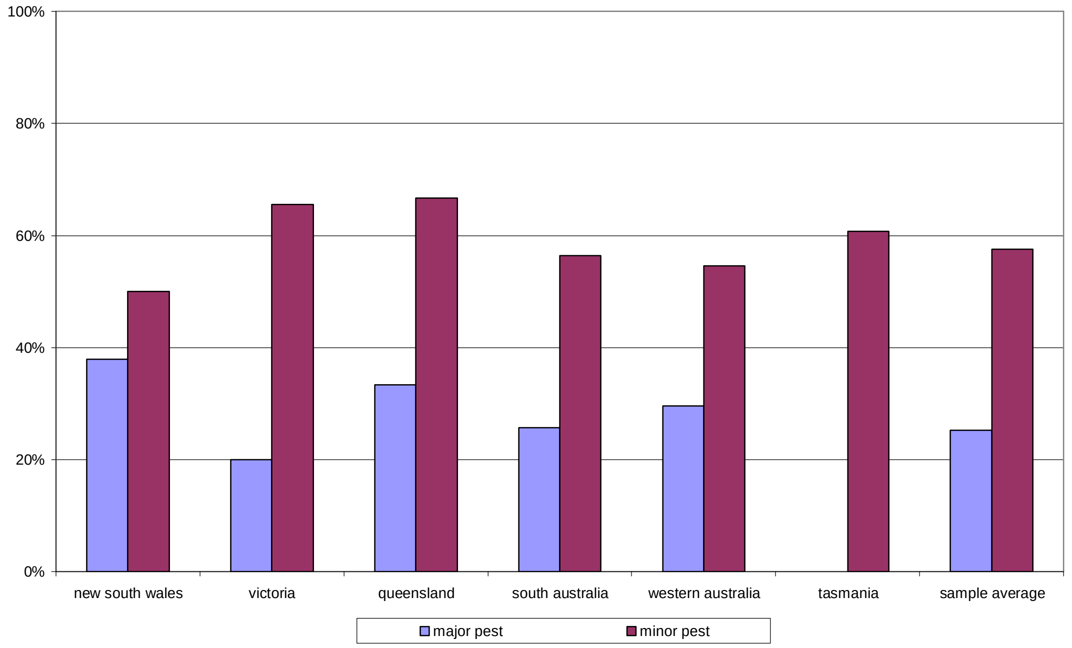

Figure 3.3: Incidence of pest mites by state

(% growers in each state)

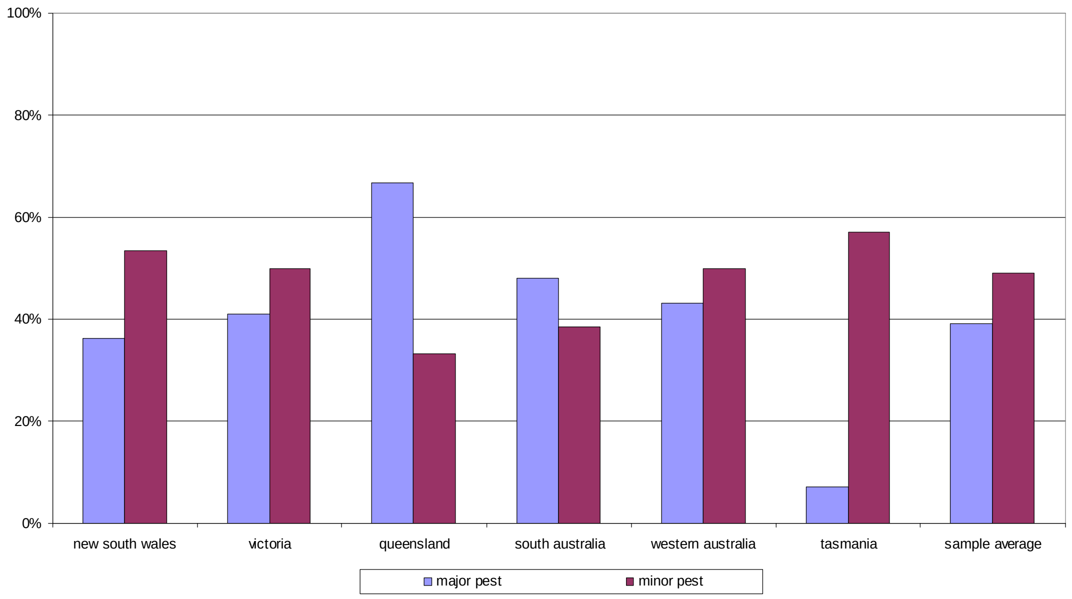

Figure 3.4: Incidence of apple dimpling bug by state

(% growers in each state)

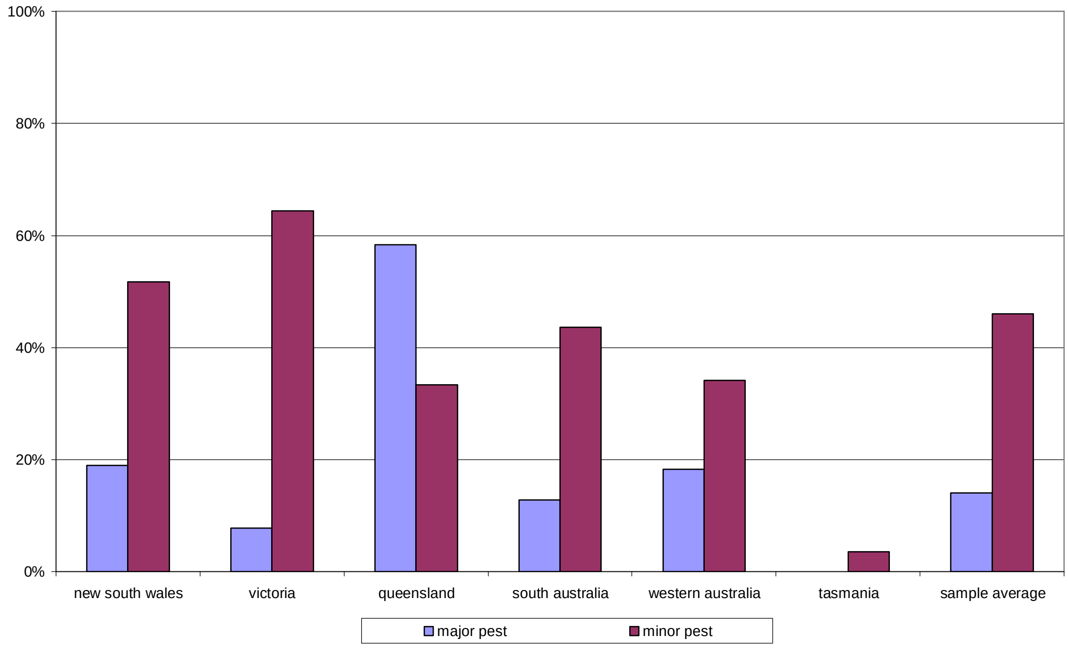

Figure 3.5: Incidence of plague thrips by state

(% growers in each state)

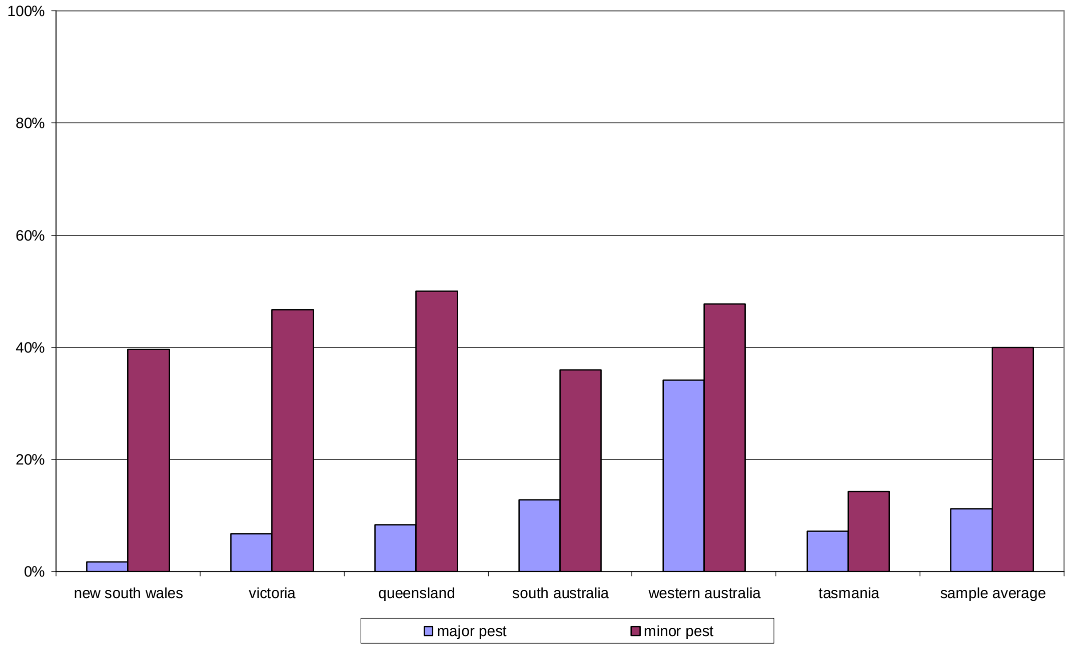

Figure 3.6: Incidence of weevils by state

(% growers in each state)

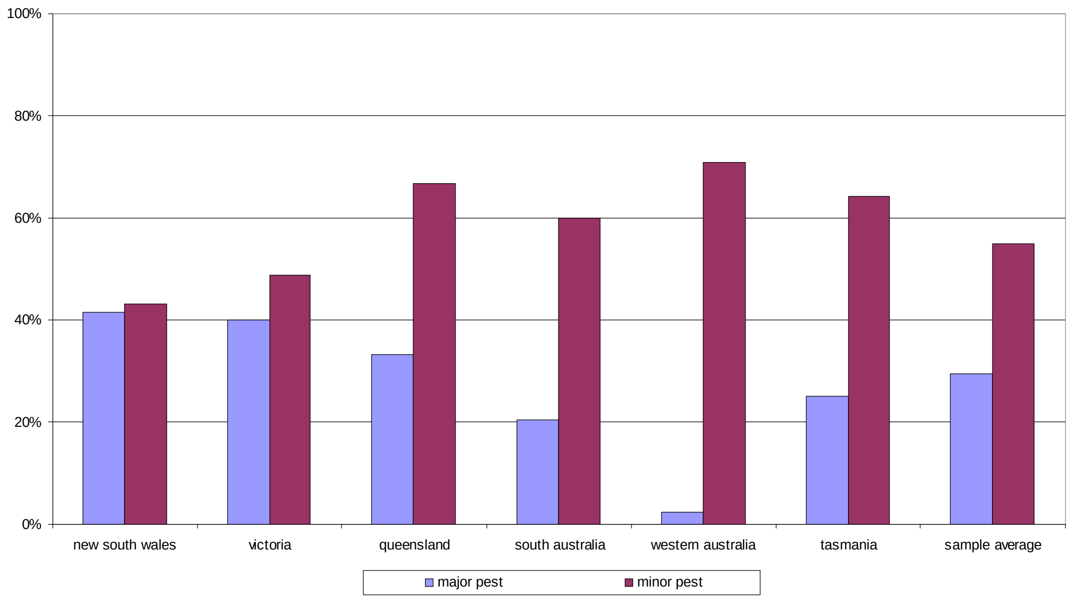

Figure 3.7: Incidence of woolly aphid by state

(% growers in each state)

