Adoption of intensive pear production

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Victorian Department of Primary Industries (VICDPI)

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Adoption of Intensive Pear Production

Final Report for HAL Project APO4009
(June 2009)

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Department of Primary Industries – Victoria

Adoption of Intensive Pear Production
Final Report for HAL Project APO4009

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Scope of the Report

This report presents the key findings and a summary of the work conducted from June 2005 to June 2009. The information presented is as complete as possible at the time of writing. More detail is presented in articles and reports produced by the project. Copies can be obtained from the authors.

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Funded By:
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1.0 Media Summary

Internationally, intensive pear production is seen as the most innovative and successful way to grow pears. Low production efficiency is a major problem for the Australian pear industry and intensive production is seen as a possible solution.

The Adoption of Intensive Pear Production Project (AP04009) was developed to capture the cutting edge technology being used in pear production overseas and combine it with the wealth of local knowledge to help the industry move towards intensive production.

The exchange of knowledge and ideas was encouraged through a range of study tours, publications and field days throughout the project. Two major highlights from the project were the development of a website (www.intensivepear.com) that will ensure continued access for growers to project outputs for the next four years and the organisation of a Winter Pear School which brought together international and local expertise to share knowledge and skills with the industry.

The project identified a number of areas that underpin the success of intensive production systems in Australia and has recommended where future work should be directed.

2.0 Introduction

Australian pear production represents approximately 0.7% of world production (including China) (Belrose Inc. 2008). On average approximately 130-140 000 tonnes of pears are produced in Australia each year with 80-90% coming from Victoria. Generally 35-40% of total pear production is sent for processing, 5-10% is exported and the remainder is sold on the domestic market. The gross value of pear production in Australia in 2005 was $89.5 million Australian (ABS, 2006).

Low production efficiency is a major issue for the Australian pear industry. When compared with other major pear producing countries, Australia ranks well behind at 10th in production efficiency and 13th in overall competitiveness (Belrose Inc 2008). This is behind our other Southern Hemisphere competitors such as Chile, Argentina, South Africa and New Zealand.

One of the major reasons for our low ranking for production efficiency is that the majority of Australia's pear production comes from inefficient production systems. These are older, low density (<600 trees/ha) systems that are often very vigorous. Redevelopment of these blocks is generally low as many blocks are still considered productive by growers, with yields ranging between 30-60 tonnes/ha. There are however many challenges associated with production from these trees including declining quality of fruit due to limb rub and russet (and therefore lower pack outs), declining health and productivity of trees within blocks and high costs of labour for harvest and pruning very large trees.

Improving production efficiency is essential if the Australian pear industry is to ensure it remains sustainable and internationally competitive. One of the ways to improve production efficiency is to move to more intensive production. The APAL 2005-2010 strategic plan (APAL 2005) identified intensification to improve scale and labour efficiencies as a medium term priority for the apple and pear industry.

Intensive production systems generally have higher initial investment costs than traditional low density systems, due to the need for large numbers of trees and in some cases the construction of a trellis/support system. However they can offer better production efficiency through:

- Earlier bearing and therefore quicker returns on investment (Sansavini *et al.* 2008, Sansavini and Musacchi 2002, Musacchi *et al.* 2005, Asin *et al.* 2005, Wertheim *et al.* 2001, Elkins *et al.* 2008).
- Improving fruit quality – but only up to certain densities and where crop loads are managed (Musacchi *et al.* 2005, Vercammen 2005, Asin *et al.* 2005, Kappell and Brownlee 2001).
- Better labour efficiency once established (e.g. more efficient harvest and pruning/training).

The Adoption of Intensive Pear Production Project was developed in 2005 as a result of the industry's desire to increase adoption of intensive pear production in Australia and to develop Australian skills in intensive pear production.

The key aims for the Adoption of Intensive Pear Production project were to

- Develop Australian expertise in intensive pear production to aid succession planning in the industry.
- Develop grower skills and knowledge in pear production, with a focus on intensive production.
- Increase the adoption of intensive pear production in Australia using demonstration blocks and an adoption strategy.

The broader longer term outcomes the project aimed to contribute to were

1. More internationally competitive and sustainable pear production.
2. A flexible and adaptable pear industry that could rapidly change variety mix through intensive production.
3. Increased access to Australian based expertise in intensive production.

A steering committee made up of growers, industry representatives and state government agency representatives was set up to guide the project. This steering committee met yearly to check progress and agree to the project directions. HAL also provided $20 000 funding in the first year of the project to pilot new techniques to develop an Adoption Strategy for the intensive pear production project. The aim of the adoption strategy was to understand the potential for adoption of intensive pear production within the pear industry (e.g. who was likely to adopt and when they were likely to adopt intensive production) and target the delivery of the project to ensure maximum impact.

