

# **An IPM manual for Australia's apple and pear industry**

Dr Shane Hetherington  
NSW Department of Industry and Investment

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## **AP07009**

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**AP07009 An IPM manual for Australia's apple and pear industry (1 March 2009)**

**Dr Shane Hetherington  
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## AP07009

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This report provides information on the development and delivery of an IPM manual for the Australian apple and pear fruit industries. The manual was developed following extensive collaboration with Australian fruit producers and the state government agencies which provide them with research and extension services. The information contained within the manual will provide producers with a logical, regional framework for pest control allowing them to reduce pesticide application.

(March 2010)

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## 1. Media Summary

Integrated Pest Management (IPM) is a science-based method of controlling pests. IPM targets 'weak points' in pest life cycles and promotes the activities of biological control agents. IPM does not prohibit the use of pesticides but management is carefully considered and uses the best available option; a reduction in pesticide application almost always occurs.

Development and implementation of IPM is a high priority for the Australian apple and pear industry in response to the demands of domestic and international markets. I&I NSW led a collaborative project to develop an IPM manual by Australian farmers. Groups of 8 to 12 farmers were interviewed in 8 key Australian apple and pear production regions to determine which pests were considered most damaging and how they are currently controlled. Although very significant regional differences were recorded, the most significant diseases included apple scab, powdery mildew and phytophthora and the most significant insect pests included codling moth, apple dimpling bug and light brown apple moth.

On the basis of this information a prioritised pest list was produced and used to develop an IPM manual. The manual details an IPM strategy designed for Australian conditions and provides detailed information on the biology and management of the main pests affecting Australian pome fruit production. For each pest information is included on its impact, life cycle, prevention, monitoring and management.

In addition, information from these group interviews has been used to provide an indication of the major management techniques used in Australian orchards. While pesticide application is critical to the production of high quality fruit, a range of other techniques are widely used.

These techniques include the use of pheromone-based mating disruption to reduce the impact of codling moth and lightbrown apple moth. Cultural management including pruning are often undertaken to reduce pest numbers.

Where pesticides are necessary off-target impacts are considered and natural biological control agents such as predatory mites are considered. There is a general trend for industry to move toward pesticides with more targeted activity; affecting only the pest for which their application is intended.

## 2. Technical Summary

Australian researchers have been providing the apple and pear industry with the tools required for IPM of apples and pears for many years. Notable examples include

- the widespread release of predatory mites (*Typhlodromus occidentalis* and *T. pyri* and subsequent others) which prey on pest mites during the 1960's and 1970's;
- the introduction, testing and promotion of pesticides with more targeted activity commencing in the late 1970's;
- the development and refinement of mating disruption to control Lepidopteran pests of apples and pears and;
- the development of disease forecasting models and hardware allowing orchardists to better time pesticide applications.

Australian orchardists produce apples and pears in widely varying regions and are confronted by a diverse range of pests. As a result of 50 years of research they have, at their disposal, a large numbers of tools to control these pests. In line with the expectations of their consumers, the apple and pear industries are moving to further implement IPM. Given a plethora of pests, regional differences and management options there is clearly a need for practical guidance.

The objective of this project was to obtain an indication of current industry pest control practice and use this as the basis of a readily implemented and practical IPM strategy. This strategy was documented as a manual and distributed free-of-charge to industry members through Apple and Pear Australia Limited (APAL).

Focus group meetings were conducted in eight major Australian apple and pear production regions: Orange (NSW), Batlow (NSW), Stanthorpe (Qld), Knoxfield (Vic), Shepparton (Vic), Perth (WA), Adelaide Hills (SA) and Grove (Tas). Meetings were dominantly attended by orchardists but also included government and private advisory staff. Meeting attendance was variable but was typically approximately ten attendees. Only one orchardist was interviewed in Tasmania.

In order to encourage a free flowing discussion about current pest problems and management, interviews were based on the following questions.

1. What are the major pests which requiring management on your orchard?
2. Given that the last 5-10 seasons have been drought affected, which were the main pests 10 years ago?
3. How do you manage each of the pests listed in questions 1&2?

This information was documented (Appendix 1) and analysed to provide an indication of which pests are of greatest concern to the Australian industry. Similarly, current management options were analysed to determine which could be recommended within the framework of IPM. Adoption of IPM is more likely if it involves a logical adaptation of current practice rather than the introduction of novel techniques.

A draft IPM manual was produced. APAL provided a list of industry participants who reviewed the document and made suggestions over a three month period. Also during this time the document was reviewed for its technical content by a group of IPM researchers and extension staff from various state government agencies. The technical reviewers were.

- Mr Graham Thwaite (I&I NSW, retired)

- Dr Mofakhar Hussain (DPI Victoria)
- Dr Stuart Learmonth (DAFWA)
- Ms Penny Domeney (DPIWE)

Specific information and images for the manual were also contributed by Ms Christine Horlock, Qld DEEDI (Alternaria leaf and fruit spot and white root rot) and Mr Paul James (PIRSA, SA).

Where necessary, amendments were incorporated into an improved draft of the manual. In addition an analysis of all pesticides registered for use on Australian apple and pear crops was undertaken to determine their suitability for use within IPM. European databases<sup>†</sup> and Australian publications (1,2) provided information on the impact of 65 insecticides, fungicides, bactericides and acaricides on adult and juvenile stages of three beneficial arthropods commonly found in Australian orchards: *Phytoseiulus persimilis*, Tichogramma and green lacewing. This information was tabulated in such a way as to give readers a quick guide to off-target impacts categorising pesticides as having:

- Low toxicity with nil or low impact on beneficials
- Moderate toxicity
- High toxicity with the ability to kill a high proportion of beneficials and a long-lasting residual effect.

A literature review was also undertaken to examine IPM research in the Australian apple and pear industry (Appendix 2). This ensured that consideration of all previous locally relevant information was considered.

All information gathered during the project was included in a spiral bound manual. The manual contains information on pesticides and hence its format will allow for future updates associated with changes to pesticide registrations.

Although the project's objective was not to produce statistically rigorous data the information generated during the grower interviews provides an indication of current pest concerns and management options. The information is summarised in this report.

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<sup>†</sup> available at [www.biobest.be](http://www.biobest.be) and [www.koppert.com](http://www.koppert.com) (May 2010)



### 3. Introduction

Pests and diseases are a perennial problem in Australian apple and pear orchards. Very little research has been conducted to determine which pests are of most concern on a national or regional basis. Rankings of pest severity are anecdotal and subjective and likely to be influenced by short-term pest pressure under the influence of seasonal weather. These ‘rankings’ have not been validated through industry consultation. The perception of researchers or orchardists as to the relative importance of a particular pest or disease could be subject to bias because of their regional affiliation or particular research interest.

The implication for industry is that particular pests or diseases may receive undue attention in formulating pest and disease management strategies. As a corollary to this, industry may allocate undue resources (financial and other) to research and management of less-important pests.

Clearly, the only way to determine the relative importance of pests and diseases and account for regional variation is to ask producers in all major apple and pear production regions.

While an accurate list of the nation’s worst pest and diseases would be a useful tool, allowing the industry’s peak body to target research funding, it is not particularly useful to growers *per se*. The list however, does allow prioritisation of pests and diseases in such a way that growers can integrate their management.

Integrated pest management (IPM) is a common management strategy for the control of arthropod pests of plants. In the context of this project and report ‘pests are defined to include both arthropod pests and diseases. The basic philosophy and principles underlying this strategy are;

1. Holistic: It considers all elements of orchard management and their long-term effect on pests and diseases
2. Knowledge-based: Better information leads to better decisions. For example, orchardists using IPM should know the costs, benefits and disadvantages of applying a particular management option.
3. Not organic: the objective of IPM is to apply the management strategy which provides the most benefit. In some cases this will be a chemical pesticide.

The Australian industry and its progress toward IPM can be evaluated in terms of these three criteria

*Holistic.* Many management decisions are taken as a precaution (cover sprays) or as a reaction to an emerging problem (spot sprays or curative sprays). In both cases orchardists are considering the effectiveness of the control against on one or a limited number of pests and diseases. Every management technique used in an orchard effects all other organisms (pests, diseases, beneficial insects, trees, weeds, soil biota). These

effects can be brief but are often long-term. Where a management option deleteriously affects an organism which would otherwise benefit fruit production, orchardists have caused a negative secondary effect. Where this secondary effect results in losses greater than those caused by the original pest or disease, it would have been better not to apply the management option.

*Knowledge-based.* The key to avoiding secondary effects is to have a thorough knowledge of the organisms in the orchard, their biology and how they interact with each other. Orchardists should know the effects of pesticides on not only their targets, but other organisms in the orchard and consider the implications before application.

Orchardists should also have a thorough knowledge of withholding periods so as to avoid residue concerns and the mammalian toxicity of any chemicals used in the orchard.

The key to IPM success is record-keeping. Because memories are imperfect written records of control options, pest and disease outbreaks and weather allow post-season assessment of management strategies.

*IPM vs organics.* IPM places no limits on the control options available to orchardists. IPM involves orchardists considering all available options and making appropriate choices after considering the long term and secondary effects of their choice. Many orchardists already do this. However, their choices are, at times, incorrect because they have insufficient knowledge.

*The Australian apple and pear industries and IPM research.* The extent of industry concern over pest and disease issues is reflected by the number of related projects sponsored since the early 1990's. A literature review outlining many of these projects is included as appended to this report (Appendix 2)

Truly holistic IPM strategies exist overseas. A good example is the Californian state-wide integrated pest management program (see <http://www.ipm.ucdavis.edu/index.html>). For the benefit of its members the Australian industry should aim to develop similar systems. However several factors make the Australian industry unique. It is geographically widespread and operates under a wide range of climates and it has a unique pest and disease spectrum. Consequently, management options are subtly different to those available to overseas orchardists. The aims of this project were therefore to develop an Australian National IPM strategy by:

- Interviewing orchardists in all major Australian apple and pear production regions to determine the most serious pests and diseases.
- Developing management strategies for these pests and diseases by examining Australian and overseas information
- Developing an IPM strategy for use in Australian apple and pear orchards
- Producing a manual outlining the IPM strategy for distribution to all Apple and Pear Australia Limited (APAL) levy-payers.

## **4. Materials and Methods**

### **4.1 Grower meetings**

Meetings were held in eight major apple and pear production regions.

1. Orange (NSW)
2. Batlow (NSW)
3. Stanthorpe (Qld)
4. Knoxfield (Vic)
5. Shepparton (Vic)
6. Adelaide Hills (SA)
7. Perth (WA)
8. Grove (Tasmania)

APAL were responsible for co-ordinating meetings. All meetings (except Tasmania) were facilitated by Mr Stuart Gray (Communications Manager, APAL).

The majority of meeting attendees were commercial growers but a small number of private and state government advisory staff also participated. Typically meetings involved ten interviewees. Only one participant was interviewed in Tasmania.

Free-flowing discussion was encouraged. Group interview sessions were framed around three questions.

1. What are the major pests which requiring management on your orchard?
2. Given that the last 5-10 seasons have been drought affected, which were the main pests 10 years ago?
3. How do you manage each of the pests listed in questions 1&2? Participants were asked to consider both pesticide and other means of management.

The information gathered at these meetings was compiled and sent to regional IPM researchers and extension agents for comment.

### **4.2 Production of an IPM manual**

The information provided by group interview participants was used to develop a prioritised list of pests affecting apple and pear production in Australia. The information also provided an indication of management practices. The frequency of mention of specific management practices provided an indication of their relative use. Current pest management practices which were effective but had limited off-target impact were emphasised within the manual. Particular attention was given to monitoring and cultural practices such as tree pruning and orchard sanitation.

This grower-based information was supplemented in two ways.

1. A draft manual was produced and circulated to a group of Australian IPM researchers and extension agents. This group included reviewers from all apple and pear producing states. Reviewers provided comment on efficacy and made suggestions for technical improvement.
2. A literature review was undertaken which examined the history of IPM research and practice in Australia (Appendix 2). This review provided information on

locally relevant pest management practices. Where appropriate, these were included in the manual.

The manual was formatted in three sections

*Section 1. Background information on IPM.* The introductory chapters of the manual define IPM and gives sufficient information to implement IPM on-farm. Specific examples include detailed information on calibrating and checking the efficiency of spray equipment and establishing mating disruption for the control of Lepidopteran pests.

*Section 2. Pests of Australian apples and pears.* All of the pests mentioned at the grower meetings were categorised as ‘Major’ or ‘Minor or occasional’.

- Nineteen chapters were devoted to major pests including apple scab, powdery mildew, codling moth and lightbrown apple moth. In some cases a number of similar pests were grouped (e.g. weevils, pest mites, Helicoverpa and loopers). For each pest (group) information was provided on basic biology (The pest and its impact), prevention and good orchard management, monitoring, responsible use of pesticides and biological control, biorational pesticides and organics.
- A further nine chapters were devoted to minor or occasional pests (e.g. Apple leafhopper, Pear leaf blister mite). Sufficient information was provided for these pests to allow identification and management.

The impact of birds was mentioned at every interview session. Mr John Tracey (I&I NSW, Vertebrate Pest Research Unit) submitted a chapter on the management of pest birds

*Section 3. Forms, schedules and resources.* This section included diverse information and references which will allow orchardists to make informed decisions during their implementation of IPM. It included information on suppliers and contacts and an extensive reference list. Particular effort was put in to classifying all of the pesticides registered for use by the Australian apple and pear industry in terms of their compatibility with IPM. European databases and Australian references were used to categorise each pesticide as having

- Low toxicity; nil or low impact on beneficials
- Moderately low toxicity; moderate impact on beneficials but populations recover quickly.
- Moderately high toxicity; moderate impact on beneficials; populations slow to recover.
- High toxicity; a high proportion of beneficials killed and populations may not recover.

This information is presented in an easily interpreted series of tables which are intended to inform pesticide choices.

### **4.3 Pests and pesticide management in Australian apple and pear orchards**

The information gathered from industry participants during this project was primarily intended to inform the content of an IPM manual it also gave an indication of which pests are considered important and the management of these pests. This information is

presented in the results section of this final report. In presenting this information it is important to emphasise that while it is considered important, it is indicative only.

## 5. Results

### 5.1 Pests and diseases of Australian apples and pears.

Note the following caveat to information within this section. The information gathered during this project was intended as an aid to the development of an IPM manual which targeted the major pests of the Australian apple and pear industries. It was not intended to provide scientifically rigorous data on pest prevalence or the frequency of various management techniques. The information presented in this section represents a summary of grower responses and should be regarded as a rough guide to the pests and management practices found in Australian apple and pear orchards.

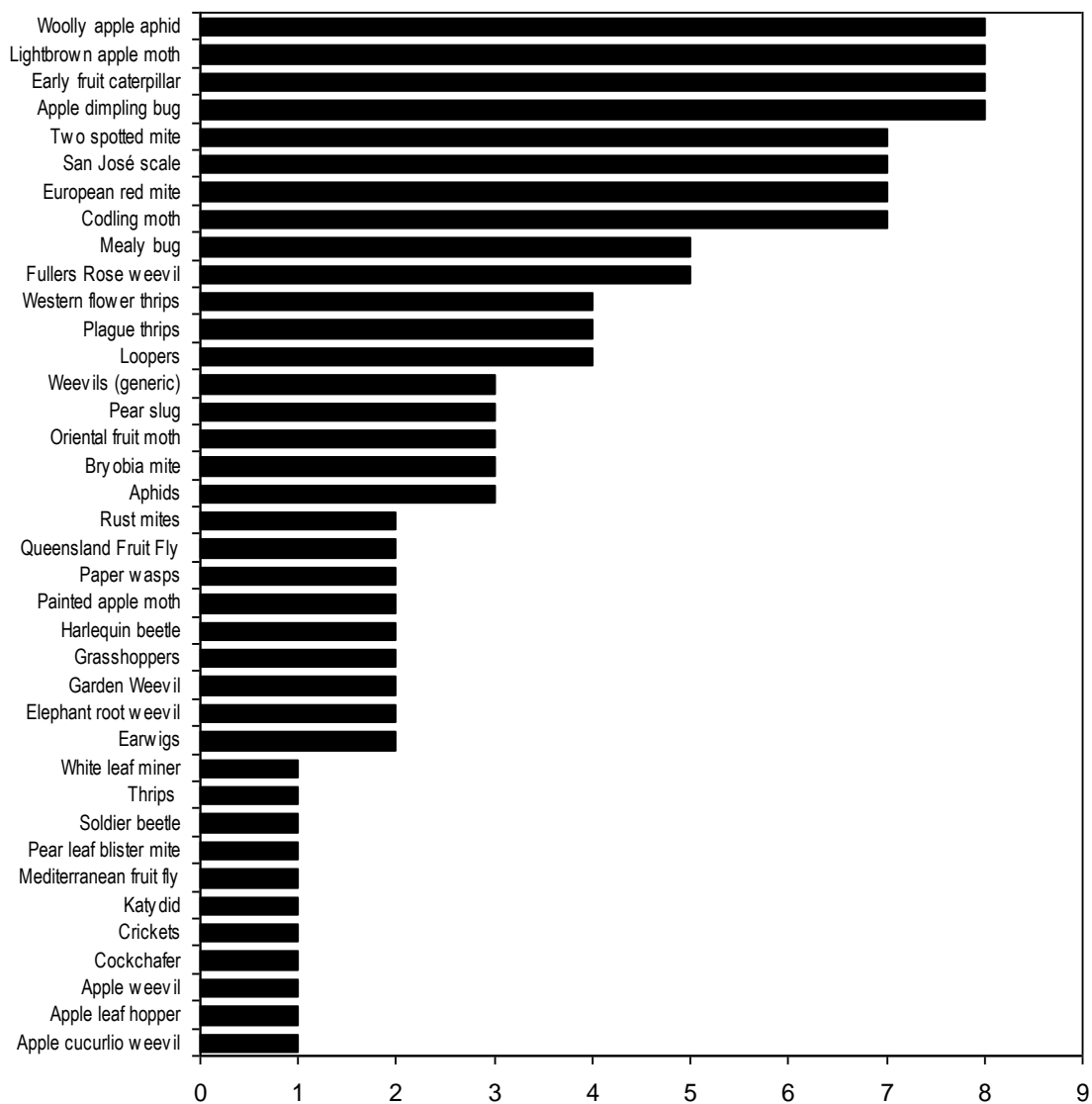
Grower responses at focus group meetings were intended to ensure the relevance of an IPM manual for the Australian apple and pear industries. This manual is the principal output arising from this project. A full PDF copy of the manual is available on the I&I NSW website at <http://www.dpi.nsw.gov.au/agriculture/horticulture/pomes/ipm-apples-pears> (May 2010). Nonetheless, while not strictly quantitative the information can be used to obtain generalisations about pest presence and pesticide use.

Woolly apple aphid (WAA), Lightbrown apple moth (LBAM), Early fruit caterpillar and Apple dimple bug (ADB) were nominated as ‘serious’ pests at all eight regional meetings (Figure 1). It should be noted that a different pest species is known as ADB in Tasmania (*Niastama punctaticollis*) compared to the mainland (*Campylomma liebkechti*) but damage attributable to these two pests is very similar.

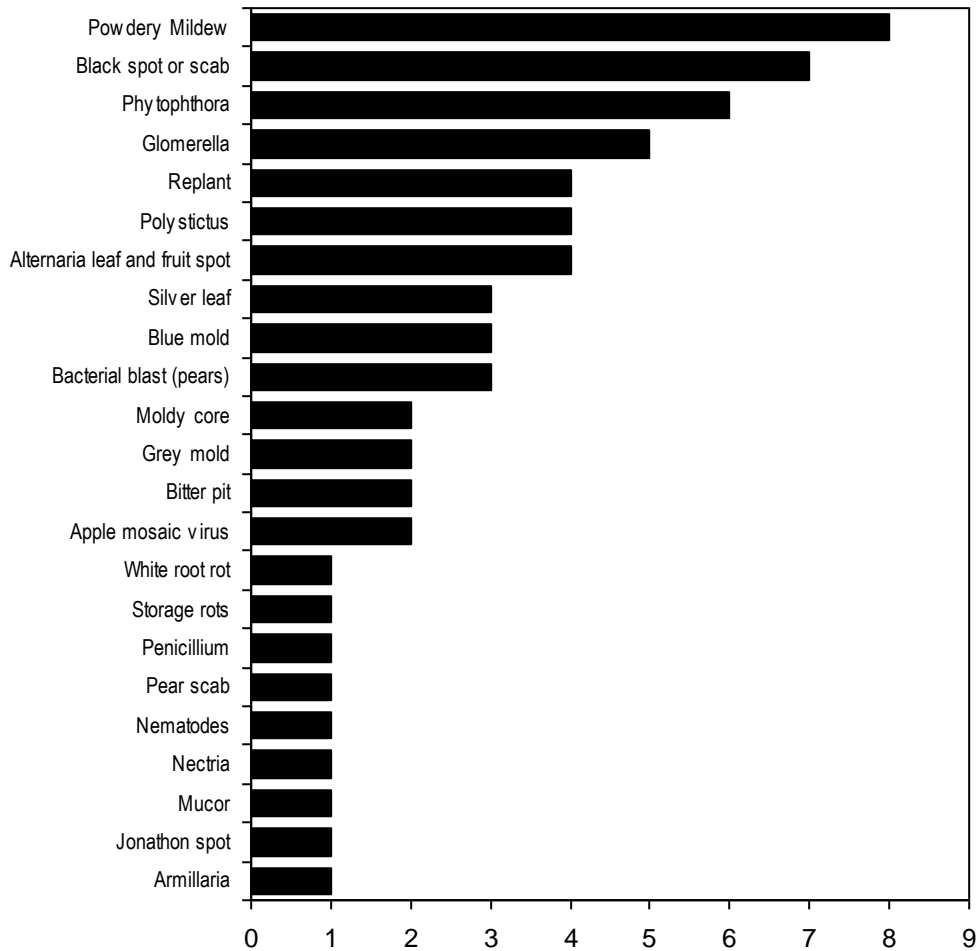
Two spotted mite, San José scale, European red mite and Codling moth were also frequently nominated as ‘serious’ by Australian orchardists (7 of 8 regions). At the time of the interviews, codling moth was not present in Western Australia, but was regarded as the most serious insect pest in other regions. Management of this pest greatly influenced the presence of techniques used to control other pests. For example, where mating disruption for codling moth was common fewer pesticide applications were made and greater numbers of other pests such as Helicoverpa were reported.