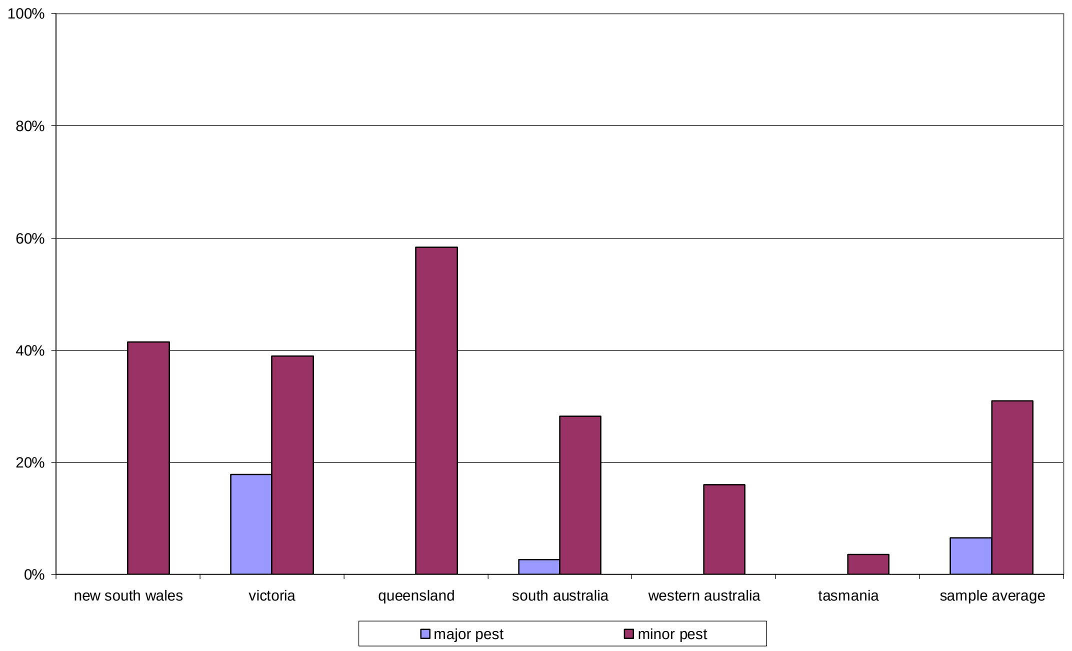

Figure 3.8: Incidence of oriental fruit moth by state

(% growers in each state)

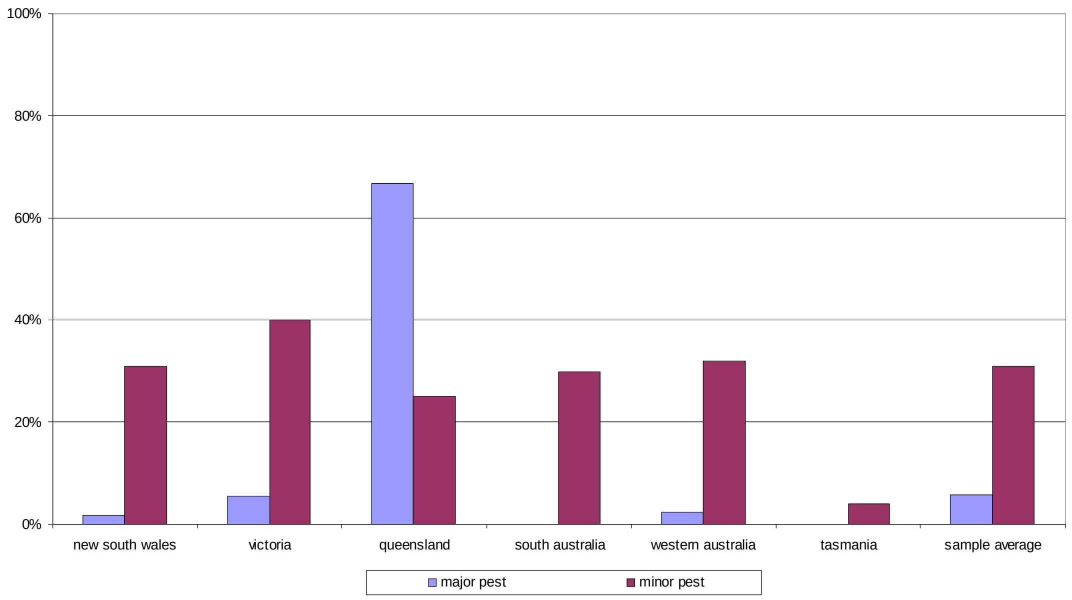

Figure 3.9: Incidence of western flower thrips by state

(% growers in each state)

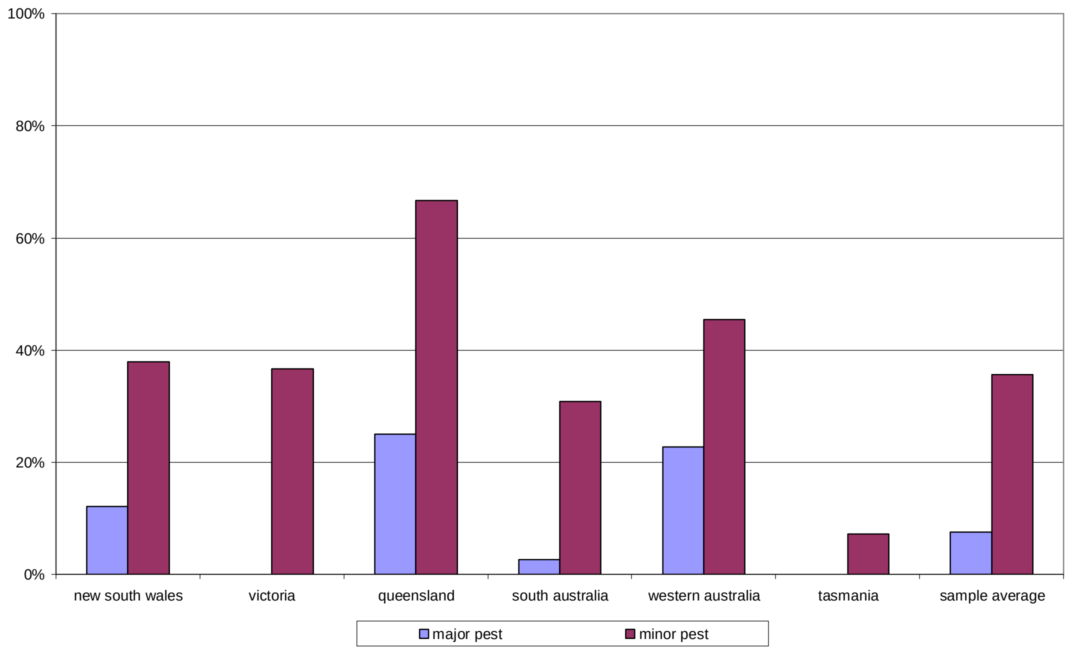

Figure 3.10: Incidence of fruit fly by state

(% growers in each state)

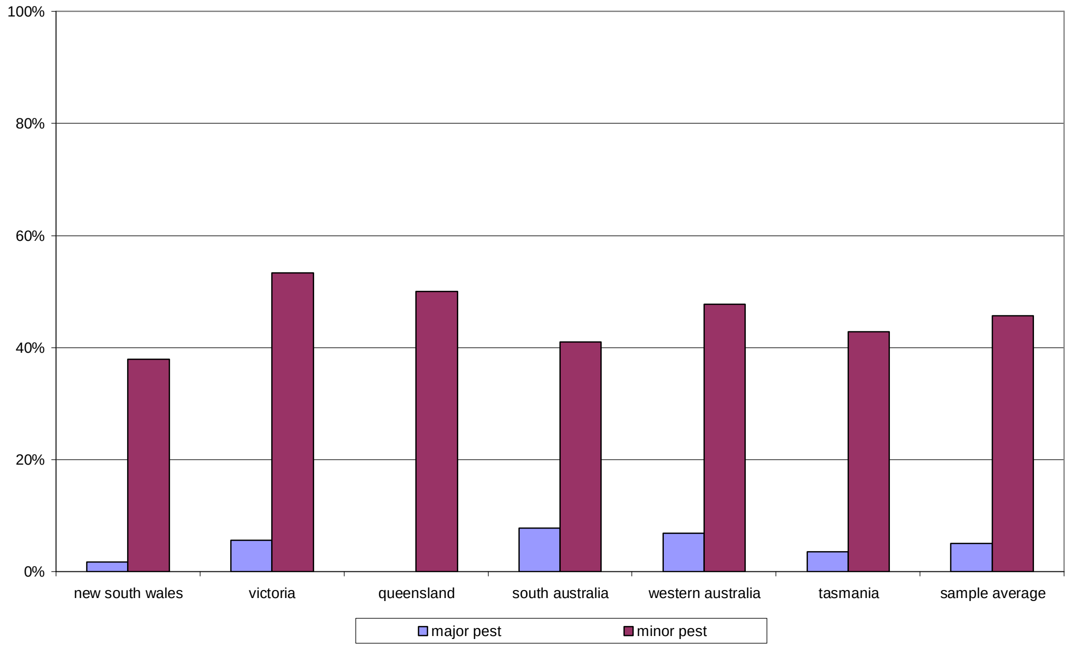

Figure 3.11: Incidence of looper by state

(% growers in each state)

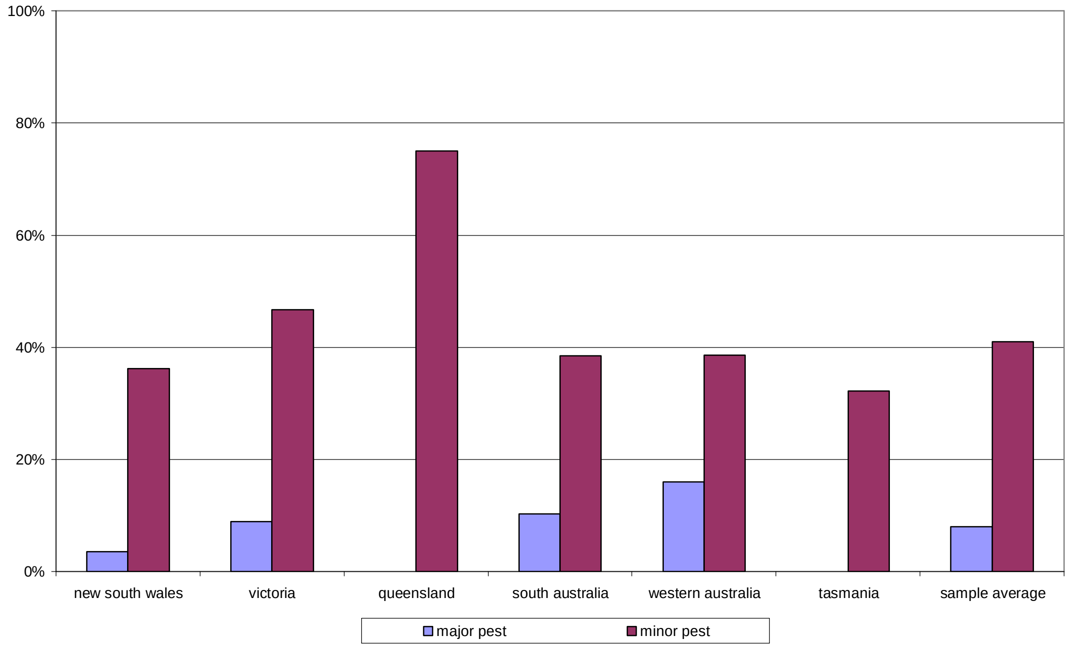

Figure 3.12: Incidence of heliothis by state

(% growers in each state)

