Horticulture Innovation Australia

Final Report

A needs analysis for IPM R&D in the Apple and Pear Industry

Kristen Stirling
RMCG

Project Number: AP15014

AP15014

This project has been funded by Horticulture Innovation Australia Limited using the apple & pear industry levy and funds from the Australian Government.

ISBN 0 7341 3838 5

Published and distributed by:
Horticulture Innovation Australia Limited
Level 8, 1 Chifley Square
Sydney NSW 2000
Tel: (02) 8295 2300
Fax: (02) 8295 2399

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July 2016

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Horticulture Innovation Australia

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ISO 9001
International Standards
Certifications

Document review and authorisation

Job Number: 39-H-08

Doc. Version	Final/Draft	Date	Author	Reviewed by	Quality check	Release approved by	Issued to	Copies
1.0	Draft	30/05/16	K. Stirling	C. Larsen	-	-	A. Cameron P. Horne	1(e)
2.0	Draft	14/06/16	K. Stirling P. Horne A. Cameron	C. Larsen K. Stirling	-	-	A-M. Boland	1(e)
3.0	Draft	21/06/16	K. Stirling P. Horne C. Larsen A. Cameron	A-M. Boland	H. Buck	A-M. Boland	B. Kranz (Hort Innovation)	1 (e)
4.0	Final	04/07/16	K. Stirling P. Horne C. Larsen A. Cameron	A-M. Boland	H. Buck	A-M. Boland	B. Kranz (Hort Innovation)	1 (e)

Note: (e) after number of copies indicates electronic distribution

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Executive summary

Purpose of needs analysis

Integrated Pest Management (IPM) is an effective combination of chemical, cultural and biological methods to control both insect pests and diseases in apples and pears. It aims to minimise the environmental impact through reduced pesticide use, while combining knowledge of orchard production and beneficial organisms (including insects, mites and microbes) in a 'whole of system' approach.

The purpose of this project was to provide a better understanding of the current use of IPM within the apple and pear industry and the efficacy of the current IPM Manual[1] in guiding practice. A key component of the review was to investigate whether IPM is an enabler or impediment to market access. The needs analysis will inform any required improvements to the IPM Manual and provide recommendations on the future direction of research, development and extension (RD&E) for the industry, which aims to ultimately improve market access of product both domestically and internationally.

This project was undertaken by RM Consulting Group (RMCG) and IPM Technologies (IPMT) for Horticulture Innovation Australia (Hort Innovation).

Key findings

Adoption of true IPM is low

The elements that can be used to form an IPM strategy in apples and pears are available in Australia, and these are known to be effective when used correctly. Proof of this was presented in the survey and interviews conducted in this project where some growers were using IPM very effectively and had been doing so for many years. Awareness of IPM is high and the perception that the industry is using IPM is common amongst sectors of the industry, but actual adoption of IPM across the industry is low.

The proportion of interviewed growers reporting they use IPM, and providing substantial evidence to suggest they really are using an integrated approach was high (75%). Although 66% of these growers suggested that they are not typical in this regard. The majority (86%) of grower survey respondents claimed that they use IPM. However, further investigation to validate whether growers were truly using an integrated approach found only 25% actually used IPM.

It is important to reiterate that the 'I' in IPM stands for 'integrated', which means integrating pesticide use with biological and cultural controls. Where pesticides are being used that are incompatible with biological controls when softer options are available, then IPM is not being implemented. This is not to say that such an approach is not valid, it is just not technically IPM.

IPM Manual is moderately useful but should be updated

The current IPM Manual provides a good reference tool for information regarding the major pests although more pests should be added. However, the information regarding beneficial species is less thorough and could be improved by providing a similar level of detail to that provided on the pests. The information on pesticides is out of date and in one important section – the information regarding effects of certain pesticides on beneficials appears to be wrong or could be misleading. More precise information, including data on sub-lethal effects of pesticides and not just acute tests, is required for growers or advisors to make good decisions on pesticide use.

[1] Industry & Investment NSW Apple and Pear Australia Limited (2009) Integrated Pest Management for Australian Apples & Pears, New South Wales Government (AP07009), Sydney

Over half (62%) of growers are aware of and use the existing IPM Manual while 91% of advisors are aware that it exists, but of these only 60% use it. However, growers and advisors are predominately using the IPM Manual as an identification guide rather than to inform the development of an IPM strategy. Researchers surveyed identified the technical content as the most important (100%) aspect to update, followed by improved information for facilitating decision-making by growers (75%), and better accessibility and ease of use (50%).

Extension is a key gap to IPM adoption and advice

There was agreement from many growers, advisors and researchers that one of the best ways to improve confidence in IPM for all involved is through on-farm demonstration. This has been proven in many types of crops.[2,3] Other measures to improve IPM adoption and advice include:

- Broader regional extension programs, with 77% of growers and 67% of advisors requesting additional farm walks as part of the Future Orchards extension program
- Improving the capacity of advisors to provide reliable and independent advice, which was identified by 77% of growers and 56% of advisors
- Increased information sharing and integration amongst growers and advisors either through groups, on-farm events or district-level resources. Further information and/or resources on the costs and benefits of an IPM approach was identified by 69% of growers, 44% of advisors
- Whole-of-orchard system approach to insect pest and disease management by growers and advisors
- Appropriate market signals that lowered chemical residue on fruit and/or accepted superficial skin marks on otherwise quality product
- Improved communication to growers and industry of the benefits of implementing an IPM approach.

Protocols are needed to align IPM with market access

IPM in itself will not provide market access but should be used as a tool to 'value add' and facilitate the expansion of export trade. IPM naturally aligns with the marketing of product from Australia in that it results in a product that has been grown in an environmentally sustainable way with reduced pesticide application. In order for IPM to be effectively used as a tool for facilitating market access the approach needs to be:

- A component of the appropriate industry-driven protocols and certification processes
- Communicated to growers
- Incentivised by markets and retailers
- Supported by the availability of appropriate pesticide products.

Consideration of protocols and regulations are essential in ensuring that future RD&E aligns IPM with market access requirements. Survey respondents felt that in order for IPM to facilitate market access, future RD&E needed to be:

- Aligned with target export market phytosanitary requirements (56% of growers, 100% of advisors)
- Address national interstate trade requirements (33% of growers, 57% of advisors)
- Better linked with Commonwealth Department of Agriculture and Water protocols (44% of growers, 14% of advisors).

[2] Horne, P.A. and Page, J. (2011) Changing to Minimal Reliance on Pesticides, p. 337 - 346 in: Pesticides in the Modern World - Pesticides Use and Management, Margarita Stoytcheva (Ed.), ISBN: 978-953-307-459-7, InTech, Available from: http://www.intechopen.com/articles/show/title/changing-to-minimal-reliance-on-pesticides

[3] Horne, P.A., Page, J. and Nicholson, C. (2008) When will IPM strategies be adopted? An example of development and implementation of IPM strategies in cropping systems. Australian Journal of Experimental Agriculture 48:1601 - 1607.

Conclusions

Current status of IPM

- The current level of adoption of IPM in Australian apples and pears is low, despite a perception by many that it is high
- The most commonly practiced elements of an IPM approach are monitoring and mating disruption technology. Typically it is the use of harsh chemicals, that are disruptive to key beneficials, that undermine what many growers call an IPM approach
- All the tools required to allow growers to use IPM effectively are available and are being used by some, but grower and advisor confidence in IPM needs to be increased across the industry
- Pesticide resistance is not currently a major concern, but has the potential to cause a significant industry wide issue if a spray-based strategy is relied upon
- The industry needs to shift to an IPM approach in order to avoid (or deal with) pesticide resistance issues and to improve export potential.

Use and value of the current IPM Manual

- Awareness of the manual is generally high amongst small to medium growers, however this is not the case with larger growers
- Usefulness is moderate amongst those industry segments that are aware of the manual
- The manual is not being used to inform the development and implementation of an IPM approach on orchards, rather as an identification guide for insect pests, beneficials and compatible 'softer' chemicals
- The main weakness of the manual is that there is no integration of the information in the manual and a lack of support on how to integrate management approaches.

Recommendations

Requirements to improve IPM best practice, advice and adoption

- While further research and development would benefit the effectiveness of IPM within the apple and pear industry, the major requirement to improve the adoption of IPM is further extension
- A key gap identified during industry consultation was the availability of appropriate, independent support and district level information to assist IPM decision-making. Therefore key extension approaches should:
  - Develop regional extension programs that include demonstrations of IPM in commercial orchards
  - Improve the capacity of advisors to provide reliable and independent advice, for example through training and accreditation
  - Improve communication to growers and industry of the benefits of implementing an IPM approach
- Key recommendations on how to update the current IPM manual to make it a more effective and useful document include:
  - Maintaining the currency of pesticide information by housing content online, enabling regular updates
  - Ensuring coverage of all pest, diseases and weeds relevant to the apple and pear industry, as there are currently gaps. For example, harlequin bug is becoming a more significant secondary pest and it is not included in the manual
  - Providing a guide on how to integrate control measures

  - Improving accessibility by having section(s) online that are more readily used by growers and advisors as a decision support tool, which would also make that manual more adaptable and easy to update when necessary

- All segments of the apple and pear industry need to be supportive of an integrated approach to pest management in order to increase the implementation of IPM within industry. This needs to include:
  - Incentivising growers to produce fruit with minimum pesticide usage and educate consumers on appropriate quality levels
  - Improving the timeliness and information flow of the registration processes for new pesticide products
  - Promoting a coordinated and consultative approach between growers (industry association), researchers and regulators so that future RD&E is designed to promote market access and that trade protocols are developed that incorporate and support an IPM approach.

How IPM can align with, and facilitate, market access

Industry should:

- Continue to promote IPM as an approach which provides a natural fit within production systems focussed on market access in that it results in reduced pesticide usage and improved product quality
- Use IPM as a tool to leverage market access, demonstrate industry best practice and demand a premium for product (recognising that in itself IPM does not provide market access)
- Incorporate IPM into trade access protocols as part of a consultative approach between regulators and industry. Any IPM approach incorporated into trade protocols needs to be:
  - Auditable and follow a risk based approach such as Hazard Analysis and Critical Control Points (HACCP)
  - Designed to ensure market access (rather than restriction)
  - Promote a truly integrated management approach rather than just monitoring protocols.

1 Introduction

1.1 Purpose of needs analysis

The purpose of this project was to provide a better understanding of the current use of Integrated Pest Management (IPM) within the apple and pear industry and the efficacy of the current IPM Manual in guiding practice. A key component of the review was to investigate whether IPM is an enabler or impediment to market access. The needs analysis will inform any required improvements to the IPM Manual and provide recommendations on the future direction of research, development and extension (RD&E) for the industry, which aims to ultimately improve market access of product both domestically and internationally.

This project was undertaken by RM Consulting Group (RMCG) and IPM Technologies (IPMT) for Horticulture Innovation Australia (Hort Innovation).

1.2 Background

IPM is an effective combination of chemical, cultural and biological methods to control both insect pests and diseases in apples and pears. It aims to minimise the environmental impact through reduced pesticide use, while combining knowledge of orchard production and beneficial organisms (including insects, mites and microbes) in a 'whole of system' approach.

The industry has been incrementally adopting this technique over the past decade and developed the IPM Manual for Australian apples and pears in 2009[4], which is a focus of this project. This manual aims to assist decision-making of growers implementing IPM through providing a nationally recognised strategy.

This strategy includes six key steps:

1. Prepare and prevent
2. Have a pest management plan for the season
3. Monitor
4. Take action only if you need to
5. Evaluate the season
6. Plan for next season.

The Productivity, Irrigation, Pests and Soils (PIPS) program has a strong focus on IPM for the pest component. The IPM component of PIPS1 (2009-2014) focussed on research into using beneficial insects to control high priority pests such as woolly aphid and codling moth, as well as investigating the interactions between pests, new and existing bio-control agents, diseases, pesticides and host crop plants. Some of the key findings from this research included:

- A key parasitoid of codling moth in Kazakhstan, *Mastrus ridens*, was approved for release and successfully released in the Goulburn Valley
- The existence of at least three different biotypes of woolly apple aphid in south eastern Australia was demonstrated
- Determined that *Heringia calcarata*, a syrphid fly native to North America that is the most abundant predator of Woolly Apple Aphid in Virginia and Washington, USA, is suitable for introduction to Australia.[5]

[4] Industry & Investment NSW Apple and Pear Australia Limited (2009) Integrated Pest Management for Australian Apples & Pears, New South Wales Government (AP07009), Sydney

The PIPS2 program is building on its predecessor, continuing research on orchard productivity and international best practice. This includes setting up and testing the effectiveness of *Mastrus ridens* release to control codling moth across a broader range of orchard environments.

1.3 Structure of this report

This report details the findings of the project undertaken by RMCG and IPM Technologies for Horticulture Innovation Australia (Hort Innovation), and is structured as follows:

- Overview of the purpose of the project and background *(this section)*
- Approach used for the needs analysis including the program logic and framework developed to guide the literature review and industry consultation process (section 2)
- Findings of the literature review and industry consultation process including specific references to survey results and interview outcomes (section 3)
- Discussion of the key themes to emerge from the needs analysis (section 4)
- Conclusions and recommendations on next steps (section 5).

[5] Stirling, K. & Boland A-M. (2016) Introducing PIPS2, online <http://apal.org.au/introducing-pips2/>, accessed 25 February 2016

2 Approach

2.1 Needs analysis framework

A needs analysis framework was developed to create a consistent way of collecting and analysing data during the project to ensure the main objectives were met (Figure 1). The framework is based on the strategic planning approach of assessing the 'now, where and how' of IPM in the apples and pear industry. The key questions addressed by this project are aligned against the three tiers of the framework.

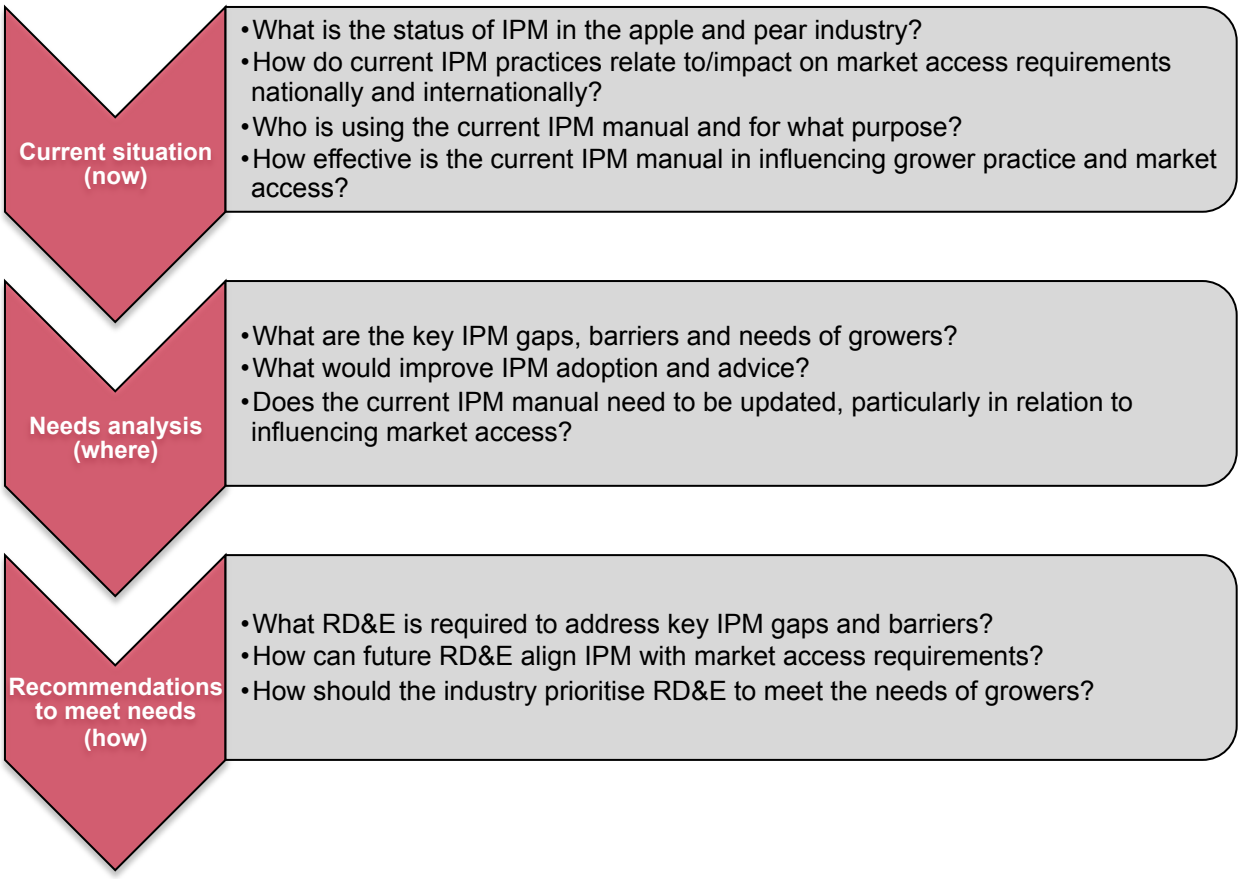


Figure 1: Needs analysis framework

2.2 Program logic

A program logic was developed to outline the hierarchy of activities to intended outcomes of IPM RD&E in the apple and pear industry (Figure 2). This logic was based on the *New Horizons 2015* strategic plan objectives and *Apple & Pear Industry Research, Development & Extension Plan 2010-2015* priority investment areas of industry development, and market access and biosecurity.

The RD&E plan highlights the development of extension packages relating to IPM, specifically:

> *… the roll-out of an Integrated Pest Management (IPM) package utilising the recently produced IPM and Biosecurity Manuals as the focal point. The package will investigate the creation of a web-based*

IPM tool incorporating a diverse range of information assembled as databases and predictive models.[6]

The program logic was used to guide the approach to the needs analysis.