Orchardists expressed difficulty in determining which species of weevil was responsible for damage in their orchard and many used the generic term ‘weevils’ rather than a specific species. Considering all generic and specific mentions, ‘weevils’ were considered serious pests in all regions.

Powdery mildew was the most widespread disease of Australian apples and pears and was reported in all 8 regions (Figure 2). Apple scab (aka apple black spot) is not present in Western Australia, but was reported as a serious disease of apples in all other regions. Other frequently mentioned diseases included Phytophthora and a range of postharvest diseases. Bacterial blast was frequently mentioned as a serious disease of pears.



**Figure 1. Presence of arthropod pests in Australia's apple and pear production regions as reported at 8 regional information sessions by commercial growers and advisory staff. Bars represent the number of meetings at which specific pests were mentioned as causing economic damage. Note that the common names presented are those mentioned by growers and that the common name 'apple dimpling bug' refers to two species (*Niastama punctaticollis*; Tasmania and *Campylomma Liebkecht*; mainland Australia).**



*Figure 2. Presence of fungal and bacterial diseases in Australia's apple and pear production regions as reported at 8 regional information sessions by commercial growers and advisory staff. Bars represent the number of meetings at which specific diseases were mentioned as causing economic damage. Note that the common names presented are those mentioned by growers.*

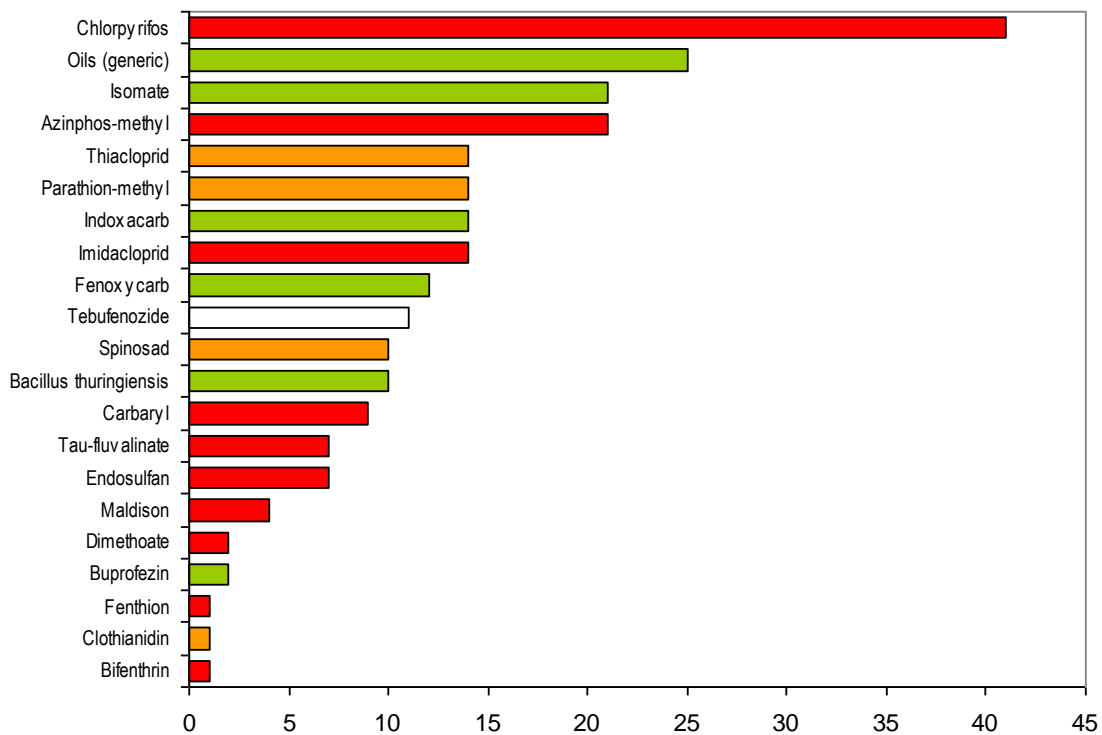
## **5.2 Management of Pests and diseases of Australian apples and pears – pesticides.**

There is significant variation between growers in the types of pesticides used to control arthropod pests in Australian apple and pear orchards (Figure3). This may reflect the type and persistence of the pests present. The use of pesticides which have long-term 'off-target' effects is not encouraged by IPM, but these pesticides (e.g. Chlorpyrifos, Azinphos-methyl) were frequently mentioned at grower meetings.

Encouragingly – in terms of IPM implementation – use of mineral oils (generically) and mating disruption for codling moth and light brown apple moth was also common, particularly in southern growing regions.

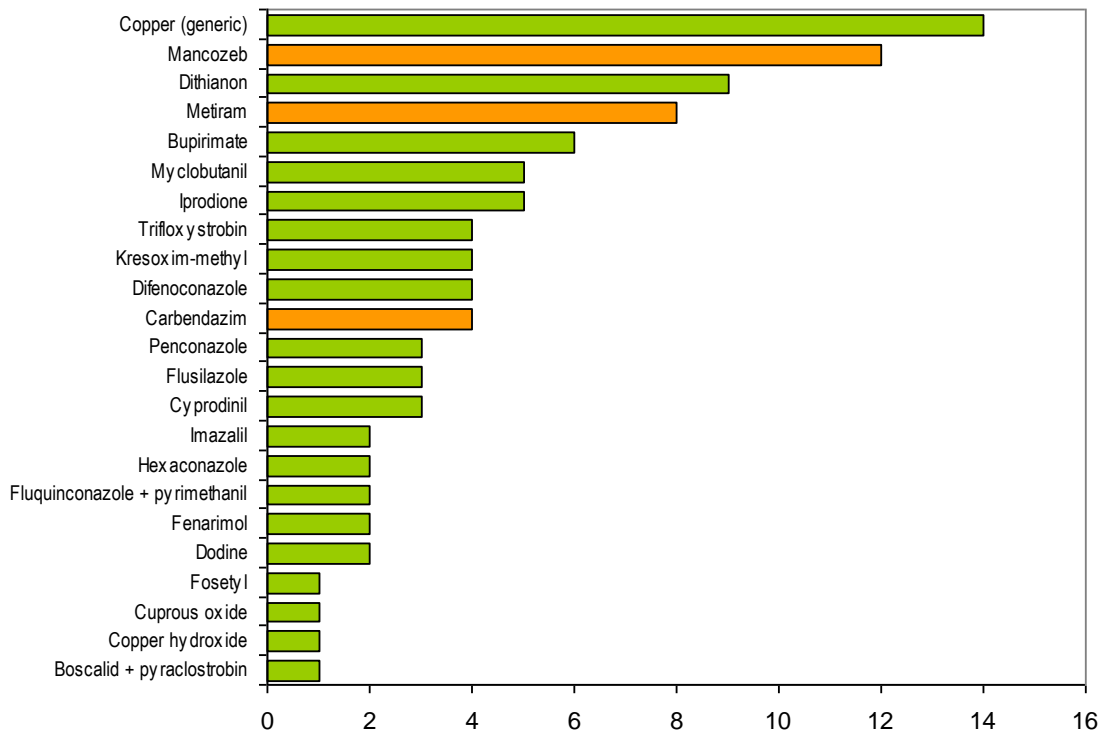


Copper application during dormancy was common practice. Growers did not distinguish between different copper-based active ingredients or formulations and most simply referred to these products generically. Most regarded the origin (manufacturer and country) as more closely aligned to efficacy than the specific nature of the product. Pesticides applied for apple scab control are under-represented in figure 4. Growers would frequently respond that apple scab was controlled with the “usual fungicides”. Responses indicated a subtle difference in the types and timing of fungicides applied for apple scab control between regions. This perception was reinforced later during the when individual growers were contacted to offer further input to the Manual and conducted review of the Manual when it was in draft form. Growers in southern regions were often concerned by the possible development of resistance by *Venturia inaequalis* (i.e. The apple scab pathogen) to the group 3 fungicides (Demethylation inhibitors) and were reluctant to use them except when it was necessary to apply a curative or systemic fungicide. They commonly controlled apple scab by applying a protectant fungicide in response to and before a forecast rain event. In contrast, growers in northern regions were more likely to apply curative / systemic fungicides after rain. Presumably this difference is largely due to the greater predictability and regularity of spring and summer rain in southern regions. Storms and unpredictable rain are more frequent in the north and hence curative fungicides are more commonly used. While growers nominated the fungicide mancozeb as causing disruption to populations of beneficial arthropods, it was also frequently used.



**Figure 3. Pesticides used to control arthropod pests in Australia’s apple and pear production regions as reported at 8 regional information sessions by commercial**

*growers and advisory staff. Bars represent the number of times specific pesticides were mentioned.*



**Figure 4. Fungicides and bactericides used in Australian apple and pear production as reported at 8 regional information sessions by commercial growers and advisory staff. Bars represent the number of times specific pesticides were mentioned.**

For each of the major arthropod pests reported by orchardists a wide variety of pesticides was used (Table 1). While growers individually varied in their philosophy toward and use of ‘softer’ pesticides, the group as a whole used pesticides with high off-target impacts against all of these pests. This was particularly the case for pests which were considered difficult to control – often with cryptic stages (e.g. underground or alternative hosts) to their life cycle. For example, heavy or high impact pesticides were often used against San José scale, apple dimpling bug and woolly aphid.

Conversely, ‘softer’, low impact pesticides and management systems (mating disruption, biological control) were used against codling moth, lightbrown apple moth, heliothis and pest mites.

**Table 1. Insecticides and acaricides used to control arthropod pests in Australian apple and pear production as reported at 8 regional information sessions by commercial growers and advisory staff. Pesticides are grouped according to their compatibility with IPM based largely on their off-target impact and persistence<sup>1</sup>. ■ A high proportion of beneficials will be killed following application of this pesticide; ■ Moderately toxic to beneficials; ■ Low toxicity; nil or low impact on beneficials.**

Pesticide	Pest							
	Apple dimple bug <sup>2</sup>	Codling moth	Lightbrown apple moth	San José Scale	Weevils (generic)	Heliothis	Woolly aphid	Mites (generic)
Abamectin								✓
Alpha-cypermethrin					✓			
Azinphos-methyl		✓	✓		✓	✓		
Bifenthrin	✓							
Carbaryl	✓		✓		✓			
Chlorpyrifos	✓	✓	✓	✓	✓	✓	✓	✓
Endosulfan	✓						✓	
Maldison		✓		✓			✓	
Methodathion				✓				
Tau-fluvalinate	✓							
Imidacloprid				✓	✓		✓	
Parathion-methyl	✓	✓	✓				✓	
Phosmet								✓
Propargite								✓
Spinosad			✓		✓	✓		
Thiacloprid	✓	✓					✓	
<i>Bacillus thuringiensis</i>			✓			✓		
Bifenazate								✓
Fenbutatin oxide								✓
Fenoxycarb		✓	✓				✓	
Indoxacarb		✓	✓		✓	✓		
Kaolin						✓		
Mating disruption		✓	✓					
Oil				✓				✓
Tebufenozide		✓	✓			✓		
Clothianidin <sup>3</sup>							✓	

1 Ratings based on information available at [www.koppert.com](http://www.koppert.com) and [www.biobest.be](http://www.biobest.be)

2 Apple dimpling bug = *Campylomma liebknechti*

3 No information on the off-target effect of Clothianidin was found at the time of publication

### **5.3 Management of Pests and diseases of Australian apples and pears – Mating disruption and biological control.**

Mating disruption for the control of codling moth and lightbrown apple moth were common in all regions affected by these two pests. Growers had the following observations on the use of mating disruption

- When pest moth pressure is high, mating disruption can be combined with other management techniques.
- For isolated orchards, where codling moth mating control (or other management) has been practised for many years it may be possible to abstain from any form of chemical control for several seasons.
- Mating disruption is less useful in pears (c.f. apples)
- Identification of the pest moth is important. Orchardists in the Shepparton region reported failure of mating disruption to reduce damage and it is believed that this may be due to the presence of the non-target oriental fruit moth.
- Mating disruption is more effective if it is also used on neighbouring properties.
- Continuous use of mating disruption (and reduced use of insecticides) can result in the re-emergence of other insect pests such as Helicoverpa, loopers and weevils.
- Mating disruption is more effective when applied over an entire enterprise rather than on a block-by-block basis.
- There can be occasional, local shortages of mating disruption ties.
- The transition from insecticides to mating disruption can be expensive because there is a period when both forms of management are used.
- Isomates for oriental fruit moth control don't last as long as those for codling moth and lightbrown apple moth.
- Long term control of codling moth with mating disruption is possible. Under Australian conditions mating disruption alone can be relied on to control codling moth for a period of 6-8 years (according to respondents). It then needs to be supplemented by insecticides for a period before reversion to mating disruption alone.
- The cost of control using mating disruption may be higher than the cost of management using insecticides alone.
- Monitoring in mating disruption blocks is important.
- Mating disruption has led to a reduction in the use of hard chemicals and an increase in beneficials. This has kept two-spotted mites and European mites down.
- Mating disruption ties must be applied at the full recommended density. Reduced densities may control pest moths for a number of seasons, but fail in high pressure years.

### **5.4 Management of Pests and diseases of Australian apples and pears – Cultural management.**

All grower groups acknowledged the importance of good orchard management in controlling pests. Certain activities were carried out primarily to improve quality or productivity (e.g. pruning) but were also seen as important in managing pests. Other activities – not involving the application of pesticides – were undertaken primarily in order to manage pests.

*Pruning.* It was common practice to remove Diseased woody tissue (e.g. from Polystictus) when it was first observed or during normal pruning operations. Painting of large pruning wounds was also noted as a means of inhibiting disease spread. Many orchardists also pruned to remove heavy powdery mildew infections. Arthropod pests were also managed using pruning. For example, detail pruning was undertaken to remove mealy bug ‘crows nests’ from the top of pear trees.

Timing of pruning operations was also seen to have an effect on pests. Pruning promotes the growth of green tissue and growers noted that this boosted numbers of pests including codling moth and helioverpa. Some growers also noted that pruning should not be undertaken during rainy weather.

The positive effect of pruning to promote light and air movement was noted as aiding the management of pests including woolly aphid and powdery mildew.

*Mowing and weed control.* Arthropod pests such as thrips and apple dimpling bug move from alternative plant hosts including weeds in to apples and pears. Others such as weevils shelter under heavy vegetation and leaf mulch. This was recognised by orchardists and activities such as mowing were timed so as to reduce the degree to which migration from weeds to trees occurred..

Mowing was also seen as a means of hastening the breakdown of fallen leaves especially when accompanied by the application of urea.

*Sanitation.* Contaminated bins were seen as a means of infesting fruit. They were also seen as a means of pest carryover between seasons. Grower recommendations included ensuring that packing facilities were large enough to store all of the enterprises bins. Bins stored in the open are more prone to contamination. Periodic steam cleaning or sterilising of bins was seen as a means of reducing the incidence of storage rots. Some saw ozone as having a role in this context.

## **6. Discussion**

The Australian apple and pear industries have facilitated world-leading research and deployment of IPM over a 50-year period. Interviews with industry participants provided evidence that a large number of management techniques which have very low off-target impacts are commonly used. Notable amongst these are the widespread use of mating disruption and encouragement of predatory mites.

Orchardists are also well aware of the impact upon pests (and beneficial organisms) of orchard practices primarily intended for other purposes. For example, training trees to open canopies and enhance fruit quality was mentioned as a means of controlling diseases. Other examples include orchard mowing and weed management, harvest and pack house sanitation.

A wide variety of pesticides are registered for the management of orchard pests. Most orchardists are attempting to bias their pesticide choices to favour those with low off-target impacts. This is seen as a means of promoting the activity of beneficial organisms which provide biological control of pests such as pest mites and woolly aphid. A number of factors negatively influence orchardist's attitudes towards these more 'IPM-friendly' products.

## **6.1 Constraints to the adoption of IPM.**

### *Problem pests.*

Newer pesticides are also often ineffective against some pests. San José scale, apple dimpling bug, mealy bugs and weevils were mentioned as difficult to control. Broad spectrum pesticides are used more frequently against these and similar pests because of their perceived 'toughness'. While IPM strategies exist the pests often have cryptic phases to their lifecycle underground, in the debris of vegetation, under bark or sheltered in the crotches of branches. Pests such as the scales, mealy bugs and woolly aphid are difficult to wet and often escape pesticide application.

*The emergence of new or previously unimportant pests.* The industry-wide transition to 'softer' pesticides and management practices such as mating disruption has led to a re-emergence of pests previously considered occasional or unimportant. The targeted mode of action of newer products contrasts to the broad spectrum activity of those used by industry in previous decades. Control of pests such as apple dimpling bug, Helicoverpa and lightbrown apple moth was an unintended – but desirable – consequence of the use of broad spectrum insecticides for codling moth control. In effect the specific activity of newer pesticides has resulted in a proliferation of active ingredients making IPM-related decisions more difficult.

*The perceived cost of IPM.* Many growers expressed an opinion that it was more expensive to control pests using IPM rather than conventional management. This was particularly the case during the transition to IPM, when both conventional and IPM are used. Specific examples included orchards which were under conversion to mating disruption to control codling moth. Pest pressure must be lowered using insecticides in order for simultaneous mating disruption to be effective. With time, insecticides can be phased out, but during transition both pesticides and mating disruption dispensers are required and this is expensive.

The cost of 'IPM-friendly' – often more modern – pesticides was also frequently mentioned. Many older broad spectrum pesticides are no longer subject to patents and generic, cheaper products are often available. Newer, targeted chemistries although more IPM compliant are also generally more expensive.

## **6.2 Factors driving the uptake of IPM**

*Off-target effects of broad spectrum pesticides.* The off target effect of broad spectrum pesticide application was well known. This was particularly the case with acaricides applied for the control of pest mites. Deliberate introduction and maintenance of existing

populations of beneficial, predatory mites was common. The consequence of broad spectrum insecticides and acaricides with long residual activity upon populations of beneficial mites was well known and growers biased pesticide application to favour beneficials. Other examples mentioned included the effect of pesticides on the parasitic wasp *Aphelinus minor*; a predator of woolly aphid

*Pesticide resistance.* Pesticide resistance was mentioned frequently and most growers were aware of the importance of pesticide rotation. In some cases resistance management strategies were questionable in the context of IPM. For example, one grower had reverted to azinphos- methyl for codling moth management as a result of parathion- methyl resistance. Other growers expressed their opinion that pesticide mixtures (e.g. Vision = Fluquinconazole + pyrimethanil) were likely to expedite the development of resistance. A practice worth investigation is the bias against the use of curative fungicides in southern growing regions. Growers in southern regions believe that reducing the number of curative (group 3) fungicide applications will reduce the likelihood of resistant apple scab developing. This may be the case, but pre-rain application of protectants may also lead to the unnecessary application of fungicides in response to predicted rainfall events which do not occur. A thorough investigation of the benefits of this strategy to IPM should be conducted.

*The effect of climate change on pests.* Although not frequently mentioned, the potential impact of climate change was acknowledged at some meetings. Growers noted that climate change might lead to changes in numbers and types of pests and beneficials. If this is the case careful monitoring and response to the biology of pests and beneficials in an IPM framework is likely to be the most appropriate response.

*Grower's personal philosophies.* A number of grower's primary motivation for using IPM (or in some cases organics) is the likely reduction in pesticide applications. In these cases improved health and environmental consequences are seen as of equal importance to economic return.

### **6.3 A need for education and research**

The way in which Australian apples and pears are produced is changing. Adoption of 'world's best practice' has led to the introduction of new training systems in intensive plantings on dwarfing rootstocks. The trend to these types of orchards is likely to continue under APAL's Production, Irrigation, Pests and Soils (PIPS) initiative. Pest management is likely to change as a consequence of orchard modernisation and research will be required to guide industry through this transition.

Most orchards within the groups of interviewees were aware of the principles underlying IPM and adoption of IPM varied across the entire group. There was scope for further education and the manual produced as an output of this project should go some way to addressing this need.

Interestingly, growers did not mention the pending legislative changes to pesticide application and availability. It is likely that many of the pesticides currently available to the industry will be deregistered or have their use limited over coming years. In many

case alternatives to pesticides will be required in the short-medium term future and this issue is likely to have a more significant impact on the industry than other, higher profile issues such as climate change.



## **7. Technology Transfer**

The principal output arising from this project is an IPM manual for the Australian apple and pear industries. A hard copy of this manual will be distributed to all APAL levy payers. The manual was ready for distribution in March 2010, in line with project milestones. APAL decided that distribution should be delayed until well after harvest and nominated June 2010 as the date for distribution. A total print run of 100 copies was made and APAL are responsible for distribution of 900 of these copies.

The remainder have been retained by Industry and Investment NSW and will be distributed to libraries and training institutions (e.g. Goulburn Ovens TAFE).

A PDF version of the manual was placed on I&I NSW and APAL websites in March 2010 and is publically accessible.

The manual's physical format (ring bound) allows for future updates. This has been discussed with the Technical Manager of APAL and funds are likely to be available to undertake this task on annual basis.