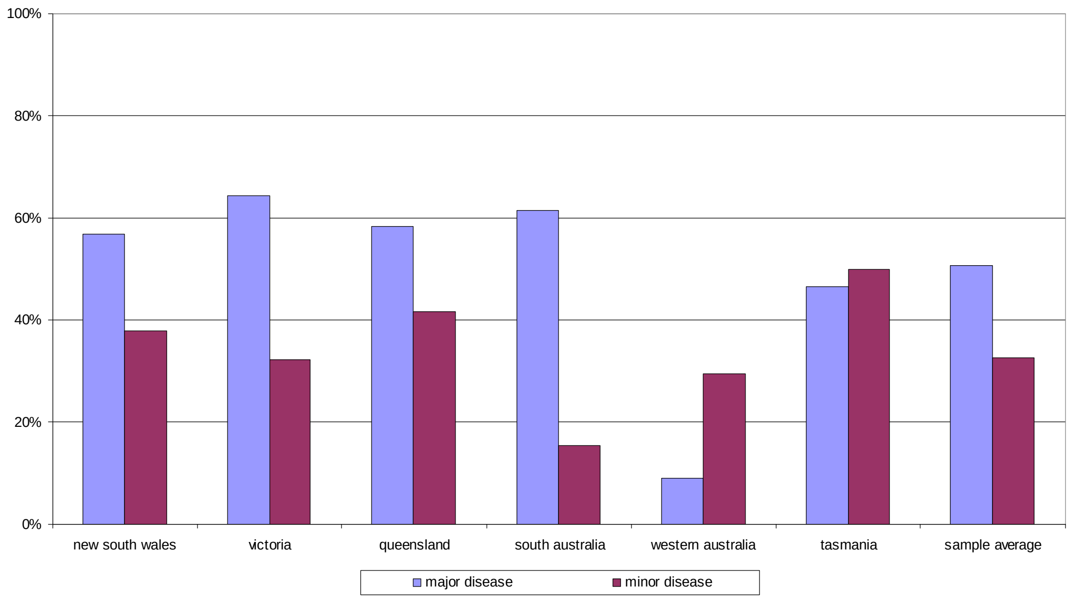

Figure 3.13: Incidence of black spot by state

(% growers in each state)

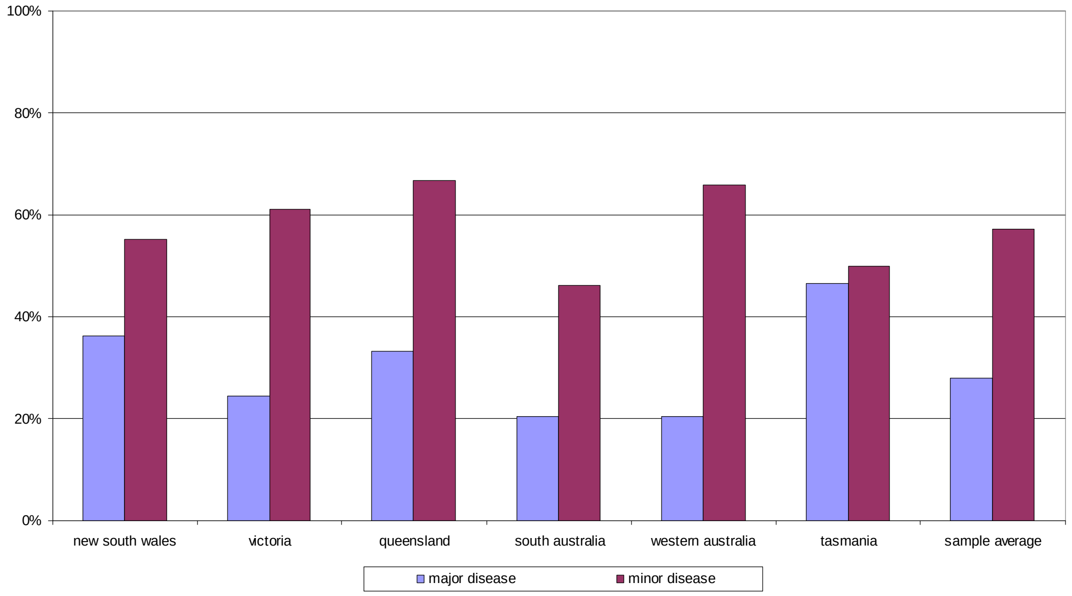

Figure 3.14: Incidence of powdery mildew by state

(% growers in each state)

4.2 Pest and disease management techniques used by apple growers

The key factors that were identified by growers as influencing their adoption of pest and disease management practices included, 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, and the effectiveness of those options.

- The climate largely dictated the type and intensity of pest and disease pressures in an orchard. For example, powdery mildew was a particularly serious problem in Tasmania because of the relatively wet conditions experienced in that region (see figure 3.14). 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 was a concentration of stone and pome fruit. The presence of stone fruit in the region, which is particularly susceptible to oriental fruit moth, adds to the population of this pest in the region (see figure 3.8). 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, and the effectiveness of those options.

- For many apple pests the only control options available were 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 was the development of resistance to chemicals by pests.

In figure 3.15 and table 3.3 the proportion of growers that have tried various techniques for managing pests and diseases, are shown for the sample as a whole and in each state, respectively. There were significant differences across the states in the proportion of growers trying each technique and the differences appeared to relate to some extent to differences in the incidence of pest and diseases among the states[3]. For example, the relatively low proportions of apple growers in Western Australia trying mating disruption, the degree day model or black spot warning services reflects the low incidence of codling moth, light brown apple moth and black spot in that state (see figures 3.1, 3.2 and 3.13).

We found a greater proportion of respondents who reported codling moth or light brown apple moth were major pests had tried mating disruption than respondents who reported these pests were a minor problem, or no problem at all (62 per cent compared to 50 per cent and eight per cent respectively)[4]. We also found a greater proportion of respondents who reported black spot was a major problem had tried using the degree day model and the black spot warning service compared to respondents who reported this disease was a minor problem, or no problem at all (39 per cent, 20 per cent and 11 per cent respectively for the degree day model and 57 per cent, 37 per cent and 11 per cent respectively for the warning service)[5].

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[3] Pest monitoring χ^2=1.2 p=0.95, disease monitoring χ^2=2.5 p=0.77, mating disruption χ^2=48.0 p=0.00, day degree model χ^2=15.2 p=0.01, weather information χ^2=11.9 p=0.04, black spot warning service χ^2=50.5 p=0.00, insect growth regulators χ^2=17.7 p=0.00, 'soft' chemicals χ^2=3.9 p=0.57, predators χ^2=46.5 p=0.00.

[4] Mating disruption and codling moth χ^2=33.3 p=0.00, mating disruption and light brown apple moth χ^2=6.0 p=0.05.

[5] Black spot and degree day model χ^2=16.5 p=0.00, black spot and warning service χ^2=27.6 p=0.00.

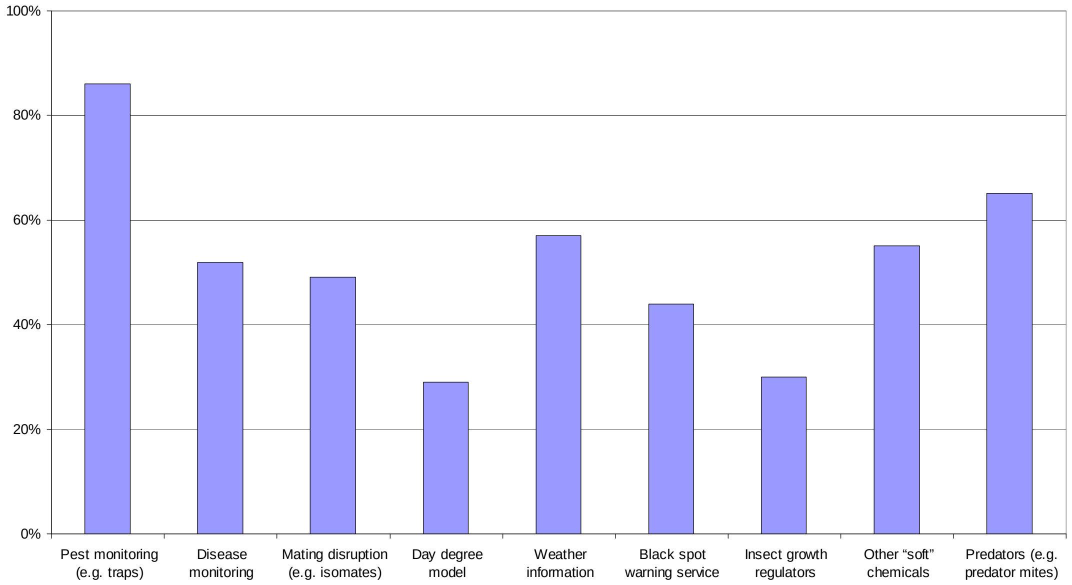

Figure 3.15: Pest and disease management techniques tried by apple growers (% growers in sample)

Table 3.3: Pest and disease management techniques used by apple growers
(% of growers in each state)

	New South Wales	Victoria	Queens land	South Australia	West Australia	Tasmania
Pest monitoring (e.g. traps)	85.7	88.6	83.3	83.3	87.2	82.1
Disease monitoring	51.8	50.0	50.0	50.0	61.5	42.9
Mating disruption* (e.g. isomates)	50.0	62.5	83.3	62.9	5.1	32.1
Day degree model*	32.1	30.7	41.7	41.7	5.1	25.0
Weather information*	62.5	59.1	66.7	72.2	35.9	53.6
Black spot warning service*	58.9	38.6	83.3	69.4	2.6	39.3
Insect growth regulators*	41.1	30.7	25.0	47.2	7.7	25.0
Other "soft" chemicals	60.7	56.8	66.7	55.6	43.6	50.0
Predators* (e.g. predator mites)	78.6	64.8	75.0	69.4	20.5	89.3

* denotes statistically significant differences in proportions across states ($p<0.05$)

In figure 3.16 and table 3.4 the experiences of growers that had tried mating disruption for managing pests are reported for the sample as a whole and for each state respectively. Approximately 49 per cent of growers in the sample had tried mating disruption and the majority of those that had tried the technique continue to use it (65 per cent). Only a small proportion of growers had abandoned the technique because they found it too costly or time consuming. Most growers who no longer used mating disruption stopped using the technique because of orchard characteristics, such as layout and topography, or because of high pest pressures and problems with secondary pests. This is consistent with the findings from our interviews with growers.

There are significant differences across the states in the proportions of growers who had tried mating disruption and in their experiences with mating disruption[6]. These differences appeared to relate to differences in the incidence of light codling and light brown apple moth among the states, and differences in orchard topography across states. For example, relatively small proportions of growers in Western Australia and Tasmania had tried mating disruption while a relatively high proportion of apple growers in South Australia had experienced problems with mating disruption because their orchards were too hilly[7]. These results seem consistent with the findings from our interviews with growers.

4.3 Pest and disease management segments

The key factors growers identified as influencing their adoption of pest and disease management practices were the climate and topography of the orchard, the isolation of orchard, the types of tree crops in the region, the chemical and biological options available for managing pests and diseases, and the effectiveness of those options. In the following sections we classify growers into segments in terms of the methods they used to control selected pests and the factors influencing that choice.

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[6] Proportion of growers in each state tried mating disruption χ^2=48.0 p=0.00.

[7] Tried mating disruption and did not need to use it because pest pressure not high enough χ^2=17.7 p=0.00, tried mating disruption and did not work well because orchard too hilly χ^2=16.5 p=0.01.