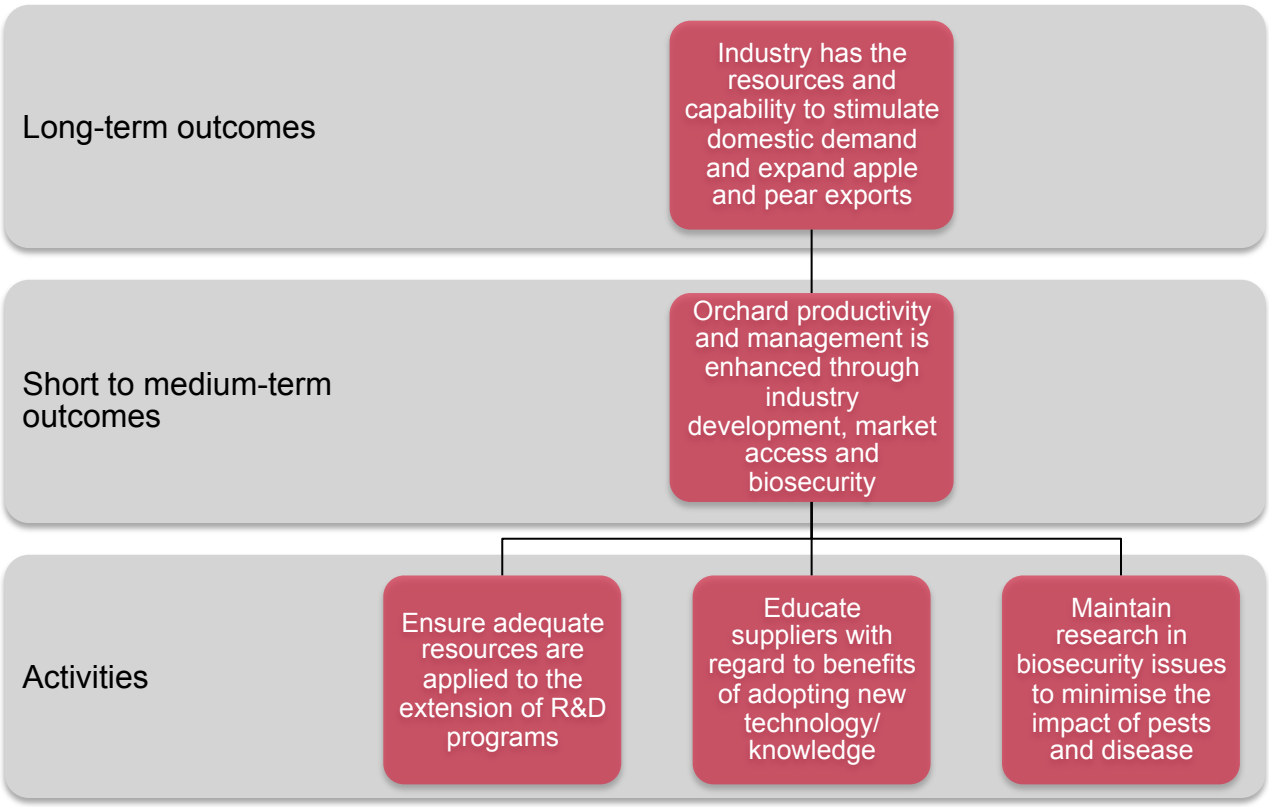


Figure 2: Program logic for IPM RD&E in the apple and pear industry[7]

[6] DR Research & Consulting (2010) Apple & Pear Industry Research, Development & Extension Plan 2010-2015, prepared for Apple and Pear Australia Limited, Melbourne, page 47

[7] Based on Apple and Pear Australia Limited (2010) New Horizons 2015; Apple and Pear Industry Strategic Plan, Melbourne and DR Research & Consulting (2010) Apple & Pear Industry Research, Development & Extension Plan 2010-2015, prepared for Apple and Pear Australia Limited, Melbourne

2.3 Desktop review

A desktop review of existing information and available data was undertaken to address the key questions in the needs analysis framework. This included industry-funded R&D, manuals and strategic plans, as well as market access requirements, literature, and lessons learnt from other industries both in Australia and overseas. The key documents referred to during the review are outlined below.

The aim of this task was to gather and review existing information and identify any data gaps. The review was conducted by IPM Technologies and focused primarily on high priority resources.

Table 1: Documents to be reviewed in chronological order[8,9]

Title	Author	Date	Priority
Productivity, Irrigation, Pests and Soils (PIPS) Integrated Pest and Disease Management (IPDM) *Mastrus ridens* project	Victorian DEDJTR	Current	High
Australian Apple and Pear Export Directory	Apple and Pear Australia Limited	2016	Moderate
Productivity, Irrigation, Pests and Soils (PIPS) Orchard Productivity Program; Interim Final Report (AP09031)	Tasmanian Institute of Agriculture	2015	High
Summerfruit to China; Integrated Pest Management Program; Draft	Summerfruit Australia and Victorian DEDJTR	2015	High
Apple and Pear Maximum Residue Limits[10]	Apple and Pear Australia Limited	2016	High
Interstate trade requirements[11]	Apple and Pear Australia Limited	2014	High
Export market major phytosanitary requirements[12]	Apple and Pear Australia Limited	2012	High
IPM Manual for Australian Apple and Pears (AP07009)	NSW Department of Primary Industries	2010	High
Apple Pest Management Transition Project[13]	Washington State University	2010	High
New Horizons 2015; Apple and Pear Industry Strategic Plan	Apple and Pear Australia Limited	2010	Moderate
Apple & Pear Industry Research, Development & Extension Plan 2010-2015	DR Research & Consulting	2010	Moderate
Integrated Pest Management for Strawberries; Second Edition	University of California	2008	Moderate
Orchard habitat management to enhance IPM systems	Peter Ridland	2005	Moderate

[8] Note: additional international IPM manuals for apple and pear will be reviewed as required, such as from the US or Europe, as well as international examples of where IPM has been used to facilitate market access
[9] ^Need to be sourced from Horticulture Innovation Australia
[10] http://apal.org.au/wp-content/uploads/2016/02/Apple-and-Pear-MRLs-March-2016.pdf
[11] http://apal.org.au/supply-chain/trade/interstate-trade-requirements/
[12] http://apal.org.au/supply-chain/trade/export-markets/
[13] http://pmtp.wsu.edu/downloads/Handbook2010/2010-PMTP-Handbook-web.pdf

Title	Author	Date	Priority
(AP00033)^	(VIC DPI)		
Integrated pest management in lettuce: information guide	McDougall et al.	2002	Moderate
Integrated Pest Management for Apples and Pears; Second Edition[14]	University of California	1999	Moderate
IPM viticulture research to practice: training workshop manual	Victorian DNRE	1998	Moderate
Australia's progress in apple IPM (AP516)^	Graham Thwaite (NSW Agriculture)	1996	Moderate
Integrated Pest Management in European Apple Orchards[15]	Blommers, L. H. M.	1994	Moderate
Integrated Pest Management for Potatoes in the Western United States	University of California	1992	Moderate
Development of pest and disease management systems for pome fruit quality and pesticide residue standards (AP030)^	David Williams (VIC DPI)	1991	Moderate

The following frameworks were used when reviewing the secondary data and documentation (Table 2 and Table 3). This ensured a consistent analysis approach and the ability for the project team to organise the main findings from the needs analysis according to the framework above.

Table 2: Document review framework

Framework level	Evidence
Current situation (now)	e.g. strengths and weaknesses of current IPM manual
Needs analysis (where)	e.g. industry plans outlining strategic directions for IPM
Recommendations to meet needs (how)	e.g. PIPS1 Interim Final Report recommendations

The current IPM manual, as the primary resource for review, was assessed in greater detail than some of the other resources listed in Table 1. The main components of the manual that were assessed are outlined in Table 3.

Table 3: IPM manual assessment framework

Manual component	Evidence
Technical content	
Accessibility (ease of use, format and length)	
Effectiveness in guiding decision-making and practice on-farm	
Market access considerations	
Strengths	
Weaknesses	
Identified improvements	

[14] http://www.ipm.ucdavis.edu/IPMPROJECT/ADS/manual_apple-pear.html
[15] http://www.annualreviews.org/doi/abs/10.1146/annurev.en.39.010194.001241?journalCode=ento

2.4 Consultation

2.4.1 Semi-structured interviews

Twenty-three (23) stakeholders were targeted for interviews during the review. Consultation was via telephone interviews and/or face to face and provided the primary source of qualitative data. The interviews were of approximately one hour in duration, and followed a semi-structured interview guide to ensure consistency in the information collected. The interview guide is provided in Appendix 1.

Interview participants were identified in collaboration with Hort Innovation based on industry segment, location and involvement in IPM and to ensure a representative sample. Interviewees were provided with an interview guide, which explained the review process and provided the interview questions. The project team aimed to have equal representation of states and relevant sectors across the twenty-three businesses interviewed. A minimum of two stakeholders in each state were contacted to be interviewed, however participation was contingent on their availability during May and early June 2016. An overview of the interview participants is provided below.

Table 4: Interview participants

Name	Industry segment	State
Angus Crawford	Industry association	VIC
Olivia Tait	Industry association	VIC
David Williams	Researcher/state government	VIC
Mofakhar Hossain	Researcher/state government	VIC
Gary D'Arcy	Researcher/state government	VIC
Stewart Learmonth	Researcher/state government	WA
Craig Boyce	Grower/packer/exporter	VIC
Peter Hall	Grower/packer/exporter	VIC
Josie Fouache	Grower/packer/exporter	VIC
Claire Fitchett	Grower/packer/exporter	VIC
Krys Lockhart	Grower/packer/exporter	VIC
Rowan Little	Grower/packer/exporter	VIC
Andrew Plunkett	Grower/packer/exporter	VIC
Michael Cunial	Grower/packer/exporter	NSW
Stephen Tomasel	Grower/packer/exporter	QLD
Brad Ashlin	Grower/packer/exporter	TAS
Paul Francis	Grower/packer/exporter	TAS
David Finger	Grower/packer/exporter	VIC
David Loxley	Advisor	VIC
Jabbar Ali Khan	Advisor	VIC
Russel Fox	Advisor	VIC
Peter Morrison	Advisor	TAS
Andrew Hennoste	Advisor	QLD

2.4.2 Online survey

Industry stakeholders were invited to provide their views on the status of IPM within the apple and pear industry via an online survey, which was advertised through the *Industry Juice* e-newsletter (emailed to all members of the APAL database) and an invite distributed to the Hort Innovation contact database. The email contained a link to the online survey hosted on SurveyMonkey™. The survey provided both qualitative and quantitative data (the findings of which are discussed in section 3 and 4), and the questions are provided in Appendix 2.

A total of 50 survey responses were received from industry stakeholders representing the following segments: grower (49%), advisor (31%), researcher/state government (14%), industry association (2%) and importer/buyer (4%) (Figure 3).

Respondents were geographically diverse and included Victoria (47%), New South Wales (14%), South Australia (12%), Queensland (8%), Western Australia (8%), Tasmania (6%) and overseas (4%, Japan).

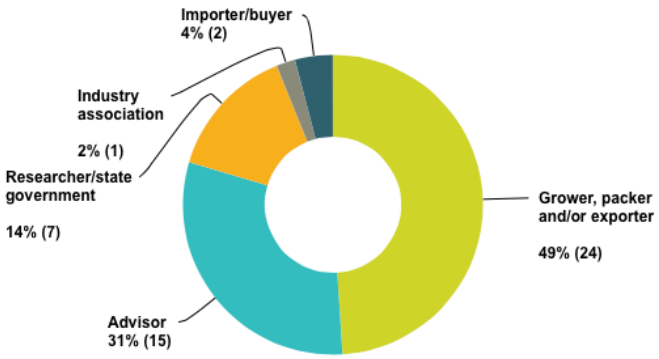


Figure 3: Survey respondents by stakeholder group (N = 49)

The composition in the size of the business differed between those growers who were surveyed and interviewed. Only 14% of the surveyed growers were classified as large (>200ha, multiple orchards) and 86% were small (<50ha, single orchard) or medium (50-200ha, potentially multiple orchards). In contrast, grower interviewees were predominately (56%) large, followed by medium (33%), with the minority being small (11%). This meant there were some differences between grower survey and interview data collected that required further exploration.

2.4.3 Synthesis and analysis

The synthesis and analysis stage of the project comprised of three main components:

1. Synthesis of information from consultation
2. Analysis against review questions
3. Provision of recommendations on improving the implementation of IPM within the apple and pear industry and how this can facilitate market access.

Data analysis techniques used for the interviews included coding of interview transcripts and case study narrative analysis to add depth and richness. This method enabled unintended consequences to be drawn out and informed the formulation of recommendations. Quantitative analysis and thematic coding of open-ended responses to identify key words and phrases was also used to analyse the survey data.

Data from the desktop review was triangulated with the qualitative and quantitative data and analysed based on the needs analysis framework to address the key questions.

3 Findings

3.1 Current situation (now)

3.1.1 Status of IPM in the apple and pear industry

Overview

There are a range of biological, cultural and compatible chemical options for controlling pests in apples and pears in Australia.

The biological control agents include a range of naturally occurring predators and parasites of almost all the pests of concern, and there are also some commercially produced biological control agents (such as *Trichogramma* wasps, *Phytoseiulus persimilis* and *Neoseiulus californicus* mites, and Green lacewings – *Mallada signatus*).

Cultural control options are many and varied, depending on location and practicality, but include factors such as hygiene, weed control and trap crops.

There are also several chemical control options for the major pests that are compatible with the biological control agents. These include Isomate lures, Altacor® (chlorantraniliprole) and Vivus® (nuclear polyhedrosis virus). Other products are not totally safe to beneficial species but can be used strategically at certain times (e.g. Delegate® (spinetoram)). Together these control measures make up an effective IPM strategy and this is being used effectively by a small sector of the industry.

Perceptions of grower practice

There is a widely held perception that growers are using IPM and that it is moderately to highly effective. All researchers and industry association members interviewed as part of this project held the view that the vast majority of growers are using IPM and that while growers can still experience problems with major pests, IPM provides effective control. All advisors interviewed indicated that they give IPM advice and when asked what proportion of their clients seek and follow such advice, all indicated between 80% and 100%. Evidence from survey responses confirms the widespread existence of these perceptions. All (100%) of surveyed researchers indicated that growers are using IPM, and all (100%) of surveyed advisors indicated that they provide IPM advice. When asked whether their growers find IPM effective in controlling pests, 92% of surveyed advisors indicated that they do. When asked whether growers are effectively using IPM to control pests, a majority (60%) of surveyed researchers indicated that growers achieve a moderate level of control (Figure 4).

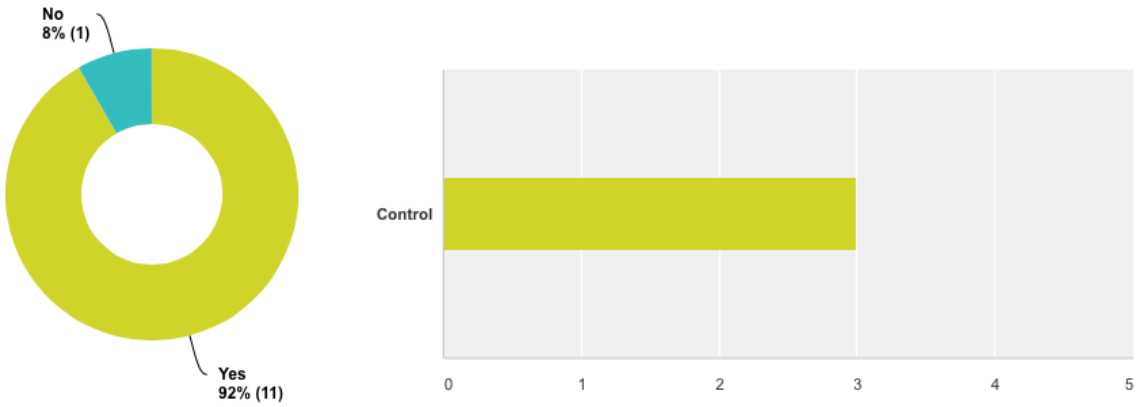


Figure 4: Effectiveness of IPM as rated by advisor (left, N = 12) and researcher (right, N = 5) survey respondents

Grower practice

Interview findings

The proportion of interviewed growers reporting that they use IPM, and providing substantial evidence to suggest that they really are using an integrated approach was high (75%). Interviewed growers listed a wide range of practices as being key to their IPM strategies. These include monitoring for both pests and beneficials; encouraging naturally occurring beneficials; introducing commercially reared biological control agents; selective and targeted use of soft pesticides; mating disruption; and cultural controls including good orchard hygiene, weed management and the use of weather stations and degree-day models to optimise the timing and therefore the effectiveness of pesticide applications. Each grower placed emphasis on different aspects of IPM. For example one grower summed up their key IPM practice in these terms:

> *"We make sure the chemicals we use don't kill the key predators."* – Grower interviewee

For other growers, the use of degree-day models to improve timing of sprays for both pests and diseases is extremely important – it has dramatically improved levels of control and avoided subsequent insecticide or miticide use.

> *"We use the predictive modelling tool RIMpro to aid decision making and optimise timing of sprays for codling moth and black spot. This tool is very useful – it has dramatically improved our ability to manage these pests and our understanding of their lifecycles and how these relate to weather conditions."* – Grower interviewee

The value of such technology was also noted by one of the advisors interviewed.

> *"The key pest to control is codling moth. If timely control actions are missed for this pest at the start of the season then it has bad implications for the control of other pests later in the season because sprays that disrupt beneficials are then required. I use a predictive model to calculate the first emergence of codling moth and this is very effective."* – Advisor interviewee

Although the proportion of interviewed growers that use IPM was high (75%), 66% of these growers suggested that they are not typical in this regard. That is, although many growers claim to use IPM, they are, in the words of one grower, *"just paying lip service."* Grower survey results correlated well with the interview findings in this regard (see next section).

Those growers interviewed who were using IPM effectively have been using it for many years, and were aware that by using IPM they were avoiding problems with what may be major pests for other (non-IPM)

growers. They also stated that they were able to achieve better pest management results using IPM than would be possible using a chemical-based approach.

A number of the interviewed growers that are using IPM expressed that the transition to IPM was necessity driven. In some cases the driver was failure to control pests using a conventional approach.

> *"I ended up changing to IPM out of desperation – I couldn't control red spider mite. The sprays we were using were bad for our health, we couldn't control the pest, and we were completely desperate. We just had to change."* – Grower interviewee

In other cases the driver has been the need to reduce sprays in order to meet export market MRL requirements.