## 8. Recommendations

Interviews with commercial apple and pear producers from across Australia revealed a high level of IPM knowledge and use. Nevertheless in order to maintain our reputation as suppliers of high quality, pest and residue fruit in a global and competitive market improvement is needed.

- *Room for improvement.* There is potential for Existing IPM techniques to be more widely used by industry.

Recommendation 1. That the apple and pear industries provide comprehensive IPM training across all significant Australian apple and pear production regions. The manual associated with this project would form the basis of this training. Regular funded updates will facilitate changes and improved information.

- *Better use of the tools we have.* Pesticide resistance strategies vary between growing regions. This may be justified but in order to prolong the useful life of pesticides investigation and optimisation are required. The use of fungicides was notably variable in this context.

Recommendation 2. That levels of pesticide resistance be quantified and measures developed to slow the development of pesticide resistance.

- *Overcoming the constraints to IPM uptake.* This report details a number of issues perceived by growers as limiting IPM uptake. A major problem is the existence of ‘problem’ and emerging pests.

Recommendation 3. That an increased research emphasis be placed on those pests for which growers are likely to apply broad spectrum pesticides e.g. Dimpling bug, San José scale, weevils.

- *Adapting IPM to changing Australian apple and pear production.* This report identified orchard modernisation (e.g. high density plantings), climate change and legislated changes to pesticide use and availability as major factors effecting Australian apple and pear IPM in coming years.

Recommendation 3. That specific research be conducted in to the effect of orchard intensification and climate change on pest types and numbers allowing IPM to be proactively modified to facilitate these changes. This research must be more than a desk top study.

Recommendation 4. That alternative pest management techniques be developed as a result of anticipated, legislated changes to pesticide use and availability.

# Appendix 1. Results of Grower focus meetings



NSW DEPARTMENT OF  
PRIMARY INDUSTRIES



Know-how for Horticulture™

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## HAL AP07009 An IPM manual for Australia's apple and pear industry.

### Grower Focus meetings

#### EXPLANATION OF THIS DOCUMENT

During September to November a series of meetings were held with apple and pear orchardists in eight of Australia's major pome fruit production regions. In the majority of cases these meetings were attended by groups of between 4 and 12 orchardists. The exception was the interview which took place in Tasmania in which only one orchardist participated.

During the meetings orchardists were asked to list the major pests (including diseases and vertebrate pests) which affected their enterprises. They were then questioned on what management options they currently undertook to control these pests.

Written notes and a voice recording were taken at each meeting.

AS FAR AS POSSIBLE, THESE NOTES ARE AN ACCURATE REPORT OF WHAT WAS SAID AT EIGHT MEETINGS.

Participants were encouraged to speak freely and interact within the group. Sometimes this presented problems for both note-taking and voice-recording. The notes here primarily come from the hand-written version but have been checked against the voice recordings and amended where necessary.

It should be noted that because these notes are an unamended recording of the meeting:

- Contradictory statements are present
- Technical details may be incorrect

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## **ORANGE MEETING**

This meeting was held in the machinery shed of the Orange campus of Charles Sturt University on the 3<sup>rd</sup> September 2007. The meeting was attended by 11 orchardists.

### ***List of diseases***

- Black spot
- Powdery mildew
- Postharvest rots
- Grey mould
- Blue mould
- Moldy core
- Alternaria leaf and fruit spot on royal galas
- Internal browning – can't be identified at harvest.
- Glomerella?

### ***List of insect pests***

- Apple leaf hopper
- White leaf miner
- Western flower thrips
- Woolly apple aphid
- Early fruit caterpillar (Heliothis)
- Apple Dimpling Bug
- Codling moth
- Light Brown Apple Moth
- Carpophilus (?)
- Weevils
- Cockchafer
- Two spotted mite
- European red mite

### ***Other Issues***

- Discussion on delivery of fungicides/bactericides/biocontrol agents to flowers by bees. Has anything been done in Tasmania on this particularly as a prevention for postharvest rots?
- Climate change might lead to changes in numbers and types of pests and beneficials.

## *Management strategies*

### **DISEASES**

#### **BLACK SPOT**

- A range of chemicals and programs are available. Weather conditions determine whether protectant or eradicant fungicides are used.
- There is a district monitoring service with three monitoring units which provide information on infection periods. Most growers consult this but largely as re-assurance that they have made the right decision.
- The DPI also provides information on the timing of spore release.
- Black spot management is such a well established practice that the largest danger is complacency, particularly after the current prolonged drought.
- Spray applications are also effected by leaf and fruit age and physiology.
- There is concern that eradicants are largely from one chemical group.
- Storage scab is also an issue because most of the fungicide applications are concentrated at the beginning of the season.

#### **POWDERY MILDEW**

- Most of the chemicals registered for black spot control are also effective against powdery mildew. Powdery mildew is largely controlled by controlling black spot. Orchardists need to know what this critical period is.
- Nimrod (BUPIRIMATE) is specific to powdery mildew.
- It was a problem in the '80s on Granny Smith
- Pink ladies can be a problem and Galas to a lesser extent.

#### **POSTHARVEST**

- With core molds calyx infection pre-harvest is seen as a critical time for infection. The fungus enters the calyx of the fruitlet before closure.
- Doesn't matter if it's dewy or dry.
- Fungaflor (IMAZALIL)
- Rovral (IPRODIONE)
- With open-calyx varieties use Delan (DITHIANON) as a floral spray (double the rate and drench the trees)
- With Pink Lady late-season CAPTAN is useful (3 in 1 week prior to harvest).
- Dipping is standard practice

#### **ALTERNARIA LEAF AND FRUIT SPOT**

- Flint (TRIFLOXYSTROBIN) application as late as registration allows
- Delan (DITHIANON), Dithane (MANCOZEB), Polyram (METIRAM) late in the season.

#### **PHYTOPHTHORA**

- Worst in Gala
- Patchy distribution
- Don't waste your money on chemicals
- Pull the trees out and replace the soil.
- Dig a deep hole and spray it with Dithane (MANCOZEB)

#### **POLYSTICTUS**

- Prune out
- Transferred by pruning and cutting equipment.
- There have been fewer problems during the drought.
- What's the best way to deal with this?
- Paint attracts jewel beetles and longicorns. Bore into the heart wood.
- Hand saws give a cleaner cut and lead to fewer problems.
- A problem in older (25 year old) Delicious.

## **PESTS**

### **WHITE LEAF MINER (Apple leaf hopper)**

- Yellow spots on leaves and brown marks on fruit (like a bad case of spider)
- May be related to temperature and change of climate.
- An emerging problem as more growers convert to IPM programs and switch to softer chemicals
- A trial is currently underway looking at the effectiveness of ABAMECTIN at budswell.
- Worse in dry years.

### **WESTERN FLOWER THRIPS**

- Yellow marking on fruit particularly on Granny Smith.
- Physically looks similar to plague thrips.
- Arrived in the Orange region last season (two seasons ago in Forbes)
- Control is very difficult
- Success (SPINOSAD)

### **WOOLLY APPLE APHID**

- Penncap (PARATHION-METHYL) and Lorsban (CHLORPYRIFOS)
- Oil sprays combined with Lorsban (CHLORPYRIFOS) and then a few sprays of Lorsban through the season. May be included as part of codling moth control
- Worse under hail net
- 7mL / L Confidor (IMIDACLOPRID) around the base of infested trees which have been tagged the previous autumn. 1L placed around butt of tree in spring. This gives 3 seasons control.
- Butt sprays are time-consuming.
- M26 rootstocks are very susceptible.
- Good woolly aphid resistant rootstocks being developed at OAI.

### **EARLY FRUIT CATERPILLAR, HELIOTHIS AND LOOPER**

- A problem during the last year or two. Confusion as to the difference between looper and heliothis. A problem nearly every year.
- Application of ENDOSULFAN for dimpling bug used to also control Heliothis but the switch to softer options for dimpling bug has led to a re-emergence of heliothis.
- Endosulfan used to control these pests, now most growers have switched to Lorsban (CHLORPYRIFOS)
- Avatar (INDOXACARB). Expensive.
- DiPel
- CARBARYL doesn't work and neither does Lorsban (CHLORPYRIFOS). Even with heavy Carbaryl thinning Heliothis is still a problem



### **APPLE DIMPLING BUG**

- Klartan, but this kills beneficials
- An early Lorsban (CHLORPYRIFOS) (by late pink) but this is only effective for a short time. The window is late pink to petal fall. All of the damage is done during a short time.
- A long flowering period means that there may be a second application of Lorsban (CHLORPYRIFOS).
- Early Lorsban (CHLORPYRIFOS) and then monitoring. If none seen then no more spray applications.
- CARBARYL for thinning has an effect.
- Monitoring by tapping at flowering into an ice cream bucket.
- New DuPont chemical?
- No mowing during flowering.

### **CODLING MOTH**

- Pennacp (PARATHION-METHYL) and Lorsban (CHLORPYRIFOS). Hitting the first flight is the important point. Timing varies with weather. This year is likely to be relatively early.
- Isomates
- Insecticides timed for first codling moth flights as advised by the monitoring service.
- Insegar (FENOXYCARB) worked very well for a while but eventually the moth “worked it out”. Might work in an isolated orchard with no in-flights out-flights but not convincing. Monitoring of fruit is important.
- For monitoring to be effective trap placement is important. Traps must be in the top 1m of trees (for 10mg lures in mating disruption blocks). This important in mating disruption blocks.
- New lure available using Pear esterase.
- Codling moth damage is more common in older trees where bark is cracked and blistered and there are galls.
- Pruning also has an effect. Late pruning is a problem particularly where late shoots are left high. Moth comes in on new growth which might be higher than where lures are.
- In problem blocks it may be necessary to combine sprays and twist ties. In blocks in which there has been a problem earlier then sprays as well as twisties should be used.
- Nets have no effect on codling moth

### **LIGHT BROWN APPLE MOTH**

- Care must be taken with ties. Isomates can be combined with codling moth control.
- Lorsban (CHLORPYRIFOS), Pennacp (PARATHION-METHYL), Gusathion (AZINPHOS-METHYL) = standard program
- Jonathon and other clustering varieties are a problem. Other varieties not generally a problem and nothing is done.

### **COCKCHAFER**

- An isolated problem
- Eat leaves, no fruit damage

- Weed sprays (Roundup) combined with Lorsban (CHLORPYRIFOS).
- An increased problem with more people converting to IPM

### **MITES**

- *Aphylinus mali*: we need to find a way to prolong the life of these
- There have been relatively few problems with mites over the past few seasons despite the drought. The emergence of apple leaf hopper as a pest and use of hard chemicals to control it may lead to a resurgence of mites.
- Mating disruption has led to a reduction in the use of hard chemicals and an increase in beneficials. This has kept two-spotted mites and European mites down.
- Use of soft chemicals has also had a role in reducing pest mite numbers.
- AZINPHOS-METHYL
- CARBARYL for thinning decreased predator numbers and therefore cylex is now going to be used.
- One grower hasn't sprayed for mites since 1992.

### **BIRDS**

- Starlings, lorikeets, sulfur-crested cockatoos.
- The problem is that there is laws to stop you from dealing with them

## STANTHORPE MEETING

6 Growers attended. All apple growers. Meeting was held at the Applethorpe Research Station 4<sup>th</sup> September 2007.

### *List of diseases*

- Alternaria leaf and fruit spot
- Black spot
- Powdery mildew – this has become more significant as the weather has become drier
- White root rot – nearly all orchards have this problem
- Glomerella – This had disappeared but is now back again. There was speculation that this may have been due to a change in the types of sprays being used (and volumes – shift to half rates) or perhaps a change in the varieties being planted.
- Polystichtus / die-back
- Bitter pit
- Moldy core
- Blue mould
- Phytophthora. MM106 common and very susceptible.
- Armillaria? More common on stone fruit.
- Bacterial canker? Not common.

### *List of insect pests*

- Mealy bug
- Codling moth
- Western flower thrip – increased spray costs
- Mites – two-spotted mites
- Light brown apple moth
- Woolly apple aphid
- European red mite – not as bad as two-spotted mite
- Queensland fruit fly
- Apple dimpling bug
- Plague thrips
- Heliothis
- Fuller's rose weevil – attack leaves late in the season; excrete on stem end particularly Pink Ladies.
  - San José scale
- ▪ ? Bacterial canker () – uncertainty about identity of this disease.

### *Other issues*

- Parrots – Crimson rosellas and Eastern rosellas, mountain lorikeets
- Bats. Occasional and last real problem was 2 years ago
- Snails.

## *Management strategies*

### **DISEASES**

#### **ALTERNARIA LEAF AND FRUIT SPOT**

- Delan (DITHIANON) early and polyram (METIRAM) late (as close to harvest as possible)
- Storage problem with Delan (DITHIANON). Store for more than 6 weeks can lead to fruit marking (Do not use for 6 weeks prior to harvest).
- Some use Polyram (METIRAM) up to harvest.
- Orchardists noted that Delan (DITHIANON) can cause storage problems and fruit sprayed with Delan can only be put into short term storage.

#### **APPLE BLACK SPOT**

- “Normal” black spot fungicides
- Only an issue with wet springs and hasn’t been a serious issue since 2001.
- Protectants early and then eradicants from green tip. Switch to protectants from November.
- QDPI&F issues warnings and these are listened to by orchardists and used as reassurance for decisions which they take independently. More reliance on warning service here than in Orange.
- Shorten spray intervals during the flowering period (critical period) to compensate for rapid emergence of new growth.
- There are three weather stations across the district.
- Postharvest. Spray urea. Mow and sweep. Also good for Alternaria.

#### **POWDERY MILDEW**

- Topas (PENCONAZOLE) applied at pink and then eradicants
- NuStar (FLUSILAZOLE)
- Nimrod (BUPIRIMATE)
- Systhane (MYCLOBUTANIL)
- Lime sulphur at budswell.
- Prune infections out.

#### **WHITE ROOT ROT**

- Trench dug across row and lined with plastic. A buffer of 3-4 healthy trees must be left on either side of infected plant before trench is dug.
- Regular applications of Shirlan (FLUAZANAM) had been recommended but had given “mixed” results. Needs to be regular applications.
- One grower believes that his problems had come when soil from a dam had been used in the orchard. This soil included roots and trash from native trees.
- Methyl bromide had been tried many years ago but hadn’t worked.
- There was some suggestion that root-stocks may offer some resistance. This based on a seedling tree which had grown well in infested soils.
- Stanthorpe is not a major nursery area; therefore the disease hasn’t been transported to other districts.

#### **GLOMERELLA**

- Dithane
- Problem in a patch of pink ladies.

- Remove infected fruit in December and go through 4 or 5 times before harvest and continue to pick out infected fruits. Rake and remove fallen fruit and leaves after harvest. Then move to a heavy (7 day interval) Dithane (MANCOZEB) program.
- Apply dithane (MANCOZEB) after harvest.
- If there is a history of problems, shorten the spray intervals and use dithane (MANCOZEB) right through the year.
- The disease is worse under netting.

### **POLYSTICHTUS**

- Prune out but don't cut branches in half. Either totally remove branches or leave them.
- Cut the entire infected branch out flush to the butt and then paint.

### **MOULDY CORE AND OTHER POSTHARVEST DISEASES**

- Postharvest diseases are uncommon in this region.
- One grower had a problem with fruit from one block (Hi early).
- Disease thought to "get into" fruit during blossom.
- Polyram (METIRAM) gives good results.

### **PHYTOPHTHORA (COLLAR ROT)**

- Dip nursery stock in quintozone especially MM106.
- Mark established trees which are starting to show signs and drench with quintozone.
- In severe cases remove infested trees and put 20L of quintozone into hole. Wait 1 or 2 years before replanting.
- Avoid dirty nurseries. Stanthorpe growers are particularly suspicious of Southern nurseries.
- Another strategy was to dig soil away from roots of infected trees and allow the roots to air and dry out before replacing soil.

### **BACTERIAL CANKER**

- The identity of this disease was unsure, but copper sprays (with oil) at green tip are normal practice and this is thought to help control this problem.

### **PESTS**

#### **SNAILS**

- Mesurool (METHIOCARB) but this is expensive. (200L costs \$2k)
- Gusathion (AZINPHOS-METHYL) has not been used for years and this may have led to an increase in snails.
- Worse under nets
- 5-10% loss to snails in galas
- Eating, discoloured or slimy deposits.
- Tree guards are where the snails gather
- Sprinkle copper, blue stone, flour. But these disperse when it rains and this is when snails are at their worse.
- Hydrated lime?
- Ducks

### **MEALY-BUGS**

- Lorsban (CHLORPYRIFOS)
- Infestations are patchy with hot-spots through the orchard.
- Infest all varieties but Granny Smith is a particular problem. Some thought this might not be the case and that infestations were simply more obvious on green apples.
- Control must be applied early. Difficult to control because they hide and have a waxy coat.
- Calypso (THIACLOPRID) (used in New Zealand)
- Orchardists (or scouts) monitor for this problem early.
- If infestations are seen at thinning it is too late.

### **CODLING MOTH**

- The degree to which mating disruption was used varied across the group.
- One grower had used mating disruption for a long period of time (15 years) and seldom had codling moth problems but noted that infestations occur every 6 or 7 years.
- Perimeter sprays seldom used
- A variety of insecticides were also used. Calypso (THIACLOPRID) and sometimes Gusathion (AZINPHOS-METHYL) or PennCap (PARATHION METHYL).
- Other orchardists used a mixture of mating disruption and insecticides. “use mating disruption and then spray in some problem spots”.
- Put mating disruption twisties in the shed.
- Bins kept in the shed are less prone to infestation, so sheds should be large enough to handle all of the enterprises bins.
- In Stanthorpe there are 2½ to 3 generations per season because hotter than other regions.
- Monitoring traps are used.
- Mating disruption twisties are used at a rate of 400 per acre. One orchardist had dropped the rate to 320 and had no problem for a couple of years. Then there was a high pressure year and mating disruption broke down.
- Mating disruption is considered to be more expensive than sprays, but it is highly effective.
- Problems with dirty neighbours.

### **LIGHT BROWN APPLE MOTH (LBAM)**

- The orchardists who spray for codling moth, have no problems with LBAM.
- LBAM is a problem in cool years and late in the season.
- LBAM is a particular problem in Fujis.
- Orchardists (and scouts) monitor with LBAM traps and when a threshold is reached insecticides are applied.
- Mimic (TEBUFENOZIDE) not widely used but specific to LBAM.

### **WESTERN FLOWER THRIPS (WFT)**

- Monitoring and when observed apply Success naturalyte (SPINOSAD).
- Remove clover
- No mowing during flowering
- Orchardists are concerned about insecticide resistance.
- ENDOSULFAN tried but doesn't work

### **WOOLLY APPLE APHID**

- Butt spray with Confidor (IMIDACLOPRID) early Spring. This is expensive but must be considered as giving three years coverage.
- Some orchardists monitor infected trees in Autumn and others butt drench the whole block.
- ENDOSULFAN but avoid because of predators.
- Lorsban (CHLORPYRIFOS) in season if there is an outbreak.
- *Aphylinus mali* as a predator.
- No real difference in rootstock susceptibility but one grower believed that Northern Spy had been better when it was commonly planted.

### **TWO SPOTTED MITE AND EUROPEAN RED MITE**

- MANCOZEB has a large effect on predators. Therefore don't use it until later in the season (November). Others have no problem with Mancozeb.
- Gusathion (AZINPHOS-METHYL) use also leads to mite outbreaks.
- ABAMECTIN. Half one year and then the other half next year.
- European red mite has largely disappeared as a problem and its place has been taken by two-spotted mite.
- Growers (and scouts) monitor predators and pests and use this to schedule spray applications.
- A particular problem in hot weather.

### **QUEENSLAND FRUIT FLY**

- Growers (and scouts) monitor.
- If Gusathion.(AZINPHOS-METHYL) used then no fruit fly problems.
- Bait sprays with yeast and Lorsban onto butts following monitoring.
- There is pressure every year.

### **APPLE DIMPLING BUG**

- Monitoring reduces the number of insecticide applications.
- Calypso (THIACLOPRID) early. One or two sprays.

### **PLAGUE THRIPS**

- Monitor. Because plague thrips cause less damage than WFT a higher threshold is tolerated.
- Thin damaged fruit out.
- Success naturalyte (SPINOSAD) is used even though it is not registered but is thought to be effective.

### **HELIOTHIS**

- A particular problem in Galas
- Look for holes in the top leaves.
- Favoured by warm, wet springs
- No ENDOSULFAN use during flowering can lead to problems.

### **FULLERS ROSE WEEVIL**

- Rarely a serious problem. If it becomes serious Gusathion (AZINPHOS-METHYL) is used.
- Bugmaster (CARBARYL) will work in vegetables but not used in apples.

- A problem in orchards where Gusathion (AZINPHOS-METHYL) is not used.
- Can be a problem in pink ladies.
- Stem end staining.

### **SAN JOSÉ SCALE**

- Winter oil and Lorsban (CHLORPYRIFOS).
- Confidor (IMIDACLOPRID) butt spray
- Many years ago, orchardists used Supracide (METHIDATHION) in oil – last resort.

### **BIRDS**

- Shooting
- Birds used t leave the district when the weather got cold; now they stay year-round.
- Exclusion netting may be an option here because of the high percentage of netting in this area. Fit skirts to hail netting.
- Crows like the colour of pink ladies. Particularly in a drought year.



## **KNOXFIELD MEETING**

Meeting was held at Knoxfield Research Station (DPI Vic), 5.00pm, 10<sup>th</sup> September 2007. 8 orchardists, 1 scout and Bill Rye attended.