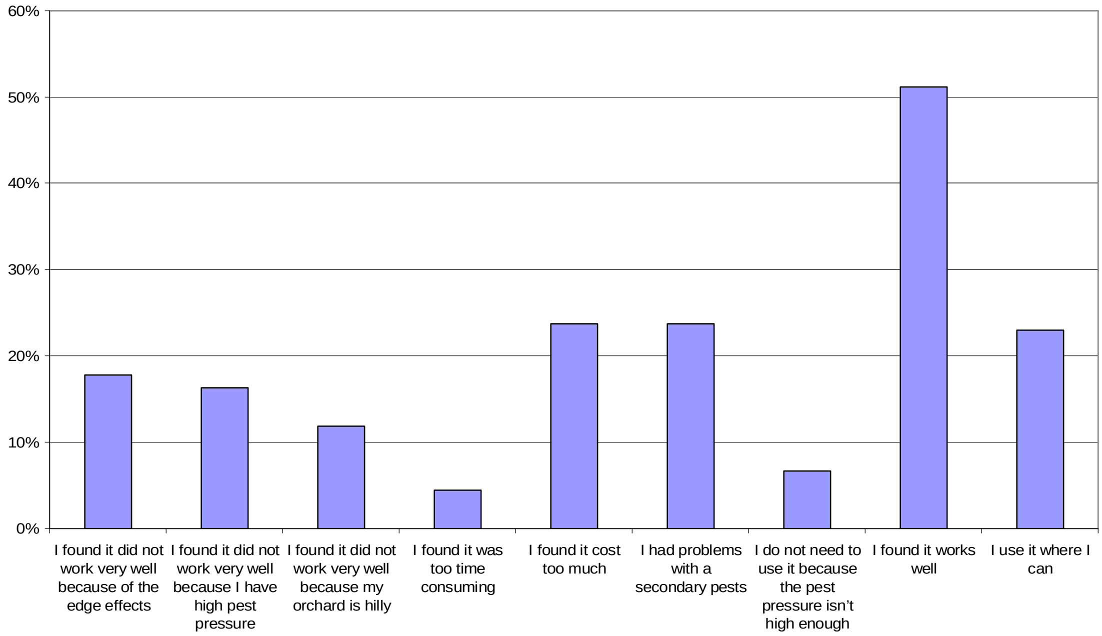

Figure 3.16: Experiences with mating disruption

(% growers in sample)

Table 3.4: Experiences with mating disruption
(% of growers trying in each state)

	New South Wales	Victoria	Queens land	South Australia	West Australia	Tasmania
Proportion tried disruption [a]	50.0	62.5	83.3	62.9	5.1	32.1
I found it works well	55.6	51.9	70.0	50.0	0.0	44.4
I use it where I can	18.5	18.5	40.0	40.9	0.0	11.1
<u>I found it did not work very well because:</u>						
I have the edge effects	14.8	13.0	20.0	22.7	0.0	22.2
I have high pest pressure	14.8	18.5	10.0	13.6	0.0	11.1
My orchard is hilly*	11.1	3.7	10.0	31.8	0.0	0.0
It was too time consuming	3.7	3.7	0.0	0.0	0.0	11.1
It cost too much	25.9	20.4	30.0	22.7	0.0	22.2
Problems with secondary pests	29.6	22.2	10.0	27.3	0.0	33.3
Pest pressure isn't high enough*	0.0	0.0	0.0	4.5	0.0	22.2

* denotes statistically significant differences in proportions across states ($p<0.05$)

[a] as a percentage of all growers in each state

4.3.1 Segments for Codling Moth

Codling moth can be controlled with broad spectrum chemicals, with "soft" chemicals, such as growth regulators, and by using pheromones to cause disruption to moth mating. The preferred strategy in terms of IPM 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.

The development of mating disruption was a significant step in the control of codling moth in particular and for IPM 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 3.3.2).

We classified growers into four segments with respect to their management of codling moth. The segments are reported table 3.5. The first segment consisted of growers who appeared to be controlling relatively small codling moth populations by strategically spraying. They used the day degree model and monitoring of moth populations in the orchard to decide when to spray. The pest pressures in these orchards may be too low to justify the expense of using mating disruption. These growers would generally be using broad spectrum chemicals though some used a program of 'softer' chemicals. A relatively high proportion of the growers in this segment had experienced problems with mating disruption due to edge effects and difficulties with secondary pests.

Bob is a grower from the first 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].*

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

George, a grower from the second segment, used 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.*

The third segment consisted of growers who followed a calendar spraying program, using broad spectrum chemicals, because they felt this was the most cost effective option given the pest pressure they faced (see table 3.6). These growers may use monitoring to evaluate the effectiveness of their spray program but, generally speaking, would not use the monitoring to change the timing of sprays unless they encounter an infestation problem.

The fourth segment consists of growers who follow a calendar spraying program using broad spectrum chemicals because they feel this is the only effective option given the high pest pressures they face (see table 3.6). 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.

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 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.*

There were no significant differences among the segments in terms of the location of growers, the equity distribution of growers, the average size of orchards or the type of irrigation systems used. There were some significant differences among the segments in the varieties of apples grown (see table 3.7). A relatively high proportion of growers in segment three grew Gala apples, a relatively high proportion of growers in segment four

Table 3.5: Codling moth segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Segment size as a proportion of respondents who control for codling moth	23.5	40.5	24.0	12.0
Calendar spray OP because of high pest pressure*	0	0	20.8	100.0
Calendar spray OP because most cost effective option*	2.1	4.9	100.0	0
Use trap catches/degree day model to determine when to spray OP because of high pest pressure*	100.0	2.5	16.7	12.5
Use trap catches/degree day model to determine when to spray with soft chemicals because cost effective*	29.8	37.0	0	12.5
I use mating disruption*	8.5	40.7	0	0
I use mating disruption and spray hotspots with OP sprays*	14.9	23.5	0	8.3
I use mating disruption and spray hotspots with soft chemical sprays*	14.9	34.6	0	0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.6: Profiles of codling moth segments on mating disruption

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Codling moth a major problem*	59.6	56.8	35.4	95.8
Tried mating disruption*	50.0	87.7	28.9	31.8
Mating disruption works well for me*,[a]	45.5	67.1	7.7	14.3
Problems with mating disruption due to edge effects*,[a]	31.8	8.6	38.5	0
Problems with mating disruption due to high pest pressure*,[a]	22.7	10.0	23.1	42.9
Problems with mating disruption due to cost*,[a]	13.6	17.1	61.5	42.9
Problems with mating disruption due to secondary pests*,[a]	27.3	15.7	38.5	57.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

[a] indicates proportion of respondents in each segment who have tried mating disruption

Table 3.7: Profiles of codling moth segments on apple varieties

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Gala*	85.1	91.4	69.8	70.8
Fuji	72.3	74.1	58.3	70.8
Red Delicious	66.0	74.1	58.3	79.2
Pink Lady	76.6	86.4	68.8	70.8
Lady Williams	25.5	18.5	27.1	20.8
Jonathan*	29.8	44.4	35.4	75.0
Braeburn*	12.8	29.6	12.5	4.2
Bonza	23.4	22.2	14.6	37.5
Sundowner	51.1	51.9	41.7	37.5
Golden Delicious	55.3	56.8	52.1	62.5
Granny Smith	80.9	76.5	81.3	91.7

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 3.8: Profiles of codling moth segments on other tree crops

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Pears*	46.8	35.8	62.5	79.2
Nectarines	23.4	21.0	20.8	20.8
Peaches	38.3	30.9	39.6	20.8
Cherries	19.1	32.1	18.8	41.7
Plums	29.8	22.2	33.3	29.2
Apricots	21.3	14.8	20.8	12.5
Apple only*	29.8	38.3	20.8	8.3

* denotes statistically significant differences in proportions across segments ($p<0.05$)

grew Gala and Jonathans, and a relatively high proportion of growers in segment two grew the Braeburn variety.

There was one significant difference among the segments in the types of tree crops grown in conjunction with apples (see table 3.8). A relatively high proportion of growers in segments three and four grew pears. Note that a relatively high proportion of growers in segments one and two did not grow a tree crop other than apples.

4.3.2 Segments for 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, New South Wales, 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.

We classified growers into four segments with respect to their management of pest mites (see Table 3.9). The first segment consisted of growers who relied on the predator mite population to control pest mites and who rarely, if ever, used a miticide. These growers relied on methods to control pests, such as codling and light brown apple moth that did 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 consisted of growers who relied on a predator mite population to control pest mites but who occasionally used a miticide to manage outbreaks on hotspots.

The third segment consisted of growers who routinely used miticides to control pest mites because, as a rule, they employed a persistent, broad spectrum chemical that was harmful to predator mites. 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 three:

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.*

Table 3.9: Mite management segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Segment size as a proportion of respondents who control for mites	23.9	45.6	17.7	12.8
Use predator mites to control pest mites*	98.1	0	0	0
Use predator mites but occasionally have to use miticide in a hotspot*	31.5	100	10.0	0
Use miticides because cannot establish predator mites*	3.7	0	0	100.0
Use miticides because of chemicals used to control other pests (e.g. weevils)*	0	0	100	31.0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.10: Profiles of mite management segments on location*

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
New South Wales	26.5	49.0	14.3	10.2
Victoria	21.9	54.8	13.7	9.6
Queensland	18.2	63.6	9.1	9.1
South Australia	33.3	33.3	20.0	13.3
Western Australia	2.7	29.7	40.5	27.0
Tasmania	50.0	40.9	0	9.1

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.11: Profiles of mite management segments on apple varieties

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Gala	84.9	84.5	75.0	82.8
Fuji*	75.9	74.8	50.0	65.5
Red Delicious*	79.6	68.0	47.5	51.7
Pink Lady	79.6	81.6	85.0	89.7
Lady Williams	22.2	18.4	30.0	24.1
Jonathan	44.4	33.0	30.0	24.1
Braeburn*	24.1	20.4	2.5	10.3
Bonza	24.1	24.3	7.5	13.8
Sundowner	51.9	48.5	55.0	51.7
Golden Delicious	61.1	53.4	45.0	48.3
Granny Smith	79.6	74.8	77.5	72.4

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 3.12: Profiles of mite management segments on other tree crops

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Pears	42.6	43.7	60.0	58.6
Nectarines*	14.8	21.4	42.5	41.4
Peaches	22.2	33.0	42.5	41.4
Cherries	29.6	26.2	20.0	27.6
Plums*	20.4	25.2	52.5	48.3
Apricots	16.7	15.5	27.5	17.2
Apple only*	37.0	31.1	17.5	24.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

The fourth segment consisted of growers who used miticides because they cannot establish a predator mite population to control pest mites. Some 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.*

Growers in segments one and two were significantly less likely to indicate that mites were a major pest problem than growers in the third and fourth segments (13, 26, 68 and 39 per cent respectively) [8].

There were no significant differences among the segments in terms of the equity of growers, the average size of orchards or the type of irrigation systems used except that a relatively high proportion of the orchards in the third segment were watered with micro jet or mini sprinkler systems. We interpreted this result to simply reflecting the high proportion of West Australian orchards in segment three where micro jet or mini sprinkler systems predominate.

There were significant differences in the distribution of segments for mite control across the states (see Table 3.10). A relatively high proportion of growers in Queensland are in segment two while a relatively high proportion of growers in Western Australia are in segments three and four. These results are consistent with the impressions we obtained in our interviews with growers and with the experiences of extension staff in those states.

There were significant differences in the distribution of apple varieties grown in each of the segments for mite control (see Table 3.11). A relatively low proportion of growers in segments three and four grew the Fuji, Red Delicious or Braeburn varieties.

There were also significant differences across the segments for mite management in the distribution of tree crops grown in addition to apples (see Table 3.12). A relatively high proportion of growers in segments three and four grew tree crops in addition to apples, particularly nectarines and plums.

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[8] χ^2=32.4 p=0.00.