> *"We have used it [IPM] for 20 years, the change was driven in pears due to export market demand for less chemical residues."* – Grower interviewee

A number of grower interviewees raised the issue that if IPM was used, they had to be prepared to see pests in the orchard (as they always arrive first, before the beneficials). Growers acknowledged that in many cases this means tolerating some level of damage. However where these issues were raised, it was also acknowledged that the overall pest management results achieved using IPM are better than would be possible using a conventional approach.

> *"[IPDM] is effective. You cannot have successful IPDM without taking some commercial hit to begin with, you have to allow for some damage, but there is undoubtedly a long-term gain."* – Grower interviewee

> *"You have to see some damage in the orchard, and not panic. You have to absorb a little bit of damage, but you get a better result in the end."* – Grower interviewee

> *"Woolly aphid can be more of an issue if we have to use a lot of insecticides in the orchard for other pests, because these sprays disrupt the parasitic wasps that naturally control the aphids. Woolly came in late this year, but if you look in the orchard now, you see that all of them have been parasitised. I very rarely use an insecticide spray for the aphids. I tolerate a bit of damage and I get a good result in the end."* – Grower interviewee

The health and environmental benefits of using IPM over a conventional approach were widely acknowledged by all stakeholder groups consulted. Growers and advisors acknowledge the impact of this practice change on their own health, and regard this as an advantage, despite IPM being more complicated to implement than a conventional approach.

> *"I started my working life on an orchard nursery and we were blasting Metasystox and Gusathion [organophosphates], you name it! I enjoy walking onto an orchard now. They smell nice, they are just nicer places to be. It is a nicer environment. I used to suffer from skin irritations from chemicals, but I don't any more. And I love being able to tell the 'townies' [the people who don't understand] that the way we grow apples and pears these days is a lot safer than it has ever been before."* – Advisor interviewee

> *"In the old days, [30-40 years ago] we used a broad-spectrum anticholinesterase insecticides and we used to see no pests. If you went out with Gusathion, you went out with one spray and you knew you didn't have to worry about pests again for the whole season. Now we spend more money on new chemistry, and we see pests and we can see more damage to fruit, but we don't want to go back to the old chemistry. It isn't safe for our staff and it isn't good to handle those products, but it was much simpler back then."* – Grower interviewee

Survey findings

The majority (86%) of grower survey respondents claimed that they use IPM. However, a series of questions were included in the survey designed to validate whether growers were truly using an integrated approach, and when analysing the results further it was found only 25% actually used IPM. This assessment is based on the type of products being used in their current program; awareness and use of biological control agents; and monitoring practices. Examples of how these assessments were made are outlined below.

Table 5: Technical assessment of grower IPM data

Grower claims in using IPM	Technical assessment
Daily monitoring; do not rely on *any* beneficial species to help control pests; and use multiple highly disruptive (non-IPM compatible) pesticide products (for example Gusathion®, Lorsban®, Paramite® and Dithane®)	This grower is not using IPM
Weekly monitoring, rely on a range of beneficial insects and mites to help control pests, release commercially produced biological control agents; and use multiple highly disruptive (non-IPM compatible) pesticide products	This grower is not using IPM
Weekly monitoring; rely on an extensive list of beneficial insects and mites to help control pests; and use mainly soft (IPM-compatible) pesticide products	This grower is using IPM

Almost half the growers surveyed (48%) claimed that they rely on beneficial insects and mites to help control pests and simultaneously indicated that they use a range of pesticide products that are highly disruptive to beneficials. One grower interviewee raised a related problem – that growers buy and release beneficials (leading to the claim that they use IPM) but then use disruptive pesticides that kill them.

> *"Growers think they're using IPM, but releasing beneficials then spraying them out before harvest – that's not IPM."* – Grower interviewee

Grower survey results confirmed this is common practice. Almost half of the growers surveyed (43%) buy and release biological control agents in their orchard, and yet 80% of these growers indicated that they also use one or more pesticide products that are know to be highly disruptive to beneficials.

Grower survey results thus confirm the view expressed by several interviewed growers, namely that the majority of their peers claim that they use IPM but do not really integrate the available control measures. While data from the grower survey suggests that certain practices and elements of an IPM approach are being widely used, e.g. monitoring (used by 82% of growers) and mating disruption technology (used by 67% of growers), the 'IPM' strategies employed by most growers completely lack 'integration'. Typically it is the use of harsh chemicals – disruptive to the key beneficials – that undermines what many growers' call an IPM approach. The use of 'soft' IPM-compatible pesticides is widespread and yet in the majority of cases the use of these products is coupled with the use of other highly disruptive products. For example, 72% of growers surveyed use the selective product chlorantraniliprole, but 92% of these growers also use one or more non-IPM compatible products.

As mentioned previously, only 14% of the surveyed growers were classified as 'large' and 86% were 'small' or 'medium'. Of the large growers, 66% said that they used (or had used) IPM, but only 33% said that it was effective. As discussed above, we consider only 25% of the surveyed growers as actually using IPM. All of these were classified as 'small', and all stated that they find IPM to be effective.

As we regard only 25% of the growers surveyed to be using IPM, then 75% follow a spray-based strategy using some of the compatible insecticides listed above, but also products that are not compatible with the

biological control agents. The sprays are often applied based on the results of scouting for pests which is better than a calendar spray program but is still not an IPM approach. The type of insecticide or miticide used is also an important issue and many of the products nominated as being used do not fit with an IPM strategy.

Only three growers surveyed identified that they did not use IPM. The reasons given by these growers were a lack of reliable, trained scouts, a lack of suitable chemicals and not knowing what IPM involves.

Key pests and diseases

Invertebrate pests

Responses from growers and advisors about which were the key pests varied depending on location. Codling moth was a key pest for most (75%) of growers who answered this question in interviews, even if they regarded it as under control. Other caterpillar pests included light brown apple moth and *Helicoverpa* species. Woolly apple aphid and mealybug were important in some places more than others, and two-spotted mite was also nominated as a key pest in most places. Black spot and powdery mildew were nominated as important diseases, but the severity depended on the location and season.

The pests and diseases that are most difficult to manage vary year-by-year, depending on seasonal conditions. For example, management of mite pests was particularly difficult due to unusually hot and dry weather during the last season. Conversely, powdery mildew was a problem in one location (in Tasmania) last season. However, according to most growers and advisors, the range of pests and diseases has remained the same over many years. Notable changes include mealybug increasing in importance as a pest in some locations (particularly the Stanthorpe region in Queensland), and harlequin bug becoming a problem in some regions (e.g. Tasmania). One grower noted that the pests and diseases were not necessarily more difficult to control now than in the past, but the lower tolerance for damage from buyers has increased pressure on growers. Advisors also raised this issue.

> *"Supermarkets demand perfect produce and growers cannot tolerate any damage."* – Advisor interviewee

Vertebrate pests

The issue of managing vertebrate pests (such as birds and bats) was not raised by any of the stakeholders consulted through either the interviews or the survey. The fact that such pests were not mentioned suggests that they are either being adequately managed, or concerns about their management simply do not rate as highly as concerns about the management of other pests and diseases. As with the control of any other pests within an integrated approach, whatever strategies are used to manage vertebrate pests must be compatible with the methods relied upon for the control of other pests. That is, they should cause minimal disruption to other elements of the IPM program. Where netting is used to exclude vertebrate pests, it should be noted that it may also exclude some transient naturally occurring beneficials such as green lacewings, and for growers wishing to implement an integrated approach that relies on such beneficials, targeted augmentative releases of some species of biocontrol agents may be of benefit.

Resistance

While there is general awareness of the issue of resistance to pesticides, growers showed a reluctance to acknowledge resistance as a problem they themselves face. The majority (63%) of growers interviewed were aware of resistance issues now, but they did not consider this at a crisis point at present. However only 19% of the growers responding to the survey saw resistance as a problem. Several growers or advisors were concerned about the small number of IPM compatible miticides that are available, and

were aware of poor results from these sprays compared with previous years, which implies the onset on miticide resistance.

Similarly, although not regarding it as resistance, several respondents noted less efficacy with Confidor ® (imidacloprid) drenches targeting woolly apple aphid compared to previous years.

> *"The Confidor drench only lasts 2-3 years at most, and it is very expensive. The more you use it, the less it works. We used to get 4-5 years out of it. We have used it for the third time now, and we only getting 3 years out of it now"* – Grower interviewee

One grower explained that resistance to miticides 25 years ago made many growers change to IPM out of necessity, but as more products (including softer products for mites and for other pests) have come onto the market, most growers have reverted back to relying on pesticides as the primary means of control. The most common approach to dealing with resistance in the industry at present is to rotate through different chemical groups rather than switch to using IPM. All (100%) advisors surveyed recommend rotation of chemical groups and 86% of growers said they did this.

While there is no suggestion that there is resistance to Altacor® (chlorantraniliprole) at present, it is very widely used to control codling moth and light brown apple moth, and it is acknowledged by the industry (in the manual) that codling moth has developed resistance to all of the other insecticides used in the past. Therefore, reliance on a single product is certain to lead to resistance.

Our assessment is that a spray-based approach, supported by monitoring is currently the most common approach to dealing with pests in the apple and pear industry. Insecticide and miticide resistance is not currently a driver for change, but there is awareness by at least some within the industry that several key pests may be about to become much more difficult to control within a spray-based strategy.

Use of Isomates and other forms of mating disruption

The use of mating disruption (mainly Isomate lures) can be a very effective IPM tool. Grower and advisor survey results suggest that it is widely used. Most (82%) of surveyed advisors recommend the use of mating disruption technology, and the majority (67%) of surveyed growers are currently using it.

> *"Other growers struggle to control codling moth, but we don't anymore. We have been using mating disputations successfully for over 20 years. It is completely off the radar for us. The Isomates work absolutely perfectly for us. We would only find about five pieces of fruit damaged per year."* – Grower interviewee

However, the development of predictive models for codling moth coupled with effective and IPM compatible insecticides (such as Altacor®) has meant that spraying can be seen as both easier and just as effective.

> *"We used to use Isomates for codling moth control, but now with predictive modelling and soft chemical options [Altacor and Insegar], it is easier to rely on well-timed insecticide applications."* – Grower interviewee

Post-harvest IPM

Post-harvest management of pests and diseases can either refer to management practices used in the orchard after harvest, or treatment of harvested fruit (typically during storage) for the management of pests either from the orchard or post-harvest rots. Only one grower discussed the use of post-harvest management techniques during an interview, making reference to the use of cold-storage disinfestation to treat pests of quarantine concern.

In an IPM program, the same principle of integration that applies to pre-harvest management of pests applies to post-harvest management within the orchard. Both prior to and after harvest, the suite of control options utilized to manage all pests in the orchard need to be compatible. Some of the in-orchard post-harvest control measures recommended in the Apple and Pear IPM Manual for pest and disease management are IPM-compatible, while others are not. For example, a post harvest urea application to aid control of black spot (apple scab) would not be disruptive to key beneficials and is therefore IPM-compatible, while a post-harvest chlorpyrifos spray on trees targeting woolly apple aphid would be highly disruptive to all key beneficials and may not be at all compatible with biological controls within an IPM approach. The compatibility of such a spray would depend on the timing of application, that is, whether or not key beneficials are still active and contributing to control of other pests at the time of spraying. Post-harvest treatments of fruit in storage (such as cold-storage disinfestation or fumigation) do not interfere with IPM in the orchard, and therefore are fully compatible with an IPM program.

Where blanket sprays of non IPM-compatible insecticides to treat pests of quarantine concern within the orchard are set as a market access requirement, growers can be prevented from adopting IPM or be forced to abandon IPM. This issue was raised by a researcher interviewee in regard to domestic interstate trade requirements, which in their words "*run at right angles to IPM*" and force growers to "*nuke the lot*". This issue was also raised by growers in relation to export market requirements for in-orchard control of pests of quarantine concern. Where market access requirements are driving growers to implement disruptive (non IPM-compatible) in-orchard pest control measures, it would be worthwhile to seek negotiations with target markets to get post-harvest management or other IPM-compatible options accepted as an alternative.

3.1.2 Use and value of the current IPM Manual

Over half (62%) of growers are aware of and use the existing IPM Manual while 91% of advisors are aware that it exists, but of these only 60% use it. These figures may seem quite high, but some growers interviewed from the larger farms were not even aware of its existence. Those who are aware of it largely see it as a reference tool and it is used only occasionally. When asked to rate the usefulness of the manual on a scale of 0 (not useful) to 5 (very useful) the majority of growers (63%) gave it a rating of 3, while equal number of advisors (33% respectively) gave ratings 3, 4 and 5 (Figure 5). High percentages of both groups (77% of growers and 80% of advisors) said that the manual needs updating.

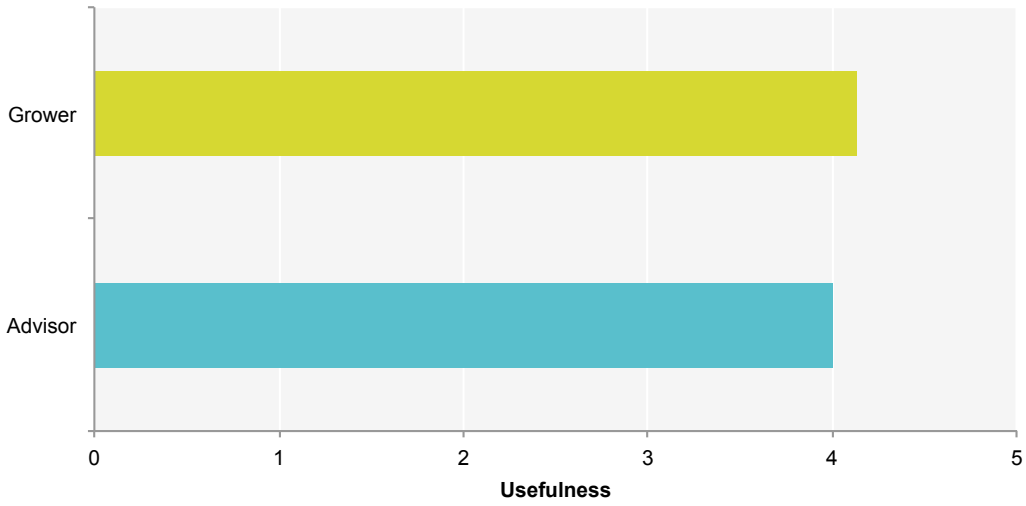


Figure 5: Usefulness of the manual as rated by grower (N = 8, mean = 4.1, SD = 0.6) and advisor (N = 6, mean = 4.0, SD = 0.8) survey respondents

Growers are predominately using the IPM Manual as an identification guide rather than to inform the development of an IPM strategy (Figure 6). The top four responses regarding how the manual is used show that:

1. 88% use it to identify beneficial insects and mites
2. 88% use it as a guide to chemical control options
3. 75% use it as a guide to identify pest and disease problems
4. 63% use it as a guide to the effects of pesticides on beneficials.

The primary use refers to a topic that is poorly covered (beneficials), the second and fourth refer to content in the manual that is very out of date (chemical control options and side effects of pesticides). The third reason (identification of pests and diseases) is something that the manual certainly would be very useful for in its current form due to the depth of information coverage.

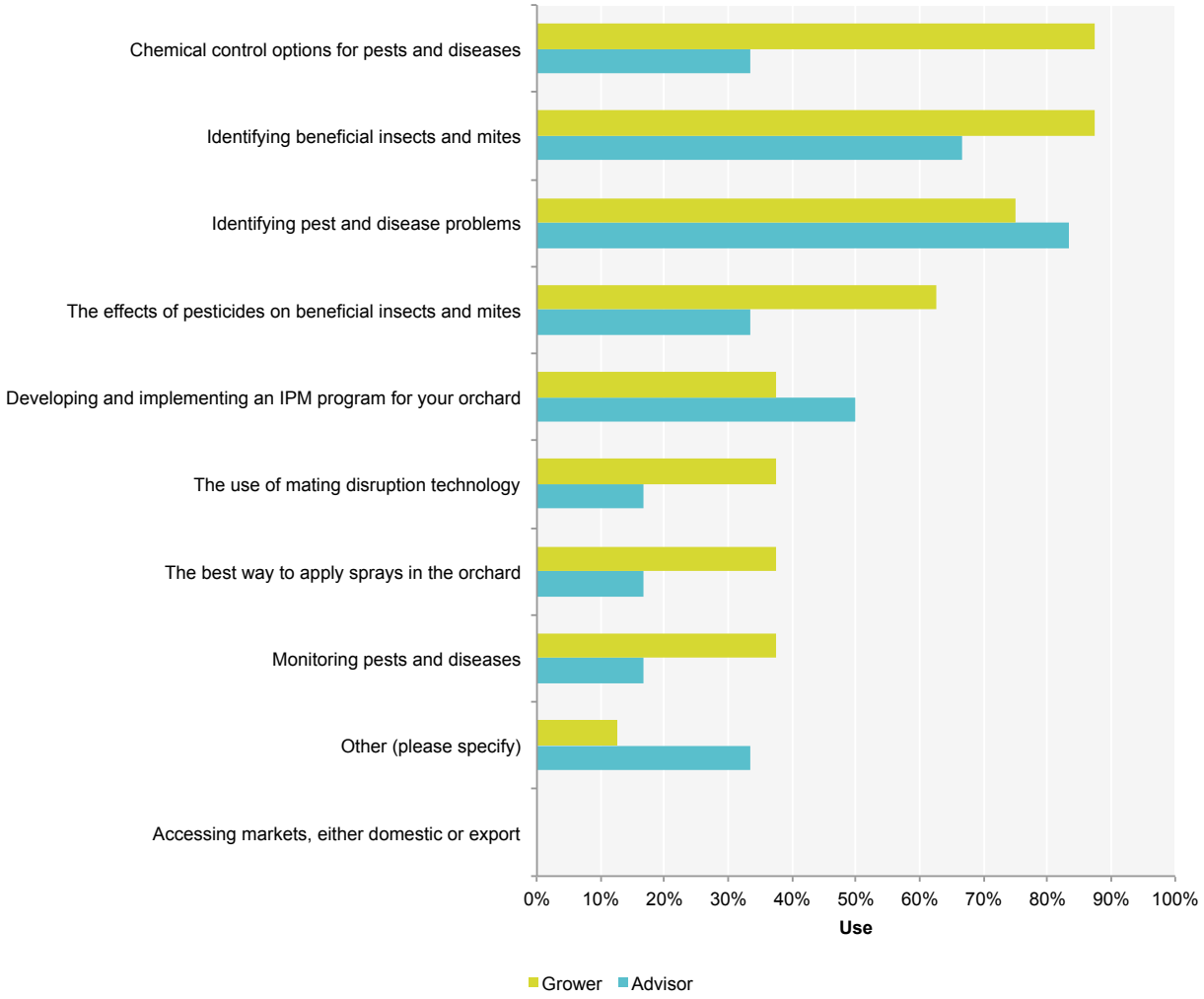


Figure 6: How the manual is used by grower (N = 8) and advisor (N = 6) survey respondents

The IPM Manual has a similar layout and content to other Australian and overseas manuals, independent of the target crop (comparison to lettuce IPM manual from Australia, and strawberry and potato IPM manuals from the USA. In all of the manuals there is a standard set of descriptions of pests and beneficial species (biological control agents). This is of course necessary to provide information on the key invertebrate species in each crop.