### ***List of Diseases***

- Apple scab
- Powdery mildew
- Silver leaf (?). Uncertainty as to the true identity of this disease. 1 orchardist only.
- Phytophthora (Collar rot)
- Storage rots

### ***List of Insect Pests***

- Light Brown Apple Moth
- Woolly Apple Aphid
- Codling moth
- Heliothis
- Apple Dimpling Bug
- Mites (Two-spotted, European Red, and Bryobia)
- Plague thrips
- Aphids
- San José scale
- Western Flower thrips
- Harlequin beetles
- Fuller's rose weevil
- Earwigs – mentioned by one orchardist; others considered it to be a beneficial
- Soldier beetle
- Mealy bug (only pears)
- Oriental fruit moth – unsure if damage is being caused by OFM but this is suspected.
- Pear slug

### ***Other issues***

- Snails
- Birds: Indian miners, cockatoos (black and white), crows
- Deer
- Hares
- Wallabies
- Bats

## *Management Strategies*

### DISEASES

#### **APPLE SCAB**

- More protectants than DMIs; no more cover sprays
- Don't like Vision (FLUQUINCONAZOLE + PYRIMETHANIL) as they believe it will build up resistance
- Protectant fungicides applied before rain is forecast. Peter Trilloff system.
- Alternatively, cover sprays every second week with a DMI.
- There is no district forecasting service but one orchardist has his own.
- Orchardist hygiene is very important. This includes leaf sweeping and mulching and urea sprays onto the trees after harvest. Some to get the leaves off rather than to control black spot.
- Problem with Galas and Pinks.
- One of the limitations to using predictive services noted by the growers was that the entire enterprise needed to be sprayed in a short time in response to rainfall or an infection period. Some orchardists thought that this was unrealistic because of a lack of spray rigs and operators.
- Vigilance also depends on pressure the year before.

#### **POWDERY MILDEW**

- This is not a large problem in this region because of the use of protectant sprays for apple scab.
- The disease is also less of a problem because there are fewer of the susceptible variety Jonathon planted now.
- Fujis, Granny Smith and Red Delicious are the most susceptible of the commonly planted varieties.
- A separate spray is only applied when the problem builds up (this could be ten years)
- Dwarf stocks also slow new growth and therefore are better for powdery mildew.
- If there was a problem growers would monitor, and spray with Nimrod (BUPIRIMATE) if needed.
- One grower reported infection of 1-year old plantings and this was thought to have been a nursery problem.

#### **SILVER LEAF**

- More on Jonathon, Galas.
- This is thought to be a viral disease.
- More often in hot, dry years
- A problem in grafted trees. Can come from nurseries.
- Not generally a big problem but can be treated with a zinc application.

#### **PHYTOPHTHORA – COLLAR ROT**

- Not a big problem.
- Growers wondered what effect new dwarfing rootstocks would have.
- Regular application of Agrifos, two sprays per year. One postharvest and the other pre-bloom. Some past pink so as to have more leaf.
- Others apply less often but still relatively regular.
- If trees are infected drench or inject.

- 20 years ago orchardists used bordeaux and lime sulphur

### **STORAGE ROTS AND BITTER PIT**

- CAPTAN or manzate (MANCOZEB) in January or February (prior to harvest) each year.
- Dip in Rovral (IPRODIONE), Bavistin (CARBENDAZIM), Ronalan
- Steam clean (or sterilise) bins.
- Orchardists initially thought Smart-Fresh would have an effect on rots but have no realized that this isn't right.
- Ozone bins before going through DPA.
- Calcium applications

### **INSECTS**

#### **WOOLLY APPLE APHID**

- CHLORPYRIFOS and oil pre-bud-burst
- Confidor (IMIDACLOPRID) soil drench every 3 years
- *Aphylinus mali* – encourage in IPM orchard.
- Parasitised mummies of woolly apple aphid are collected at the end of the season and placed in the orchard early in the season.
- Rootstocks are dipped in Confidor (IMIDACLOPRID) in the nursery and sprayed again before planting.
- Other suggested dips included CHLORPYRIFOS.
- Butt drench with Lorsban (CHLORPYRIFOS) and oil.
- Not many of the orchardists tag in Autumn. Most just butt drench everything.
- Debate about whether Regalis could be used to slow down the pest and make it more susceptible to other management strategies.
- Train trees to be calmer. Woolly apple aphid likes vigorous sap flows.
- Woolly apple aphid is also more of a problem in trees with dense foliage. Prune for light and air movement.
- Some growers had tried Pirimor (PIRIMICARB) but this hasn't worked. Others said that it had worked but needed still weather in the pre-Christmas period.
- Woolly Apple aphid is worse on Granny Smiths and Fujis
- Some of the orchardists were having trouble getting Confidor (IMIDACLOPRID) to work when sprayed on the whole tree.

#### **CODLING MOTH**

- Insegar (FENOXYCARB). ½ - strength application every fortnight.
- Isomates commonly used. One grower who is isolated is now trying a season with no control at all after many years of isomates.
- Mimic (TEBUFENOZIDE) and Insegar (FENOXYCARB) every second row, every second week.
- Monitoring common
- Fruit left in bins is a source of infestation. Particular problem in pears.
- Isomates are less useful in pears.
- There is very little Gusathion (AZINPHOS-METHYL) use.
- Some growers use Insegar (FENOXYCARB) and mating disruption combined.
- Rogue trees have to be eliminated.

- One orchardist mentioned that he felt he had only a small problem partially because he was isolated. He also thought that eucalypts between his property and neighbours acted as a barrier and wondered if it was their scent.
- Monitoring of degree days to establish first flight as a basis for insecticide application is common practice. 10-12 days after first catch.
- Plaster markers for degree days. Used for monitoring plasma – Cedric Lethbridge.
- Folidol (PARATHION METHYL) is applied if there is a major problem. One orchardist sprays because there is one spot in the orchard where isomates don't seem to work. They believe it might be oriental fruit moth. DPI Vic are trying to trap and identify this year.
- Very few would use the old schedule which included calendar sprays of Gusathion (AZINPHOS-METHYL).

### **LIGHT BROWN APPLE MOTH (LBAM)**

- Mimic (TEBUFENOZIDE). One regular spray early in the season and then Insegars (FENOXYCARB) for codling moth are sufficient for LBAM control.
- Likes new varieties and Red Delicious
- Mimic (TEBUFENOZIDE) also gives an effect on heliothis as well.
- First sprays are applied mid-October.
- Problem is worse when corn and tomatoes are grown close-by.

### **HELIOTHIS**

- Success naturalyte (SPINOSAD) is expensive but it works
- Other growers generally use Mimic (TEBUFENOZIDE).
- Trichogramma
- No DiPel used.

### **APPLE DIMPLING BUG**

- Dimpling bug has been a major problem in this region for some growers with up to 5% loss in Golden Delicious.
- Growers apply between 1 and 4 sprays of Mavrik (TAU-FLUVALINATE) (10 days apart) but this leads to secondary mite problems.
- Talstar (BIFENTHRIN) is also used.
- Wattle is a secondary host of dimpling bug and may be the cause of localized problems.
- Susceptible varieties include Granny Smiths and Golden Delicious.
- The problem tends to occur on the north-west corner of orchards and this is thought to be related to the pest blowing in from the Riverina and Goulburn Valley.
- If the Goulburn Valley doesn't have a problem neither does the Yarra Valley.
- Some people believe that if fruit is infested early it is likely to fall. Others disagreed with this – it may be related to less stressful conditions.
- Some orchardists believe that apple dimpling bug leads to fruit fall and that early infection leads to fruit thinning.
- Stressed trees are more susceptible.

### **MITES**

- Predators are introduced into the orchard.
- Problem is less severe in cooler orchards.

- Last year was a problem because it was drier and warmer.
- One orchardist had a strategy of gradually trickling predators into an orchard by having small fortnightly releases. Concentrating on hot spots.
- Sprays for mites at ½-strength. Acramite (BIFENAZATE), Omite (PROPARGITE), Paramite (PHOSMET).
- Monitor and spray wind breaks (at full-strength)
- Predators must be present early in the season. One grower grew grass longer in every second row as this provided pollen for survival of predators when pest mite numbers are low.
- *Typhlodromus pyri* has been introduced to this region but has not been successful on many orchards. One orchardist said that it had become endemic on their property

### **PLAGUE THRIPS**

- These are relatively rare in this district.
- Monitor weather conditions.
- Last large problem was 5-6 years ago
- If the problem occurs late in the season orchardists do not apply control.
- Problem in late-flowering varieties but this is usually thinned out.

### **WESTERN FLOWER THRIPS**

- Orchardists in this region were unsure if there was a problem, but those growing close to strawberry farms were worried.
- Success naturalyte (SPINOSAD) was applied where the problem was thought to exist and early sprays are important.
- Orchardists are worried because this pest seems to be spreading into new districts.
- Some growers in the Goulburn Valley are spraying with Success. Up to 4 sprays until fruit hardens. May be related to tomatoes.

### **APHIDS**

- More of a problem in nursery trees
- Lorsban (CHLORPYRIFOS) in oil helps to control aphids early in the season.
- Lady beetles, hover flies and stethorus are good beneficials for aphids.
- Where rain occurs in summer and there is a flush of new growth infestations can occur.
- Some orchardists mentioned small birds (e.g. wrens) as being useful in eating aphids.

### **SAN JOSÉ SCALE**

- Winter oil every year.
- Lime sulphur.
- Less common in pears (3-4 years since seen)
- Spray in the season when seen.

### **HARLEQUIN BEETLES**

- One orchardist had a large problem with harlequin beetles.
- This was thought to relate to unkempt roadsides with blackberry and rubbish.
- These are sap-sucking and foul fruit.
- Folidol (PARATHION-METHYL).

- Spray weeds with Lorsban (CHLORPYRIFOS).

#### **SNAILS**

- 44 gallon drum of snail baits dispersed by hand. One handful at the base of each tree. Annual application for four years reduced the problem.
- Snail bait mixed with fertilizer.
- Spread with fertilizer spreader.
- Problem on Galas.
- This is a fairly common problem in this region.

#### **FULLERS ROSE WEEVIL**

- Not a major problem.
- Eat leaves and fowl fruit
- Success naturalyte (SPINOSAD) if necessary; but nothing usually done.

#### **EARWIGS**

- Eat damaged fruit
- Eat mealy bugs and aphids.
- Some people put pipes out to try and encourage them.
- Generally considered a beneficial as they eat mealy bugs and woolly apple aphid.

#### **MEALY BUGS**

- Mainly a problem in pears.
- In apples Golden Delicious, Jonathons and Granny Smith are problem varieties.
- They infest the calyx-end (particularly pears)
- Generally not regarded as a serious pest and no specific sprays.
- Predators were introduced from Queensland but these were not successful as Victoria is too cold (don't overwinter).

#### **SOLDIER BEETLE**

- A predator / beneficial.

#### **ORIENTAL FRUIT MOTH**

- Mimic (TEBUFENOZIDE)
- It's unsure whether this is the problem in this region or not.
- Orchardists were basing this identification on the fact that a number of smaller moths had been caught in codling moth traps.

#### **PEAR SLUG**

- Lorsban (CHLORPYRIFOS), DiPel
- Fungicides
- CARBARYL
- Can be in an occasional problem after Christmas; in January. Distribution is patchy through the orchard.
- Rotary hoeing under the tree creates dust which smothers the slugs.

#### **BIRDS**

- Musk Lorikeet

- One orchardist spoke about a product which was being trialed at Harcourt (DSE trials) which he thought was a by-product of the grape industry. Applied through a fogging machine.
- Crows won't go under nets.
- Netting in the district ranges from 15% of enterprises to full coverage and some had full exclusion netting for birds.

## **SHEPPARTON MEETING**

Meeting was held at the Shepparton RSL on the 11<sup>th</sup> of September 2007, 4.00pm.  
4 orchardists attended. 3 DPI Vic staff were present.

### ***List of Diseases***

Black spot  
Powdery mildew  
Bacterial canker / bacterial blast (Corellas prone)  
Summer rot / Glomerella / Target rot  
Phytophthora  
Replant disease

### ***List of Insect Pests***

San José scale  
Codling moth  
Oriental fruit moth  
Light brown apple moth  
Apple dimpling bug  
Plague thrips  
Western flower thrips  
Fuller's rose weevil  
Elephant root weevil  
Garden weevil (Harcourt)  
Apple weevil  
Two spotted mite  
European red mite (not common; not a serious problem)  
Bryobia mite  
Loopers  
Mealy bug (pears)  
Heliothis (occasional and can be a problem at Harcourt)  
Painted apple moth (young trees where there's not a full program)  
Aphids  
Woolly Apple Aphid  
Pear slug – becoming more common

### ***Other issues***

Birds – Crows, musk lorikeets, cockatoos, corellas



## *Management strategies*

### **DISEASES**

#### **BLACK SPOT**

- MANCOZEB or Polyram (METIRAM) as a protectant; DMIs if you get caught out.
- Tailor your protectant vs eradicant schedule dependent on rainfall.
- Protectant before hand if the rain event is big as this reduces the need to get out after wards.
- Use protectants (Chorus (CYPRODINIL); rainproof, Stroby (KRESOXIM-METHYL); up to 50mm rainfall) rather than eradicants and avoid DMIs if possible.
- Copper on pears.
- Syllit (DODINE) is the first spray.
- For Williams – Use Dithane (MANCOZEB) covers (perceived as lowest toxicity risk); if an application is missed use Bogard (DIFENOCONAZOLE) or Rubigan (FENARIMOL).
- For packham use Delan (DITHIANON), Bogard (DIFENOCONAZOLE) (softer on the skin), Polyram and NuStar.
- In apples use Polyram (METIRAM) and Delan (DITHIANON; if it's wet) Systhane (MYCLOBUTANIL) as this also takes care of powdery mildew.
- Urea sprays post harvest.
- Some growers occasionally rake leaves out from under trees and mulch them with the slasher.
- Infection periods are monitored. There is a district service and some growers use this while other growers have their own equipment.

#### **POWDERY MILDEW**

- Black spot sprays generally cover powdery mildew.
- Younger trees may have specific programs because they're more susceptible.
- Sulfur sprays.

#### **BACTERIAL CANKER (Blossom Blast)**

- Copper at early blossom (green tip or first movement).
- 2-3 home-made Bordeaux applications (copper sulfate and lime)
- Programs vary between pears and nashis
- Some people use cuprofix (COPPER HYDROXIDE) but some people feel this isn't "strong" enough.
- Tri-base blue (TRIBASIC COPPER SULFATE)

#### **GLOMERELLA**

- CAPTAN through summer. Especially a month prior to harvest. This is done on anything intended for storage (Don't worry about Galas).
- Dithane (MANCOZEB).
- Sundowners are particularly susceptible.
- People get caught during dry years with postharvest rots because they don't apply as many fungicides.
- Those who don't dip (ie. Those who use Smart-fresh) have to take control in the orchard.

- Most growers believe that in-orchard sprays are more effective than dips.

### **PHYTOPHTHORA**

- Hilling up – don't let trees get wet feet.
- Phosphonic acid
- MM106 is very susceptible
- Keep the soil profile dry
- One grower removes infected trees and replaces soil before re-planting.
- Sprinklers vs drippers
- One grower believes that fertilizers have an effect on Phytophthora.

### **SILVER LEAF**

- Cultural practice is the only effective treatment.
- Rare but does occur in Nashis; close to cherries.
- Trunk injection with phosphonic acid. Some growers were satisfied with this treatment.
- Cut trees out as they're already dying.
- Paint pruning wounds for prevention.

### **PESTS**

#### **CODLING MOTH**

- IPM orchardists – particularly those who are isolated – don't have an issue with codling moth.
- Isomates are more effective if your neighbours are also using them.
- Mating disruption is widely used but sometimes oversprayed with Insegar (FENOXYCARB) or Avatar (INDOXACARB).
- Avatar (INDOXACARB) use can lead to a blow out in loopers.
- Effect of dirty neighbours.
- Avatar is used because isomates led to a blow out of loopers. Timing of sprays for codling moth is an issue for heliothis vs loopers.
- Insegar (FENOXYCARB) and then Calypso (THIACLOPRID) at peak pressure times.
- Folidol (PARATHION-METHYL) and Gusathion (AZINPHOS-METHYL) are common – every second row, every second week.
- Isomate has to be used over an entire enterprise not block by block.
- Spray neighbours boundaries at peak times
- Occasional shortage of isomate ties.
- “PARATHION users are still in the majority with Gusathion (AZINPHOS-METHYL) as their fall-back”
- Others use Calypso (THIACLOPRID).
- PARATHION-METHYL resistance is an issue.
- Area wide management (AWM) has had mixed success because of small block sizes. Current financial difficulties are also leading to people pulling out of AWM.
- Deserted blocks are a problem.
- Bin cleaning is important.
- Transition period is expensive as both isomates and pesticides are used.

#### **ORIENTAL FRUIT MOTH (OFM)**

- Isomates. OFM plus (OFM + codling moth) in pears.
- OFM isomates don't last as long.
- Codling moth and OFM combined has not been effective because it doesn't last long enough for OFM. OFM can come in at the end.
- Combined isomates only last 1½ OFM generations
- One grower has not sprayed for 7 years because of isomates.

### **LIGHT BROWN APPLE MOTH (LBAM)**

- Avatar (INDOXACARB)
- Lorsban (CHLORPYRIFOS)
- Mimic (TEBUFENOZIDE)
- LBAM ties
- OFM ties led to a reduction in number of insecticide applications and LBAM numbers went through the roof.
- In nashi Avatar controls LBAM when pressure is high. Success is applied 3 days prior to harvest. (also gets pear slug) Avatar (INDOXACARB) again after harvest.
- Apply insecticides to non-cropping trees
- Gusathion (AZINPHOS-METHYL) and PARATHION-METHYL are still used by many in the industry
- DiPel (*Bacillus thuringiensis*)

### **DIMPLING BUG**

- Monitor and spray with Mavrik (TAU-FLUVALINATE) if seen
- ½ strength (Low rate) PARATHION-METHYL
- Lorsban (CHLORPYRIFOS) 3 days before bee hives are put in the orchard. However, this causes problems where apple blocks are near cherry and Nashi blocks as they flower earlier and Lorsban kills fruit.
- Some orchards use two Mavrik (TAU-FLUVALINATE) applications but with correct timing only one is necessary.
- Only on big fruit.
- Monitoring by tapping flowers; if you see one you've got damage.
- After full bloom there is no point in trying to control Dimpling Bug as the good fruit is set. All that can be done is to thin out damaged fruit.

### **WESTERN FLOWER THRIPS**

- Monitor and apply Success (SPINOSAD) when seen.
- WFT tends to appear in drought years when there is no other green grass around.
- Keep grass short
- No damage on pears despite large numbers

### **PLAGUE THRIPS**

- Monitor and ½ strength PARATHION-METHYL
- Mavrik (TAU-FLUVALINATE) for Dimpling bugs also kill plague thrips
- Worst on Granny Smith and Sundowners

### **ELEPHANT ROOT WEEVIL**

- Correct name is Fruit tree root weevil. Note that different Elephant weevils exist in different areas.

- Used to use Gusathion (AZINPHOS-METHYL) straight after flowering, but for the last two or three years it is controlled as a secondary consequence of Avatar (INDOXACARB) use.
- The length of the life span in-ground is a problem (larvae up to 5 years)
- Spread to cherries
- There may be a relationship with wattle.
- May be more of a problem under nets
- Some orchardists felt that it was reasonably common but it may not cause damage.
- Problem in Granny Smith.
- More common where there is freshly worked ground.
- Monitor with trunk traps.
- Confidor (IMIDACLOPRID)
- Butt spray double-strength Gusathion (AZINPHOS-METHYL) but all contact points with ground must be sprayed.

#### **FULLERS ROSE WEEVIL AND GARDEN WEEVIL**

- Eats the apples and half way through the fruit stems.
- Avatar (INDOXACARB)
- Fuller's Rose Weevil doesn't eat the fruit (only leaves) blocks irrigation with its eggs.
- Project report tells which type of irrigation you can use which doesn't block.
- Apple weevil is similar to garden weevil.

#### **TWO SPOTTED MITE**

- Some orchardists don't spray ; Not too much of a problem.
- Sorcerer (ABAMECTIN)
- Vertimec (ABAMECTIN) doesn't work anymore
- Use paramite (PHOSMET) and acramite (BIFENAZATE) instead
- Mavrik applications lead to increased mite problems. Therefore drop rates of Mavrik (TAU-FLUVALINATE) application as a first step.
- Worst under nets.
- There is a commercial monitoring service.

#### **EUROPEAN RED MITE**

- Not a problem

#### **BRYOBIA MITE**

- Sometimes on Williams pears
- CHLORPYRIFOS with or without oil at green tip

#### **LOOPERS**

- Mimic (TEBUFENOZIDE)
- DiPel or Lorsban (CHLORPYRIFOS) for LBAM has led to fewer loopers
- Insegar (FENOXYCARB) for codling moth has led to fewer loopers
- Mimic (TEBUFENOZIDE) has a long withholding period which restricts use and loopers will eat until the end of the season.
- Tank mix DiPel with cover sprays (every second row, every second week) for codling moth
- Sprays applied every second year or so in Nashis.

## **HELIOTHIS**

- More widespread use of Avatar (INDOXACARB) has led to fewer Heliothis
- Mimic (TEBUFENOZIDE).
- Monitor and spray if needed.