Finally, there were significant associations between membership of mite management segments and the segments for managing codling moth (see Table 3.13). Growers that relied on predator mites to control pest mites (segments one and two for mites) were more likely to have used mating disruption or soft chemicals to control codling moth (segments one and two for codling moth). Growers that relied on miticides to control pest mites (segments three and four for mites) were more likely to control codling moth by calendar spraying a broad spectrum chemical (segments three and four for codling). This result is consistent with the expectations of extension specialists.

Table 3.13: Association between codling and mite management segments*

(% of growers in each codling segment)

	Mite segments			
	Segment one	Segment two	Segment three	Segment four
Codling segments				
Segment one	27.3	50.0	15.9	6.8
Segment two	27.2	43.2	19.8	9.9
Segment three	8.7	17.4	34.8	39.1
Segment four	30.0	25.0	40.0	5.0

* denotes statistically significant differences in proportions across segments ($p<0.05$)

4.3.3 Segments for 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. We classified growers into five segments for managing light brown apple moth. The segments are roughly similar to those we identified for codling moth and are outlined in table 3.14. The first segment consisted of growers who used trap monitoring and chemical sprays to manage infestations of light brown apple moth. These growers used monitoring and moth growth forecasting to decide when and if to spray. They would generally be following a program using softer chemicals such as growth regulators. Jack is representative of growers in this 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.*

The second segment consisted of growers who used a calendar spray program and believed routinely spraying a broad spectrum chemical to control light brown apple moth was the most cost effective option for them. From segment two:

> *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.*

The third segment consisted of growers who used mating disruption as the basis for control of light brown apple moth. These growers had 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. 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.*

The fourth segment consisted of growers who used trap monitoring and chemical sprays to manage infestations of light brown apple moth. These growers used broad spectrum chemicals but the timing of spraying would be based on monitoring information and they would only spray when target thresholds were reached.

The fifth segment consisted of growers who used a calendar spray program and believed routinely spraying a broad spectrum chemical to control light brown apple moth was the best option for them because they face high pest pressure.

Interestingly, there were no significant differences among the segments in the proportion of growers indicating light brown apple moth as a major pest problem. This may be because growers generally felt well in control of this particular pest.

There were no significant differences among the segments in terms of the equity of growers, the average size of orchards or the type of irrigation systems used. There were significant differences in the distribution of segments for control of light brown apple moth across the states (see Table 3.15). A relatively high proportion of growers in Queensland are in segment three while a relatively high proportion of growers in New South Wales and Western Australia are in segment two.

There were no significant differences among the segments in terms of the varieties of apple grown or in the types of tree crops grown in addition to apples.

Finally, there were significant associations between membership of management segments for light brown apple moth and the segments for managing codling moth (see Table 3.16). The results indicate that growers tended to use the same management technique to control both types of pests. For example, growers that relied on trap catches to determine when to spray for codling also relied on trap counts to decide when to spray for light brown apple moth. Growers that used mating disruption to control codling also relied on mating disruption to control light brown apple moth. While growers that calendar sprayed for codling also calendar sprayed for light brown apple moth.

Table 3.14: Light brown apple moth management segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four	Segment five
Segment size as a proportion of respondents who control for LBAM	29.7	33.1	13.1	16.3	16.3
Calendar spray OP because of high pest pressure*	0	8.3	0	0	100.0
Calendar spray OP because most cost effective option*	0	100.0	0	0	0
Use trap catches/degree day model to determine when to spray OP because of high pest pressure*	16.3	6.3	5.3	100.0	0
Use trap catches/degree day model to determine when to spray with soft chemicals because cost effective*	100.0	0	15.8	0	0
I use mating disruption*	2.3	0	52.6	0	0
I use mating disruption and spray hotspots with OP sprays*	2.3	0	31.6	0	0
I use mating disruption and spray hotspots with soft chemical sprays*	7.0	0	21.1	0	0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.15: Profiles of light brown apple moth management segments on location*

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four	Segment five
New South Wales	14.3	50.0	0	21.4	14.3
Victoria	38.5	20.0	12.3	20.0	9.2
Queensland	25.0	0	50.0	25.0	0
South Australia	15.0	35.0	30.0	15.0	5.0
Western Australia	26.7	60.0	0	6.7	6.7
Tasmania	34.8	39.1	8.7	8.7	8.7

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 3.16: Association between codling and light brown apple moth segments*

(% of growers in each codling moth segment)

	Light brown apple moth segments				
	Segment one	Segment two	Segment three	Segment four	Segment five
Codling segments					
Segment one	44.4	22.2	11.1	18.5	3.7
Segment two	48.9	6.7	28.9	15.6	0
Segment three	5.0	75.0	0	7.5	12.5
Segment four	0	14.3	0	42.9	42.9

* denotes statistically significant differences in proportions across segments ($p<0.05$)

4.3.4 Segments for 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

We classified growers into two segments based on the information collected in interviews (see table 3.17). The first segment consisted of growers who could not tolerate any damage from dimpling bug from a marketing perspective and growers who had experienced severe losses from apple dimpling bug infestations. The growers in this segment followed a preventive program of cover spraying 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.*

Also:

> *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.*

The second segment consisted of growers who could tolerate some damage to fruit from dimpling bug and who routinely monitored for apple dimpling bug and sprayed if a population threshold was reached. 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.*

The growers in the second segment appeared to have experienced much lower levels of dimpling bug infestation, and slower rates of population expansion, than the growers in the first segment.

The growers in the first segment were more likely to report that apple dimpling bug was a major pest problem than the growers in the second segment (57.5 per cent and 25.4 per cent respectively)[9]. There were no significant differences among the segments in terms of the equity of growers, the average size of orchards or the type of irrigation systems used.

There were some significant differences among the segments in terms of the varieties of apples grown and in the types of tree crops grown in addition to apples. Compared to growers in other segments, the growers in segment one were more likely to grow Granny Smith and less likely to grow Braeburn apples[10]. Growers in segment one were less likely to the grow nectarines in addition to apples[11].

There were significant differences in the distribution of segments for control of apple dimpling bug across the states (see Table 3.18). A relatively high proportion of growers in South Australia were in segment one.

Finally, there were significant associations between membership of management segments for apple dimpling bug and the segments for managing codling moth (see Table 3.19). The results indicate that growers that used mating disruption to control codling were the most likely to rely on monitoring to decide when to spray for apple dimpling bug. Growers that relied on trap catches to determine when to spray for codling and growers that calendar sprayed for codling moth were most likely to calendar spray for apple dimpling bug.

There were no significant associations found between membership of management segments for apple dimpling bug on the one hand, and the segments for managing pest mites or light brown apple moth on the other.

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[9] χ^2=21.3 p=0.00.

[10] For braeburn χ^2=4.95 p=0.03, for granny smith χ^2=5.3 p=0.02.

[11] χ^2=9.2 p=0.00.

Table 3.17: Apple dimpling bug management segments

(% of growers in each segment)

	Segment one	Segment two
Segment size as a proportion of respondents who control for ADB	69.8	30.2
Cover spray because cannot risk any damage*	74.8	4.5
Cover spray because of severe losses*	33.5	3.0
Not had much of a problem so monitor and spray if detected *	0	100.0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.18: Profiles of apple dimpling bug management segments on location*

(% of growers in each segment)

	Segment one	Segment two
New South Wales	61.7	38.3
Victoria	77.6	22.4
Queensland	58.3	41.7
South Australia	84.8	15.2
Western Australia	58.3	41.7
Tasmania	57.1	42.9

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.19: Association between codling and apple dimpling bug segments*

(% of growers in each codling moth segment)

	Apple dimpling bug segments	
	Segment one	Segment two
Codling segments		
Segment one	84.1	15.9
Segment two	59.4	40.6
Segment three	75.6	24.4
Segment four	81.8	18.2

* denotes statistically significant differences in proportions across segments (p<0.05)

4.3.5 Segments for 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 the survey we classified growers into four segments (see table 3.20). The first segment, the largest segment, consisted primarily of growers who used a combination of protectants and eradicants throughout the black spot season. Many of these growers may employ a cover spray program throughout much of the season, following up with eradicants from time to time as needed necessary.

The second segment consists primarily of growers who followed a cover spray program for black spot early in the season and used an eradicant as needed later in the season. For example:

> *Jeff and Jacinta run an apple orchard near Orange in New South Wales. 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.*

The third segment consists of growers who had a control program for black spot based on monitoring of weather conditions. These growers relied 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. From the third 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.

The fourth segment consisted of growers who followed a cover spray program throughout the whole season for black spot. Many of the growers in this segment did not feel that they had a viable alternative to routinely spraying. The growers in this segment may be located in areas with high disease pressure or are in areas where actual infection periods did not correlate well with forecast infection periods. From segment four:

Mal has 62 acres of apples just out of Orange in New South Wales. 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 four:

Euan and his brothers run 60 hectares of orchard at Huonville. 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 were no significant differences among the segments in terms of the severity of growers' problems with black spot, the equity of growers, their location, the average size of orchards, or the type of irrigation systems used.

There were significant differences among the segments in terms of trying disease monitoring and the degree day model (see table 3.21). Growers who relied on a warning service to spray for black spot (segment three) were significantly more likely than growers in other segments to have tried using the degree day model and weather information to assist them in managing pests and diseases. In contrast, growers who controlled black spot by following a cover spray program with a protectant over the whole season (segment four) were significantly less likely than growers in other segments to have tried using the degree day model and weather information to assist them in managing pests and diseases. However, there were no significant differences among the segments in the proportion of growers who had tried a black spot warning service.

Table 3.20: Black spot management segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Segment size as a proportion of respondents who control for mites	48.4	23.3	5.9	22.4
Use combination of protectants and eradicants throughout the season*	100	0	23.1	38.8
Cover spray with protectant early in season and eradicants as needed later *	0	100	7.7	24.5
Spray only on black spot warnings*	0	0	100	0
Cover spray with protectant over whole season*	0	0	0	87.8

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.21: Profiles of black spot management segments on disease management techniques

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Tried or use day degree model*	31.1	44.0	75.0	14.6
Tried or use weather information*	64.1	60.0	91.7	50.0
Tried or use black spot warning service	53.4	48.0	75.0	43.8

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 3.22: Association between mite and black spot management segments*

(% of growers in each codling segment)

	Black spot segments			
	Segment one	Segment two	Segment three	Segment four
Mite segments				
Segment one	35.4	16.7	6.3	41.7
Segment two	52.7	28.6	6.6	12.1
Segment three	69.2	15.4	3.8	11.5
Segment four	33.3	23.8	14.3	28.6

* denotes statistically significant differences in proportions across segments (p<0.05)

There were some significant differences among the segments in terms of the varieties of apples grown. The growers in segment two were less likely than growers in other segments to grow the Red Delicious and Bonza varieties[12]. There were no significant differences among the segments in terms of the types of tree crops grown in addition to apples.

We found significant associations between membership of management segments for black spot and the segments for managing pest mites (see Table 3.22). The results indicate that growers that rely entirely on predator mites to control pest mites (mite segment one) are more likely to rely on a cover spray program throughout the season to control black spot (segment four for black spot) than other growers. Also, growers that use miticides to control pest mites because they cannot establish predator mites (mite segment three) are more likely than other growers to use a combination of protectants and eradicants throughout the season to control black spot (segment one for black spot).

There were no significant associations found between growers' membership of the management segments for black spot on the one hand, and the segments for managing codling moth, apple dimpling bug or light brown apple moth on the other.

4.4 Innovativeness in pest and disease management

A key objective in this study was to establish the relationship, if any, between the type of pest and disease management techniques used by growers and their innovativeness. To this end we included a condensed version of the Hurt, Joseph and Cook (1977) scale of innovativeness in the questionnaire we sent to growers. The condensed scale consists of eleven statements describing a person's willingness to try new ideas and methods.