In the apple and pear IPM Manual this information is provided as a set of factsheets that comprise 127 pages of the 212-page manual. This is obviously a major focus of the manual – simply describing the range of pests and beneficials and providing information on how to identify them. This is separate to controlling pests.

The remaining sections of the manual are on controlling diseases (21 pages), the impact of birds (5 pages), references to sources of information and index (11 pages). There is also a section devoted to mating disruption (6 pages) and information about pesticides registered for controlling pests and diseases and the impact of these products on beneficial species (25 pages), suppliers of biological control agents and useful contacts (4 pages). There is an introductory page on IPM that is mostly taken from a USA manual.

The most familiar method for farmers to deal with pests is by the application of pesticides. This remains the standard today. The IPM Manual has a substantial amount of information on pesticide application. The manual lists the insecticide and miticide options for each pest and this also makes up a substantial amount of the manual (21 pages).

The manual lists the pesticides that can be used but also the impact of these pesticides on beneficial species. In many (most) cases, the pesticides are totally incompatible with beneficial species. This is an important point as the manual is suggesting the use of beneficial invertebrates but then also the use of pesticides that would kill them.

Use of information in the manual

Although the manual contains a substantial amount of information on the application of pesticides, a lot of this information is out of date, contains products that are no longer registered and also omits products that are widely used in the industry. In this capacity the manual is not succeeding as an IPM manual.

The main problem with the manual, as strongly stated by one Victorian grower interviewee, is that there is no integration of the information in the manual and so anyone wanting to use an integrated approach would have great difficulty in extracting the relevant information, even if it were there. This is a problem that is not restricted to the current apple and pear manual, but is a fault of most manuals that are called IPM manuals regardless of target crop type.

3.1.3 Alignment of IPM and market access

There was consensus (100% of grower interviewees) that IPM could be used to assist with market access and no one believed that it caused impediments to market access. There were two main reasons for this:

1. A reduction in chemical use was seen as something that was either necessary (export markets) or would be seen as positive (domestic and export markets).

   "IPM certainly improves market access – we use less chemicals. In an ideal world you'd use no chemicals." – Grower interviewee

   "We can't rely on broad spectrum chemicals when exporting." – Grower interviewee

   "I think it improves market access – we speak with our customers regularly and they like to hear that we use natural methods and try to reduce insecticide use in the orchard. It helps to improve our relationships with our buyers. People understand and appreciate this good story." – Grower interviewee

2. IPM should result in better pest control and so deliver a better product to market. This is certainly very true when insecticide resistant pests are concerned.

"Anything that helps with pest management creates better market access – minimising the amount of insect damage and presenting a marketable product." – Grower interviewee

The first reason may be due to a requirement from export countries that certain chemicals cannot be used. The image that can be marketed of reduced chemical use is advantageous for both export and domestic markets.

The second reason is reflective of a progressive industry that has chosen a sustainable approach to pest management that will reduce reliance on pesticides.

Grower survey responses largely echoed the views expressed by grower interviewees. When asked whether IPM is an impediment to gaining access to the domestic, Asian, European or American markets, over half (59%) of surveyed growers selected none of the above. When asked whether IPM could improve access to the same set of markets, a significant proportion (45%) of surveyed growers said that it could for the domestic market (Figure 7).

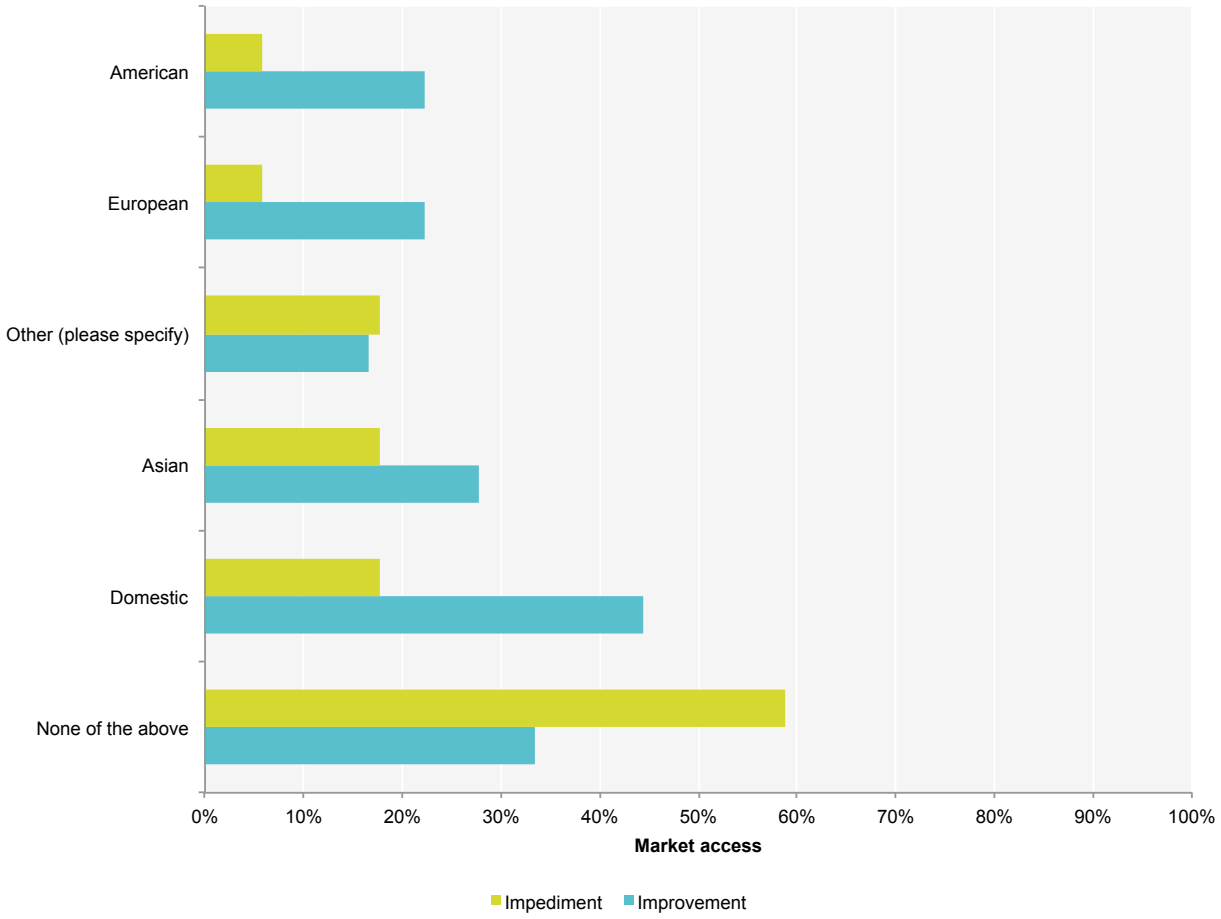


Figure 7: Perceptions of impediments (N = 17) and improvements (N = 18) of IPM to market access by grower survey respondents

The majority (80%) of surveyed researchers suggested that IPM could improve market access, both internationally and domestically. The reason given by one interview participant was:

"As an IPM approach is the only practical way to produce virtually any crop, it is vital to market access." – Researcher interviewee

However, while IPM was generally perceived to facilitate market access by those consulted as part of this project there are a number of issues and potential barriers that must be considered. The desktop review identified three major issues:

1. Quarantine issues – preventing market access both domestically and internationally (for example Queensland fruit fly)
2. Growers must comply with target market regulations regarding the use of pesticides – they must meet maximum residue limit (MRL) requirements set by that market
3. 'Clean and green' image (if growers really use IPM) can be used as a marketing tool both domestically and internationally (this was acknowledged in industry strategic plans reviewed as part of desktop review).

Current pest management practices that rely on pesticides can present barriers to export market access in some cases. The MRL's for different pesticides vary from country to country, but the older, broad-spectrum products such as organophosphates, synthetic pyrethroids and some carbamate insecticides are of particular concern, especially in the European Union. The problem is that products that are legal to use in Australia at present are either unacceptable in target markets overseas or are likely to result in above MRL breaches.

One such example is widespread reliance on carbaryl. The grower survey undertaken as part of this project found this product to be used by 56% of growers. The Australian MRL for this product is 0.2ppm, while for the European Union (EU) it is 0.01ppm.[16] The MRL for the EU is so low that it is too risky for growers to use this product at all if they are targeting the EU market. Clearly, in such a case, growers using IPM (and thus avoiding the need to rely on such a product) are at an advantage with regard to accessing the EU market.

The IPM practices that are currently available could be used to assist market access by reducing reliance on pesticides, but quarantine requirements or export protocols that only accept the use of pesticides that are disruptive to IPM are a major problem.

[16] Apple and Pear Australia Limited (2016) Apple and Pear Maximum Residue Limits <http://apal.org.au/wp-content/uploads/2016/02/Apple-and-Pear-MRLs-March-2016.pdf>, accessed 6 May 2016

3.2 Needs analysis (where)

3.2.1 Key IPM gaps, barriers and needs of growers

There was consensus amongst growers, advisors and other industry segments surveyed that pests and diseases in apples and pears were becoming harder to manage (ranging from 40-70% of survey respondents by segment). The predominant reasons for this increasing difficulty identified by those surveyed were:

- Weather and climatic factors enhancing pest pressure and/or negatively affecting beneficials (8)

  "Climate change and relating this back to yearly or seasonal decision-making – what does this mean, not in thirty or fifty years? There are also short-term more frequent and severe events that need to be managed, like heat waves and cold snaps." – Advisor interviewee
- Increasing resistance to existing chemical control options (7)
- Reduced access to products and effectiveness and/or withholding periods of remaining products (5)

  "Having population rise in insect that doesn't respond to IPM [is an issue]." – Grower interviewee
- Increasing cost of management options (2).

  "IPM is costly – either time in monitoring or reduced pack out, or both." – Advisor interviewee

This mainly related to the insect pests codling moth, woolly aphid and two-spotted mite, with scab being the only disease identified by a minority of survey respondents. Researchers unanimously agreed (100%) that pest management within the apple and pear industry could be improved.

The confidence in knowledge of controlling insect pests and diseases varied amongst growers from very low (1/5) to very high (5/5). However, confidence was generally moderate (3 to 3.4/5 weighted average) for insect pests, beneficial insects, insect life cycles and diseases.

The top challenges to implementing IPM in orchards identified by growers and advisors included:

- Not enough suitable chemicals (58% of growers, 30% of advisors)

  "The industry really needs more 'soft' miticides in particular." – Advisor interviewee
- Chemical based methods of pest control still offer better protection (43% of growers, 50% of advisors)
- Damage cannot be tolerated (43% of growers, 70% of advisors)

  "Supermarkets demand perfect produce and growers cannot tolerate any damage." – Advisor interviewee
- Lack of grower interest (30% of advisors) (Figure 8).

  "IPM adoption is at a high level but the standards could be raised. Growers are generally not interested in turning up to a field day on this topic and they expect that their agronomist is doing the job for them." – Industry association interviewee

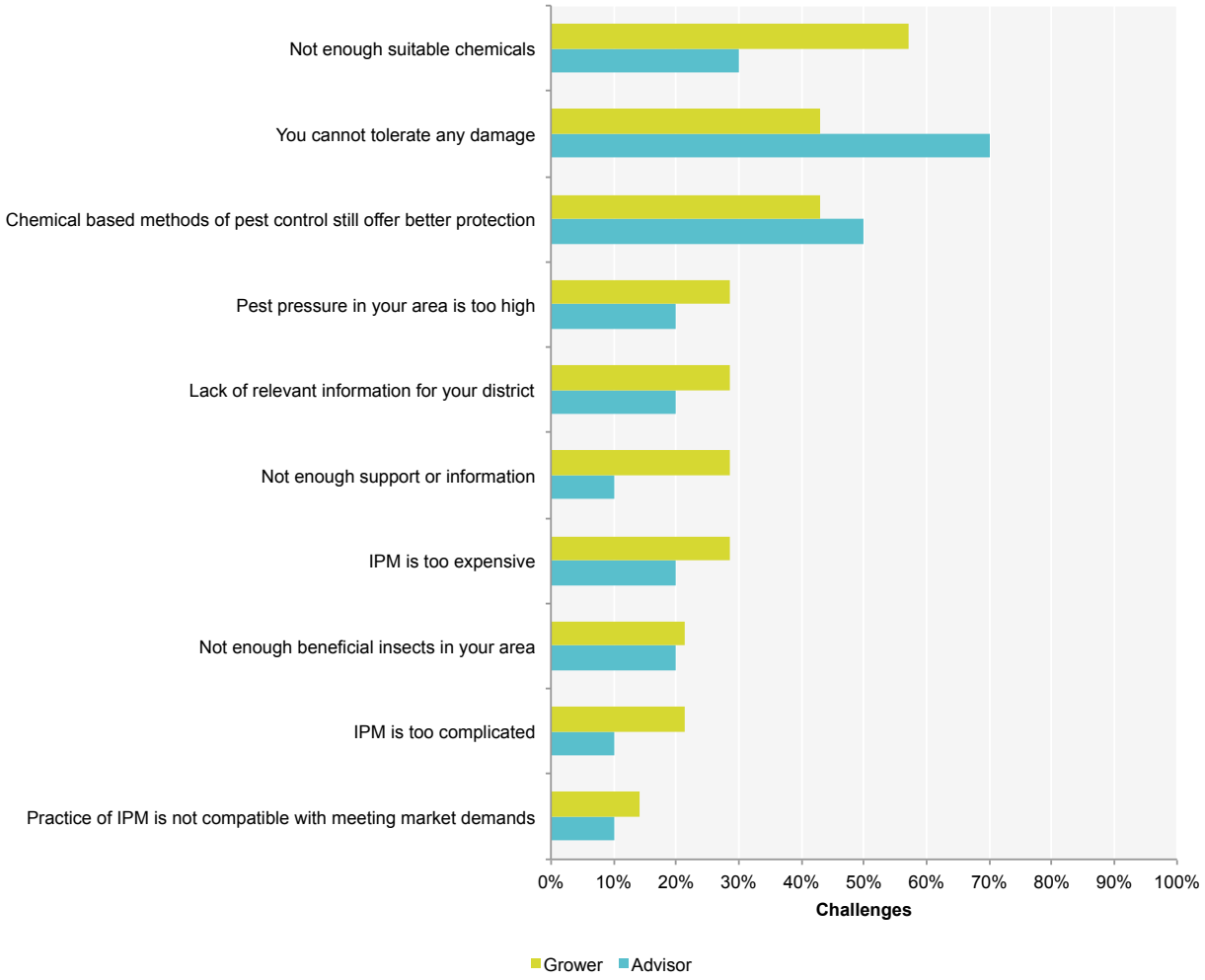


Figure 8: Challenges identified by grower (N = 14) and advisor (N = 10) survey respondents in implementing IPM

Not enough support or information (30% of growers) and lack of relevant district information (30% of growers and 20% of advisors) were also significant barriers identified in the survey. This correlated strongly with the interview data that showed relevant and timely extension of research and development is a major barrier to growers being adequately aware and knowledgeable of IPM, and having the necessary support and decision-making processes at their disposal to implement IPM. A large component of the decision-making was being able to balance the more strategic approach of IPM with more reactive day-to-day issues relating to fluctuations in pest pressure. However, this mainly related to the smaller to medium sized growers rather than the larger producers.

> *"Poorly serviced by private and public sectors for independent advice – extension is missing, it's the most important part of this."* – Grower interviewee

> *"We need extra support. Internally nobody really understands IPM. Our reseller agronomists don't either. We need expert advice."* – Grower interviewee

> *"I do a bit of agronomy with several growers from different areas on the mainland, and I sometimes cringe when I hear what they are doing or not doing. I question whether they have the know-how or resources to be doing the right thing."* – Advisor interviewee

> *"How is the new research being extended to growers and advisors? This is really lacking. We are finding out about research too late."* – Advisor interviewee

> *"Better adoption, extension is not being done correctly, while there is really good research being undertaken no one knows about it."* – State government interviewee

Lack of access to independent advice about pesticide effects on beneficial species is a key factor that is impeding adoption of IPM. This is especially true when the advisors are re-seller agronomists whose information about the toxicity of pesticides on beneficial species comes from the chemical companies whose products they sell.

> *"Not using IPM, but don't have advisor support locally – only chemical representatives."* – Grower interviewee

> *"We get information from chemical companies that is pretty good, but sometimes they just make a product look good and we find that the chemicals are more toxic to predatory mites or insects than they originally claimed."* – Advisor interviewee

> *"Growers should get access to more independent consultants who don't sell chemicals. Companies now offer a fee to service for monitoring and advice but their businesses are still underpinned by sales."* – Industry association interviewee

In the absence of a crisis, there is little incentive to change. While current pesticides are legal, available and they work the familiar approach of spraying is likely to remain.

> *"Guys have their head in the sand – 'if it ain't broke, don't fix it.' We use the simplest tools at hand. If the sprays still work, why do something different?"* – Grower interviewee

3.2.2 Improvements to IPM adoption and advice

All (100%) researchers surveyed agreed that adoption of IPM in the apple and pear industry could be improved.

There were a range of factors identified to improve IPM adoption and advice, most of which focus on grower level information provision and access to support. These include:

- **Regional extension programs** – These could include in-field demonstration of IPM in commercial crops, including local demonstrations of IPM being implemented successfully, supported by the information required for growers and advisors to make decisions.