## **PAINTED APPLE MOTH**

- In young trees where pesticide program is not up to speed.
- PARATHION-METHYL.
- Monitor and apply parathion if needed.
- Patchy distribution and not common

## **WOOLLY APPLE APHID (WAA)**

- Less of a problem since orchardists have begun to butt drench with Confidor (IMIDACLOPRID)
- Liquid Lorsban (CHLORPYRIFOS) postharvest (fairly strong mixture)

## **MEALY BUG**

- Monitor for crawlers and then Applaud (BUPROFEZIN)
- PARATHION-METHYL.
- Nashi application of Applaud (BUPROFEZIN) (with Mavrik(TAU-FLUVALINATE)). 3 weeks apart in November (1<sup>st</sup> and last week of November).
- Put out lady beetles.
- Tokuthion (PROTHIOFOS) results in a russet problem and it's therefore not used. It also leads to mite problems.
- Finger stage application versus November application.
- One grower had re-developed a block, partially as result of mealy bug problems
- Detail pruning to remove 'crows nests' in tops of trees
- There are several species of mealy bug in Shepparton (eg. Long-tailed mealy bugs bear live young) therefore it's important to be careful with recommendations. This means that timing of applications etc will be difficult.

## **PEAR SLUG**

- Success naturalyte (SPINOSAD) instead of one application Avatar (INDOXACARB).
- Calypso (THIACLOPRID) after harvest
- PARATHION-METHYL
- Only occurs in young trees without a proper program.
- There is a relationship with proximity to cherry blocks

## **SAN JOSÉ SCALE**

- Cover spray with oil and liquid Lorsban (CHLORPYRIFOS) as late as possible before flowering.

## **BIRDS**

- Some growers have less problems. The odd musk lorikeet to two rows in near home garden.
- Exclusion netting is the only real solution

- Crows scare off other birds (e.g. starlings).
- Scare guns
- At Harcourt musk lorikeets won't go under netting even if it's not full exclusion.
- Crows on Nashis, Corellas and Williams.
- Repellants being worked on by Conservation Branch.
- "Bird-attractive" gardens have maintained sedentary populations so birds no longer follow pollen flows.
- Birds like tall trees.

## **BATLOW MEETING**

Meeting was held at the Batlow RSL on the 12<sup>th</sup> of September 2007, 7.00pm.  
5 orchardists attended and 2 Batlow Co-op staff. 2 NSW DPI staff were present.

### ***List of diseases***

- Black spot
- Powdery mildew
- Replant disease
- Penicillium
- Glomerella – target rot
- Mucor
- Pseudomonas syringae (Pears)
- Jonathon spot
- Bitter pit
- Nectria
- Core rot in red delicious and fuji
- Phytophthora
- Polystichtus – trametes
- Silver leaf

### ***List of pests***

- Codling moth
- Woolly Apple Aphid
- San José scale
- Apple dimpling bug
- European red mite
- Two spotted mite
- Heliothis
- Loopers
- Harlequin beetles
- Light brown apple moth
- Painted apple moth
- Crickets
- Grasshoppers
- Rust mites
- Elephant weevil
- Queensland fruit fly
- Fullers Rose Weevil
- Apple aphid

## *Management strategies*

### **DISEASES**

#### **BLACK SPOT**

- Protectant sprays
- Apple scab warning service
- Protectants to pink, applications at 10 day intervals with protectants and eradicants (keep in mind activity against powdery mildew). If there is an infection period during this period apply a curative (eradicant). After this critical window apply protectants at various intervals in response to rain and crop maturity.
- Rotate fungicide groups to avoid resistance
- Sweep leaves in autumn and winter
- Alternatively, usually nothing until pink. Coppers every 2-3 years. Protectant at pink and then dependent on the forecasting curatives as needed until early November.
- Keep schedules tight until 14 days after bloom and then repond to weather.
- Batlow growers don't like HEXACONAZOLE.
- Urea tree sprays at 5%

#### **POWDERY MILDEW**

- Becoming a larger problem
- Many of the newer varieties are susceptible (e.g. Galas, Braeburn, Pink Ladies)
- Where powdery mildew is a problem a specific schedule would include Nimrod (BUPIRIMATE) at pink and other DMIs during flowering
- 1-2 strobilurins
- Nimrod (BUPIRIMATE) October – November, then monitor and apply if needed
- Younger trees are put on a slightly longer program
- Mostly covered by black spot sprays.

#### **REPLANT SYNDROME**

- Mustard BQ Mulch as biofumigants
- Chlorpicrin, methyl bromide
- Rest for a couple of years and remove as many old roots as possible
- Rip, plough and superphosphate
- M9 and M26 are less susceptible than M106
- Lime and phosphorous

#### **POSTHARVEST**

- Smart fresh
- Anecdotally it's felt that postharvest problems are greater in dry seasons. This may be because there are fewer in-orchard sprays.
- A problem in Fuji and Pink Lady because of stem punctures
- Blossom sprays are important for control of postharvest disease
- Alternaria core rots are uncommon
- CAPTAN during the season is important.

#### **SCALD**



- DPA or Smart-fresh
- Not a major problem because of the variety mix in Batlow.

### **JONATHON SPOT**

- Dithiocarbamates in spring and CAPTAN
- Jonathons and Bonzas

### **NECTRIA**

- Nothing registered
- Prune out

### **PHYTOPHTHORA**

- Rarely treated
- Gala on MM106 is a susceptible combination
- Replace MM106 with M9

### **TRAMETES**

- Cut back below the infection

### **ARMILLARIA**

- Nothing done
- Remove as many roots as possible when the block is replanted.
- Not common
- Look for mushrooms in may.

### **POLYSTICTUS**

- Cover pruning wounds
- Cut out infected limbs
- Smaller wood is less prone to infection
- Be careful when reworking trees
- Stressed trees result in more of these types of diseases (either too dry or wet)

### **SILVER LEAF**

- Do not prune during wet weather
- Galas are a particular problem
- Urea spread as soon as seen to promote active growth and heal wounds.

### **PESTS**

#### **CODLING MOTH**

- 3 Generations per season in Batlow
- Mating disruption with or without sprays
- Monitoring
- 70-80% of growers use isomates alone without insecticide applications
- Combination lures: pear ester and 10mg pheromones
- Spray boundaries with Insegar (FENOXYCARB)
- Calypso (THIACLOPRID)
- Phenology model for biofix
- AZINPHOS-METHYL, PARATHION-METHYL.
- Insegar (FENOXYCARB) is better for your predators
- Take infected fruit off and remove it from the orchard.

- Put discarded fruit in a “super” bag and leave it in the sun.

### **WOOLLY APPLE APHID (WAA)**

- Confidor (IMIDACLOPRID) butt drench
- CHLORPYRIFOS as a spray
- Earwigs. Growers find it difficult to keep these alive and would like to know ways to promote them. In addition to AZINPHOS-METHYL and Calypso (THIACLOPRID), Carbaryl for thinning can wipe out earwigs.
- Reducing Gusathion (AZINPHOS-METHYL) use leads to increased WAA parasitism by Aphelinus.
- Spray the bottom half of the tree as this saves the predators.
- Hot dry weather leads to cracking of the ground and allows WAA to breed.
- Young trees get a root drench with Confidor (IMIDACLOPRID) before planting
- The whole block is usually treated with Confidor (IMIDACLOPRID) rather than flagged hot spots.

### **SAN JOSÉ SCALE**

- 3% oil spray
- More prevalent now and orchardists are moving to annual sprays.
- White oil
- Tree guards can promote the problem. Make sure they’re removed after a couple of years.
- The ‘crawler’ stage is the only susceptible part of the life-cycle.

### **APPLE DIMPLING BUG**

- Application thresholds are in place which correspond to tree phenology.
- Calypso (THIACLOPRID), ENDOSULFAN, Lorsban (CHLORPYRIFOS) applied at late pink stage
- ENDOSULFAN leads to problems with bees
- Orchardists are willing to tolerate a level of damage.
- Some of the damaged fruit falls off with thinning sprays.
- There are zones within blocks where problems are worst.
- There is a relationship with wattles.
- Spray every second row with ENDOSULFAN or Calypso (THIACLOPRID). This acts as a repellent.
- It’s important to apply during flowering but there is a very small window.

### **TWO SPOTTED MITES**

- Predatory mites (Typhlodromus) introduced
- Removal of organophosphates has led to an increase in rust mites.
- Miticides are applied in response to thresholds which rely on mite numbers and numbers of predators.
- Alternate row mowing is standard practice for most. Pollen from grasses is a food source for predators.
- Avoid chemistry which affects beneficials.
- Drought leads to a decrease in grass which reduces predator numbers and increased two spotted mite numbers.
- Rotate miticide groups to avoid resistance.

## **EUROPEAN RED MITES**

- Oil sprays at bloom for European Red Mite (around petal fall) 2% or 1%.

## **HELIOTHIS AND LOOPERS**

- Because ENDOSULFAN isn't used as much these days these two pests have made a resurgence.
- Calypso (THIACLOPRID) is now registered for Dimple bug and this should mean fewer looper and heliothis problems.
- Thin out any damage
- Lorsban (CHLORPYRIFOS)
- Rain around blossom will wash out the eggs and this means that loopers and heliothis are a seasonal problem. This is similar for codling moth.

## **HARLEQUIN BUGS**

- Absence of OPs has led to their emergence
- Migratory and associated with marshmallow
- Ground spray
- More common on the edge of a block

## **LIGHT BROWN APPLE MOTH (LBAM)**

- Not a major problem
- More frequent on clusters, so thin to singles or doubles.
- Can be a serious problem on Bonzas

## **PAINTED APPLE MOTH**

- Can be a problem on young trees
- Monitor for leaf skeletonisation and squash

## **APHIDS**

- A rare problem
- Not much damage
- Almost any insecticide can be used

## **CRICKETS**

- Be careful with your mulch and tree guards
- Don't use straw
- Bran baits laced with Lorsban (CHLORPYRIFOS)
- A problem in dry years when the ground cracks and creates refuges.

## **WINGLESS GRASSHOPPERS**

- Wingless grasshoppers can strip leaves
- Crows eat them
- Spray young trees some years

## **WEEVILS**

- Defoliate trees
- Difficult to control with insecticides
- Synthetic pyrethroids.
- Orchardists have been told that they have apple root weevils but there is little knowledge of what they are, what they do or how to control them

### **QUEENSLAND FRUIT FLY (QFF)**

- No control is applied
- QFF is monitored because of interstate access issues
- Stone fruit from Tumut may bring QFF into the region
- Favoured by mild winters and hot summers
- ICA prescribes treatment

### **BIRDS**

- Getting worse because of the drought
- Shoot a few birds
- Exclusion netting.

## **PERTH MEETING**

Meeting was held at the Western Australian Fruit Growers Association offices at Canning Vale on the 2<sup>nd</sup> October 2007, 1.00pm.

5 orchardists attended and 2 WAFGA staff. 1 DAFWA staff member was present.

Two orchardists grew pears.

1 grower had an orchard which was certified organic but ran a conventional pack house. His responses are marked “(Organic)”.

### ***List of diseases***

- Powdery mildew
- Pear scab
- Alternaria
- Spot rot
- Grey mold (pears)
- Blue mold

### ***List of pests***

- San José scale
- Birds (White tailed black cockatoos, Boudin cockatoos)
- Apple dimpling bug
- Weevil – Fullers, Garden
- Apple cucurlio weevil
- Thrips
- Mediterranean Fruit Fly
- Woolly apple aphid
- Heliothis
- Looper
- Two spotted mite
- Light brown apple moth
- Snails
- Mealy bug
- Wingless grasshoppers
- Katydid (long antenna)
- European red mite (Manjimup)

## *Management strategies*

### **DISEASES**

#### **POWDERY MILDEW**

- Potassium silicate as a nutritional product to improve tree health (Grower in transition to organic)
- A problem every year.
- Topas (PENCONAZOLE) usually 3 sprays per year but in years with humid, mild conditions the number of sprays increases to 4 or 5.
- Prune infections out
- Other fungicide options include: NuStar (FLUSILAZOLE), Systhane (MYCLOBUTANIL), Polyram (METIRAM), Pristine (PYRACLOSTROBIN + BOSCALID), Flint (TRIFLOXYSTROBIN), Bogard (DIFENOCONAZOLE), Vision (FLUQUINCONAZOLE + PYRIMETHANIL), Stroby (KRESOXIM-METHYL), Rubigan (FENARIMOL), Lime-sulfur.
- Sulfur
- Copper and Winter oil

#### **PEAR SCAB**

- No Topas (PENCONAZOLE)
- Systhane (MYCLOBUTANIL)
- NuStar (FLUSILAZOLE) but the orchardist who mentioned this didn't feel that it had been very effective.
- Bogard (DIFENOCONAZOLE)
- Dithane (MANCOZEB)
- Bogard and dithane used as a mixture.
- Polyram (METIRAM)
- A mixture of protectants and curatives.
- Calendar based sprays with 10-14 day intervals; this is the most common program. Can be stretched in really dry weather.
- Leaf rake and mulch
- Urea.
- Copper and lime after harvest.

#### **ALTERNARIA LEAF AND FRUIT SPOT**

- Nothing is generally done for Alternaria
- 2004 was a bad Alternaria year.

#### **SCALD**

- DPA

#### **POSTHARVEST ROTS**

- Fungaflor (IMAZALIL) has been used on pears but it is no good on apples.
- Rovral (IPRODIONE)
- Bavistin (CARBENDAZIM) but not on pears for export.
- Ozone is rarely used
- Benlate (BENOMYL) was used before Bavisitin.
- Summer pruning to open canopies (especially for powdery mildew)

## **PESTS**

### **SAN JOSÉ SCALE**

- 3L Winter oil and lime sulfur – “most important spray of the year”.
- High volume 2000 to 3000L
- Important that coverage reaches the tops of trees
- If an infestation occurs during the season Gusathion (CHLORPYRIFOS) or Supracide (METHIDATHION).

### **BIRDS**

- Lead
- Official figure is \$24 annual damage per tree in WA.
- Exclusion netting would be an option if it was subsidised.
- No recognised method for assessing fruit damage.
- Only target high value varieties in susceptible areas.

### **APPLE DIMPLING BUG**

- Insurance spray with Mavrik (TAU-FLUVALINATE)
- Worse in warm weather
- Monitor during flowering
- Worse in blocks close to wattle
- Monitor for damage, particularly in southern regions. Occurs every year in Perth Hills therefore annual spray applied.
- Ice cream container for monitoring.
- Organophosphate / Lorsban (CHLORPYRIFOS) at pink.

### **APPLE WEEVIL**

- The most common weevil
- Chews stems

### **GARDEN WEEVIL**

- First to appear.
- Can damage fruit

### **FULLERS ROSE WEEVIL**

- Butt drench with Dominex (ALPHA-CYPERMETHRIN) or high-rate Gusathion (AZINPHOS-METHYL)(both registered)
- Foliar application of Avatar (INDOXACARB) (permit but will be registered soon)
- Weevils generically: Dominex with summer oil or canola oil.
- Drip-line sprays
- Chooks
- Pepper: sprayed without filters – deterrent.
- Be careful with mowing. When long grass is mowed the weevils escape into the trees and then you have to do something.

### **THRIPS**

- Same class as dimpling bug
- Western flower thrips is in Perth Hills but it is isolated there. It is less mobile than other thrips species. Not in Manjimup/Donnybrook area.

- Plague thrips are associated with wild flower season
- Controlled with SPINOSAD
- Both thrips considered minor pests in apples
- Dimpling bug control takes care of thrips

#### **MEDITERANNEAN FRUIT FLY**

- Fruit fly traps are put out but flies are rarely found.
- Used to bait with MALDISON
- Cover spray with Rogor (DIMETHOATE) once
- Some never spray.
- Fruit fly is worse where stone fruit or town is close by
- Used to be a scheme to spray backyard trees in Donnybrook, but it's not sure if this still happens.
- Flies are prevalent in Manjimup
- Can see the stings in apples.
- Fruit fly is bad in the Perth Hills
- One cover with Lebaycid (FENTHION) and then bait spray.

#### **WOOLLY APPLE APHID**

- Confidor (IMIDACLOPRID) butt drench of susceptible varieties. New varieties don't need to be done.
- Powder (?) put around base in winter
- Sea minerals (Organic)
- Certain rootstocks and varieties are more susceptible e.g. old granny smiths
- Heavy winter pruning leads to problems
- Ventilation helps

#### **HELIOTHIS**

- Occurs on sporadic years
- There is a taxonomic problem in distinguishing Heliothis from looper
- Gusathion (AZINPHOS-METHYL) (low-level) once a year when seen for looper.
- DiPel
- Heliothis traps at Manjimup
- Surround (KAOLIN)
- Success Naturalyte, Entrust naturalyte (SPINOSAD)

#### **TWO SPOTTED MITE**

- No problems because of 'tree health' (Organic)
- A problem in Perth Hills following hot, dry spells and requiring spraying
- Vertimec (ABAMECTIN) early in the season (November - pre- Christmas).
- Dust from motorbikes (scaring cockatoos away) makes the problem worse
- Can cockatoos spread mites?
- Acramite (BIFENAZATE)
- Omite (PROPARGITE)
- Torque (FENBUTATIN OXIDE)
- Decision to spray or not is based on threshold numbers of pest mites and beneficials
- Fuji and hi-early Delicious are the most susceptible and there are now fewer of these varieties grown.



- Summer oil at the end of season.
- At Manjimup there was a flare-up of European Red Mite about two years ago but no real control was applied.
- Spray application depends on harvest time. If you're picking early you might not bother.

### **LIGHT BROWN APPLE MOTH**

- Not a huge problem
- DiPel if present
- Only apply management if they are present.

### **SNAILS**

- French backpacker / pickers eat them
- Copper sprays (1kg / 100 L) on the butt
- This is a yearly problem
- Copper sulfate
- Rake leaves out of the orchard and other general orchard hygiene measures lead to fewer snail problems. No real problem in the Perth Hills.
- Chooks

### **MEALY BUGS**

- Some growers have more problems than others
- Pink ladies and Fujis are the worst affected
- Supracide (METHIDATHION)
- Tokuthion (PROTHIOFOS) in apples
- Mealy bugs occur more often in apples than pears
- A problem in older blocks and orchards
- Prune them out

### **WINGLESS GRASSHOPPERS**

- Not a problem in the Perth Hills
- Rogor (DIMETHOATE) on the boundaries gives a short-term result for grasshoppers.
- Bran baits (short term; half day).

### **CRICKETS (KATYDIDS)**

- Crickets can be a problem in Pink Ladies
- Nice little neat, round hole in Fujis
- Cricket damage usually happens 2-3 weeks pre-harvest in Donnybrook but control is usually not needed.
- Guinea fowl

### **PAPER WASPS**

- An OHS issue for pickers
- Building up over the last 3-4 years.
- Has only become a serious problem over the last few years.
- A problem in empty bins.
- Mortein on every orchard tractor.

## **ADELAIDE HILLS MEETING**

Meeting was held at the Lenswood Research Station on the 3rd October 2007, 7.00pm.

### ***List of diseases***

- Black spot
- Powdery mildew
- Alternaria
- Phytophthora
- *Pseudomonas syringae* / blossom blast (pears)
- Replant disease
- Moldy core (particularly Fujis)
- Scald
- Postharvest rots
- Internal browning (Pink Ladies)
- Silver leaf
- Mosaic
- Trametes
- Nematodes (Riverlands)

### ***List of pests***

- Codling moth
- Apple Dimpling bug
- Weevils
- Light brown apple moth
- Heliothis
- Woolly Apple Aphid
- Earwigs
- Loopers
- Long tailed mealy bug
- Two spotted mites
- European red mite
- Rust mites (pest or beneficial)
- Bryobia mites
- Earwigs
- Plague thrips
- San José scale
- Cherry slug (on pears)
- Pear leaf blister mite
- Oriental Fruit Moth (maybe)
- Snails / slugs
- Birds (Adelaide rosellas, rainbow lorikeets, purple-crowned lorikeets, Sulphur crested cockatoos, yellow-tailed black cockatoos)
- Wasps
- Deer
- Kangaroos

## *Management strategies*

### **DISEASES**

#### **BLACK SPOT**

- This region has adapted its black spot control according to Peter Triloff's strategies.
- There is less reliance on kick-backs and more reliance on protectants before rainfall events. Avoids resistance problems.
- New (unprotected) shoot growth is also considered.
- Start with urea sprays and leaf sweeping and mulching after harvest.
- Rotate groups of fungicides as a resistance management strategy.
- Start the season with 2 Dodine (SYLLIT) applications followed by DMI (for powdery mildew control), Flint (TRIFLOXYSTROBIN) or Strobry (KRESOXIM-METHYL) and then CAPTAN.
- Rapid orchard rotation does not allow black spot to build up.
- Run a tight schedule through spring and summer up to Christmas.
- Fruit acids lower pH which ruptures fungal spores
- Alternate pH has an effect on spores (sulfur)
- Lime sulfur
- Hygiene and orchard sanitation are important
- Sweep leaves and compost
- Compost teas to get "biology" to break it down.
- Some of the orchards in this district have high copper concentrations.

#### **POWDERY MILDEW**

- Generally controlled by black spot sprays
- Mop up with the DMIs.
- Flint (TRIFLOXYSTROBIN) is sometimes specifically applied for powdery mildew control
- If black spot sprays are missed you can end up with powdery mildew
- A problem in wet years
- Can also be a problem in dry years because orchardists don't put out as many sprays.
- A particular problem in Jonathons
- Prune out
- Nimrod (BUPIRIMATE)
- Worse in Pink Ladies and Galas on MM106 (compared to M9 or 26) because they are more vigorous.
- Regalis also has an effect.

#### **ALTERNARIA**

- Relationship to reduction in copper use?
- This disease is new to this region and therefore there is not much known
- Can lead to 25-30% loss in storage
- CAPTAN worked for some but tends to burn eyes and skin.
- Worst on Sundowners and Galas.
- Emerging disease and not a lot known about it.