Responses to the scale were coded such that higher scores corresponded to a greater propensity to exhibit innovative behaviour. Theoretically, scores on the scale could range from a minimum of one to a maximum of seven. For our sample scores ranged from 2.3 to 6.9 with a mean of 5.1. The scale exhibited a high degree of internal

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[12] For red delicious χ^2=12.2 p=0.01, for bonza χ^2=10.3 p=0.02.

consistency indicating the scale was a reliable indicator of producers' perceptions of their willingness to try novel ideas (Carmines and Zeller 1979)[13].

To begin with we found a statistically significant association between grower's innovativeness as measured by the Hurt, Joseph and Cook (1977) scale and their education (see table 3.23). The higher the level of formal education of growers the higher they scored on the innovativeness index. However, inspection of table 3.23 indicates that, although the mean scores for education level were significantly different, the differences themselves are marginal.

We also found a significant positive correlation of 0.19 between innovativeness and farm size. There was no significant association between innovativeness and grower's equity in their orchards.

In terms of pest and disease management, an examination of table 3.24 reveals that, with the exception of black spot warning services, growers who have tried the more progressive pest and disease management techniques rated significantly higher on the innovativeness index than those who had not. Again, however, the differences, while statistically significant, are in themselves marginal.

Note that, with the exception of the use of growth regulators and other 'soft' chemicals, there were no significant differences in the age of growers who tried the more progressive pest and disease management techniques compared to those who had not. And, in the case of growth regulators and soft chemical use, although the age differences were statistically significant they were trivial in magnitude[14].

In table 3.25 the average innovativeness score for growers in each of the pest and disease management segments is reported. The differences in the averages for management of codling moth, pest mites and light brown apple moth are statistically significant. However, in our opinion, the differences are minor. Broadly speaking, the differences indicate that growers who relied on calendar spraying of broad spectrum chemicals to control codling moth and light brown apple moth were marginally less innovative than growers who relied on monitoring and used soft chemicals and mating disruption to control these pests.

The differences also indicate that growers who relied on miticides to control pest mites were marginally less innovative than growers who relied on predator mites to control these pests.

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[13] Cronbach's alpha = 0.83

[14] For example, the average age of growers who had tried using growth regulators was 49.5 years while the average age of growers who had not tried this technique was 53.0 years.

Table 3.23: Innovativeness and level of formal education*

	Innovativeness score
Primary or part of secondary school	4.82
Completed secondary school	4.84
Course at TAFE, technical or agricultural college	5.34
Part or all of a degree course at a University or CAE	5.40

* denotes statistically significant differences in proportions across levels (p<0.05)

Table 3.24: Innovativeness and trialling of pest and disease management techniques

Management technique	Innovativeness score Tried or used	Innovativeness score Not tried
Pest monitoring (e.g. traps)*	4.31	5.17
Disease monitoring*	4.92	5.18
Mating disruption (e.g. isomates)*	4.77	5.35
Day degree model*	4.89	5.44
Weather information*	4.77	5.25
Black spot warning service	5.01	5.12
Insect growth regulators*	4.94	5.33
Other “soft” chemicals*	4.84	5.23
Predators (e.g. predator mites)*	4.82	5.19

* denotes statistically significant differences in proportions (p<0.05)

Table 3.25: Innovativeness and membership of management segments

(Mean innovativeness score of growers in each segment)

	Segment one	Segment two	Segment three	Segment four	Segment five
Codling moth*	5.23	5.27	4.66	4.58	
Pest mites*	5.06	5.28	4.83	4.56	
Light brown apple moth*	5.31	4.64	5.30	4.80	5.05
Apple dimpling bug	4.99	5.12			
Black spot	5.04	5.08	5.38	4.70	

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 3.26: Innovativeness and experiences with mating disruption

	Innovativeness score Agree	Innovativeness score Disagree
I found it works well	5.24	5.23
I use it where I can	5.44	5.17
<u>I found it did not work very well because:</u>		
I have the edge effects	5.17	5.25
I have high pest pressure	5.28	5.22
My orchard is hilly	5.47	5.20
It was too time consuming*	4.59	5.27
It cost too much	5.03	5.30
Problems with secondary pests	5.23	5.24
Pest pressure isn't high enough	4.92	5.26

* denotes statistically significant differences ($p<0.05$)

In our view these results indicate that grower's innovativeness plays only a limited role in their selection of pest and disease management techniques. This view was reinforced when we investigated growers' experiences with mating disruption. With the exception of growers who had abandoned mating disruption because it was too time consuming, we failed to identify any significant association between the innovativeness of growers and their experience with mating disruption (see table 3.26).

There were no significant differences in the mean age of growers across the management segments for any of the pests and diseases we investigated.

Apart from two minor exceptions we did not find any statistically significant relationship between a grower's education and their use of pest and disease management techniques, their membership of management segments for the pests and diseases we investigated, or their experiences with mating disruption. The two exceptions were that growers who had completed secondary education were less likely than other growers (including growers who had only completed primary school) to have tried using the day degree model or growth regulators to manage pests.

4.5 Conclusion

In this chapter we reported on the incidence of apple pests and diseases. Growers from different regions had to contend with different pest and disease problems. Codling moth, light brown apple moth and dimpling bug were the major pests and black spot was the key disease in most regions except Western Australia which was largely free of codling moth and black spot.

We also investigated the methods growers used to manage pests and diseases. We classified growers into segments based on the techniques they use to manage pests and diseases. We also identified some relationships between segment membership and contextual factors such as grower's location.

We also investigated the relationships between grower's use of pest and disease management techniques and demographic factors such as the age, education and innovativeness. In essence we found little evidence to suggest that demographic factors played a major role in the adoption of pest and disease management techniques. While statistically significant relationships were found, in all instances the relationships were marginal in magnitude.

This finding is consistent with the impressions we obtained in our interviews with growers. When interviewed, growers indicated that the particular combinations of pest and disease management practices they used were determined primarily by their orchard circumstances, rather than their attitudes towards sustainability and the environment. The key factors that growers identified 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, and the effectiveness of those options.

5. Irrigation management

In this chapter we report on the irrigation systems used by apple growers. We classify growers into irrigation management segments based on their reasons for investing in new irrigation technologies. We also classify growers into segments in terms of soil moisture monitoring. In the final section of the chapter the relationships between segment membership and demographic factors such as the age, education and innovativeness of growers are explored.

The information on irrigation management we gathered during our interviews with growers (Kaine and Bewsell 2003) was consistent with our previous work (see Kaine and Bewsell 1999; 2000) in which the adoption of new irrigation technologies was found to depend on the benefits these technologies offered the grower.

5.1 Irrigation management segments

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 stated they had 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 had been redeveloped to a high density planting design (closer plantings), in some cases on dwarfing rootstock, and pressurised irrigation allowed growers to control water application.

This information was used to develop a set of statements describing reasons for installing pressurised irrigation systems. In the survey questionnaire growers who had installed a pressurised irrigation system were asked to select from this set those statements that best reflected their reasons for installing such systems. The results were used to classify growers into seven irrigation management segments (see table 4.1). Note that only four growers in the sample relied entirely on furrow or bay irrigation.

Segment one consisted of growers who installed micro-irrigation because they needed to conserve water in the orchard. These growers were 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 needed to make the most of their water. For example:

> *Mal has 62 acres of apples just out of Orange in New South Wales. 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 two consisted of growers who installed micro-irrigation primarily because the topography or soils in their orchard was not suitable for flood irrigation.

Segment three consists of growers that had installed micro-irrigation because they wished to save time irrigating and may 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.*

Segment four consisted of growers who had 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.*

Segment five, consisted of growers that had installed micro-irrigation because they wished to better manage the quality of their apples while the growers in segment six installed micro-irrigation because they wished to better manage the quality of their apples and to save time irrigating.

Table 4.1: Irrigation management segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Segment size as a proportion of respondents	13.6	10.2	23.3	11.2
Redeveloping to higher density planting*	0	0	43.8	0
Replanting to new varieties*	7.1	28.6	43.8	4.3
Converting to save time and labour*	0	0	77.1	100.0
Increase flexibility in managing orchard activities *	0	0	100.0	0
Experiencing tree health problems	0	0	10.4	0
Best suits soil types/topography*	17.9	76.2	41.7	21.7
Needed to save water due to limited supply*	100.0	0	54.2	39.1
Needed to save water as it is getting expensive	7.1	0	25.0	13.0
Wanted to improve quality of apples*	0	0	45.8	0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 4.1continued: Irrigation management segments

(% of growers in each segment)

	Segment five	Segment Six	Segment seven
Segment size as a proportion of respondents	14.6	12.1	15.0
Redeveloping to higher density planting*	0	48.0	100.0
Replanting to new varieties*	13.3	32.0	48.4
Converting to save time and labour*	0	92.0	22.6
Increase flexibility in managing orchard activities *	0	0	0
Experiencing tree health problems	0	4.0	3.2
Best suits soil types/topography*	23.3	28.0	3.2
Needed to save water due to limited supply*	36.7	56.0	35.5
Needed to save water as it is getting expensive	10.0	20.0	9.7
Wanted to improve quality of apples*	100.0	100.0	0

* denotes statistically significant differences in proportions across segments (p<0.05)

The final segment, segment seven, consisted of growers who had installed micro-irrigation primarily because they have redeveloped their orchard to a closer planting design. From segment seven:

> *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.*

These segments largely correspond with those we had identified in previous work on irrigation in stone and pome fruit. However, the installation of micro-irrigation systems to improve apple quality is a new finding.

We found statistically significant differences in the distribution of irrigation segments across the states (see table 4.2). The most notable results were:

- A relatively high proportion of growers who had installed pressurised irrigation primarily to save water (segment one) were located in New South Wales and Queensland.
- A relatively high proportion of growers who had installed pressurised irrigation at least partly because they redeveloped their orchards to higher density planting systems (segments three and seven) were located in Victoria.
- A relatively high proportion of growers who had installed pressurised irrigation primarily to improve the quality of their apples (segment five) were located in New South Wales.

We also found significant differences among the irrigation segments in the varieties of apple trees grown (see table 4.3). The most notable results were:

- A relatively high proportion of growers who had installed pressurised irrigation primarily to save water (segment one) grew Fuji, Red Delicious and Bonza varieties.
- A relatively high proportion of growers who had installed pressurised irrigation because they redeveloped their orchards to higher density planting systems and wanted to save time irrigating (segment three) grew Pink Ladies and Lady Williams varieties.
- A relatively high proportion of growers who had installed pressurised irrigation primarily to improve the quality of their apples (segments five and six) grew Fuji, Red Delicious and Braeburn varieties.