  > *"Field demonstrations are an effective way of encouraging growers to have confidence in particular changed methods."* – Researcher interviewee

  > *"Don't really need more research. When any new chemical or technology comes out it is generally not accepted until your neighbour is doing it – then it gets accepted. People reasonably fearful of complete failures. Just getting someone to use it once is usually the key to adoption."* – Grower interviewee

- **Improving the capacity of advisors to provide reliable and independent advice** – By training of advisors in all aspects of IPM via an accredited course. Information that could be covered within the course includes information about beneficial insects and mites, pest and beneficial lifecycles, the impact of pesticides on these beneficials, or monitoring. For example, the NSW Department of Primary Industries are currently developing an online training module for crop scouting and monitoring.

  > *"I think it is important to work with both consultants and growers themselves to give them more confidence in their decision making. Try to make it as simple as possible. No different to a lot of the other decisions they make – just need to build confidence."* – Researcher interviewee

"Should always be looking to raise industry best practice baseline, however state government does not have the capacity to work in this space anymore so it's a gap." – State government interviewee

- **Increased information sharing and integration amongst growers and advisors either through groups, on-farm events or district-level resources** – An example of this could be the re-instatement of programs such as 'Crop Watch', which until recently was managed by Fruit Growers Victoria (FGV). This program involved scouts regularly monitoring crops at a district level, putting information into a centralised system and advising growers on management options. While this program is no longer being conducted by FGV they still have the licence to do it if required/wanted.

  "It would be good to see this re-instated to provide reputable, independent advice" – Researcher interviewee

- **Whole-of-orchard system approach to insect pest and disease management by growers and advisors** – By recognising where and how IPM fits with the broader orchard agro-ecosystem and business management objectives of growers. There also needs to be an increased focus on integration and how chemical, cultural and biological controls are combined and interact with each other.

  "Prioritisation of issues compared to the whole farm system – market prices, chemical prices, fuel prices, business management, labour, pest and disease management, of which IPM is a small component." – Advisor interviewee

  "Growers are businessmen with a whole raft of things going on and IPM is not high on their list of priorities." – Industry association interviewee

- **Appropriate market signals that lowered chemical residue on fruit and/or accepted superficial skin marks on otherwise quality product** – Communicating and assisting growers to strategically grow fruit to a specific market using IPM, be this domestic or international, with due consideration of MRLs and phytosanitary requirements. This is in contrast to the more reactive approach of selling into a market without adequate planning and primarily based on price (e.g. only exporting internationally when prices are good, but exceeding specified MRLs). Consumer preference and education is also an important consideration when targeting a specific market (e.g. Ugly Fruit and Veg Campaign).

  "Market pressure should be the carrot to getting more growers to use IPM." – Grower interviewee

  "Market access and having appropriate protocols and consistent whole-of-industry approach." – Advisor interviewee

- **Improved communication to growers and industry of the benefits of implementing an IPM approach** – This is linked to the previous point about the importance of demonstrating the practical benefits of IPM, then appropriately communicating this through existing industry channels and where growers are currently sourcing information. Communication methods could include cost benefit case studies, videos on technology and practice change, articles in e-newsletter such as *Industry Juice*, or more in-depth analysis in industry magazines such as the *Australian Fruitgrower*.

  "Need to understand costs and benefits of making the change to IPM – 'crunch the numbers' with our advisor and collate and make numbers make sense in-house." – Grower interviewee

  "Need to take out some of the marketing, for example californicus can offer control, but will not be able to control alone." – Advisor interviewee

Survey responses confirmed the information provided by researchers (as discussed above), that the required support to improve IPM adoption and implementation should include:

- Additional farm walks as part of the Future Orchards extension program (77% of growers, 67% of advisors)
- Better access to reliable IPM advice (77% of growers, 56% of advisors)
- Further information and/or resources on the costs and benefits of an IPM approach (69% of growers, 44% of advisors) (Figure 9).

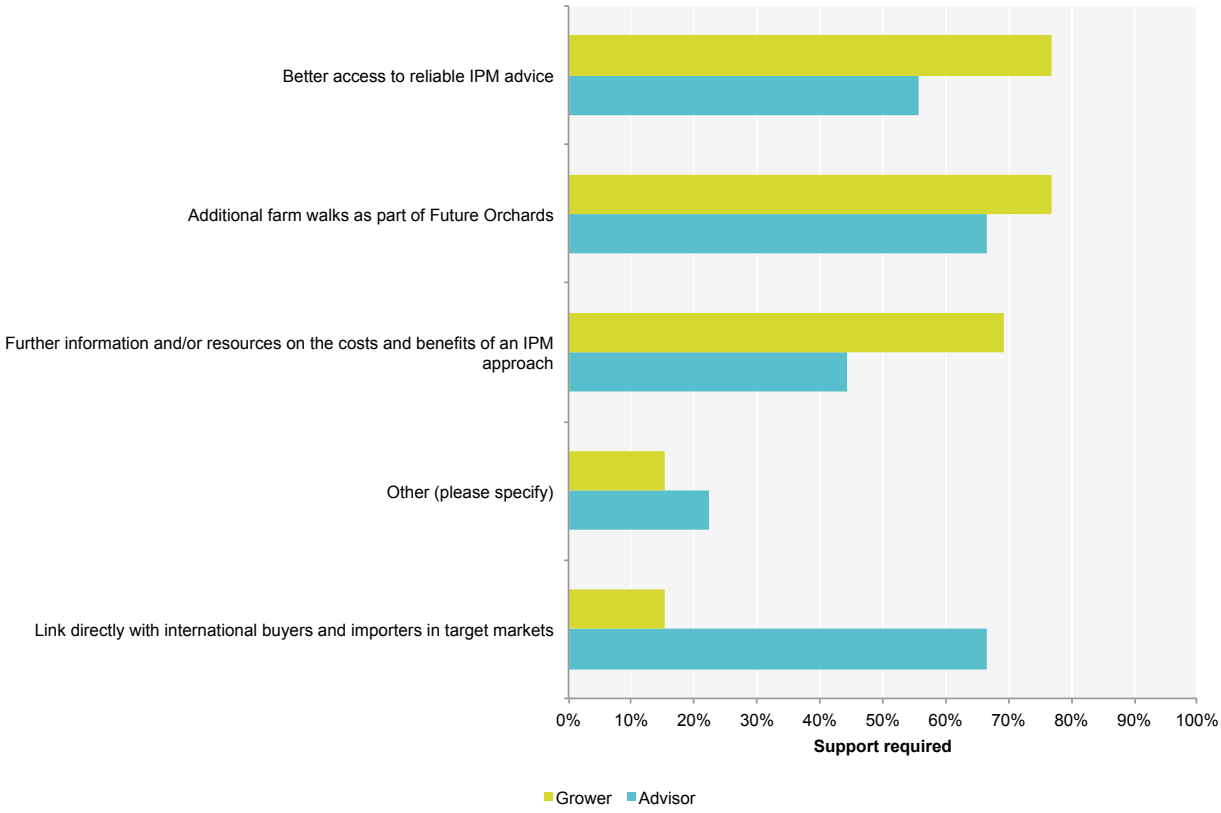


Figure 9: Support required to improve adoption and implementation of IPM identified by grower (N = 13) and advisor (N = 9) survey respondents

3.2.3 Updates to the current IPM Manual

Researchers identified the main strengths of the current IPM Manual as breadth of pest and disease coverage applicable to Australian growing conditions and strategies focussing on pests. The weaknesses identified included lack of coverage of weed pests, disease management and postharvest management.

There was consensus amongst growers, advisors and other industry partners surveyed that the current IPM Manual needed to be updated (77% of growers, 80% of advisors).

> *"The part completely missing from the manual is the word 'integration'. It needs a completely different approach. The manual needs to explain how to integrate control measures. Growers need help to see and understand the orchard as an ecosystem. I suggest a decision tree model be used to show how decisions made in relation to the control of one pest or disease impact control (or control failure) for other pests or diseases."* – Grower interviewee

> *"Need to improve readability and need more specific information on how to actually manage the pests – it doesn't help us to make decisions."* – Grower interviewee

> *"Should be updated annually to incorporate new pests, new beneficials, update chemical list, new work and research, impacts of climate change and recent seasonal conditions on IPM, impact of chemicals on beneficials, what pests and beneficials are native or introduced. For example, light brown apple moth with huge numbers in traps but limited damage to crop, doesn't mean you have to control."* – Advisor interviewee

Researchers surveyed identified the technical content as the most important (100%) aspect to update, followed by improved information for facilitating decision-making by growers (75%), and better

accessibility and ease of use (50%) (Figure 11). This could also play a part in improving IPM adoption and advice provided the manual contained useful information communicated where and when the target audience needs to access it.

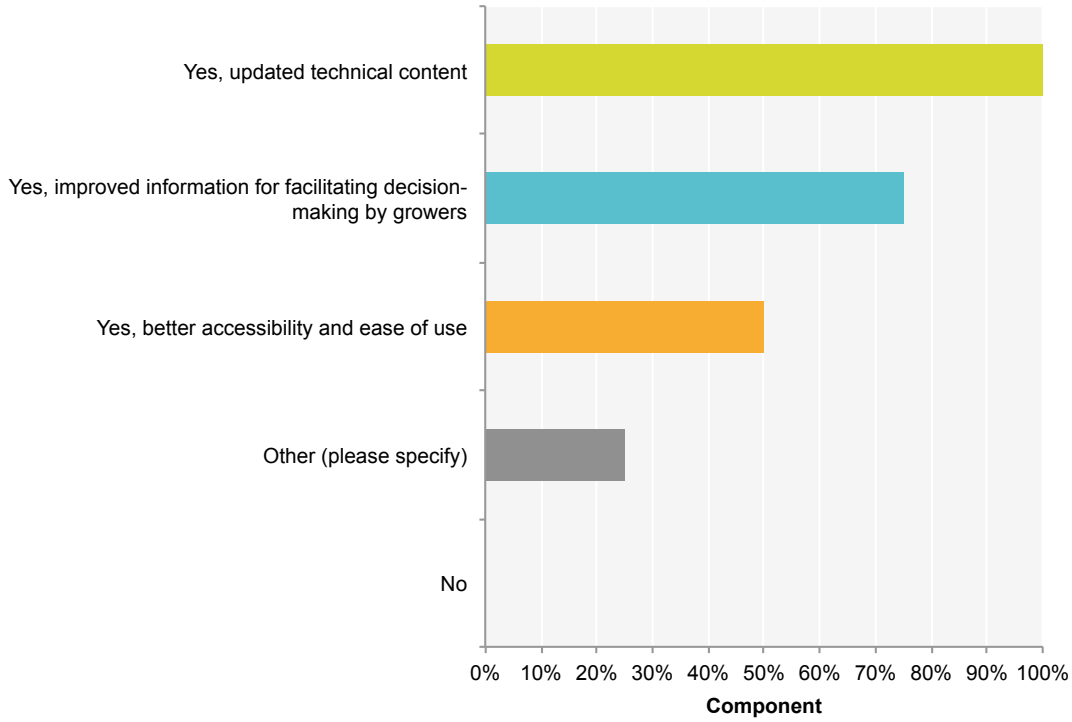


Figure 10: Improvements to the current IPM Manual identified by researcher survey respondents (N = 4)

The main improvements to the current manual include:

- Update the pesticide component as this is no longer current, and possibly remove the information about pesticides from the manual and incorporate in a separate, online access site that is updated regularly
- Improve information on beneficial insects and mites, including identification
- Ensure coverage of all pest, diseases and weeds relevant to the apple and pear industry, as there are currently gaps. For example, harlequin bug is becoming a more significant secondary pest and it is not included in the manual
- Spray calibration should include the use of three-row volume, spray drift and tower sprayers
- Provide a guide on how to integrate control measures
- Improve accessibility by having section(s) online that are more readily used by growers and advisors as a decision support tool, which would also make that manual more adaptable and easy to update when necessary.

A minority of growers did not think the manual should be updated. This was based on the current manual not containing appropriate information to inform decision-making in an accessible format. However, updating the manual would be valuable to the industry.

> *"The manual has limited value in terms of supporting IPM use. As soon as a new chemical is registered the manual becomes out of date."* – Grower interviewee

> *"It's a good resource, it's just not being used. It's sitting on the shelf or in the draw somewhere, but growers are not using it because why should they – they're not required to."* – Grower interviewee

> *"I think any document like that has to be kept relevant. It is one of those things that needs to be a dynamic document and will need to be updated."* – Advisor interviewee

International importer survey respondents (100%) did not think that an IPM approach facilitated market access for apples and pears both internationally and domestically. However, there was insufficient qualitative data collected to substantiate or explore the rationale behind this finding.

Concerns relating to the update of the manual as a 'market access' document

It was noted during a number of interviews with researchers and APAL that an update to the IPM Manual, with a view to facilitating market access, should consider the potential for the document to restrict access rather than promote it. While the development of a 'systems approach' would be beneficial in terms of how pests are managed by industry it could also provide opportunity (if documented) for export markets to potentially exclude product based on minor pests, that have been included in the manual for management purposes, but are not of prime concern. Instead it may be of more benefit for the manual to identify the pests of prime market/biosecurity concern and focus on those.

> *"The danger of producing a manual which covers all pests opens up a whole lot of other problems, in that it could be used as a market restriction document rather than a market access document"* – Researcher interviewee

A number of interviewees also referred to the *Summerfruit to China; Integrated Pest Management Program; Draft*[17] document and how a similar document could be of benefit to the apple and pear industry in promoting export market access.

Upon review of the document, it was viewed (by IPMT) as not an appropriate model for the apple and pear industry to use as an 'IPM' market access tool as it does not actually present an IPM program or IPM solutions to pest problems. While the document claims in its title to be an IPM program, it is actually an outline of the pest monitoring and control requirements for growers wishing to register for export of summer fruit to China. Registered growers are required to employ an 'IPM' program that includes:

- Knowledge of the pests of concern for China
- Maintenance of orchard sanitation
- Monitoring of identified pests every two weeks
- Maintenance of pest monitoring records
- Application of in-orchard control measures for pests of quarantine concern
- Maintenance of control measure records.

If action is required to control a pest or disease, they are to refer to the *Integrated Pest and Disease Management for Australian Summerfruit* manual[18], which is almost identical in layout, approach and content to the Apple and Pear IPM Manual. The problem here is that the control options either required or suggested are spray-based, rather than truly *integrated* control strategies, and in many cases the sprays recommended are highly disruptive to beneficials and likely to flare other (both major and minor) pests.

[17] Summerfruit Australia Limited (2015) Summerfruit to China; Integrated Pest Management Program; Draft, Albury
[18] Summerfruit Australia Limited (2005) Integrated Pest and Disease Management for Australian Summerfruit, NSW Department of Primary Industries, Sydney

This document, coupled with the Summerfruit IPM Manual that it is to be used in conjunction with, present little more than a monitoring protocol and an (out-dated) spray program. This is not an IPM program, and in its current form, would likely disturb attempts to properly implement IPM, by placing pressure on growers to use disruptive in-orchard controls for pests of quarantine concern.

Such an attempt to brand pest monitoring and chemical-based control as IPM should not be viewed as an appropriate model for the apple and pear industry in its current form. If such a model is to be used, it is imperative that both pest and beneficial monitoring are suggested, and that truly integrated IPM options are presented as acceptable means of controlling pests within the export registration protocol.

3.3 Recommendations to meet needs (how)

3.3.1 RD&E required to address key IPM gaps and barriers

Research and development

Growers and advisors surveyed identified the following areas as the four top priorities for further research and development in order to address key IPM gaps and barriers:

- Development of more soft chemicals compatible with an IPM approach (80% of growers and 67% of advisors)
- Research into cover crop options to improve weed, pest and disease management (73% of growers and 45% of advisors)
- Additional research on key insect pest and disease life cycles (67% of growers and advisors)
- Additional research on beneficial insects and mites (60% of growers and 45% of advisors).

Other areas for research and development identified by growers and advisors included:

- Assessment of the interaction between pesticide application and other crop management practices (such as nutrient management, irrigation and application of soil amendments) on pest management
- Further development of decision support tools and systems to capture data (such as degree day models (like RimPro) to strategically manage pest issues)
- Use of companion planting to mitigate pest damage
- Improved understanding of the mode of action of various chemical groups.

> *"Management of black spot could be improved with many poor choices being made on which group of fungicides to apply and when*" – Industry association interviewee

Researchers identified that a lot of the research conducted in the past tends to be pest specific but because growers are dealing with a range of pests this information needs to be integrated to create a program approach. At the moment this isn't happening:

> *"PIPS2 isn't as fully integrated as it could be. Need to look at how the outcomes of the individual projects could be integrated into a systems approach"* – Researcher interviewee

An example of this relates to one of the key outcomes of the IPM research conducted within the PIPS1 program, which identified a number of biocontrol agents (*M. ridens* and *H. calcarata*) for the management of codling moth and woolly aphid. While these biocontrol agents show promise for assisting growers to manage these insect pests, they are not compatible with the current mainstream orchard practices that involve continued reliance on broad-spectrum insecticide products that will be toxic to both of these biological control agents. If, and when, these exotic biocontrol agents reach the stage of being ready for commercial rearing and release into orchards, they will only be of value to the industry if growers know how to successfully integrate them into their control practices.

In addition to this work on potential biocontrol agents for codling moth and woolly apple aphid, PIPS1 also included a desktop review aimed at identifying the important interactions between pests, diseases, host plants, and the biological agents and pesticides used to control them; and a review to compare current scab models from around the world and work towards developing a new model combining the best attributes of the earlier models. Of these, the work on scab modelling has the greatest potential to translate into adoption-ready technology that could significantly influence IPDM outcomes in the near future. Scab modelling improves decision making around fungicide use, helping growers optimize the timing and therefore effectiveness of fungicide applications.

Extension

It was generally agreed by those interviewed that while there is a good level of research and development (R&D) occurring into effective pest management within the apple and pear industry, it is the effective extension of this R&D that is lacking.