#### **PHYTOPHTHORA**

- Occurs sporadically

- Clean up new blocks before planting – cultivation.
- MM106 and sundowners is particularly prone to Phytophthora
- Ridomil (COPPER + METALAXYL)(granular)
- Phosphonic acid – foliar sprays.
- Alliette (FOSETYL)
- Butt drench
- Trunk injections
- Particularly bad in wet spots and low-lying areas.
- Third or 4<sup>th</sup> year trees with heavy crop – gone by Christmas.

### **ARMILLARIA**

- Super phosphate around the butt.

### **PPSEUDOMONAS SYRINGAE**

- Generally not a bad problem but can be serious in some years.
- Wet, cold weather is a problem.
- Whole limbs can die in Corella Pears. Corella is the first pear to reach green tip and is therefore the most prone to early frost damage.
- Copper
- Frost control is important.
- Cut out 25-30% of blackened foliage

### **REPLANT**

- Well-documented control strategies available (note that Paul James supplied me with some info)
- No good diagnostic system available for Australian growers. Gordon Brown was working on this before he left the Department.
- Chlorpicrin
- Brassica crops prior to planting produce methane which kills soil pathogens. Plant and plough back in.
- Compost
- 10-20 tons of composted fowl manure

### **MOLDY CORE (ALTERNARIA)**

- A particular problem in Fujis and other open calyx varieties
- Rovral (IPRODIONE) dip
- Rovral at full bloom (not registered but it did work). Several growers were using this effectively.
- No ozone

### **OTHER STORAGE ROTS**

- Close to harvest sprays
- Late CAPTAN, particularly if there is a long rain delay in the lead up to harvest
- DPA
- Nil residue levels will be a big concern.
- Some orchardists use Bavistin (CARBENDAZIM) (not for exports)

### **SILVER LEAF**

- An issue in re-grafts and damaged trees.

- Granny Smith
- Symptoms for a year and then it disappears.
- Nothing done

## **PESTS**

### **CODLING MOTH**

- Monitoring service. Modeling using a degree day model
- Isomates and growth regulators
- A problem in younger orchards
- Resistance to Pennacap leads to reversion to Gusathion (AZINPHOS METHYL)
- Issues with topography.
- Pennacap (PARATHION-METHYL)
- M & M spray. Magnesium and manganese spray. Mimics seed smell (100kg / hectare)
- Back up isomates with one spray in high pressure orchards. One spray at first flight.
- Insegar (FENOXYCARB) with ½ strength Hy Mal (MALDISON).

### **APPLE DIMPLING BUG**

- Calypso (THIACLOPRID) but this is expensive (woolly aphid and codling moth).
- One grower was “semi-organic” and had not put out any specific sprays for Apple Dimpling Bug for 4 years.
- Kelp sprays and fish emulsion.
- A particular problem in Granny Smiths, Sundowners and Red Delicious
- A problem during windy springs
- No monitoring for dimpling bug and therefore just spray.
- ENDOSULFAN and CHLORPYRIFOS. Possible russetting problem
- Lorsban (CHLORPYRIFOS); Pink tip and then 7-10 days later.

### **THRIPS**

- Historically (30-40 years ago) thrips were a much larger problem.
- No real problem
- Largely controlled by dimpling bug sprays
- Worst when there are northerly winds and the season has a hot, dry start.
- Lots in the Riverlands.

### **WEEVILS**

- This has been an increasing problem over the last 8-10 years.
- Weevils girdle stems (earwigs can do the same thing).
- The problem has come up since the introduction of softer programs for codling moth control (particularly where isomates are used).
- Dominex (ALPHA-CYPERMETHRIN) on strip rows (synthetic pyrethroids)
- Cracked wheat baits with Lorsban (CHLORPYRIFOS)
- More of a problem where cherries are grown nearby.
- Diatomaceous earth applied to the tree (October – November)
- The main problem is garden weevils
- Fuller’s rose weevils block sprinklers.

### **LIGHT BROWN APPLE MOTH (LBAM)**

- Worse next to vineyards
- Bunches worse than singles. Therefore worse in lighter years.
- Bad damage in pears.
- No mating disruption in orchards
- Presence monitored with traps
- Codling moth program takes care of them
- Start early with Lorsban (CHLORPYRIFOS) and/or CARBARYL (for thinning)
- A problem on younger trees where there isn't a full codling moth program.

### **HELIOTHIS**

- Some locals called this 'cut-worm'. There could be some confusion as to what Heliothis is.
- Taken care of by apple dimpling bug sprays.
- More problem when using a disruption program.
- They make perfectly round holes in leaves.
- Use Avatar (INDOXACARB) and this also takes care of weevils.
- DiPel not used because the pest needs to take a bite before it works. Therefore the damage has already been done. Seen as unreliable.

### **WOOLLY APPLE APHID (WAA)**

- A problem from mid-harvest onwards
- A problem on high vigour varieties on vigorous rootstocks. Related to a lot of damage.
- Hy Mal (MALDISON) was used in the past.
- Fuji is the biggest problem
- Apply Confidor (IMIDACLOPRID) to trees which have been tagged the previous autumn.
- Confidor applied through the drip irrigation lines.
- *Aphylinus mali* doesn't work well here as the summers are too hot.
- A good codling moth schedule also works against WAA. Use Gusathion (AZINPHOS-METHYL) when codling moth is detected and also use one powder CHLORPYRIFOS (mid-season).
- Lorsban (CHLORPYRIFOS) doesn't last in hot weather.
- Insegar (FENOXYCARB) (40g rate)
- Calypso (THIACLOPRID) or Samurai with a silicon wetter.
- Oils sprays after harvest mixed with Lorsban (CHLORPYRIFOS).
- M9 are a particular problem
- Postharvest sprays to clean it up.

### **LOOPERS**

- An occasional problem
- A problem when it becomes dry outside of orchards. It requires an occasional spray.
- Neat round hole.
- CARBARYL for thinning usually cleans them up.
- You see the damage on fruit when it is fingernail size.

## **TWO SPOTTED MITE**

- Adelaide Hills has a good monitoring service (Staffords)
- Use predators
- They show up more in pears
- The region has had a 10 year effort to build up predator mite numbers.
- When liquid Lorsban (CHLORPYRIFOS) is used to kill WAA there is an increased problem with two-spotted mite
- Liquid Lorsban in the middle of the season for WAA leads to a serious mite problem. The more sprays that you put on the more pest mites you'll get.
- 75% of orchardists don't put on any mite sprays.
- Pyri has increased in numbers. This works well and then occidentalis starts to work.
- There is a problem with vertimec (ABAMECTIN)
- Pest mite problems correlated with the number of pesticide applications.
- There are increasing numbers of predators without artificial introductions.
- Use mite thresholds to decide when sprays are applied.
- Two spotted mite numbers peak early.
- A bigger problem in pears because the trees are generally older with rougher bark. Most pear orchards will have a full program.
- Lower threshold in pears.
- Pears are less tolerant

## **BRYOBIA MITE**

- Numbers are building up but oils sprays control them

## **SAN JOSÉ SCALE**

- Rare in this area
- Oil sprays close to bud break
- A problem on Granny Smiths and Red Delicious
- Hy Mal (MALDISON) with oil
- Winter oil (3L / 100L)
- More in pear orchards. Related to chemical use.

## **EARWIGS**

- Similar to weevils
- Earwigs are a predator for WAA.
- They like poly pipes and butt guards.
- They can be a serious problem if they are stripping young trees
- Baits.
- Diatomaceous earth doesn't work as well as on weevils.

## **CHERRY SLUG**

- A problem in pears
- Any insecticide – timed well – is effective. Sprayed once or twice.
- Lorsban (CHLORPYRIFOS)
- Two generations in the Adelaide Hills. October/November and March. If you get the first generation then you won't have any problems with the second generation.
- Associated with Hawthorn.

### **APPLE MOSAIC VIRUS**

- Spread by contaminated planting material or root grafting (rarely).
- Symptom expression more in cold, wet years.
- Where conditions are colder crinkle virus is also a problem.
- Avoid dirty nurseries.

### **NEMATODES**

- A problem on sandy soils therefore not much in the Adelaide Hills.
- A problem in the Riverlands.
- Fumigation prior to planting.

### **SNAILS**

- An increasing problem
- Cause damage on both the stem and calyx end
- A ring of copper wire around the butt
- Baiting

### **BIRDS**

- Lead
- Birds are staying in the district right through the season now – until harvest.
- Black cockatoos are a problem particularly because they are protected.
- Presence related to presence of pollen on native trees.
- Not much netting in this region. Orchardists are giving more consideration to netting partly because of climate change.

### **KANGAROO AND DEER**

- Lead
- Electric Fences



## **TASMANIA: MEETING WITH ANDREW GRIGGS**

Meeting was held at Andrew Grigg's home at grove, Tasmania. A focus group was not available in Tasmania. Instead it was suggested that I interview Andrew Griggs. Andrew is an orchardist who has put a number of IPM practices in place on his enterprise. The interview followed the same format as used in the focus group meetings.

### ***List of diseases***

- Black spot
- Powdery mildew
- Core rot
- Phytophthora
- Target spot on Fuji
- Apple Mosaic Virus
- Replant disease

### ***List of pests***

- Light brown apple moth
- Codling moth
- San José scale
- Woolly apple aphid
- Weevils
- Birds
- Apple Dimpling bug
- Heliothis
- Wallabies
- Possums
- Rabbits

## *Management strategies*

### **DISEASES**

#### **BLACK SPOT**

- Calendar- based sprays from early spring at 14 day intervals.
- Spraying alternate rows at 7 day intervals.
- If the weather is dry, application intervals are stretched.
- Copper or sulfur at green tip
- Delan (DITHIANON) at bloom as this is soft on beneficials.
- Chorus (CYPRODINIL) because it is rain-fast
- Delan (DITHIANON) or CAPTAN post bloom
- Try to finish spray applications by November
- One spray application might happen in February for Fuji and other late varieties.
- Urea is applied at the end of the season.

#### **POWDERY MILDEW**

- Two early sulfur applications. The first at green tip and then 14 days later.
- At bloom, Systhane (MYCLOBUTANIL) or Viva (HEXACONAZOLE) with Chorus (CYPRODINIL).
- Three Strobby (KRESOXIM-METHYL) applications through early shoot development
- Regalis
- Prune out infections
- Jonagold is particularly susceptible

#### **CORE ROT**

- Apply Rovral (IPRODIONE) at late pink and full bloom or Bavistin (CARBENDAZIM) before the calyx closes on Fujis, Golden Delicious or Red Delicious.
- Pick out infected fruit during grading
- Nylate in dip water

#### **PHYTOPHTHORA**

- Mounding of rows in low lying areas
- Prevention
- Rootstock choice is important. MM106 is not good.
- MM111 is resistant

#### **TARGET SPOT**

- Fuji is most susceptible
- May have to put 1 spray of CAPTAN on Fujis dependent on the season.
- Also much more of a problem during the second pick.

#### **MOSAIC**

- Nothing done. A nursery problem

#### **REPLANT**

- Use to fumigate with methyl bromide

- Because of use restrictions Andrew tried incorporating compost and dipping roots in Trichoderma and kelp.
- He also put compost and new soil into the furrow.
- After two years the trees are still not growing so he has gone back to Chlorpicrin

## **PESTS**

### **LIGHT BROWN APPLE MOTH (LBAM)**

- Isomates alone for the past eight years but has had to apply some sprays recently.
- Dipel at peak infestation time calculated by trapping and degree day model.
- If both codling moth and LBAM are controlled with isomates you get increased costs.

### **CODLING MOTH**

- Avatar (INDOXACARB) for light infestation pressure
- Has used Calypso (THIACLOPRID) since the year after it was introduced
- Destroy stung apples
- Codling moth comes from neglected orchards
- Sprays are later than LBAM
- There is only 1 generation of codling moth at Grove.

### **SAN JOSÉ SCALE**

- Lorsban (CHLORPYRIFOS) kept populations in check for eight years
- Moved away from oil applications because there were no mite infestations happening
- Has now gone back to oil at green tip (3%, high volume)

### **WOOLLY APPLE APHID**

- Not a big problem because of broad spectrum insecticides.
- Aphylinus is present.
- There are a few areas in the orchard with problems, notably the Fujis
- Butt drench with Confidor (IMIDACLOPRID) on infected trees.
- Uses Confidor at the lower rate and this means that he can only guarantee control for 1 season.
- Regalis to keep soft growth in check.

### **WEEVILS**

- Not a big problem. A few turned up a few years ago and damaged small numbers of pink Ladies
- Monitor with wood with slots cut in it laid on orchard floor.
- Avatar (INDOXACARB) for LBAM and codling moth have reduced the problem.

### **APPLE DIMPLING BUG**

- Nothing is done because they are not a big issue
- They can damage Golden Delicious
- Calypso (THIACLOPRID)

## **HELIOTHIS**

- Serve-Ag monitor for presence of Heliothis
- They have about the same timing as LBAM
- Spray with Avatar (INDOXACARB) or Mimic (TEBUFENOZIDE)
- Often nothing specific is done.

## **BIRDS**

- Currawongs, crows and green mountain parrots
- Prefer Fujis over Red Delicious.
- There is very little netting over apples in this district. There is bird exclusion netting over cherries.
- A secondary problem associated with birds is that they encourage European wasps. The birds damage the fruit and create feeding sites for the wasps.
- Shooting and hang up carcasses
- Air cannons don't work.

## **WALLABIES**

- Shoot
- Paint the butts of trees.

## Appendix 2. Literature Review

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# **Integrated Pest Management (IPM) of Australian Apples and Pears**

Cost-effective production of high quality pome fruit requires producers to control a range of pests and diseases.

## **IPM?**

Integrated pest management (IPM) has been variously defined, for example:

- The combined use of a variety of methods including biological, cultural, physical and chemical to reduce pest abundance whilst minimising the use of pesticides and at the same time producing a profitable crop (Readshaw 1993)
- Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment. (University of California)

Simply put, IPM is the most effective means of controlling pests giving consideration to the long-term consequences of control measures. These consequences include efficacy over an entire season and beyond, the environment, personal and community health and consumer perception

Increasing consumer awareness of pesticide application has led to the use of IPM as a trading chip in global fruit sales.

## **AN AUSTRALIAN HISTORY OF APPLE AND PEAR PEST CONTROL**

*This section of the review provides context in outlining the pest management strategies of the Australian pome fruit industry during the period following the Second World War up until the 1960s.*

### ***Synthetic, broad spectrum pesticides for ease and reliability***

Following World War II insect pest control was revolutionised with the introduction of synthetic pesticides, notably DDT. The Australian apple and pear industry responded quickly to these new pesticides with Western Australian trials commencing in 1944 (Kemp 1946) and other states following close behind (Hogan and Stephens, 1946; Watson, 1946). These early trials acknowledged that while control of codling moth was good, applications led to increased damage from pests such as the mites

*Bryobia praetiosa* (Koch) and *Tetranychus urticae* (Koch). Anecdotally, older orchardists report that massive outbreaks of two spotted mite occurred during the 1950s and 60s. The studies of Watson (1946) linked an increase in the numbers of the pest *Eriosoma lanigerum* (Woolly Apple Aphid) with the deleterious effect of DDT on its natural predator, *Aphelinus mali*. However, because DDT was effective against a wide range of pests application was less complex and this was seen as a positive attribute. A steady stream of effective, broad-spectrum pesticides were released over the following decades

A pre-occupation with efficacy as the sole criterion defining pesticide use continued until the 1960s. Confidence was high when in 1960 the NSW Department of Agriculture published an article publicising its trials with Phenyl Mercuric Chloride (PMC) in the Australian Country magazine entitled “Black Spot is finished” (Wrigley, 1960). No mention was made of off-target health or environmental concerns.

Early Australian research also acknowledged the influence of the orchard environment on pest numbers. For example, dock (*Rumex* spp.) provides a food source for light brown apple moth, *Epiphyas postvittana*. This observation led to a recommendation that clean cultivation be used as a means of pest control (Hogan and Morris 1949).

The elements of IPM existed but the efficient pest control provided by synthetic pesticides meant that there was no prerogative to formulate these elements into a strategy.

### ***The emergence of IPM***

*This section of the review examines the origins of IPM during the 1960s-1980s. In particular it deals with the factors that drove the change of pest management philosophy and gives examples of early successes and failures.*

By the 1960s the secondary effects of continued reliance on broad spectrum pesticides including DDT were becoming obvious. Pests previously regarded as secondary emerged to cause significant problems. Populations of light brown apple moth [*Epiphyas postvittana* (Wlk.)], woolly apple aphid [*Eriosoma lanigerum* (Hsm.)], two spotted mite [*Tetranychus telarius* (L)] and, in Tasmania, the European red Mite (*Panonychus ulmi*) increased as DDT killed their natural predators. Additionally

strains of Codling moth [*Cydia pomonella* (L)] – the target species for DDT – were beginning to emerge which were resistant to DDT (Morris and Van Baer 1959; Lloyd et al. 1970). Collaborative trials were conducted over three years commencing in 1966 in New South Wales, Victoria, South Australia and Tasmania in which the only insecticide applied was ryania (a botanical insecticide made from the ground stems of *Ryania speciosa*; for the control of codling moth). The response of populations of pest insects to the removal of DDT varied (Table 1).

**Table 1. The response of various species of arthropods to the removal of DDT from an orchard pest management schedule.**

Population response	
Increase	Decrease
<i>C. pomonella</i>	Eriosoma
<i>Thrips imaginis</i> Bagn. (NSW only)	<i>T. telarius</i> <sup>†</sup>
<i>Heliothis</i> (SA only)	<i>P ulmi</i> <sup>†</sup>
<i>Campylomma livida</i> Reut. (NSW only)	
<i>Quadraspidotus perniciosus</i> (NSW only)	

<sup>†</sup>Usually but varied across trial sites

These studies established in a fairly crude way, which pests remained problematic following the re-establishment of natural predators.

Another trial conducted at Bathurst, NSW (Thwaite 1980) during 1969-70 and 1970-71 concluded that DDT disrupted populations of the predatory mite *Phytoseius fotheringhamiae* and the coleopteran *Stethorus* to such a degree that they were not able to contain populations of the pest mites *T. urticae* and *P. ulmi*.

Practically these trials highlighted the continued need for pesticide application to control pest insects but also demonstrated that industry required a more sophisticated way to manage pests while maintaining predator numbers where possible.

The Australian industry responded in four ways: A move toward more targeted (pest specific) pesticides, more strategic timing of insecticide applications to minimise total number, introduction of predators of pest species and greater emphasis on cultural / non-pesticide management.



### **Pest specific pesticides**

The keystone species in formulating pest management strategies in Australia are *C. pomonella* (Codling moth) and *Venturia inaequalis* (the fungal pathogen causing apple black spot). It should be noted that neither codling moth nor apple black spot are present in Western Australia where the keystone species are *Eriosoma lanigerum* (apple dimpling bug) and *Podosphaera leucothricha* (the fungal pathogen causing powdery mildew).

Repeated application of broad spectrum pesticides for the control of codling moth often results in the emergence of secondary pests such as two spotted mite. During the 1970s new pesticides were developed and tested which were effective against codling moth but with limited damage to beneficial arthropods. Trials such as those of Bower (testing the insect growth regulator diflubenzuron; 1980) specifically examined the effects of pesticides proposed for use by the Australian apple and pear industry on beneficial arthropods and other “off-target effects” rather than concentrating entirely on efficacy.

However, a careful examination of pesticide registrations and recommendations during the 1970s and 1980s<sup>†</sup> shows that very few new pesticides introduced onto the Australian market were more compliant with IPM than their predecessors. In general pesticide releases tended to be reactionary reflecting the immediate needs of industry rather than long term strategic management. The synthetic pyrethroid Fluvalinate was released on the Australian market for the control of apple dimpling bug in 1988. This was despite research indicating that the synthetic pyrethroids were toxic to mites which preyed on two-spotted mite (e.g. *Typhlodromus occidentalis* and *T. pyri*) but was not toxic to pest mite species (Wong and Chapman 1979). An insert in the 1988-89 New South Wales Department of Agriculture Deciduous Fruits Spray Calendar (Johnson et al 1988) announces the release of Fluvalinate for control of dimpling bug despite acknowledgement of the likely increase in pest mite numbers due to the broad spectrum of action of this pesticide. Overall numbers of pesticides recommended for use on temperate fruits rose from 22 in 1971 to 49 in 1990. Pesticide releases during these two decades included the organo phosphate Methamidophos (1977), the carbamates Methomyl (1978) and methiocarb (1981) and the pyrethroid Fluvalinate (1988) amongst other pesticides which reduce numbers of beneficial organisms.

Another factor driving pesticide diversification during these two decades was the emergence of pest populations which were resistant to popular pesticides. The fungicide Benomyl was first used by the Australian apple and pear industry in 1969 to control the diseases black spot and bitter rot (caused by the fungal pathogens *Venturia inaequalis* and *Colletotrichum*

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<sup>†</sup> NSW Department of Primary Industries Orchard protection Guides 1971-1990

*gloeosporioides* respectively). In 1974 the Australian apple and pear industry became the first in the world to report populations of *V. inaequalis* resistant to benomyl (Wicks 1974). During the 1970s and 1980s an effective resistance management strategy was developed and implemented so as to allow sustainable use of fungicides. The introduction of new fungicide groups (table 2) allowed orchardists to diversify their fungicide applications and avoid over-reliance on a single chemical type.