The combination of the yearly steering committee review and the overall Adoption Strategy outcomes helped to guide the project to specific activities to help achieve the aims of the project.

The project also collaborated with other pear R&D throughout its existence and often provided a channel through which project outcomes were communicated to growers. This included involvement in

- Australian National Pear Breeding Project.
- Australian Pome Fruit Improvement Program (APFIP) National Pear Rootstock. Trial - APO4001.
- Future Orchards 2012.
- Integrated Management of Bacterial Diseases in Pome Fruit project.

One of the major limiting factors for the project was the on-going need for the project officer to be involved in drought response. This often meant delays in implementing project activities and disruption to the project's momentum.

3.0 Technology Transfer Strategy, Methodology and Activities

The project began with the formation of a steering committee from representatives within the pear industry. This included growers, state government department of primary industries representatives from NSW, SA and WA as well as a representative from APFIP, HAL and APAL. The steering committee initially helped review the original project proposal and develop direction for the project. The group met annually for the remaining three years of the project to review outputs and ensure project direction remained relevant to the industry.

Increasing the adoption of intensive pear production in Australia using demonstration blocks and an adoption strategy

Adoption Strategy

During the initial project development, HAL provided $20 000 to pilot new techniques to develop an adoption strategy for the project. This process involved piloting a Framework (Johnson 2005) that was adapted for the DPI horticulture program. The framework consisted of a sequence of questions and utilised social research methodologies to understand

- The environment the project existed in.
- The current farm context for pear growers.
- The drivers and barriers to adoption of intensive pear production.

The aim of this process was to provide the project with an indication of the likelihood of adoption of intensive pear production and help with developing strategies and project activities that would be well targeted for maximum impact and adoption. This also would provide a good planning framework for the project. The detailed methodology and results of this work can be found in the report 'Adoption of Intensive Pear Production – Adoption Strategy Report' (Grills and Mansfield 2006). This report was submitted to Horticulture Australia Limited in January 2006.

The research found that it was not necessarily skills and knowledge that would limit the adoption of intensive pear production. The rate of adoption would be influenced mainly by the rate of redevelopment on orchards and the ability for intensive pear systems to meet growers' criteria for replanting. Growers would only be in the market to adopt intensive pear production once they had decided that their current pear blocks, or other fruit blocks were unprofitable or if they were looking to develop a green field site. Once they had made this initial decision to redevelop (or change their land use), they would then look to replant with a crop that that offered profitability, ease of management and continuity with their current orchard management system.

When these results were considered in the context of the current environment for pear production it indicated that the likelihood of adoption of intensive pear production during the project would be limited and subsequently the number of growers in the 'market' for information would be low. This would be largely because of factors external to the projects influence such as commodity prices and production costs.

Firstly the rate of orchard redevelopment was generally low. Existing pear blocks were rarely redeveloped as they were still considered productive and profitable well into old age. Green field sites were also limited in many pear production regions as most available land was already used and other factors such as council planning controls inhibited horticultural expansion. The most likely opportunities for block redevelopment would occur when ‘other’ fruit was considered unprofitable. This was unpredictable and would vary from orchard to orchard.

Secondly if growers did make the decision to redevelop it was still unlikely they would choose to replant with intensive pear production. Low prices for fresh and canning pears meant that pear production was generally viewed as unprofitable and therefore intensive pear production did not meet grower replanting criteria. Often growers would choose a more profitable fruit to replant such as apples.

The research results did however also indicate that growers may be making decisions about the suitability of intensive pear production based on misinformation about system management requirements. This was identified as an area the project would be able to influence.

Initial project strategies were developed as a result of the adoption research results. These strategies looked to target growers who had made the decision to redevelop and ensure that they were making decisions about intensive pear production based on accurate information.

The research results and initial strategies were then presented to the steering committee for review and further development. The committee agreed that whilst adoption of intensive production was likely to be limited during the project, it was still critical to develop expertise and knowledge within the industry. Changes in external factors that made pear production more profitable, such as increased pear prices, could increase the rate of adoption at any time. It was important that information was ready for when this occurred. The strategies for project activities were then organised into three key strategic areas:

1. Create resources on intensive production that could be readily accessed by growers when they were in the market to adopt to ensure informed decision making on the basis of accurate information.
2. Provide information to the industry about intensive production systems and management requirements, trends from around the world and areas that the industry needed to focus efforts on (rootstocks, varieties and nursery trees) to ensure intensive production systems could be successful.
3. Target practical activities towards management options for intensive production systems that could also be applied in existing systems to improve productivity.

Specific activities aligned to these strategies were then agreed on with the committee and are outlined below. The detail of activities and outputs and the strategies they aligned to can be found in Tables 1 and 2.