Some key examples of where improved extension of R&D is required include:

- **Sterile Insect Technology plus Area Wide Management (SITPlus)** – an increased proportion of industry stakeholders should know what this is, why it's relevant and what it means for them. For example, some growers and advisors are not aware of the potential of releasing sterile male Queensland fruit fly (Q-fly) for disrupting insect mating, nor the particular population thresholds that must be reached through other control measures for SITPlus to be effective. The SITPlus facility in Port Augusta, South Australia, will also have the capacity to produce 50 million sterile male Q-flies each week and is due for completion in October 2016, with the first flies produced late 2017 and fully optimised by late 2019. There have recently been measures put in place to address this, in part, through the appointment of a National Coordinator for Queensland Fruit Fly and Area Wide Management by Hort Innovation
- **The communication and adoption of improved selective (softer) chemistries** – to reduce the time required to approve new chemistries, researchers should be required to engage with regulators to inform the process. Chemical companies should also invest further in communication and engagement to improve the adoption of new chemistry by industry
- **Area Wide Management (AWM) protocols for domestic and international trade** – the development of AWM protocols require the involvement of researchers and other key industry stakeholders to ensure that protocols facilitate trade. This process needs to determine the desired industry outcome and what tool will be most appropriate to achieve this outcome, considering the International Standards for Phytosanitary Measures (ISPM) under the International Plant Protection Convention (IPPC) such as Areas of Low Pest Prevalence (ALPP, ISPM 30), Pest Free Areas (PFAs, ISPM 29), or Pest Free Places of Production (PFPP). For example, this has occurred in the citrus industry within the Central Burnett region of Queensland as well as the table grape industry in the Sunraysia region of Victoria
- **Facilitating co-innovation** – involving growers and advisors earlier in the research and development process to ensure the practicality and adoption of outputs.

  > *"One of the better systems has been with APAL with speed updating and a snapshot of what is going on – to understand breadth, as well as the AUSVEG model with extension of potato research."* – Advisor interviewee

There are also a range of other measures to improve IPM adoption and advice already discussed in section 3.2.2, including:

- Regional extension programs
- Improving the capacity of advisors to provide reliable and independent advice

- Increased information sharing and integration amongst growers and advisors either through groups, on-farm events or district-level resources
- Whole-of-orchard system approach to insect pest and disease management by growers and advisors
- Appropriate market signals that lowered chemical residue on fruit and/or accepted superficial skin marks on otherwise quality product
- Improved communication to growers and industry of the benefits of implementing an IPM approach.

3.3.2 RD&E aligning IPM with market access requirements

Consideration of protocols and regulations are essential in ensuring that future RD&E aligns IPM with market access requirements. Survey respondents felt that in order for IPM to facilitate market access, future RD&E needed to be:

- Aligned with target export market phytosanitary requirements (56% of growers, 100% of advisors)
- Address national interstate trade requirements (33% of growers, 57% of advisors)
- Better linked with Commonwealth Department of Agriculture and Water protocols (44% of growers, 14% of advisors) (Figure 11).

Key to this will be an IPM approach being used to leverage market access by demonstrating that market sensitive pests or diseases can be controlled. This could be through certification of monitoring protocols and registration of field scouts. An example of this is the online block registration process used in the table grape industry.

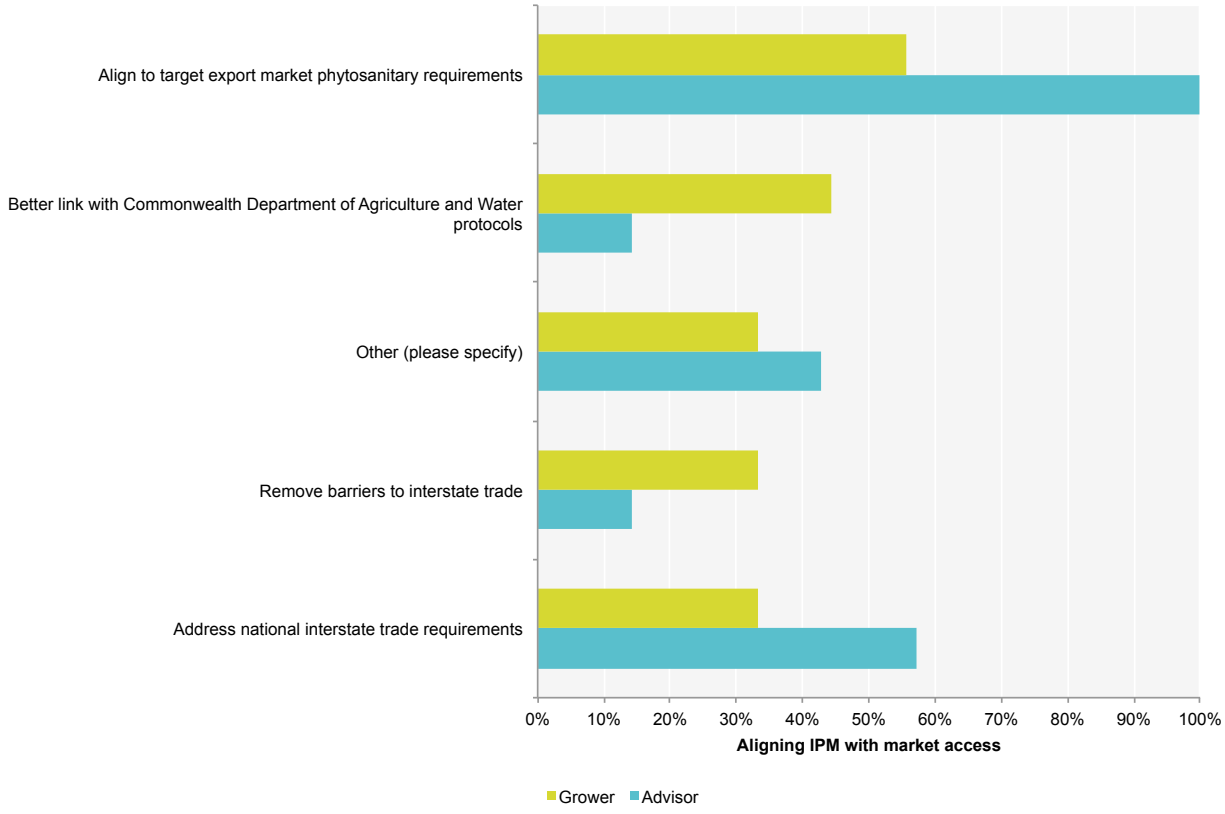


Figure 11: RD&E required to align IPM with market access requirements as identified by grower (N = 9) and advisor (N = 7) survey respondents

It was noted by researchers and government organisations that the development of market access protocols require a more strategic approach, rather than the sometimes 'left of field' and reactive development that has occurred to date. This would require a more coordinated and consultative approach

between the peak industry body (APAL) and relevant organisations (such as Plant Health Australia (PHA)) and regulators (both Commonwealth and state) to ensure that industry needs are understood and met within the development of trade protocols.

A key example is the potential development of a coordinated approach for management of Q-fly that should require APAL to engage with PHA in a targeted way to ensure understanding of:

- **Objectives** – what does the industry want to achieve and what does success look like. For example, is it market access, and if so why access to that particular market?
- **Priority of the pest for industry** – the degree to which Q-fly is, or has the potential to, cause significant crop damage and/or loss and therefore economic loss. As this is the case for apples and pears, the issue should be included in the PHA work plan and questions remain as to why this is not the case
- **Need for development of appropriate protocols** – addressing the management gap through International Standards for Phytosanitary Measures (ISPM) under the International Plant Protection Convention (IPPC) such as Areas of Low Pest Prevalence (ALPP, ISPM 30), Pest Free Areas (PFAs, ISPM 29), or Pest Free Places of Production (PFPP).

Most interviewees agreed that while IPM wouldn't provide market access in itself it does provide the opportunity to 'value add' to current and future trade through the provision of high quality fruit with minimum chemical residues. Promoting market access through the implementation of an IPM approach requires that practices are auditable and follow a quality assurance process, such as Hazard Analysis and Critical Control Points (HACCP), to address risks and demonstrate that entry requirements have been met.

> *"Summerfruit and cherries have been very effective in employing IPM for a market access advantage – to promote 'clean green image' as well as assurance to importers the fruit is going to, that we are monitoring the orchard and only spraying when we need to control the pests we have. Important when we are not competing on price and demanding a premium … Something similar should happen in apple and pears."* – Advisor interviewee

> *"Putting in place an auditable system with a third party assessment at harvest. Industry wants to show how good they are but wont mean anything unless they can document and prove they are using that systems"* – Researcher interviewee

However until there is a clear requirement for growers to meet these types of regulations, and while there are effective chemistries to manage pests, it is unlikely that large sectors of the industry will adopt a fully integrated pest management approach.

3.3.3 Prioritising RD&E to meet the needs of growers

Identifying value to whole of industry

Researchers felt that before industry invests further in activities that will facilitate and promote export trade there needs to be further investigation on the benefit this will provide to the whole industry (since only a small percentage of the total crop is exported) and the current capacity and ability of individual growers to meet the expectations and demands of export markets.

This could include assessment of:

- The number of growers who are resilient to the costs and uncertainty of exporting to international markets

- How current production systems can be refined to meet the rigorous standards of export markets including the dedication of blocks to fruit grown for exporting (rather than using fruit opportunistically when opportunities arise)
- Sociological studies to segment growers and identify what would be required to incentivise growers to take on production practices required to consistently meet export demands
- The potential for domestic markets to reward growers for meeting more exacting standards.

Increasing coordination between all sectors of industry to improve RD&E outcomes

There is also a significant gap in meaningful two-way information exchange from the grower level up to researcher, policy makers and regulators and vice-versa.

> *"[There are] a range of committees and forums where researchers, regulators and others get together and bombard each other with information to the point where they cant make decisions. If industry is going to invest – they need to quantify the outcomes and understand risk through a needs analysis. Don't assume this will happen through a presentation at a forum or relationships or osmosis – needs to be more deliberate."* – State government interviewee

There would be value in industry playing a proactive role in having input and seeking information through the relevant national forums to ensure appropriate and timely sharing of information. This could be through existing channels, for example various PHA committees or the National Fruit Fly Taskforce.

Ensuring that all industry segments support the use of IPM

While RD&E can, and should, focus on assisting growers to implement IPM within their business, for this to be successful all segments of the industry need to be supportive of this approach. The activities of particular sectors such as retailers and the chemical registration process will impact on how effectively IPM can be used to facilitate trade.

Retailers

The International Federation for Produce Standards (IFPS) has identified an issue with European retailers specifying non-regulatory MRLs that are much less than regulatory MRLs, to the detriment resistance management in particular, which is a key consideration of IPM. These non-regulatory MRLs may be arbitrarily set at, for example, 50% of the regulatory MRL without any understanding of the consequences for producers. There is a real risk that other retailers will follow suit, including Australian retailers, and that European retailers with a footprint outside of Europe in markets more likely to be supplied by Australian exports will demand the same requirements. This is a global issue, hence why it has been taken up by the IFPS and the Southern Hemisphere Association of Fresh Fruit Exporters.

This behaviour by retailers limits the ability of growers to select the best product to meet a range of outcomes (including those desired within an IPM approach). By imposing requirements aimed simply at reducing residues (quantity and concentration) growers are not able to pursue IPM in its true form. This also undermines environmental sustainability.

Chemical registration process

Given the long process of Plant Protection Products (PPP) registration, of equal concern is that producers may have to use older, less desirable and more hazardous PPPs, possibly making it more difficult to comply with new IPM practices. This issue was noted by one grower as a barrier to using IPM for the production of export quality fruit:

> *"In a lot of the markets we export to there is a lag between when the chemical is available in Australia for use and the acceptable MRL in the receiving company. Not because there is an issue but because the process hadn't been finalised. This means we have to use second or third-choice chemical product."* – Grower interviewee

Ensuring registration processes for new chemical products are managed effectively and quickly will enable growers to select the most appropriate products for use within an IPM approach and to meet the residue limits set by receiving countries.

4 Discussion

4.1 Adoption of true IPM is low

The elements that can be used to form an IPM strategy in apples and pears are available in Australia, and these are known to be effective when used correctly. Proof of this was presented in the survey and interviews conducted in this project where some growers were using IPM very effectively and had been doing so for many years. Awareness of IPM is high and the perception that the industry is using IPM is common amongst sectors of the industry, but actual adoption of IPM across the industry is low.

There are several likely reasons for this, including the apple industry historically being one of the first crops to use IPM and problems with mites over 25 years ago driving a change to using predatory mites as part of an IPM approach. Monitoring crops is a well established practice, but often now this is more pest monitoring allowing decisions on when to spray an insecticide or miticide. The term IPM is therefore rather vague at present as it means different things to different people. It is clear that to some simply conducting monitoring means IPM and to others, simply buying beneficial insects or mites is IPM. Then there are those who are genuinely using IPM. The results of this project show that there is actually a low level of adoption of IPM across the industry as a whole despite a perception by many that the industry uses IPM. This situation is actually very similar in many crops around the world, where adoption rates of IPM are typically low and slow.[19]

It was clear from the consultation undertaken in this project that there were very different attitudes to pest management (by both growers and advisors) and that the type of advice available was one very strong factor in whether IPM was being implemented or whether a spray-based approach was used. This result has been found before in Australia[20] where IPM adoption by potato growers was strongly linked to the capability of the advisors to deliver IPM advice. Training of advisors in IPM would be necessary in many locations where there is currently not a lot of confidence in either using IPM (grower) or giving advice based on beneficial populations and cultural control measures and not just a pesticide based approach.

4.2 IPM Manual is moderately useful but should be updated

The current IPM Manual provides a good reference tool for information regarding the major pests although a couple more pests should be added. However, the information regarding beneficial species is less thorough and could be improved by providing a similar level of detail to that provided on the pests. The information on pesticides is out of date and in one important section – the information regarding effects of certain pesticides on beneficials appears to be wrong or could be misleading. More precise information, including data on sub-lethal effects of pesticides and not just acute tests, is required for growers or advisors to make good decisions on pesticide use.

Pesticide resistance is recognised by some in the industry, but it is clear that there are several key pests (Codling moth and two-spotted mite in particular) that may develop resistance to the existing available pesticides, and it is unlikely that any new insecticide or miticide groups will become available in the next few years. Therefore, while there is no crisis with pesticide resistance at the present time – it may develop extremely soon. The apple and pear industry needs to shift to an IPM basis for pest management in order to avoid or else deal with such a crisis.

[19] Horne, P.A. and Page, J. (2011) Changing to Minimal Reliance on Pesticides, p. 337 - 346 in: Pesticides in the Modern World - Pesticides Use and Management, Margarita Stoytcheva (Ed.), ISBN: 978-953-307-459-7, InTech, Available from: http://www.intechopen.com/articles/show/title/changing-to-minimal-reliance-on-pesticides

[20] Horne, P.A., J. Rae, J., Henderson, A. and Spooner-Hart, R. (1999) Awareness and adoption of IPM by Australian potato growers. Plant Protection Quarterly 14: 139-142

In its current form the manual is not sufficient to provide a grower or advisor with the information or guidance on how to develop an IPM strategy. The information is too compartmentalised and the lack of integration means that it would be extremely difficult to impossible for growers to successfully implement an IPM strategy based on the manual in its current form.

This limitation means that it would also be difficult to impossible for the manual as it is now to be used to influence market access if adoption of IPM is the key factor.

To be able to use the manual to influence market access it would be necessary to:

1. Clearly show growers how to implement an IPM strategy as outlined in the manual (not there at present)
2. Provide better information on beneficial species including identification, life-cycles, target pests, effects of pesticides on these species (not there at present)
3. Provide accurate and up to date information on pesticides that are registered and also the MRL's or limitations required by target countries for export. This would be best placed in an on-line format, not as part of a hard copy manual[21]
4. Provide an IPM option, not just an insecticide or miticide spray, in export protocols. If the only choice in an export protocol is a pesticide that is disruptive to IPM (the current situation) then it cannot be hoped that the IPM manual can be used to assist export market access.

4.3 Extension is a key gap to IPM adoption and advice

There was agreement from many growers, advisors and researchers that one of the best ways to improve confidence in IPM for all involved is through on-farm demonstration. This has been proven in many types of crops.[22,23] Basically, growers wanted to see an IPM strategy work in a commercial situation, and know that it was both effective in controlling all pests and that it was economically viable. Such demonstrations are also extremely valuable in giving advisors who are not currently comfortable with providing IPM advice the confidence that something other than a spray-based program can work.

Other measures to improve IPM adoption and advice include:

- Broader regional extension programs
- Improving the capacity of advisors to provide reliable and independent advice
- Increased information sharing and integration amongst growers and advisors either through groups, on-farm events or district-level resources
- Whole-of-orchard system approach to insect pest and disease management by growers and advisors
- Appropriate market signals that lowered chemical residue on fruit and/or accepted superficial skin marks on otherwise quality product
- Improved communication to growers and industry of the benefits of implementing an IPM approach.

While not as high a priority as extension of existing research, the following areas were identified as priority for future R&D:

- Development of more soft chemicals compatible with an IPM approach
- Research into cover crop options to improve weed, pest and disease management

[21] Apple and Pear Australia Limited (2016) Apple and Pear Maximum Residue Limits, <http://apal.org.au/wp-content/uploads/2016/02/Apple-and-Pear-MRLs-March-2016.pdf>, accessed 6 May 2016

[22] Horne, P.A. and Page, J. (2011) Changing to Minimal Reliance on Pesticides, p. 337 - 346 in: Pesticides in the Modern World - Pesticides Use and Management, Margarita Stoytcheva (Ed.), ISBN: 978-953-307-459-7, InTech, Available from: http://www.intechopen.com/articles/show/title/changing-to-minimal-reliance-on-pesticides

[23] Horne, P.A., Page, J. and Nicholson, C. (2008) When will IPM strategies be adopted? An example of development and implementation of IPM strategies in cropping systems. Australian Journal of Experimental Agriculture 48:1601 - 1607.

- Additional research on key insect pest and disease life cycles
- Additional research on beneficial insects and mites.