**Table 2. Fungicides released to the Australian temperate fruits industries 1970 - 1990**

Fungicide	Year of introduction	Fungicide group <sup>1</sup>
Mancozeb	1972	Y
Thiophanate methyl	1975	A
Carbendazim	1975	A
Chlorothalonil	1978	Y
Triforine	1978	C
Bupirimate	1979	H
Fenarimol	1979	C
Metiram	1979	Y
Cupric hydroxide	1980	Y
Procymidone	1980	B
Etaconazole	1981	C
Bitertanol	1984	C
Propiconazole	1984	C
Zineb	1985	Y
Ziram	1985	Y
Penconazole	1987	C
Flusilazole	1989	C

<sup>1</sup> Source: The Pesticide manual, 12<sup>th</sup> Edition, 2000 (British Crop Protection Council)

Introduction of a greater range of curative fungicides also allowed fewer; more strategic fungicide applications (see More effective use of pesticides, page 82)

Following the emergence of codling moth populations resistant to DDT and DDT's withdrawal from the market the Australian apple and pear industry was in need of effective alternative management strategies in the early 1970s. It was well-known that broad-spectrum alternatives had a detrimental effect on predators of mites. An early alternative proposed the use of Lead arsenate during the first generation of codling moth. Lead arsenate is relatively harmless to *Stethorus* (a Coccinellid predator of pest mites). This application of lead arsenate

was thought to allow *Stethorus* populations to remain unaffected, controlling pest mites early in the season. Having gained mite control, subsequent pesticide applications could be less selective (Readshaw, 1971). This alternative was later rejected because lead arsenate when applied in this manner failed to provide commercially acceptable control of codling moth (Readshaw 1972).

Chlordimeform was released onto the Australian market in 1975 with its initial application being as a miticide. Research was conducted during the early 1970s to evaluate its potential as a control agent for codling moth based on its ovicidal action (Walters 1976a). Subsequent trials showed however that Chlordimeform did not provide commercially acceptable control of codling moth under high infestation pressure (Thwaite et al 1977). The product was withdrawn from the Australian market in 1977 for health reasons.

Diflubenzuron – the first insect growth regulator registered for use against codling moth in Europe – was also trialled in Australia. This product was considered more IPM-compliant and its potential was evaluated (Bower 1980). Despite initial success, the product failed to provide consistent control of codling moth and also suppressed *Stethorus* through its toxicity to eggs (Bower and Kaldor 1980).

The industry standard became 3-9 applications per season of Azinphos-methyl for codling moth control. This practice spanned nearly 35 years before populations of codling moth resistant to Azinphos-methyl were found in 1991 (Thwaite, 1996). It quickly became apparent that resistance was wide spread (Thwaite 1999) and that no other insecticide offered comparable efficacy.

Pest mites are a secondary pest which arose as a consequence of pesticides applied for other arthropod pests such as codling moth (e.g. DDT and Azinphos-methyl). In the absence of these pesticides, predators control pest mites. Nevertheless under the pest management regime put in place by the Australian apple and pear industry, pest mites became a significant problem. Trials at Bathurst Agricultural Research Station during the 1960s showed that it took predatory species such as *Stethorus* three years to become re-established following cessation of DDT sprays (Walters 1976b). During the early 1970s only broad spectrum insecticides (largely organophosphates) were available for the control of pest mites. A series of trials were conducted searching for miticides which were specific to pest mites (e.g. Walters 1976a, 1976b) and new acaricides were introduced including the Sulfite ester propargite (1977), and the Organotin cyhexatin (1976) and azocyclotin (1979). The ability of pest mites to develop resistance to acaricides is a major hurdle to the development of

sustainable new products. Both pest mite species have become resistant to a series of pesticides. Periodically, orchardists run out of effective miticides, particularly in warmer production areas such as the Goulburn Valley. Orchards then suffer severe mite outbreaks until new products become available. Two such events occurred during the 1980s; first with resistance to the organotin and then with resistance to the ovicides Clofentezine and hexythiazox. Clearly an ecological approach was required.

### **More effective use of pesticides**

Adoption of IPM requires orchardists to use pesticides in the most efficient way considering efficacy, economy and sustainability. Hence, strategies have been developed which allow for the minimum number of pesticide applications at the lowest concentration needed to control pests.

*Reduced rates and volumes.* In South Australia trials during the 1980s showed that commercially acceptable control of black spot and codling moth could be achieved with low volume pesticide application with rates as low as 25% of the commercially accepted norm (Wicks and Nitschke 1986, Wicks and Granger 1989). This research emphasised the importance of being aware of infection / infestation pressure and the potential value of the crop (particularly with respect to variety).

*Introduction of curative fungicides and forecasting systems.* In theory it has always been possible for orchardists to apply fungicides in response to weather which is perceived to favour disease development.; in practice this is very difficult. Unexpected rain events and inaccurate weather forecasts render this approach far too risky for commercial production and most orchardists operated on a calendar basis with the residual action of fungicides providing a continuous protective cover against disease. Dodine (Melprex, Syllit) was the first curative / systemic fungicide available to the Australian apple industry when it was released in 1969. In contrast to earlier fungicides which kill fungal spores on contact, Dodine is able to kill pathogens up to 36 hours after they have infected and penetrated fruit (the kickback period). Orchardists were now able to wait until after infections had occurred and “cure” infected fruit before symptoms were visible. This 36 hour window of opportunity was difficult to exploit, but during the 1970s and 1980s a series of Demthylolation Inhibitor fungicides offered gradually longer kickbacks (table 3). These fungicides allowed orchardists to adopt a less conservative approach to black spot management. They only needed to be applied when an infection was likely to have occurred.

**Table 3. Curative fungicides available to the Australian pome fruit industry.**

<b>Fungicide</b>	<b>Kickback period</b>	<b>Year of introduction</b>
------------------	------------------------	-----------------------------

Triforine	3 days	1978
Fenarimol	4 days	1979
Triadimefon	4 days	1981
Penconazole	4 days	1987
Flusilazole	5-6 days	1989

A logical extension of this new technology was to determine more accurately when infections had occurred. Black spot infections occur following deposition of spores and incubation at suitable moisture and temperatures. The relationship between infection, moisture and temperature is constant and models were first developed to predict disease occurrence during the 1950s ( Mills and LaPlante 1951).

The first attempts to verify that disease could be effectively controlled using these predictive models was carried out in Victoria and showed that effective control of black spot could be achieved using 2-3 less spray applications (c.f. a protectant cover schedule) (Washington 1980, 1981). In 1983 newly developed, computerised black spot prediction units were collaboratively tested in Queensland, New South Wales, Victoria and South Australia (Penrose et al. 1985) and was found to show significant potential for use under Australian conditions. The performance of these units was refined over following seasons (Penrose 1989, 1992). Curative application of fungicides in response to infection became and remains a viable option for black spot management.

*Monitoring of pest phenology to optimise pesticide efficacy.* In many cases it is easier to kill pests when they are at certain stages of their life cycle. In these cases applying control strategies at the wrong time will result in wasted effort and money.

An early attempt at optimising pesticide effectiveness by monitoring for the presence of codling moth was made in the Adelaide Hills (Madge 1972). Lure pots were used to detect the presence of adult male moths. Azinphos-methyl was applied at half-strength when moths were first trapped. This trial concluded that restricted use of chemical control, with careful timing had kept populations of codling moth and other Tortricid moths at low levels. However this method is relatively inaccurate. Lure pots were difficult to interpret and often female moths were often not caught until after mating and oviposition had occurred.

Improvements were made during the 1980s through the use of pheromone lures. Pheromone lures were used to trap moths and monitor populations. Having established population thresholds phenology models based on accumulated degree days can be used to predict key

events in the codling moth life history and optimise the efficacy of pesticide application through appropriate timing (Williams 1984, 1989).

### **Introduction of predators and other biological control agents**

The most significant example of biological control in the apple and pear industry is the introduction of predatory mites. This program was initiated in the late 1960s and continues to be successful today. In 1969 a mite predator (*Typhlodromus occidentalis*) of two spotted mite was found in Washington State, USA which had developed resistance to Azinphos-methyl (Hoyt 1969). This discovery allowed integration of biological control of a pest mite and chemical control of codling moth. The predaceous mite was introduced into Australia from North America and released into an orchard near Canberra in 1972. The mite effectively controlled the pest species two spotted mite and by 1976, the predaceous mite had been released to another 30 sites throughout Australia (Readshaw, 1975(b); Ford 1976). A series of predatory mites were introduced into Australia but only one, *Typhlodromus pyri* (a pesticide resistant strain identified in New Zealand) became established and controlled European red mite (*Panonychus ulmi*) (Hoyt 1973)

The introduction of predatory mites required that growers avoid using a number of pesticides which would be toxic to the predators. Many of these were popular and included Carbaryl, methidathion and benomyl. Especially contentious was avoidance of DDT which was an effective control of early season pests such as apple dimpling bug and plague thrips. Because these pests cause sporadic, serious damage the residual effect of DDT was seen as an advantage over less persistent substitutes such as endosulfan. This situation was resolved when DDT was withdrawn from the Australian market in 1987 (Thwaite, 1997).

*Bacillus thuringiensis* is a gram-negative, soil-inhabiting bacterium and is the active ingredient in a bacterial insecticide effective against lepidopterous hosts (DiPel®). The product was first released in 1972 and has been used by the Australian industry to control surface feeding pests such as light brown apple moth and heliothis (Thwaite 1997). It has the practical and economic disadvantage of requiring frequent applications to maintain coverage. However, it has established and maintained markets-hare.

### **Cultural / non-pesticide management**

Many common orchard practices reduce the numbers of pests which infest orchards. These practices can be exploited to minimise insect pests and disease. Urea is commonly applied to pome fruit orchards as a fertiliser. Research carried out in the late 1980s verified the value of post-harvest, pre- leaf fall urea sprays following a bad black spot season. Urea expedites

breakdown of the fallen leaves which usually harbour overwintering spores of *V. inaequalis*. It also promotes worm activity. Ground application of 5kg/100L was shown to reduce carry-over spores by up to 95% (Penrose 1993)

Application of pesticides after harvest facilitates long term storage and enables the pome fruit industry (particularly apples) to extend the period for which markets can be supplied. Logically these are the last pesticides applied before consumption. They are also applied directly to fruit. From both a public health and regulatory point-of-view there has been a long history of developing non-chemical pesticide treatments for after-harvest application. Chlorination of dump tank water can be used to reduce post harvest rots in apples (Combrink and Visagie 1982). Australian attempts to improve control of postharvest rots using UV irradiation. An experimental ultraviolet irradiation treatment of water in a fruit-handling system reduced spore numbers of *Penicillium expansum* (the fungal pathogen causing blue mould), but not to a level which would suggest that the technique is worth pursuing to commercial application (Penrose et al. 1987)

### **IPM TODAY**

*This section of the review examines the current status of IPM in the Australian pome fruit industry. It focuses on the research which has occurred during the last two decades (1990-2008) and examines which management techniques have been successfully adopted by orchardists. Particular emphasis is placed on recent research administered and partially funded by Horticulture Australia Limited (HAL). It is notable that the spectrum of pests and diseases dealt with which the research deals has expanded greatly over the last two decades. This expansion is a result of the reduction in use of broad spectrum pesticides, the introduction of specific management techniques and the consequent increase in importance of pests previously considered secondary.*

The Australian apple and pear industry peak body APAL (formerly AAPGA) through Horticulture Australia Limited have made a significant investment in development of IPM in Australia and adaptation of international methods to Australian conditions. During the period from 1988 to 1995 \$1.67 million AUD was devoted to IPM research. The percentage of Research and Development funding devoted to IPM varied annually between 30-50% of the total research budget. (Thwaite 1997).

A report commissioned by the Australian Apple and Pear Growers Association (the predecessor of APAL) reviewed investment in pest, weed and disease management research and extension projects from 1991-92. The report found that the investment was well-managed, focused and had accelerated IPM (Final Report – HAL AP98067).

### ***‘Soft’ or alternative pesticides***

IPM advocates the use of pesticides which effectively control pests but minimise off-target damage. It is costly to develop new pesticides and – given the comparatively small size of the Australian pome fruit industry – all of the pesticides available have been developed for larger markets. ‘Softer’ chemistry is available in Australia because of the movement toward IPM and regulatory restrictions in larger production regions; particularly North America and Western Europe. The overseas and in-country testing of these chemicals is largely done under ‘commercial-in-confidence’ arrangements and is not part of the IPM literature. However there are several recent examples of research examining the benefits of alternative chemistry.

*Kaolin:* A sprayable formulation of kaolin (3% solution) was applied at 10-14 day intervals under mild, Tasmanian conditions to Gala and Fuji apple trees. This treatment reduced aphid infestation from 26 to 9 colonies per tree. Because of the opaque nature of the substance there have been concerns about its effect on tree growth and photosynthesis and fruit colouring. However under these conditions there was no effect on vegetative growth including fruit yield and quality (Brown et al. 2000, Brown et al. 2001). Kaolin is registered for use on pome fruit (Surround<sup>®</sup>), but isn’t widely used<sup>†</sup>.

*Hydrated lime:* Increasing the pH of apple leaf surfaces to 9.0 inhibits apple black spot spore germination and formation of infection hyphae. As a consequence regular applications of hydrated lime have been shown to control apple black spot (Wong 1997).

*Insect Growth Regulators:* The first insect growth regulator to be tested under Australian conditions was diflubenzuron (see “Pest specific pesticides” page 79). This pesticide was not commercialised because of inconsistent efficacy against codling moth and because of its deleterious effect upon the predatory insect *Stethorus*.

Fenoxycarb (Insegar<sup>®</sup>) was evaluated and released to the Australian market in the early 1990s (Henderson 1990). Fenoxycarb was promoted as suitable for IPM programs. It was also shown to be effective against codling moth, even at high infestation pressures (Readshaw and Cambourne 1991).

Another Insect growth regulator – tebufenozide (Mimic<sup>®</sup>) was released soon after. Again, the product proved to give comparable control of codling moth to the industry standard azinphos-methyl (Valentine et al. 1996). Tebufenozide has also been shown to allow rapid build-up of natural enemies of pest mites and other arthropod pests (Gurr et al. 1999)

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<sup>†</sup> According to grower interviews conducted 2007-08 as part of HAL AP07009.



*Other environmentally soft pesticides (Spinosad and thiacloprid):* There is a group of insect pests which occur during flowering and which cause damage which reduces fruit quality later in the season. These pests include thrips (Western flower thrips and plague thrips) and Apple Dimpling Bug. Management of these pests is difficult because of their sporadic appearance and due to the fact that they attack developing ovules where they are protected from spray applications by outer floral parts (petals, calyces). In the past these pests have been managed by applications of Endosulfan and Chlorpyrifos (both IPM disruptive). A range of ‘softer’ insecticides have been tested to determine their efficacy and the extent to which they disrupt populations of predators of orchard pests (Nimmo 2005). Spinosad at a range of rates significantly reduced numbers of plague thrips and western flower thrips, effectively reducing the ‘pansy spot’ symptoms associated with infestation. Apple dimpling bug damage was significantly reduced following thiacloprid applications and there was no mortality to the predatory mite *Typhlodromus pyri*.

Although not popularly recognised as disruptive of populations of beneficial organisms several broad spectrum fungicides are harmful to IPM. The suite of fungicides available today includes many with specific action which have low off-target toxicity. Trifloxystrobin uses its ecological credentials as a selling point.

***Monitoring and models: the right pesticide at the right time***

During the last twenty years the Australian apple and pear industry have continued to use pest monitoring as a tool allowing strategic application of fewer pesticides. Models have been refined to allow greater accuracy and new pests have been the subject of research.

*Black spot:* Much of the work to establish electronic black spot warning services was completed during the 1980s (see “more effective use of pesticides” page 82). During the 1990s black spot warning services became widely distributed throughout production regions in which black spot is a problem. Emphasis during the 1990s was upon improving the models driving these forecasting units (Penrose 1992, Penrose and Dodds 1994, Penrose and Nicol 1997) and extending the results to farmers (Washington et al. 2001, Dray et al. 1997). Models were developed which incorporated the likely level of overwintering inoculum based on assessment of foliar scab levels after harvest (Washington et al. 2001)

*Codling moth:* With the development and availability of codling moth pheromone traps and more accurate electronic means of monitoring temperature it became possible to offer a practical service allowing orchardists to reduce numbers of pesticide applications. A codling moth phenology model was developed in the USA which enables the life-cycle to be

measured through heat units commonly known as ‘degree days’ (Thwaite 1997). Pheromone traps are used to determine when early flights occur (‘biofix’) and degree days are calculated enabling orchardists to spray only when mated females are likely to be present. This system of timed pesticide application was tested in Victoria (Williams 1989) and NSW (Thwaite 1993). This resulted in the establishment of an Orange District codling moth warning service (Thwaite 1994), which became available to growers in 1995/96. In recent years, with the advent of a new generation of electronic pest monitoring equipment this model has been integrated into units previously exclusively used for black spot (Hetherington and Thwaite pers. comm).

Difficulties arise with this system where codling moth control relies on a combination of mating disruption (see Mating disruption and Area wide management page 90) and reduced pesticide applications. Because mating disruption saturates the orchard with pheromones, the numbers of moths caught in monitoring traps is reduced. In these cases an alternative lure, not reliant on sex pheromones is required.

In 2001-02 field trials were conducted in Victoria (Il’Ichev 2004a, Il’Ichev et al.2004) and NSW (Thwaite et al. 2004) the use of ethyl (2E, 4Z)-2,4-decadienoate (pear ester) as a species-specific and attractive pear-derived kairomone for male and female moths was tested. The ability to also trap females allowed greater accuracy to be built into degree-day models. The technique was promising and work on this system continues. It should be noted that monitoring appears to be less effective in pear orchards, possibly because of the level of background pear volatiles masking the effects of the pear ester.

*Mites:* the publication of the Mite Management Manual (Bower and Thwaite 1995; funded by HAL project AP002) represented the distilled knowledge gathered through research from 1976-1972. It provided orchardists with practical techniques for managing pest mites using IPM techniques. IPM for mites became known as IMC (Integrated mite control). At the core of these techniques is monitoring to gain a knowledge of the relative size of pest and beneficial mite populations and action based on these thresholds.

In 1990-92 the feasibility of releasing predatory mites in Western Australian orchards was examined (Learmonth 2000). Mass releases of the predatory mites *Typhlodromus occidentalis* and *Phytoseiulus persimilis* were made and populations of two-spotted mite monitored. The study found that *T. occidentalis* became more abundant than *P. persimilis* after release *T. occidentalis* reduced mite numbers but not enough to obviate the need for miticide application.

## ***Improved application techniques: Hitting the target***

### **Integration**

Australian IPM research has tended to concentrate on one or a small complex of pests. The majority of early IPM research in Australia concentrated on controlling individual pests. There is now a tendency to consider pest complexes and the interaction between species and the management techniques applied to control them. Thwaite (1997) provides a list of such projects carried out up until the late 1990s (AP004, AP130, AP201, AP206 etc). More recent studies include AP00008 (Nimmo 2005; plague thrips and apple dimpling bug) and AP99034 (Readshaw 2001; Codling moth, mites and woolly apple aphid)

Even with the trend toward more specific pesticides it is rare for a pesticide to only be effective against a single pest. In the past blanket coverage of broad spectrum pesticides obviated the need for orchardists to deeply consider pesticide scheduling. One of the greatest – and often least recognised – contributions to IPM is the publication of IPM compliant pesticide schedules by state government agricultural agencies which allow orchardists to integrate management to control a number of pest species with a single action.

### **Application technology**

*Bait sprays for fruit fly.* Perhaps the best example of targeted pesticide application is the use of insecticide bait sprays to control fruit flies. Full cover sprays for the control of Mediterranean fruit fly (*Ceratitis capitata* Wiedemann) can be reduced or even fully avoided in Western Australian orchards through the use of bait sprays (de Lima 1998). These bait sprays consisted of traps which were similar to the Lynfield type lured with Capilure® a male Mediterranean fruit fly attractant, and a killing agent of 1 cm<sup>2</sup> dichlorvos impregnated plastic squares. This approach works much better on larger orchards or where an area-wide management strategy can be undertaken. It should also be emphasised that where orchards are mixed with pome and stone fruit (or other fruit fly hosts) all trees susceptible to fruit fly infestation require treatment.

Both Dimethoate and Fenthion are extremely disruptive to IPM. Additionally, both insecticides (particularly dimethoate) are likely to be withdrawn in the near future.

*Butt sprays.* A number of insect pests of pome fruit have a soil inhabiting phase in their life cycle. For example, under Australian conditions woolly apple aphid (*Eriosma lanigerum*) overwinter underground and migrate into tree canopies from mid-October. Following a rapid build up in numbers, aerial populations usually peak in January. The registered application method for Imidacloprid for use against woolly apple aphid is to identify and tag infested apple trees during autumn and then to apply the pesticide in a solution at the base of the tree.

The label of this product claims that this treatment is likely to give two years of control (Product label: Bayer Confidor® 200SC; 2008). Similarly, butt drenches of cypermethrin are registered for use against weevils (Learmonth 2000). Both cypermethrin and imidacloprid are toxic to beneficial insects but drenching minimises both the probability of off target damage and the total amount of pesticide applied.

*High volume versus concentrate spraying.* There is a tendency for apple and pear growers to move from conventional dilute or high volume pesticide applications toward low volume or concentrate spraying. A possibility exists that this tendency to apply more concentrated pesticides may increase the toxicity of these products toward beneficial arthropods. Research was conducted to determine if this was the case. Populations of green lacewings (*Mallada signata*), brown lacewings (*Micromus tasmaniae*), parasitic wasps (*Trichogramma spp*), an predatory mites (*Typhlodromus occidentalis*, *T. pyri* and *Phytoseiulus persimilis*) and other beneficial arthropods were monitored following application of pesticides at low and high volume. The results showed that application of chemicals by concentrate spraying machinery does not generally increase harm to beneficial arthropods populations over dilute spraying (Cole and Laukart 2001).