Strategy 1 – Creating resources for ready access by growers:

Aims:

- Develop an easily accessible tool that growers can use when they are considering installing an intensive pear production system – including system establishment and management, land suitability for pears and key factors to consider when redeveloping old orchards.
- Provide a central location for all outputs generated by the pear project to be housed and accessible to growers.

Activities/outputs to achieve aims:

1. Online guide for intensive pear production in Australia.

Strategy 2 – Providing information on intensive production systems and requirements for success:

Aims:

- Provide information about optimal planting and management strategies for new /future pear developments that are suited to Australian conditions and are cost effective to establish.
- Present information from overseas study tours and the latest in local and international pear research (incorporating breeding, rootstock trials and pest/disease research) to pear industry.
- Bring overseas and local pear expertise together to present to industry the latest on intensive pear production systems.

Activities/outputs to achieve aims:

1. Organisation of grower technical field days in Victoria, South Australia and Western Australia.

2. Organisation of 'Winter Pear School' in 2009.

3. Distribution of technical articles to industry publications.

Strategy 3 – Targeting practical activities for management of intensive systems:

Aims:

- Provide growers with practical skills and advice on managing pear orchards – applicable to intensive and traditional systems.

Activities/outputs to achieve aims:

1. Incorporation of practical 'training' sessions into grower technical field days.
2. Demonstrations of intensive pear production management techniques at rootstock trial site.

Tom Deckers from Belgium demonstrating pruning an intensive pear orchard at the 2009 Winter Pear School.

Demonstration Blocks

The initial project proposal was developed with the aim of establishing demonstration sites of intensive pear production systems across the pear growing regions in Australia. These would be established on commercial orchards and managed by the growers. After consultation with the steering committee it was agreed that the demonstration blocks would not be possible in this project for a variety of reasons

- Lack of availability of planting material – specifically dwarfing rootstocks.
- Impracticality of growers planting small trial blocks into their orchards.
- Lack of resources to manage, monitor and maintain the sites.
- Lack of time within four year project to implement trials that would require at least 6-10 years of commitment.

In lieu of the demonstration sites, the project was able to form a good collaborative working arrangement with the APFIP Pear Rootstock Trial Site (Project APO4001) in the Goulburn Valley. This trial was identified as a key project to work with as its outcomes would be integral to the ability for growers to adopt intensive pear production. It provided an ideal demonstration site for field days where management practices could be demonstrated to growers and followed up. The project officer also played a leading part in collecting data on growth and yields for this site and helping to communicate trial outcomes to growers through articles and field days (tables 1 and 2)

Rootstock trial data collection included:

- Trunk Circumference (2007, 08, 09) and Shoot growth (2007) measurements.
- Yield measurements (2008, 2009).

Developing of Australian expertise in intensive pear production to aid succession planning and improve grower knowledge and skills.

In order to develop expertise in intensive pear production three international overseas study tours were organised and a literature review of intensive pear production was prepared. The outcomes of these were important in the development of the technology transfer activities in the project.

International Study Tours

The project was written to include yearly overseas study tours to important pear production regions. These tours aimed to identify:

- Why intensive pear production systems were being adopted.
- The characteristics of different intensive pear production systems.
- How intensive pear systems were being refined
- The advantages and disadvantages of intensive pear systems.

The study tours were also seen as an opportunity to develop links with organisations and expertise to further the development of intensive pear production knowledge and skills in Australia.

The initial study tour was held in Europe in August 2005. During this tour the project officer visited pear growing regions in Belgium, Netherlands, Spain and Italy. A range of international pear growing experts including nurserymen, growers, researchers and industry representatives were consulted on this tour.

Nurseryman and grower in an intensive 'Conference' pear orchard in the Netherlands. This orchard was highly productive and only in its 3rd year.

The second study tour was incorporated into the APAL 2006 grower study tour which visited Switzerland, Germany, Italy and France to investigate characteristics of intensive apple and pear orchards in Europe. A further return visit to Belgium and the

Netherlands was included at the end of this tour. Again this provided an opportunity to meet with a range of pear growing experts.

The third study tour was to the 10th International Pear Symposium held in Portugal in May 2007. This was an opportunity to find out the latest research occurring in pears from around the world and meet with a variety of international pear researchers. It was also an opportunity to co-author a paper on the Australian and New Zealand Pear Industries that was presented by John Palmer from HortResearch New Zealand.

As a result of each of these study tours, reports and industry articles were published. Information was also disseminated to growers through various field days held across Australia and one-to-one discussions. See tables 1 and 2 for further detail. The articles and reports are also available from the project website (www.intensivepear.com).

Literature Review

A literature review was undertaken to understand the existing body of research and development outcomes on intensive pear production from around the world. The main focus for the literature review was to identify relevant developments in the areas of

- Nursery tree quality.
- Rootstocks.
- Planting systems.
- Management methods to improve productivity.