Table 4.2: Profile of irrigation management segments by location*

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
New South Wales	50.0	4.8	8.5	17.4
Victoria	28.6	33.3	42.6	21.7
Queensland	14.3	4.8	4.3	4.3
South Australia	0	19.0	19.1	8.7
Western Australia	3.6	28.6	12.8	26.1
Tasmania	3.6	9.5	12.8	21.7

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 4.2 continued: Profile of irrigation management segments by location*

(% of growers in each segment)

	Segment five	Segment six	Segment seven
New South Wales	43.0	16.0	23.3
Victoria	20.0	28.0	46.7
Queensland	3.3	4.0	0
South Australia	13.3	28.0	10.0
Western Australia	6.7	16.0	10.0
Tasmania	13.3	8.0	10.0

* denotes statistically significant differences in proportions across segments (p<0.05)

Table 4.3: Profile of irrigation management segments by apple varieties

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Gala	85.7	81.0	78.7	69.9
Fuji*	82.1	57.1	58.3	65.2
Red Delicious*	85.7	42.9	54.2	69.6
Pink Lady*	64.3	76.2	95.8	78.3
Lady Williams*	10.7	9.5	37.5	13.0
Jonathan	39.3	38.1	29.2	43.5
Braeburn*	28.6	14.3	4.2	13.0
Bonza*	42.9	4.8	4.2	17.4
Sundowner	35.7	47.6	58.3	43.5
Golden Delicious	42.9	47.6	50.0	52.2
Granny Smith	82.1	66.7	79.2	73.9

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 4.3 continued: Profile of irrigation management segments by apple varieties

(% of growers in each segment)

	Segment five	Segment six	Segment seven
Gala	90.0	96.0	87.1
Fuji*	90.0	80.0	67.6
Red Delicious*	73.3	76.0	58.1
Pink Lady*	80.0	72.0	77.0
Lady Williams*	3.3	20.0	32.3
Jonathan	43.3	52.0	35.5
Braeburn*	43.3	28.0	6.5
Bonza*	26.7	24.0	22.6
Sundowner	50.0	72.0	58.1
Golden Delicious	46.7	76.0	54.0
Granny Smith	46.7	88.0	77.4

* denotes statistically significant differences in proportions across segments ($p<0.05$)

There were no statistically significant differences among the irrigation segments in terms of the types of pressure irrigation systems installed; the types of fruit trees grown in addition to apples; the equity of growers; and whether growers had full time employment off-farm. There were no statistically significant differences among the irrigation segments in terms of the age, education or innovativeness of growers.

Finally, there were no statistically significant differences among the irrigation segments in terms of the way in which growers scheduled their irrigation or in their use of soil moisture monitoring equipment. Most growers relied on experience, soil moisture monitoring equipment or a fixed rotation to schedule their irrigations (71 per cent, 34 per cent and 26 per cent respectively).

Relatively small proportions of growers also employed soil sampling or evaporation information to schedule irrigations (16 per cent, and 12 per cent respectively). Only two per cent of growers relied on advice from consultants or extension officers.

5.2 Soil moisture monitoring segments

During our interviews we discovered grower's used soil moisture monitoring equipment for a variety of reasons. Some growers needed to maximise their production per unit of water used in the orchard. Generally, these growers had 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.*

Approximately 34 per cent of respondents to our survey used soil moisture monitoring equipment such as tensiometers. Just over one third of these growers (36 per cent) indicated they used monitoring equipment to save water because their water supplies were limited.

Some growers who had a problem in the orchard that they believed they could solve by improving their irrigation management. Growers in this segment may have had problems controlling vigour or an area in their orchard which was poorly drained. These growers were 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.

Approximately 21 per cent of the respondents to our survey who used soil moisture monitoring equipment indicated they used monitoring to help them control a vigour problem. Almost 25 per cent of the respondents to our survey who used soil moisture monitoring equipment indicated they used monitoring to help them control the quality of their fruit.

Other growers used soil moisture monitoring to check the efficacy of irrigations. Often these growers were managing large orchards and wanted to check the irrigation management. Approximately 22 per cent of the respondents to our survey who used soil moisture monitoring equipment indicated they used monitoring in this fashion.

Most growers did not use soil moisture monitoring. These growers did not need to save water, did not have a problems with water logging and they believed their irrigation management was 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.

Similarly:

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.*

In short, 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 vigour or 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 did 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 were 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.

Based on this reasoning we classified growers into three segments based on whether they had access to water 'on demand' and whether they irrigated with a micro-irrigation system (see table 4.4). The first segment consisted of fruit growers who were able to water 'on demand' and who had a micro-irrigation system (see tables 4.4 and 4.5). Approximately 40 per cent of the growers in this segment used soil moisture monitoring equipment.

The second segment consisted of fruit growers who were able to water 'on demand' but who did not have a micro-irrigation system (see tables 4.4 and 4.5). Only seven per cent of the growers in this segment used soil moisture monitoring equipment.

The third segment consisted of fruit growers who could not water ‘on demand’ but did have a micro-irrigation system (see tables 4.4 and 4.5). Approximately 36 per cent of the growers in this segment used soil moisture monitoring equipment.

These results support the proposition that growers without micro-irrigation systems (drip, micro-jets or mini-sprinklers) cannot effectively use soil moisture monitoring equipment. They also indicate that growers with micro-irrigation systems can make use of soil moisture monitoring equipment even when they do not have access to water ‘on demand’.

We found statistically significant differences in the distribution of soil moisture monitoring segments across the states (see table 4.6). The most notable results were:

- A relatively high proportion of growers who had installed micro-irrigation and had access to water ‘on demand’ (segment one) were located in South Australia, Western Australia, Queensland and Tasmania.
- The majority of growers who had access to water ‘on demand’ but had not installed micro-irrigation (segment two) were located in Victoria and New South Wales.
- The majority of growers who had installed micro-irrigation but did not have access to water ‘on demand’ (segment three) were located in Victoria.

We also found significant differences among the soil moisture monitoring segments in the varieties of apple trees grown (see table 4.7). The most notable results were:

- A relatively high proportion of growers who had installed micro-irrigation and had access to water ‘on demand’ (segment one) grew Gala, Fuji, Pink Lady and Sundowner varieties.
- A relatively high proportion of growers who had installed micro-irrigation but did not have access to water ‘on demand’ (segment three) grew Gala, Pink Ladies, Lady Williams and Sundowner varieties.

We found significant differences among the soil moisture monitoring segments in the types of fruit tree grown in addition to apples (see table 4.8). The most notable results were:

Table 4.4: Soil moisture monitoring segments

(% of growers in each segment)

	Segment one	Segment two	Segment three
Segment size as a proportion of respondents	67.8	10.7	21.5
Installed micro-irrigation*	100.0	0	100.0
Can irrigate ‘on demand’*	100.0	53.6	0
Use soil moisture monitoring equipment*	39.2	7.1	35.7
Tried monitoring equipment but didn’t find it to be of much use *	4.5	0	16.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 4.5: Profile of soil moisture monitoring segments by irrigation system

(average proportion of orchard area in each segment)

	Segment one	Segment two	Segment three
Furrow/bay irrigation with channels*	0.8	7.8	1.5
Furrow/bay irrigation with pipe and risers*	0.4	8.2	0.6
Under tree knocker sprinklers*	2.6	28.6	0.5
Overhead sprinklers	2.2	5.9	0.9
Drip or trickle irrigation*	48.6	10.1	39.0
Micro jets or mini sprinklers*	45.4	7.1	57.4

* denotes statistically significant differences in proportions across segments ($p<0.05$)

- A relatively low proportion of growers who had installed micro-irrigation and had access to water ‘on demand’ (segment one) grew pears in addition to apples.
- A relatively high proportion of growers who had installed micro-irrigation but did not have access to water ‘on demand’ (segment three) grew apricots in addition to apples.

These differences probably reflect differences in the geographic distribution of the segments.

There were no statistically significant differences among the soil moisture monitoring segments in terms of the equity of growers and whether growers had full time employment off-farm. In addition, there were no statistically significant differences among the irrigation segments in terms of the age or education of growers. However, there were statistically significant differences across the segments in the mean innovation score of growers. Growers in segment two exhibited a lower mean score compared to growers in segments one and three (4.7, 5.1 and 5.1 respectively). Although statistically significant, given the magnitude of these differences, they are inconsequential in our opinion.

Table 4.6: Profile of soil moisture monitoring segments by location*

(% of growers in each segment)

	Segment one	Segment two	Segment three
New South Wales	20.1	33.3	19.6
Victoria	24.1	29.6	64.3
Queensland	6.3	0	1.8
South Australia	17.2	11.1	7.1
Western Australia	20.7	11.1	5.4
Tasmania	11.5	14.8	1.8

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 4.7: Profile of soil moisture monitoring segments by apple varieties

(% of growers in each segment)

	Segment one	Segment two	Segment three
Gala*	86.4	57.1	76.8
Fuji*	74.6	64.3	48.2
Red Delicious*	67.8	75.0	44.6
Pink Lady*	83.6	60.7	83.9
Lady Williams*	16.9	17.9	37.5
Jonathan	36.7	42.9	30.4
Braeburn	15.3	17.9	16.1
Bonza	16.9	21.4	17.9
Sundowner*	57.1	14.3	50.0
Golden Delicious	55.4	42.9	46.4
Granny Smith	75.1	75.0	82.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 4.8: Profile of soil moisture monitoring segments by other tree crops grown

(% of growers in each segment)

	Segment one	Segment two	Segment three
Pears*	43.5	64.3	57.1
Nectarines	23.2	32.1	28.6
Peaches	29.9	28.6	46.4
Cherries	28.2	17.9	21.4
Plums	29.4	28.6	41.1
Apricots*	12.4	10.7	37.5

* denotes statistically significant differences in proportions across segments ($p<0.05$)

5.3 Conclusion

A variety of irrigation systems were used, from flood irrigation through to drip irrigation, in apple production. Most fruit growers used some form of micro-irrigation such as mini sprinklers, micro jets or drip irrigation. Growers had 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;
- A desire to improve the quality of apples they produce;
- The orchard had been redeveloped to a high density planting design (closer plantings), in some cases on dwarfing rootstock, which only suited micro-jet or drip irrigation.

These results are largely consistent with the findings from our previous work Kaine and Bewsell (1999; 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 always 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 (such as tree vigour) that the grower believed could be fixed through improving their control over irrigation management.

We found little evidence to suggest that demographic factors played a major role in the adoption of irrigation systems and soil moisture monitoring techniques. While statistically significant relationships were found, in all instances the relationships were marginal in magnitude.

6. Quality assurance and record keeping

A key feature of IFP 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 IFP we questioned growers about their experiences with quality assurance schemes, whole farm planning where appropriate, and sought their views on record keeping and orchard management. As noted in Kaine and Bewsell (2003) fruit growers did not view whole farm planning as a key management tool. Only growers in Shepparton were familiar with the term 'whole farm planning' and many had obtained a plan when redeveloping their orchards in order to qualify for a subsidy. Growers in Shepparton viewed a whole farm plan primarily as an irrigation design plan. 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.

6.1 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).

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 four segments in terms of their propensity to adopt or comply with quality assurance programs. The segments are outlined in table 5.1 and their participation in quality assurance schemes is reported in table 5.2.

The first segment consisted of those growers who exported but did not pack fruit. Many of these growers would require quality assurance in order to export. An 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 consisted 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.*

The third segment consisted of growers who packed and grew fruit primarily for the domestic fruit market. These growers were more likely to have a quality assurance system than growers in the fourth 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 5.1: Post harvest segments

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Segment size as a proportion of respondents	18.3	21.9	31.7	28.1
Supply export markets*	100.0	100.0	0	0
Pack and store fruit*	0	100.0	100.0	0
Store fruit only*	27.5	0	0	16.7
Pack fruit only *	9.8	0	0	15.4
No packing or storage facilities*	60.8	0	0	55.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 5.2: Profile of post harvest segments by quality assurance

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Audited scheme (e.g. ISO9000)*	44.0	65.6	36.4	25.6
Approved supplier certificate*	17.6	14.8	23.9	23.1
Never had audited quality assurance *	29.4	8.2	27.3	32.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

The fourth segment consisted of those growers who did not export and did not pack fruit, and who therefore felt there was less of a need for quality assurance. A typical example of a grower from segment four was 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.*

In table 5.3 the reasons growers gave for adopting audited quality assurance are reported. Most growers that had audited quality assurance had clearly adopted the system in order to meet buyer requirements. Interestingly, the main reason growers without an audited quality assurance gave for not having an audited system was that they could sell their fruit without it (34 per cent of the growers in our sample without quality assurance).