### ***Mating disruption and area wide management***

Virgin female moths disperse sex pheromones as a means of attracting male moths. Mating disruption involves the utilization of synthesized sex pheromones to disrupt reproductive cycles. Inundative applications of synthetic sex pheromones are released into the orchard, confusing male moths, preventing them from locating and mating with females. An important characteristic of this management technique is that it is most effective in larger orchard blocks or –preferably – where it is applied by all orchardists in a district (Vickers et al. 1998). Hence, mating disruption often occurs as a component of area-wide management.

*Light brown apple moth:* Research on mating disruption of light brown apple moth began in the 1960s and continued during the 1970s (Bartell 1968, Bartell and Lawrence 1977). The evolution and current status of light brown apple moth mating disruption have been extensively reviewed (e.g. M Williams 1993, M Williams 1995, Cockerill 1996). Mating disruption is now a commonly used for management of this pest by commercial orchardists.

*Codling moth and Oriental Fruit moth:* Development of a mating disruption technique for codling moth in Australian orchards commenced in 1980 (Rothschild and Vickers 1982). Several reviews and reports have been written on the early development commercialisation and implementation of this system (Nicholas et al. 1999, Vickers et al. 1993). The product Isomate® C was released in 1993. In cases where pest pressure is low Isomate® C provides

adequate control of codling moth without the need for supplementary insecticide sprays. Under higher pressure supplementary insecticide applications are required but orchardists are advised to aim to reduce pest pressure over several seasons to a point where mating disruption alone provides sufficient control. This technique has been widely accepted by growers and the orchard area in which Isomate<sup>®</sup> C was used to control codling moth gradually increased (Thwaite 1997)

Oriental fruit moth (OFM) is primarily a pest of peaches and nectarines. However, during the 1990s it became a significant pest of pome fruit (particularly pears) in some regions including northern Victoria. OFM was successfully controlled in stone fruit orchards in the Cobram region using an area wide management approach in which 40 contiguous orchards (1100 hectares) were treated with Isomate during the 1997-199 seasons.

Orchardists in the Shepparton region were interested in participating in research which would examine the establishment of area wide management Mating disruption IPM strategy for OFM and codling moth in both stone and pome fruit orchards (Il'ichev 2004). Specific investigations within this research included

- Effectiveness of reduced application rate of mating disruption for OFM together with the full registered rate for codling moth control on pears. (Application of dispensers for both pests at full rate was prohibitively expensive)
- Effectiveness of new Isomate C/OFM dispensers for mating disruption of OFM and codling moth together on pome fruit.
- Longevity, release rate and emission characteristics of new C/OFM dispensers.
- Effectiveness of sprayable micro-encapsulated pheromone formulation for mating disruption of OFM on peaches and pears.

The results of the trial indicated that effective control of both pests could be obtained using half rates of OFM dispensers and full rates of Isomate<sup>®</sup> C . However, pheromone release rates where separate dispensers were applied were uneven with OFM pheromones being released over a 100 day period and codling moth pheromones over a longer period of approximately 200 days. Effective control could also be obtained by using the combined product and this gave amore even length of dispersal between OFM and codling moth pheromones. The micro-encapsulated product gave similar performance to dispensers and offered significant savings in labour during application.

### ***Cultural management***

Beyond the use of pesticides, orchardists are able to control their pests by adopting orchard management practices to develop environments which are inhospitable for pests. Many orchardists are aware of these practices and adopt them as a matter of course without the need

for research. The specific examples given here are those which have been developed or verified scientifically during the last two decades.

### **Crop regulation**

Carbaryl is frequently used a crop regulator which thins fruit (allowing the remaining fruit to acquire greater size). Unfortunately carbaryl is not compatible with IPM. Benzyladenine was developed as an IPM compliant alternative and its first commercial release was in 1996 (Thwaite 1997).

Prohexadione-ca (Regalis<sup>®</sup>) is a registered crop regulator. It is applied to over-vigorous trees leading to shorter internodes, more open canopies and thickening of shoots. Woolly apple aphid (*Eriosoma lanigerum*) favours young, vigorously growing, closed canopies. In trials during 2004-05 application of Regalis<sup>®</sup> on Fuji apple trees at label rates inhibited development of Woolly apple aphid colonies (Frost 2006). Regalis<sup>®</sup> may be a useful tool in the management of infestations in vigorous trees.

### **Ground Covers**

Some insect species (e.g. weevils and thrips) rely on orchard ground covers to provide them with food, shelter or breeding sites. Certain species of ground cover are preferred by specific pests and replacement of these ground covers with less desirable species should reduce pest numbers. Control of weevils is difficult and orchardists often resort to pesticides which are not IPM compliant. Studies in Western Australia examined whether ground covers could be used to reduce pest populations (Learmonth 2005). Initial pot trials showed that weevil larvae did not like clover. However, when pots were planted with both clover and apple trees this inhibitory effect did not persist. There was no effect where another food source (apple roots) was present; there was no real inhibitory effect beyond the larvae simply not liking to eat clover. Further research identified annual ryegrass (with and without an insect-toxic endophyte) to be truly inhibitory toward weevil larvae. Other grass species ryegrass, kikuyu, oats) were inhibitory to adult weevils. Field trials of ground covers are still to be completed. It is noteworthy that the researchers provide the warning that any change to ground cover composition should consider the effects on other pest and beneficial organism in the orchard ecosystem.

A second strategy is to plant ground cover species which favour beneficial arthropods. A Victorian study monitored populations of beneficial insects and fruit damage (pears and apples) in orchards planted with various ground covers (e.g. buckwheat, white mustard, chicory, yarrow, fennel, borage, Queen Anne's Lace, perennial ryegrass, fescue, fenugreek) (Ridland et al. 2006). This trial was plagued with difficulties in establishing ground covers largely as a result of drought but showed sufficient promise to warrant further investigation.

### **Unwanted alternative hosts**

Apple dimpling bug (*Campylomma liebknechti*) is one of the most serious pests of apples in mainland Australia. In the absence of codling moth, orchardists consider apple dimpling bug to be the most serious pest of apples in Western Australia. Apple dimpling bug survive on many plant species. A study conducted in the early 1990s found apple dimpling bug on 62 plant species from 18 plant families (Bower et al. 2000). Most notable amongst these hosts was wattle (*Acacia spp.*). Dispersal from tree-to-tree provides a means of long distance spread for this pest. It is recommended that where possible, wattles should be removed close to the orchard and if wattles are present extra care is required with monitoring and subsequent pesticide application.

### ***Varieties and breeding for resistance***

Breeding of apple varieties for resistance to pests is a difficult task. Screening often requires mature or semi-mature trees and resistance tends to be polygenic. This means that breeding takes both time and – because large numbers of progeny require screening - resources

This is particularly the case for arthropod pests. Several Australian studies have examined the susceptibility of common commercial varieties to pests. For example San Gupta and Miles (1975) and Asante (1994) examined the susceptibility of various apple varieties to woolly apple aphid, Bengston (1995) examined the susceptibility of varieties to two spotted mite and Washington et al. (1998) examined the susceptibility of varieties to apple black spot. and powdery mildew.

*Apple black spot:* World-wide there are six known races of *Venturia inaequalis* which infect apples resulting in the disease black spot. Australia has only one of these races (race 1) (Heaton et al. 1991) greatly simplifying efforts to breed black spot resistant varieties.

In 1984 a program was commenced in Queensland to produce black spot resistant varieties of apples (Baxter and Heaton 1986). Improved genetic material was accessed when the plant breeder travelled to North America and used Australian pollen to cross with a range of disease resistant varieties. Resistant parents used were the cultivar Prima and the selection Co-op 18 from the United States of America. These parents have the major gene, Vf, derived from the crab apple *Malus floribunda* Siebold ex Van Houtte 821 which is resistant to *V. inaequalis* races 1 to 5 (Heaton et al. 1995). Seedlings from this cross-pollination work were planted at Applethorpe Research Station in winter 1995 with the first fruit being harvested in 1997. At this stage selections demonstrating resistance to black spot were assessed on the basis of agronomic desirability and fruit quality.

Climatically adapted apples with black spot resistance were selected during four years of progeny and consumer evaluations from 2000 – 2004. Of several superior selections identified, RS103-130 is one of outstanding promise. An application has been lodged for plant breeder's rights protection of RS103-130 and trees are available for commercial release. A number of other promising black spot resistant varieties have come from this work (Zeppa 2006). Several reviews of this work have also been published (Zeppa et al 2001, Zeppa et al. 2002, Middleton et al. 2007, Tancred et al 2005a, Tancred et al. 2005b).

*Woolly apple aphid:* A breeding project commenced in 1996 with the specific aim to develop woolly apple aphid-resistant dwarfing apple rootstocks for Australian conditions. This project, initiated by NSW DPI, and funded by APAL through HAL has utilised resistant parent material from around the world. The Malling-Merton (MM) series of rootstocks and its MM derivatives are a great source of resistance and have been used in this program. Other sources of resistance include *Malus seiboldii* and *Malus robusta*. The *Malus robusta* component has been introduced through the CG (Cornell University, Geneva) series which have *M.robusta* as one parent. It has been important to incorporate a diversity of species into the program for both WAA resistance and dwarfing characteristics.

The program is now split into two parts. Following an expansive culling program for material with non desirable horticultural traits, enough productivity data is now available from the first group of crosses to select a group of elite stocks. These stocks possess, suitable dwarfing traits and yield capacities equivalent to or better than M9. Parentages of these stocks include M26, M9, Ottawa 3 and MM110. Selected elite stocks have been compared with M9, M26 and MM106 in the evaluation orchard. It is anticipated that newer rootstocks like CG202 (Cornell-Geneva 202) from Cornell University, Geneva and JM 7 from the Morioka Research Station in Japan will be used in the program as further comparisons.

The second group of crosses were planted to the evaluation orchard in 2004 and require further evaluation although some stocks were eliminated due to excessive vigour. It is anticipated that within three more seasons an elite group will emerge to be included in the APFIP program.

*Genetic modification:* Several early projects developed the tools necessary to produce transgenic apple varieties expressing genes for pest resistance (AP108, AP122)

In conjunction with a conventional breeding program to develop resistance to the disease black spot (see section above), genetically transformed material demonstrating black spot



resistance was obtained from the University of Sydney (Zeppa 1998). In 1997 a number of these transgenic lines commenced cropping and work is ongoing.

A gene from an ornamental tobacco plant, which makes the plant naturally resistant to insects, has been successfully introduced into Royal Gala apples. This gene produced a substance that made the apple unpalatable to insect larvae. An insect feeding trial showed that about 40% of the light brown apple moth which fed on the tree with the introduced gene died. Adults which developed from larvae fed with transgenic leaves were smaller than normal. As smaller adults are less fecund, feeding on transgenic apple leaves may have an effect on the population dynamics of the light brown apple moth (Maheswaran et al. 2001)

### ***Biological control***

Many of the advances in IPM have involved biological control. Improved management of pest mites has involved the release of introduced biological control agents and increases in populations of endemic beneficial arthropods as a result of reduced use of ‘hard’ insecticides. This has been dealt with earlier in this review (see for example ‘Soft’ or alternative pesticides page 86). This section examines biological control agents which have been studied during the last two decades specifically for the control of pests of pome fruit.

*Woolly apple aphid:* The tiny parasitic wasp *Aphelinus mali* was introduced into Australia in the 1920s and provided effective control of woolly apple aphid until the pome fruit industry began to use broad spectrum pesticides in the 1940s (Thwaite 2007). As the Australian pome fruit industry reduces use of broad spectrum pesticides *A. mali* is once again emerging as a biological control agent for woolly apple aphid. However, in cooler climates such as Tasmania and the New England Tablelands of New South Wales, *A. mali* alone will not prevent woolly apple aphid causing damage which exceeds economic damage levels (Asante and Danthanaryana 1992, Asante 1994, 1999). Note also the emergence of biological control agents and their negative effects on populations of woolly apple aphid in early insect growth regulator work carried out by Readshaw (Thwaite 1987). Recent work has suggested that – at least in some cases - the key beneficial arthropod predator of woolly apple aphid is European earwigs. In trials at Bathurst NSW, *A. mali* and other flying natural enemies of woolly apple aphids (e.g. ladybirds, lacewings, hoverflies) were unable to reduce populations of the pest below economic thresholds without earwigs (Nicholas et al. 2004, Nicholas et al. 2005).

*Codling moth:* an early attempt to use the codling moth granulosis virus (CMGV) as a biological control agent (Lloyd et al 1970) was not successful because the pathogen was not sufficiently persistent as the virus was inactivated by UV light (Morris 1972, Huber 1986).

With the availability of European formulated commercial products using CMGV as their active ingredient (Carbovirusine<sup>®</sup> and Granupom<sup>®</sup>) research on CMGV re-commenced at Applethorpe in 1991 and slightly later in Victoria. CMGV failed to provide adequate control of codling moth with damage 30 times greater than plots treated with azinphos-methyl (Page 1993).

The entomopathogenic nematode *Steinernema carpocapsae* parasitises and kills 90-100% of overwintering codling moth larvae under ideal conditions in the laboratory. However HAL project AP201 found that under more realistic field conditions this pathogen was unable to control codling moth to the extent that it did not cause economic damage.

*Light brown apple moth:* Sexton (1995) reported that the parasitic wasp *Trichogramma carverae* showed potential as a biological control agent for light brown apple moth. *Trichogramma* are minute wasps, less than 0.5 mm long. The adult female lays her eggs into moth eggs. When the wasp eggs hatch, the larvae devour the developing caterpillar inside the moth egg. The *trichogramma* larvae pupate and grow into fully formed wasps inside the moth eggs.

The principal limitation to the use of *Trichogramma* is its sensitivity to the majority of commercially used pesticides. It is therefore most suitable as supplementary control where mating disruption is practiced (for light brown apple moth and/or oriental fruit moth and/or light brown apple moth). *Trichogramma carverae* is now available from commercial suppliers of biological control agents (e.g. Bugs for Bugs)

*Powdery mildew:* A strain (AQ10) of the mycoparasitic yeast *Ampelomyces quisqualis* was tested in HAL project AP249 - Biological control of apple powdery mildew. Apple powdery mildew fungicide applications were reduced by at least 50% and powdery mildew maintained at acceptable levels when the biological product AQ10 was substituted for fungicide applications, under suitable weather conditions.

*Weevils:* weevils are a serious pest in some regions, particularly western Australia and northern Victoria. Control of weevils is difficult and often relies almost exclusively on application of non-IPM compliant broad spectrum insecticides. The parasitic larvae *Heterorhabditis zealandica* had shown promise as a biological control agent against soil-dwelling beetle pests and its efficacy against three species of weevil in Australian pome fruit orchards was studied by Learmonth (2005). Nematodes provided insufficient control of weevils to warrant further study. It was thought that the failure of nematodes was due to a

series of factors including the size of the target species and inappropriate temperatures and soil moisture conditions.

Core rots: Certain fungi and bacteria which exist on plant surfaces have been shown to inhibit fungal pathogens by a variety of mechanisms (nutrient or space competition, antibiosis, or predation). An isolate of the fungus *Gliocladium roseum* was isolated from apple fruit, cultured and a concentrated propagule suspension applied to apples during blossom during a one year preliminary trial (Archer 1997). This treatment was shown to inhibit infections by the core rot pathogens *Pezizula spp.* And *Alternaria alternata* on Red Delicious. This study also demonstrated the capacity of honey bees to effectively transfer propagules of *Gliocladium roseum*. Although this preliminary study was promising a lot of work remains to be done prior to commercial release of a bio-product based on *Gliocladium*. Work remains to be done on large-scale production, storage and product registration in addition to many other issues.

### ***Quarantine***

Perhaps Australia's most powerful IPM tool (and usually most overlooked) is our national quarantine system which prevents many of the most destructive pests of pome fruit from entering.

Domestic quarantine has also played a significant role and shapes pest management, notably in South Australia (Mediterranean and Queensland Fruit Fly exclusion) and Western Australia. Black spot (caused by the fungal pathogen *Venturia inaequalis*) is not present in Western Australia. This greatly reduces the number of pesticide applications required on apples in this state. However between 1989 and 1990 the disease detected numerous times and an eradication program was initiated. The eradication plan involved the surveying of orchards and nurseries throughout the apple growing areas, containing new outbreaks, preventing spread within districts, breaking the lifecycle of the fungus during winter, and preventing infection and disease build-up in the spring-early summer period (Doepel 1997). Western Australia declared itself free of this disease in 2001 (McKirby et al. 2001)

Similarly codling moth is not present in Western Australia, again reducing the number of pesticide applications required to produce good quality fruit. Western Australia has –with research assistance from HAL – developed an effective surveillance grid for this pest using pheromone traps (Woods 1997). In 1993 a codling moth outbreak was detected at Bridgetown, Western Australia and an established eradication procedure was undertaken. The eradication program took 3 seasons to successfully eradicate codling moth at a total cost of \$2 million. The cost and ease of eradication was reduced because a strategy was in place

pre-emptively. The cost could be compared to an earlier eradication campaign following an outbreak of Queensland Fruit Fly (where no plan was in place) which cost \$7 million.

***Extension: Is the message getting through?***

Thwaite (1997) prepared a summary of extension activities undertaken by researchers to transfer their findings to the Australian pome fruit industry. In large part a very similar summary of field days, grower meetings and workshops forums, seminars and industry gatherings could be presented today.

However, a number of novel extension activities have featured during the last decade. The Alternative Plant Protection Field Days commenced in 1994 in Stanthorpe. The field days were an off-shoot of HAL project AP402 (Pesticide reduction in pome fruit for year 2000). Perhaps a more notable off shoot of this work was MothWatch (a community approach to monitoring and reducing codling moth populations). Although, essentially an extension package this project drew on participation from a large group of orchardists and the wider community to expand knowledge on implementation strategies for alternative management of codling moth. In the four seasons (1997 to 2000) of moth monitoring some 123 647 codling moths were trapped in 386 traps on the orchards of the 88 participating growers. The area under mating disruption increased from 120 hectares to over 500 hectares. Project participants included growers, QDPI staff, chemical company representatives, the Stanthorpe shire council, agronomists from local chemical retailers and students and agricultural teachers from Stanthorpe High School (Tancred 2002)

Future Orchards 2012 was developed as a research, extension and training package for the Australian pome fruit industry. Its primary objective was to engage orchardists and enable the industry to adopt 'world's best practice by 2012. Although its charter is comprehensive it contains elements of IPM extension. In light of increasing pressure to produce fruit with low or no residues, perhaps more should be made of the opportunities offered through this project.

**AUSTRALIAN IPM IN A COMPETITIVE MARKET**

*This section of the review examines the place of IPM in a market place which is likely to change rapidly over the next decade. What will be the incentives driving increased uptake of IPM?*

***IPM: What drives change?***

In 1995 Penrose pondered the incentives for growers to use less pesticides and move toward IPM. As he pointed out the financial reward resulting from pesticide reduction is minimal, and calendar based pesticide application is less risky and requires less intellectual input than IPM techniques. "The benefits of decreased pesticide use are largely public, while the risks are private". Penrose proposed an accreditation scheme (PestDecide) and accompanying

premiums for low fungicide fruit (HAL AP430, Penrose 1996). In practice this seems unlikely.

Three factors are likely to drive change over coming decades

### **1. Economically rational decisions**

There is currently a dearth of information upon which Australian orchardists can rely to make rational decisions about the level of management which is required to control pests on specific crops. In some cases the cost of management cannot be justified given the extra return for undamaged fruit. Thresholds need to be established for major pest species and more studies like that of McNab et al. (1997; establishing an economic damage threshold for two-spotted mite in William pears) need to be conducted.

### **2. Increasingly competitive markets**

Australian apple and pear growers are likely to move into a more competitive, global marketplace during the next decade. Greater volumes of high quality fruit will be sold on the global market. To maintain or expand market share Australian orchardists will need to produce high quality fruit with minimal (and perhaps zero) residues. This may be the impetus for increased adoption of IPM.

### **3. Loss of pesticides**

Additional pressure will be brought to bear through the deregistration and use restrictions of pesticides which are currently widely used such as dimethoate and fenthion.

### ***Australia responds: pome fruit orchards are changing***

All aspects of pome fruit production are rapidly evolving and the Australian industry will adopt whatever management systems allow them to produce fruit which is of competitive cost and quality

#### **Planting densities, training systems and netting**

Industry is being encouraged to plant dwarfing rootstocks (AP532) and adopt intensive production systems (AP99033, AP98022, AP532, AP00022). Netting of orchard blocks is also being promoted as a means of boosting productivity (AP320, AP96014)

These trends have implications for pest management. It will be increasingly important that pest management systems developed in Australia are appropriate for 'modern' orchards. A good example of this is the breeding program for woolly aphid resistant dwarfing apple rootstocks (Menzies and Snare 2005). The full implications for IPM of the transition to dwarfing rootstocks and intensive plantings remain unknown.

### **Industry rationalisation and deserted orchards**

One of the negative implications of industry modernisation under the current agro-economic climate is the trend for orchards to leave the land. Increasing urban encroachment on rural land also leads to an increase in the numbers of abandoned orchards.

Abandoned orchards become sinks for pests which migrate onto neighbouring blocks (Thwaite 1993). Mating disruption underpins codling moth, light brown apple moth and oriental fruit moth management in several regions. Mating disruption is most effective where it is adopted over large areas with contiguous blocks (Il'Ichev 2006). Orchard abandonment threatens the network of managed blocks needed to optimise the performance of mating disruption.

### **Organics**

Organic apple and pear producers represent a rapidly growing sector within the Australian pome fruit industry. Many of the innovations and principles of IPM are directly transferrable to organic production.

For example, organic producers must be more aware of the susceptibility of their varieties to pests (Weibel and Leder 2007). Other research directly applicable to pest control in organics includes pH modification of leaf surfaces to control black spot (AP130, AP218), the use of kaolin (Brown et al. 2000, Brown et al 2001) and black spot resistant apple varieties (Middleton et al. 2007, Brown 2007)

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