4.4 Protocols are needed to align IPM with market access

As discussed in the findings, IPM in itself will not provide market access but should be used as a tool to 'value add' and facilitate the expansion of export trade. IPM naturally aligns with the marketing of product from Australia in that it results in a product that has been grown in an environmentally sustainable way with reduced pesticide application. In order for IPM to be effectively used as a tool for facilitating market access the approach needs to be:

- **A component of the appropriate industry-driven protocols and certification processes** – the development of protocols requires the involvement of researchers and other key industry stakeholders to ensure that protocols facilitate trade. This requires determination of the desired industry outcome and the most appropriate tool to achieve this outcome, considering the International Standards for Phytosanitary Measures (ISPM) under the International Plant Protection Convention (IPPC) such as Areas of Low Pest Prevalence (ALPP, ISPM 30), Pest Free Areas (PFAs, ISPM 29), or Pest Free Places of Production (PFPP). Key to an IPM approach being used to leverage market access will be the demonstration that market sensitive pests or diseases can be controlled. This could be through certification of monitoring protocols and registration of field scouts.
- **Communicated to growers –** as an approach that will enable them to produce high quality fruit that meets MRL standards in a range of export markets. While a high proportion of growers are aware of the environmental and sustainability benefits of using IPM, the ability of IPM to facilitate export trade has not been as well promoted.
- **Incentivised by markets and retailers** – use of an IPM approach within a production system is more complex and does require a higher skill set from growers. To encourage them to become 'fully integrated' in their approach to pest management, retailers and markets (both domestic and export) should be incentivising growers, which could also include better consumer education on acceptable quality standards. This could link with the recent agreement between major grocery retailers and Hort Innovation to streamline fresh produce safety requirements.[24]
- **Supported by the availability of appropriate pesticide products** – timely registration of PPPs will enable growers to select the most appropriate pesticides to use within an IPM approach while meeting the chemical residue limits of receiving markets.

[24] Horticulture Innovation Australia (2016) Global-first agreement with retailers to benefit horticulture growers, <http://horticulture.com.au/global-first-agreement-with-australian-retailers-to-benefit-horticulture-growers/>, accessed 29 June 2016

5 Conclusions and recommendations

5.1 Conclusions

Current status of IPM

- The current level of adoption of IPM in Australian apples and pears is low, despite a perception by many that it is high
- The most commonly practiced elements of an IPM approach are monitoring and mating disruption technology. Typically it is the use of harsh chemicals, that are disruptive to key beneficials, that undermine what many growers call an IPM approach
- All the tools required to allow growers to use IPM effectively are available and are being used by some, but grower and advisor confidence in IPM needs to be increased across the industry
- Pesticide resistance is not currently a major concern, but has the potential to cause a significant industry wide issue if a spray-based strategy is relied upon
- The industry needs to shift to an IPM approach in order to avoid (or deal with) pesticide resistance issues and to improve export potential.

Use and value of the current IPM Manual

- Awareness of the manual is generally high amongst small to medium growers, however this is not the case with larger growers
- Usefulness is moderate amongst those industry segments that are aware of the manual
- The manual is not being used to inform the development and implementation of an IPM approach on orchards, rather as an identification guide for insect pests, beneficials and compatible 'softer' chemicals
- The main weakness of the manual is that there is no integration of the information in the manual and a lack of support on how to integrate management approaches.

5.2 Recommendations

Requirements to improve IPM best practice, advice and adoption

- While further research and development would benefit the effectiveness of IPM within the apple and pear industry, the major requirement to improve the adoption of IPM is further extension
- A key gap identified during industry consultation was the availability of appropriate, independent support and district level information to assist IPM decision-making. Therefore key extension approaches should:
  - Develop regional extension programs that include demonstrations of IPM in commercial orchards
  - Improve the capacity of advisors to provide reliable and independent advice, for example through training and accreditation
  - Improve communication to growers and industry of the benefits of implementing an IPM approach
- Key recommendations on how to update the current IPM manual to make it a more effective and useful document include:
  - Maintaining the currency of pesticide information by housing content online, enabling regular updates

  - Ensuring coverage of all pest, diseases and weeds relevant to the apple and pear industry, as there are currently gaps. For example, harlequin bug is becoming a more significant secondary pest and it is not included in the manual
  - Providing a guide on how to integrate control measures
  - Improving accessibility by having section(s) online that are more readily used by growers and advisors as a decision support tool, which would also make that manual more adaptable and easy to update when necessary
- All segments of the apple and pear industry need to be supportive of an integrated approach to pest management in order to increase the implementation of IPM within industry. This needs to include:
  - Ensuring that retailers don't impose non-regulatory MRLs to the detriment of IPM and resistance management as identified by the International Federation for Produce Standards (IFPS), incentivise growers to produce fruit with minimum pesticide usage and educate consumers on appropriate quality levels
  - Improving the timeliness and information flow of the registration processes for new pesticide products
  - Promoting a coordinated and consultative approach between growers (industry association), researchers and regulators so that future RD&E is designed to promote market access and that trade protocols are developed that incorporate and support an IPM approach.

How IPM can align with, and facilitate, market access

Industry should:

- Continue to promote IPM as an approach which provides a natural fit within production systems focussed on market access in that it results in reduced pesticide usage and improved product quality
- Use IPM as a tool to leverage market access, demonstrate industry best practice and demand a premium for product (recognising that in itself IPM does not provide market access)
- Incorporate IPM into trade access protocols as part of a consultative approach between regulators and industry. Any IPM approach incorporated into trade protocols needs to be:
  - Auditable and follow a risk based approach such as HACCP
  - Designed to ensure market access (rather than restriction)
  - Promote a truly integrated management approach rather than just monitoring protocols.

Appendix 1: Interview guides

OVERVIEW

Interviews will be semi-structured and of approximately 45 minutes in length. Semi-structured interviews allow open-ended exploration of key concepts, and the opportunity for participants to contribute further details. This is particularly important to identify improvements and future directions for RD&E. Given the national distribution of industry stakeholders, the majority of interviews will be conducted via telephone.

The interview guides below will be used for targeted interviews and collection of in-depth primary data. Up to 20 interviews will be undertaken with the following stakeholders covering a representative geographic sample across the main growing regions:

- Grower/packer/exporter (8)
- Advisor (4)
- Researcher/state government (4)
- Industry association (2)
- Importer/buyer (2).

The consultation schedule outlining stakeholders to be interviewed is presented in Appendix 1. Interviews will be undertaken from 2 May to 3 June 2016. Stakeholders have been classified in the following priority order:

- High: must be interviewed (24)[25]
- Moderate: could interviewed based on the availability of high priority stakeholders (9)
- Low: could be interviewed or used as contingency for 'moderate' priority stakeholders (14).

Interview participants will be reminded that Integrated Pest Management (IPM) is an effective combination of chemical, cultural and biological methods to control both insect pests, vertebrate pests and diseases in apples and pears, as IPM can mean different things to different people.

GROWER/PACKER/EXPORTER

About your business

1. Which state(s) do you produce in?
2. What size producer are you?
   - Small (<50ha, single orchard)
   - Medium (50-200ha, potentially multiple orchards)
   - Large (>200ha, multiple orchards)
3. What are your target markets?

Current situation (now)

4. How do you currently manage insect pests and diseases?

Prompts:

- What are the key practices you use in an IPM approach?
- What are the key insect pests and diseases, and which are most difficult to manage?

[25] Note: some interviews will be combined to include two or more participants where appropriate.

- Has the insect pest spectrum changed in recent years?
- Are there problems with insecticide and miticide resistance?
- Do you rely on any beneficial insects or mites to help control pests? Can you list any?
- Do you need to buy beneficial insects or mites in order to use IPM?

5. If you are using IPM, is it effective?

Prompts:

- Is there a reduction in pest pressure?
- Has it resulted in increased pack out and marketable yield?
- Are there improved human and environmental health outcomes?
- Is it assisting to achieve business objectives?

6. Where do you access pest and disease management advice?
7. Are you aware of the current IPM manual (*Integrated Pest Management for Australian Apples and Pears*)? If so, do you use the manual, and is it effective?
8. Does IPM present challenges to meeting market access requirements, or does IPM improve market access? (considering both domestic and international markets)

Needs analysis (where)

9. Do you have adequate support to use IPM?

Prompts:

- Do you have access to enough IPM compatible pesticides? If not, where are the gaps?
- Do you have access to reliable information about the effects of pesticides on beneficial insects and mites?

10. What are the most significant challenges or barriers to implementing IPM in apples and pears?
11. Does the current IPM manual need updating or improvement?

Recommendations to meet needs (how)

12. What research and development (R&D) could be undertaken to address key IPM gaps and barriers?

Prompt:

- For example, is mating disruption for Queensland fruit fly or other pests a high priority for further research?

13. What support could be provided to improve IPM adoption and advice?
14. What RD&E is required to align IPM with market access requirements?

Prompt:

- How could IPM be used to facilitate market access?
- Are regulatory changes required to make IPM compatible with market access requirements?

ADVISOR

About your business

1. What state(s) do you operate in?
2. What is your position? (e.g. reseller agronomist, independent agronomist etc.)
3. How long have you been providing pest and disease management advice to the apple and pear industry?

Current situation (now)

4. What insect pest and disease management advice do you currently provide?

Prompts:

- Do you provide IPM advice?
- What proportion of your clients seek IPM advice and follow it?
- What are the key insect pests and diseases, and which are most difficult to manage?
- Has the insect pest spectrum changed in recent years?
- Are there problems with insecticide and miticide resistance?
- Do you recommend that growers rely on any beneficial insects or mites to help control pests? Can you list any?
- Do your growers need to buy insects or mites in order to use IPM?

5. If your growers are using IPM, is it effective?

Prompts:

- Is there a reduction in pest pressure?
- Has it resulted in increased pack out and marketable yield?
- Are there improved human and environmental health outcomes?
- Is it assisting to achieve business objectives?

6. Where do you access IPM information?
7. Are you aware of the current IPM manual (*Integrated Pest Management for Australian Apples and Pears*)? If so, do you use the manual, and is it effective?
8. Does IPM present challenges to meeting market access requirements, or does IPM improve market access? (considering both domestic and international markets)

Needs analysis (where)

9. Do apple and pear growers have adequate support to use IPM?

Prompts:

- Do growers have access to enough IPM compatible pesticides? If not, where are the gaps?
- Do you have access to reliable information about the effects of pesticides on beneficial insects and mites?
- Are you confident in making IPM decisions and providing IPM advice?

10. What are the most significant challenges or barriers to implementing IPM in apples and pears?
11. Does the current IPM manual need updating or improvement?

Recommendations to meet needs (how)

12. What research and development (R&D) could be undertaken to address key IPM gaps and barriers?

Prompt:

- For example, is mating disruption for Queensland fruit fly or other pests a high priority for further research?

13. What support could be provided to improve IPM adoption and advice?
14. What RD&E is required to align IPM with market access requirements?

Prompt:

- How could IPM be used to facilitate market access?
- Are regulatory changes required to make IPM compatible with market access requirements?

RESEARCHER/STATE GOVERNMENT

About your organisation

1. What state are you located in?
2. What is your position?
3. What agricultural industries do you cover?

Current situation (now)

4. Are growers using IPM?
5. What are the key practices being used by growers within an IPM approach to control pests?
6. What has changed in recent years regarding the pest spectrum?
7. Are growers effectively controlling pests using IPM (i.e. has pest pressure been successfully reduced? Are yield losses reduced?)
8. Are growers and advisors currently using the IPM Manual – how?
9. Do you think an IPM approach could be used to facilitate market access both domestically and internationally? If so, how?

Needs analysis (where)

10. Could pest management within the apple and pear industry be improved? How?
11. Could adoption of IPM within the apple and pear industry be improved? How?
12. What are the strengths and weaknesses of the current IPM manual?
13. Could the current IPM manual be improved? (i.e. in terms of technical content, ease of use and in facilitating decision-making by growers?)

Recommendations to meet needs (how)

14. What research is required to improve pest management in the apple and pear industry?
15. Does industry have the capacity/resources to address barriers to IPM implementation? If not, what is required to improve capacity?
16. What RD&E is required to align IPM with market access requirements?

INDUSTRY ASSOCIATION

About your organisation

1. What state are you located in?
2. What is your position?
3. How long have you been providing industry development services?

Current situation (now)

4. Are growers using IPM?
5. What are the key practices being used by growers within an IPM approach to control pests?
6. Are growers effectively controlling pests using IPM (i.e. Has pest pressure been successfully reduced? Are yield losses reduced?)
7. Are growers and advisors currently using the IPM Manual – how?
8. Do you think an IPM approach could be used to facilitate market access both domestically and internationally? If so, how?

Needs analysis (where)

9. Could pest management within the apple and pear industry be improved? How?
10. Could adoption of IPM within the apple and pear industry be improved? How?
11. What are the strengths and weaknesses of the current IPM manual?
12. Could the current IPM manual be improved? (i.e. in terms of technical content, ease of use and in facilitating decision-making by growers?)
13. How could the IPM manual impact/influence market access both internationally and domestically?

Recommendations to meet needs (how)

14. What RD&E is required to improve pest management in the apple and pear industry?
15. Does industry have the capacity/resources to address barriers to IPM implementation? If not, what is required to improve capacity?
16. What RD&E is required to align IPM with market access requirements?

IMPORTER/BUYER

About your organisation

1. What are you located?
2. What is your position?
3. How long have you been importing or buying apples and pears from Australia?

Current situation (now)

4. What are the key market access drivers for apples and pears?
5. What are the key international market access requirements for apples and pears produced in Australia?
6. Are international markets interested in how pests are managed in apple and pear orchards? Does this influence decisions relating to purchase of product?
7. Are you aware of the current IPM manual for the apple and pear industry? How does the manual impact/influence market access?

Needs analysis (where)

8. What is required to improve market access for apples and pears both internationally and domestically?
9. What are the key barriers to increased market access for apples and pears both internationally and domestically?
10. Does an IPM approach facilitate market access for apples and pears both internationally and domestically?

Recommendations to meet needs (how)

11. How could apple and pear growers improve their pest management practices to improve market access?
12. How could IPM be used as a market access tool for apple and pears?

Appendix 2: Survey questions

OVERVIEW

To capture the views of the broader industry an online survey will be conducted. The survey software Survey Monkey® will be used to gain input from a wider group of stakeholders. We have a number of techniques for ensuring high participation rates, including posting news items and reminders in the weekly *Industry Juice* e-newsletter, distribution through the Hort Innovation newsletter and incentivising responses. The online survey will complement the qualitative data from the industry interviews and will ensure that input from the wider apple and pear industry is captured. It will include closed quantitative questions as well as the ability to capture open-ended qualitative responses.

The main stakeholder groups will drive the line of inquiry for the survey:

- Grower/packer/exporter
- Advisor
- Researcher/state government
- Industry association
- Importer/buyer.

It is important to note that respondents will not be required to answer every question, as this will be based on their role and past experience in IPM.

The survey will be open from 2 May to 3 June 2016 and will take less than 10 minutes to complete. Participation is voluntary and all responses will remain confidential.

To acknowledge respondents' time is valuable and to say thank you for their participation, all completed responses with contact details will go into the draw for the chance to win a $150 R.M. Williams voucher.

Respondents will be reminded that Integrated Pest Management (IPM) is an effective combination of chemical, cultural and biological methods to control both insect pests and diseases in apples and pears, as IPM can mean different things to different people.

SECTION 1: INTRODUCTION

1. Where are you located? *(multiple choice, one answer)*
   - Victoria
   - New South Wales
   - Queensland
   - Western Australia
   - Tasmania
   - South Australia
2. What best describes your role? *(multiple choice, one answer)*
   - Grower, packer and/or exporter [GO TO SECTION 2]
   - Advisor [GO TO SECTION 3]
   - Researcher/state government [GO TO SECTION 4]
   - Industry association [GO TO SECTION 5]
   - Importer/buyer [GO TO SECTION 6]

SECTION 2: GROWER/PACKER/EXPORTER

About your business

3. What size producer are you? *(multiple choice, one answer)*
   - Small (<50ha, single orchard)
   - Medium (50-200ha, potentially multiple orchards)
   - Large (>200ha, multiple orchards)
4. What aspects of production and the supply chain do you cover? *(multiple choice, multiple answer)*
   - Growing
   - Packing
   - Logistics
   - Exporting
5. What are your target markets? *(multiple choice, multiple answer)*
   - Domestic market
   - Export market – Asia
   - Export market – Europe
   - Export market – America
   - Export market – Other (please specify)

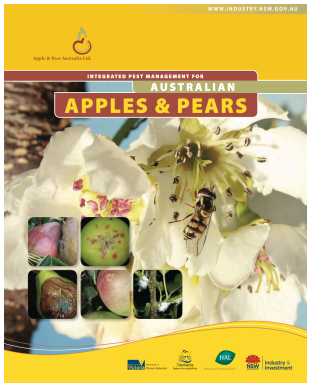
Current situation (now)

6. Do you use integrated pest management (IPM) in your orchard? *(multiple choice, one answer)*
   - Yes [GO TO QUESTION 7]
   - No [GO TO QUESTION 8]
7. Is IPM effective in controlling pests in your orchard?
   - Yes [GO TO QUESTION 10]
   - No [GO TO QUESTION 10]
8. Have you tried using an IPM approach in your orchard before? *(multiple choice, one answer)*
   - Yes [GO TO QUESTION 9]
   - No [GO TO QUESTION 9]
9. Select any of the reasons listed that describe why you do not use IPM in your orchard: *(multiple choice, multiple answer)*
   - IPM does not work
   - You do not have insect pest problems
   - IPM is too expensive
   - You need more support or information
   - You do not know what it involves
   - Lack of relevant information for your district
   - Chemical based methods of pest control still work
   - IPM is too complicated
   - Not enough suitable chemicals
   - Not enough beneficial insects in your area
   - Pest pressure in your area is too high
   - You cannot tolerate any damage
   - Other (please specify)

10. Do you monitor, or employ somebody to monitor, insects (pest or beneficial) and diseases in your orchard? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 11]
    - No [GO TO QUESTION 12]
11. How often do you monitor? *(multiple choice, one answer)*
    - Daily
    - Weekly
    - Fortnightly
    - Monthly
12. Do you rotate chemical groups to avoid the development of pesticide resistance? *(multiple choice, one answer)*
    - Yes
    - No
13. Do you rely on any of the following beneficials to help control pests in your orchard? *(multiple choice, multiple answer)*
    - Green lacewings
    - Hoverflies
    - Stethorus ladybird beetles
    - Cryptolaemus ladybird beetles
    - Persimilis predatory mites
    - Galendromus (formerly Typhlodromus) predatory mites
    - Californicus predatory mites
    - Aphelinus parasitoid wasps
    - Trichogramma parasitoid wasps
    - Other (please specify)
    - No – none of the above
14. Are there enough naturally occurring beneficials in your area for IPM to be successful? *(multiple choice, one answer)*
    - Yes
    - No
15. Do you buy and release biological control agents in your orchard? *(multiple choice, one answer)*
    - Yes
    - No
16. Do you use mating disruption technology (e.g. Isomate lures) in your orchard? *(multiple choice, one answer)*
    - Yes
    - No
17. Do you use any of the following fungicides in your orchard? *(multiple choice, multiple answer)*
    - Trifloxystrobin (FLINT)
    - Mancozeb (e.g. DITHANE)
    - Metiram (e.g. POLYRAM)
    - Ziram
    - Other (please specify)
18. Do you use any of the following miticides in your orchard? *(multiple choice, multiple answer)*