We found statistically significant differences in the distribution of irrigation segments across the states (see table 5.4). The most notable results were:

- A relatively high proportion of growers who supplied apples to the domestic market (segments three and four) were located in New South Wales.
- A relatively high proportion of growers who did not pack and store (segments one and four) were located in Victoria.
- A relatively high proportion of growers who export (segments one and two) were located in Western Australia and Tasmania.

We also found significant differences among the post harvest segments in the varieties of apple trees grown (see table 5.5). The most notable results were:

- A relatively high proportion of growers who export (segments one and two) grew Pink Lady, Lady Williams, and Sundowner varieties.
- A relatively high proportion of growers who did not export (segments three and four) grew Red Delicious, Jonathan and Bonza varieties.

Table 5.3: Profile of post harvest segments by reasons for adopting quality assurance (% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Requirement to supplier buyer	90.9	77.5	90.6	100.0
Requirement to supplier exporter *	63.6	42.5	6.3	5.0
Managing packing operation*	0	25.0	18.8	5.0
Systematic method for record keeping	40.9	32.5	28.1	20.0
Buyer recommendation	0	10.0	21.9	10.0

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 5.4: Profile of post harvest segments by location*

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
New South Wales	3.9	6.6	30.2	34.2
Victoria	31.4	21.3	46.5	28.8
Queensland	3.9	4.9	4.7	4.1
South Australia	19.6	13.1	5.8	23.3
Western Australia	21.6	34.4	9.3	5.5
Tasmania	19.6	19.7	3.5	4.1

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 5.5: Profile of post harvest segments by apple varieties

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Gala	80.4	88.5	80.7	70.1
Fuji*	60.8	72.1	78.4	52.6
Red Delicious*	54.9	59.0	75.0	57.7
Pink Lady*	88.2	88.5	75.0	69.2
Lady Williams	27.5	26.2	23.9	11.5
Jonathan*	25.5	18.0	50.0	35.9
Braeburn	7.8	11.5	18.2	21.8
Bonza*	3.8	11.5	21.6	29.5
Sundowner*	64.7	68.9	36.4	38.5
Golden Delicious	56.9	55.7	52.3	43.6
Granny Smith*	62.7	80.3	83.0	66.7

* denotes statistically significant differences in proportions across segments ($p<0.05$)

Table 5.6: Profile of post harvest segments by other tree crops grown

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Pears*	39.2	52.5	62.5	35.9
Nectarines*	19.6	37.7	30.7	12.8
Peaches	25.5	41.0	40.9	25.6
Cherries*	13.7	42.6	25.0	17.9
Plums*	27.5	49.2	31.8	21.8
Apricots	15.7	24.6	21.6	12.8

* denotes statistically significant differences in proportions across segments ($p<0.05$)

We also found significant differences among the post harvest segments in the varieties of tree crops grown in addition to apples (see table 5.6). The most notable results were:

- A relatively high proportion of growers who pack and store fruit (segments two and three) grew pears and nectarines in addition to apples.
- A relatively high proportion of growers who export as well as packing and storing fruit (segment two) also grew cherries and plums in addition to apples.

There were no statistically significant differences among the post harvest segments in terms of the types of pressure irrigation systems installed[15]; the equity of growers; and whether growers had full time employment off-farm. However, growers in segment two (exporters with packing and storage facilities) had significantly larger orchards than growers in other segments[16]. There were no statistically significant differences among the post harvest segments in terms of the age, education or innovativeness of growers.

6.2 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 Manjimup in Western Australia said:

> *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".*

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:

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[15] Except growers in segment three had a higher proportion irrigated by overhead sprinklers (5.9 per cent compared to less than 2 per cent in the other segments).

[16] 21.0, 50.2, 17.1 and 12.0 hectares respectively for segments 1 through 4 (F=10.1. p=0.00)

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.

These views were generally supported by the survey results. In table 5.7 the proportions of growers keeping written records on various orchard activities are reported. The high incidence of record keeping in relation to pesticide and fertiliser applications and fruit packout was clearly evident. The incidence of record keeping appears lower among growers that did not export fruit.

6.3 Conclusion

The documentation of orchard activities and decision making was a key element of IFP 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 IFP, 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 did not always believe these claims.

In relation to market access, growers had 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 necessarily mean exclusion from markets.

Table 5.7: Profile of post harvest segments by documentation*

(% of growers in each segment)

	Segment one	Segment two	Segment three	Segment four
Chemical spray applications	100.0	100.0	95.5	91.0
Pest and disease monitoring	78.4	70.5	61.4	53.8
Pumping hours	62.7	44.3	27.3	46.2
Soil moisture monitoring	41.2	37.7	21.6	23.1
Fertiliser applications	88.2	91.8	76.1	73.1
Soil tests	74.5	77.0	59.1	51.3
Yield	94.1	75.4	72.7	76.9
Packout	82.4	72.1	54.5	50.0

* denotes statistically significant differences in proportions across segments ($p<0.05$)

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 believed that, apart from using spray diaries to assist in pest and disease management, there was limited 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 IFP, is likely to make in terms of creating exclusive access to markets or improving orchard management and profitability.

7. Discussion and Conclusion

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 more by reasoned consideration of risks and benefits of change, and less by innovativeness as a personality trait of growers.

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. The results of the grower survey support this view.

7.1 Pest and disease management

Growers' pest and disease management practices depended 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 influenced the mix and intensity of pests and diseases present in an orchard were the climate and topography of the orchard, the relative isolation of orchard, the crop types in the region. The key factors that influenced the range of control options available to a grower were the set of chemical and biological options available for managing pests and diseases, mediated by the requirements of the markets the grower was 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 was determined by chemical and biological options available for managing pests and diseases, and the effectiveness of those options.

The financial performance of an apple operation was 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 exhibited behaviour similar to brand loyalty when it came to changing pest and disease management practices. This means that once growers had discovered a combination of management options that were 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 had 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 IPM programs. The prospect of IPM “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 IPM programs. Growers’ feared that their IPM programs would be compromised if they had to resort to using broad spectrum chemicals to control secondary pests.

Our interview results indicate that it was unlikely that a lack of knowledge, skills or information was 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.

The results of the interviews were largely supported by the quantitative analysis of the survey of growers. We classified growers into segments based on the techniques they used to manage a range of pests and diseases. We identified strong relationships between segment membership and contextual factors such as grower's location and severity of pest pressure. We also found systematic relationships between segment membership for different pests that were consistent with the type of management techniques used to control different pests (e.g. membership of codling moth, mite and light brown apple moth segments). We found only weak, if any, relationships between grower's use of pest and disease management techniques and demographic factors such as the age, education and innovativeness. Importantly, substantial differences in the age, education or innovativeness of growers were not consistently evident across pest and disease management segments. In essence we found little evidence to suggest that demographic factors play a major role in the adoption of pest and disease management techniques. While statistically significant relationships were found, in all instances the relationships were marginal in magnitude.

These results suggest that the particular combinations of pest and disease management practices growers used were determined primarily by their orchard circumstances, rather than their attitudes towards sustainability and the environment, or their inherent innovativeness. The key factors that growers identified 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, and the effectiveness of those options.

7.2 Irrigation management

Our results with respect to irrigation management were consistent with those reported in Kaine and Bewsell (1999; 2000; 2003). We found that most growers were using pressurised irrigation systems such as micro-jets and drip irrigation. However relatively 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 were also investing in pressurised irrigation systems to improve the quality of their apples by, for example, gaining better control over tree vigour.

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, because there was a need to check the efficacy of irrigations or because water was scarce. We found growers in most areas had the flexibility to respond to soil moisture monitoring as most were able to irrigate on demand.

We did not find any statistically significant differences among the irrigation segments in terms of the age, education or innovativeness of growers but there were significant differences in terms of location and types of tree grown.

Similarly, there were no statistically significant differences among the soil moisture monitoring segments in terms of the age or education of growers. There was a significant, though small difference, among the segments in terms of the innovativeness of growers.

These results indicate that the adoption of new irrigation technologies depends on the perceived benefits these technologies offered the grower rather than grower's inherent innovativeness. 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.

7.3 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 easier 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 limited 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 had become sceptical of these claims as well because, in their experience, access to markets had remained open to participants and non-participant alike and market premiums have failed to materialise.

Growers who were involved 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.

The results of the grower survey did show that growers who were exporting and who operated packing and storage facilities were the most likely to participate in an audited quality assurance scheme, and that their motivation was market access. However, we found there were no statistically significant differences among growers in different post harvest management segments in terms of their age, education or innovativeness. There were significant differences in terms of location, varieties of apples and types of other tree crops grown.

7.4 Comparisons with past studies

In our review of previous studies into pest and disease management we concluded there was 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 IPM and therefore training and extension was essential. Other authors have argued the popularity of programs, such as farmer field schools, was 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 was 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 was determined by the mix of chemical and biological options available for managing pests and diseases, and the effectiveness of those options. These findings implied that growers followed 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 followed a decision process that resembles complex decision making when establishing a pest and disease management regime.

We also found that once growers had discovered a combination of management options that was successful they would not change that combination unless forced to by circumstances because the perceived risk of failure was high. Circumstances which would force growers to change their pest and disease management included the repeated failure to control pests due to increasing resistance, the emergence of a new pest which could not be controlled without disrupting the control of other pests, the withdrawal from sale of a key management option or use of an option was declared unacceptable in export markets. 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 IPM use are misguided (unless all orchards are the same and all IPM 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 analysis of the survey of growers was consistent with those obtained from the grower interviews. We found weak, if any, relationship between factors such as the age, education or innovativeness of growers and their management of pests and diseases, their management of irrigation and their participation in quality assurance schemes. The same can be said in relation to orchard size and grower equity in their orchard.

We did find significant relationships between contextual factors such as location and pest intensity and growers' management of pests and diseases that accorded with the expectations of extension personnel. We found significant relationships between contextual factors such as location and growers' management of irrigation that accorded with the expectations of extension personnel. And we found significant relationships between contextual factors such as location, type of market supplied and post harvest facilities and growers' involvement in quality assurance schemes that accorded with our expectations.

Importantly, we found little evidence to suggest that innovative growers are at the forefront in adopting new technologies in apple production. If this were the case then we would have expected to find growers in the segments adopting the most advanced techniques in each activity (mating disruption in pest management, degree day models in disease management, soil moisture monitoring in irrigation management) to be consistently more innovative than growers in other segments. We would also expect to find consistency in the membership of such segments. These expectations were not satisfied.

We found, at best, a variable and weak relationship between segment membership and innovativeness. We also found that where there was a systematic relationship between membership of segments (say for codling moth management and mite management) this could be explained by systematic interactions between the management techniques used.

These findings 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 IPM. 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.

The same principle applies promoting adoption of best management practices in irrigation and encouraging participation in quality assurance schemes and similar programs such as environmental management systems.

7.5 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 IFP 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 IFP program will generate significant practical benefits?

Currently, the practical benefits to participating in an IFP 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 cynicism about the rewards of participating in assurance programs. Until experience demonstrates that non-participation does mean permanent exclusion from markets that cynicism will remain.

The attractiveness to growers of an IFP 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 IFP program, especially given the likely emphasis in such a program on IPM.

In our view, participation in an IFP program is likely to be limited in the present circumstances. We believe there is little opportunity to promote the adoption of an IFP 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 IFP 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 IFP program that is sufficiently flexible to accommodate variation in pest and disease management practices within and between regions
- Design an IFP 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 IFP 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.

7.6 Conclusion

In this project we investigated the factors influencing adoption of pest and disease management, irrigation systems, soil moisture monitoring, 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 also found that demographic and psychographic characteristics such as the age, education and innovativeness of apple growers have a very limited influence on their adoption of pest and disease management, irrigation systems, soil moisture monitoring, record keeping and quality assurance.

We believe that there is little incentive at present for apple growers to participate in an IFP 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.

8. References

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