- Abamectin (e.g. VERTIMEC)
- Clofentezine (APOLLO)
- Bifenazate (ACRAMITE or FLORAMITE)
- Hexythiazoxs (CALIBRE)
- Propargite (OMITE)
- Fenbutatin oxide (TORQUE)
- Etoxazole (PARAMITE)
- Other (please specify)

19. Do you use any of the following insecticides in your orchard? *(multiple choice, multiple answer)*
    - Pirimicarb (PIRIMOR or APHIDEX)
    - Imidacloprid (e.g. CONFIDOR)
    - Chlorantraniliprole (ALTACOR)
    - Azinphos-methyl (e.g. GUSATHION)
    - Carbaryl (BUGMASTER)
    - Chlorpyrifos (e.g. LORSBAN)
    - Other (please specify)
20. Are you aware of the IPM manual titled *Integrated Pest Management for Australian Apples and Pears (multiple choice, one answer)*
    - Yes [GO TO QUESTION 21]
    - No [GO TO QUESTION 24]



21. Do you use this manual? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 22]
    - NO [GO TO QUESTION 24]
22. Select any of the following options that describe the way you use this manual. As a guide to: *(multiple choice, multiple answer)*
    - Identifying pest and disease problems
    - Monitoring pests and diseases
    - Identifying beneficial insects and mites
    - Chemical control options for pests and diseases
    - The effects of pesticides on beneficial insects and mites
    - The best way to apply sprays in the orchard
    - The use of mating disruption technology
    - Developing and implementing an IPM program for your orchard
    - Accessing markets, either domestic or export

- Other (please specify)

23. How would you rate the overall usefulness of the manual? *(rating scale from 1 = not useful to 5 = very useful)*
24. Is IPM an impediment to gaining access to the following markets? *(multiple choice, multiple answer)*
    - Domestic
    - Asian
    - European
    - American
    - Other (please specify)
    - None of the above
25. Can IPM improve access to the following markets? *(multiple choice, multiple answer)*
    - Domestic
    - Asian
    - European
    - American
    - Other (please specify)
    - None of the above

Needs analysis (where)

26. Are insect pests in apples and pears becoming harder to manage? *(multiple choice, one answer)*
    - Yes
    - No
27. Are diseases in apples and pears becoming harder to manage? *(multiple choice, one answer)*
    - Yes
    - No
28. Which pests and diseases are most difficult to control? *(comment box)*
29. How confident are you with your knowledge of: *(rating scale from 1 = low to 5 = high)*
    - Insect pests
    - Beneficial insects
    - Insect life cycles
    - Diseases
30. What are the top three challenges to implementing IPM in your orchard? *(multiple choice, multiple answer)*
    - IPM is too expensive
    - Not enough support or information
    - Lack of relevant information for your district
    - Chemical based methods of pest control still offer better protection
    - IPM is too complicated
    - Not enough suitable chemicals
    - Not enough beneficial insects in your area
    - Pest pressure in your area is too high
    - You cannot tolerate any damage
    - Practice of IPM is not compatible with meeting market demands
31. What would improve IPM adoption and advice? *(comment box)*

32. Does the current IPM manual titled *Integrated Pest Management for Australian Apples and Pears* need to be updated? *(multiple choice, one answer)*
    - Yes
    - No
    - Unsure

Recommendations to meet needs (how)

33. What research and development (R&D) could be undertaken to address key IPM gaps and barriers? *(multiple choice, multiple answer)*
    - Additional research on beneficial insects and mites
    - Additional research on key insect pest and disease life cycles
    - Additional research on mating disruption technology
    - Additional research on sterile male technique for control of Queensland fruit fly
    - Development of more soft chemicals compatible with an IPM approach
    - Research into cover crop options to improve weed, pest and disease management
    - Other (please specify)
34. What support could be provided to improve adoption and implementation of IPM? *(multiple choice, multiple answer)*
    - Additional farm walks as part of Future Orchards
    - Further information and/or resources on the costs and benefits of an IPM approach
    - Link directly with international buyers and importers in target markets
    - Better access to reliable IPM advice
    - Other (please specify)
35. How can future RD&E align IPM with market access requirements? *(multiple choice, multiple answer)*
    - Align to target export market phytosanitary requirements
    - Address national interstate trade requirements
    - Remove barriers to interstate trade
    - Better link with Commonwealth Department of Agriculture and Water protocols
    - Other (please specify)

[GO TO SECTION 7]

SECTION 3: ADVISOR

About your business

36. What type of advisor are you? *(multiple choice, one answer)*
    - Reseller agronomist
    - Independent advisor
    - Other (please specify)
37. Do you provide insect pest and disease management advice to the apple and pear industry? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 38]
    - No [GO TO QUESTION 59]
38. How long have you been providing insect pest and disease management advice to the apple and pear industry? *(multiple choice, single answer)*
    - 1-5 years
    - 5-10 years
    - 10+ years

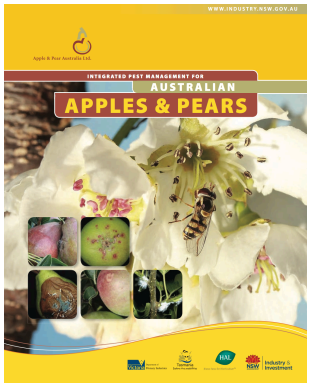
Current situation (now)

39. Do you provide integrated pest management (IPM) advice? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 40, SKIP QUESTION 45]
    - No [GO TO QUESTION 45]
40. How many of the apple and pear growers that you service follow IPM advice? *(multiple choice, one answer)*
    - 1-5
    - 5-10
    - 10+
41. Do your growers find IPM effective in controlling pests?
    - Yes
    - No
42. Do you recommend any of the following fungicides for IPM crops? *(multiple choice, multiple answer)*
    - Trifloxystrobin (FLINT)
    - Mancozeb (e.g. DITHANE)
    - Metiram (e.g. POLYRAM)
    - Ziram
    - Other (please specify)
43. Do you recommend any of the following miticides for IPM crops? *(multiple choice, multiple answer)*
    - Abamectin (e.g. VERTIMEC)
    - Clofentezine (APOLLO)
    - Bifenazate (ACRAMITE or FLORAMITE)
    - Hexythiazoxs (CALIBRE)
    - Propargite (OMITE)
    - Fenbutatin oxide (TORQUE)
    - Etoxazole (PARAMITE)
    - Other (please specify)

44. Do you recommend any of the following insecticides for IPM crops? *(multiple choice, multiple answer)*
    - Pirimicarb (PIRIMOR or APHIDEX)
    - Imidacloprid (e.g. CONFIDOR)
    - Chlorantraniliprole (ALTACOR)
    - Azinphos-methyl (e.g. GUSATHION)
    - Carbaryl (BUGMASTER)
    - Chlorpyrifos (e.g. LORSBAN)
    - Other (please specify)
45. Select any of the reasons listed that describe why you do not provide IPM advice: *(multiple choice, multiple answer)*
    - IPM does not work
    - Your growers do not have insect pest problems
    - IPM is too expensive
    - You need more support or information
    - Lack of relevant information for your district
    - Chemical based methods of pest control still work
    - IPM is too complicated
    - Growers are not comfortable with IPM
    - Not enough suitable chemicals
    - Giving IPM advice is too risky
    - Not enough beneficial insects in your area
    - Pest pressure in your area is too high
    - Growers cannot tolerate any damage
    - Growers do not seek IPM advice
    - Other (please specify)
46. Do you monitor pests, diseases and beneficials for your clients? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 47]
    - No [GO TO QUESTION 48]
47. How often do you monitor? *(multiple choice, one answer)*
    - Daily
    - Weekly
    - Fortnightly
    - Monthly
48. Do you advise growers to rotate chemical groups to avoid the development of pesticide resistance? *(multiple choice, one answer)*
    - Yes
    - No
49. Do you advise growers to rely on any of the following beneficials to help control pests in their orchards? *(multiple choice, multiple answer)*
    - Green lacewings
    - Hoverflies
    - Stethorus ladybird beetles
    - Cryptolaemus ladybird beetles

- Persimilis predatory mites
- Galendromus (formerly Typhlodromus) predatory mites
- Californicus predatory mites
- Aphelinus parasitoid wasps
- Trichogramma parasitoid wasps
- Other (please specify)
- No – none of the above

50. Are there enough naturally occurring beneficials in your area for IPM to be successful? *(multiple choice, one answer)*
    - Yes
    - No
51. Do you advise growers to buy and release biological control agents? *(multiple choice, one answer)*
    - Yes
    - No
52. Do you recommend the use of mating disruption technology (e.g. Isomate lures)? *(multiple choice, one answer)*
    - Yes
    - No
53. Are you aware of the IPM manual titled *Integrated Pest Management for Australian Apples and Pears (multiple choice, one answer)*
    - Yes [GO TO QUESTION 54]
    - No [GO TO QUESTION 57]



54. Do you use this manual? *(multiple choice, one answer)*
    - Yes [GO TO QUESTION 55]
    - No [GO TO QUESTION 57]
55. Select any of the following options that describe the way you use this manual. As a guide to: *(multiple choice, multiple answer)*
    - Identifying pest and disease problems
    - Monitoring pests and diseases
    - Identifying beneficial insects and mites
    - Chemical control options for pests and diseases
    - The effects of pesticides on beneficial insects and mites
    - The best way to apply sprays in the orchard
    - The use of mating disruption technology
    - Developing and implementing an IPM program for your orchard

- Accessing markets, either domestic or export
- Other (please specify)

56. How would you rate the overall usefulness of the manual? *(rating scale from 1 = not useful to 5 = very useful)*
57. Is IPM an impediment to gaining access to the following markets? *(multiple choice, multiple answer)*
    - Domestic
    - Asian
    - European
    - American
    - Other (please specify)
    - None of the above
58. Can IPM improve access to the following markets? *(multiple choice, multiple answer)*
    - Domestic
    - Asian
    - European
    - American
    - Other (please specify)
    - None of the above

Needs analysis (where)

59. Are insect pests in apples and pears becoming harder to manage? *(multiple choice, one answer)*
    - Yes
    - No
60. Are diseases in apples and pears becoming harder to manage? *(multiple choice, one answer)*
    - Yes
    - No
61. Which pests and diseases are most difficult to control? *(comment box)*
62. How confident are you with your knowledge of: *(rating scale from 1 = low to 5 = high)*
    - Insect pests
    - Beneficial insects
    - Insect life cycles
    - Diseases
    - Making IPM decisions and providing IPM advice
63. What are the top three challenges to implementing IPM? *(multiple choice, multiple answer)*
    - IPM is too expensive
    - Not enough support or information
    - Lack of relevant information for your district
    - Lack of grower interest
    - Chemical based methods of pest control still offer better protection
    - IPM is too complicated
    - Not enough suitable chemicals
    - Not enough beneficial insects in your area
    - Pest pressure in your area is too high

- Growers cannot tolerate any damage
- Practice of IPM is not compatible with meeting market demands

64. What would improve IPM adoption and advice? *(comment box)*
65. Does the current IPM manual titled *Integrated Pest Management for Australian Apples and Pears* need to be updated? *(multiple choice, one answer)*
    - Yes
    - No
    - Unsure

Recommendations to meet needs (how)

66. What research and development (R&D) could be undertaken to address key IPM gaps and barriers? *(multiple choice, multiple answer)*
    - Additional research on beneficial insects and mites
    - Additional research on key insect pest and disease life cycles
    - Additional research on mating disruption technology
    - Additional research on sterile male technique for control of Queensland fruit fly
    - Development of more soft chemicals compatible with an IPM approach
    - Research into cover crop options to improve weed, pest and disease management
    - Other (please specify)
67. What support could be provided to improve adoption and implementation of IPM? *(multiple choice, multiple answer)*
    - Additional farm walks as part of Future Orchards
    - Further information and/or resources on the costs and benefits of an IPM approach
    - Link directly with international buyers and importers in target markets
    - Better access to reliable IPM advice
    - Other (please specify)
68. How can future RD&E align IPM with market access requirements? *(multiple choice, multiple answer)*
    - Align to target export market phytosanitary requirements
    - Address national interstate trade requirements
    - Remove barriers to interstate trade
    - Better link with Commonwealth Department of Agriculture and Water protocols
    - Other (please specify)

[GO TO SECTION 7]

SECTION 4: RESEARCHER/STATE GOVERNMENT

Current situation (now)

69. Are growers using IPM? (multiple choice, one answer)
    - Yes
    - No
70. What are the key practices being used by growers within an IPM approach to control pests? (*multiple choice, multiple answer*)
    - Rotation between chemical groups to avoid the development of pesticide resistance
    - Use of beneficial insects to help control pests
    - Monitoring of insects (both pest and beneficial) and diseases
    - Use of mating disruption technology
    - Use of 'softer' chemicals that are compatible with beneficial insects
    - Disease prediction forecasting through monitoring of climatic conditions
71. What has changed in recent years regarding the pest spectrum? (*comment box*)
72. Are growers effectively controlling pests using IPM (i.e. has pest pressure been successfully reduced? Are yield losses reduced?) (*rating scale*)
    - Rate level of control on a scale of 1 (no control) to 5 (highly effective control)
73. Are growers and advisors currently using the IPM Manual? (*multiple choice, one answer*)
    - Yes (if yes – how?) (comment box)
    - No
74. Do you think an IPM approach could be used to facilitate market access both domestically and internationally? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No

Needs analysis (where)

75. Could pest management within the apple and pear industry be improved? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No
76. Could adoption of IPM within the apple and pear industry be improved? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No
77. What are the strengths of the current IPM manual? (comment box)
78. What are the weaknesses of the current IPM manual? (comment box)
79. Could the current IPM manual be improved? (*multiple choice, one answer*)
    - Yes (if yes – How? (*multiple choice, multiple answer*)
      Updated technical content
      Better accessibility and ease of use
      Improved information for facilitating decision-making by growers
    - No

Recommendations to meet needs (how)

80. What research is required to improve pest management in the apple and pear industry? (*comment box*)
81. Does industry have the capacity/resources to address barriers to IPM implementation? If not, what is required to improve capacity? (*comment box*)
82. What RD&E is required to align IPM with market access requirements? (*comment box*)

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SECTION 5: INDUSTRY ASSOCIATION

Current situation (now)

83. Are growers using IPM? (multiple choice, one answer)
    - Yes
    - No
84. What are the key practices being used by growers within an IPM approach to control pests? (*multiple choice, multiple answer*)
    - Rotation between chemical groups to avoid the development of pesticide resistance
    - Use of beneficial insects to help control pests
    - Monitoring of insects (both pest and beneficial) and diseases
    - Use of mating disruption technology
    - Use of 'softer' chemicals that are compatible with beneficial insects
    - Disease prediction forecasting through monitoring of climatic conditions
85. What has changed in recent years regarding the pest spectrum? (*comment box*)
86. Are growers effectively controlling pests using IPM (i.e. has pest pressure been successfully reduced? Are yield losses reduced?) (*rating scale*)
    - Rate level of control on a scale of 1 (no control) to 5 (highly effective control)
87. Are growers and advisors currently using the IPM Manual? (*multiple choice, one answer*)
    - Yes (if yes – how?) (comment box)
    - No
88. Do you think an IPM approach could be used to facilitate market access both domestically and internationally? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No

Needs analysis (where)

89. Could pest management within the apple and pear industry be improved? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No
90. Could adoption of IPM within the apple and pear industry be improved? (*multiple choice, one answer*)
    - Yes (if yes – How?) (comment box)
    - No
91. What are the strengths of the current IPM manual? (comment box)
92. What are the weaknesses of the current IPM manual? (comment box)
93. Could the current IPM manual be improved? (*multiple choice, one answer*)
    - Yes (if yes – How?) (*multiple choice, multiple answer*)

      Updated technical content,

      Better accessibility and ease of use and in

      Improved information for facilitating decision-making by growers
    - No
94. How could the IPM manual impact/influence market access both internationally and domestically? (*comment box*)

Recommendations to meet needs (how)

95. What research is required to improve pest management in the apple and pear industry? (*comment box*)
96. Does industry have the capacity/resources to address barriers to IPM implementation? If not, what is required to improve capacity? (*comment box*)
97. What RD&E is required to align IPM with market access requirements? (*comment box*)

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SECTION 6: IMPORTER/BUYER

Current situation (now)

98. What are the key market access drivers for apples and pears? (*comment box*)
99. What are the key international market access requirements for apples and pears produced in Australia? (*comment box*)
100. Are international markets interested in how pests are managed in apple and pear orchards? (*comment box*)
    – Yes (*go to next question*)
    – No
101. Does this influence decisions relating to purchase of product? (*comment box*)
102. Are you aware of the current IPM manual for the apple and pear industry? (*multiple choice, one answer*)
    – Yes (*go to next question*)
    – No
103. How does the manual impact/influence market access? (*comment box*)

Needs analysis (where)

104. What is required to improve market access for apple and pears both internationally and domestically? (*comment box*)
105. What are the key barriers to increased market access for apple and pears both internationally and domestically? (*comment box*)
106. Does an IPM approach facilitate or impede market access for apple and pears both internationally and domestically? (*multiple choice, one answer*)
    – Yes (*go to next question*)
    – No

Recommendations to meet needs (how)

107. How could apple and pear growers improve their pest management practices to improve market access? (*comment box*)
108. How could IPM be used as a market access tool for apple and pears? (*comment box*)

[GO TO SECTION 7]

SECTION 7

109. Please provide your contact details to go into the draw to win a $150 R.M. Williams voucher (optional) *(demographic information)*
    - Name:
    - Business:
    - Address:
    - Phone:
    - Email:

Otherwise, click done below to submit your response. Thank you for your time.

[END SURVEY]