After reviewing the literature, the relevance to Australian conditions and recommendations for work in each area were explored. The literature review was a working document throughout the project and helped to provide a theoretical basis for the activities in the project and guide the development of the project website. It will also provide a useful point of reference for any further pear production projects. The literature review is included as an appendix to this report (Appendix 1).

Outcomes

In order to be successful an intensive pear system must produce sustained high annual yields of quality fruit beginning as early as possible in the life of the orchard (preferably by year 3). Factors such as climate, soil, cultivar, rootstock and management regimes will influence the ability of a system to technically achieve this. Profitability of the system will then also depend upon economic factors including pear prices and input costs.

The study tour outcomes and literature review development highlighted that there was no recipe for an ideal intensive pear production system that could ensure success in Australia. They were however able to provide key principles for establishment and management of intensive production systems to ensure maximum potential for profitability. This included:

- Using high quality nursery trees and suitable rootstocks to ensure maximum potential for canopy development and early cropping.
- Integrating tree density, training systems, rootstocks, cultivars and management regimes to suit site conditions.
- Carefully managing young tree growth to ensure the development of a good canopy structure for optimal light interception and distribution.

- Management of vigour in established trees to retain a balance between shoot growth and cropping and maintain a canopy structure that maximises light interception and distribution.

The disappointing performance of existing local intensive production systems was often identified to be a direct result of the failure to address these key principles particularly in orchard establishment. Major focus was therefore placed on these principles in technology transfer activities. However it was difficult to confidently demonstrate the production potential of intensive pear systems because of the lack of availability of high quality nursery trees and suitable rootstocks. This is an ongoing challenge that the industry must continue to work to address.

An intensive 'Corella' orchard in the Goulburn Valley. This orchard is nearly 10 years old and still hasn't achieved its full production potential. This was because it was established using poor quality nursery trees and vigour was not adequately controlled to encourage fruit production.

Limiting factors for project activities

The major limiting factor for project activities was that of the prolonged dry conditions in the Goulburn Valley during the 2006-2008 seasons.

The drought conditions increased the costs of production through higher water costs. In 2006 the dry conditions also resulted in a major frost event across the region which affected pear yields and lowered grower returns.

The project officer was required to carry out drought response work as a priority for some extended periods from late 2006 to early 2008, which meant delays in project activities and often a loss of project momentum.

Table 1: Summary of grower activities from 2005-2009

Date	Activity	Purpose	Audience	Attendance	Strategy
Apr -May 2005	Orchard visits	Determining the types of intensive systems that existed in Australia through visiting growers	9 Goulburn Valley Growers	NA	2
30 Nov 2005	Presentation to South Australian growers	Presenting the findings of the overseas study tour and National Pear Breeding Project update	South Australian Pear Growers	25	3
5 Dec 2005	Presentation to Goulburn Valley Young Growers group	Presenting the findings of the 2005 overseas study tour to Goulburn Valley Young Growers Group	Goulburn Valley Young Growers Group	6	3
27-31 March 2006	Scoping the WA pear industry and presenting project findings	Visits to WA pear growers through the WA Dept. of Agriculture and presentation of the findings of the 2005 overseas study tour to growers and WA Department of Agriculture staff	WA Pear growers	6	2,3
26 March 2007	Organisation of Jef De Coster Visit to pear rootstock trial site	Grower field walk with Jef De Coster at the APFIP pear rootstock trial site in Ardmona to look at management options for intensive production systems. Marcel Veens also provided expertise during the visit.	Growers	12	3
27-28 March 2007	Organisation of grower visits by Jef De Coster in Goulburn Valley	Visits by Jef De Coster to five orchards in Shepparton to look at management options for pear production systems	Growers	10	3
29 March 2007	Organisation of Jef De Coster visit to DPI Tatura to inspect pear breeding	Jef De Coster meeting with the National Pear Breeding Program to look at promising selections and trees in the field and provide management guidance	NA	NA	2

13 August 2007	Pear workshop, South Australia	Presentation of pruning theory, report on ISHS 10th Pear symposium and update on other pear projects (rootstock trial site, breeding program, bacterial blast research)	Adelaide Hills Growers	23	2,3
14 August 07	Pear workshop, Perth Hills	Presentation of pruning theory, report on ISHS 10th Pear symposium and update on other pear projects (rootstock trial site, breeding program, bacterial blast research)	Perth Hills Growers	14	2,3
15 August 07	Pear workshop, Donnybrook	Presentation of pruning theory, report on ISHS 10th Pear symposium and update on other pear projects (rootstock trial site, breeding program, bacterial blast research)	Donnybrook Growers	5	2,3
17 August 07	Pear workshop, Shepparton	Presentation of pruning theory, report on ISHS 10th Pear symposium and update on other pear projects (rootstock trial site, breeding program, bacterial blast research)	Goulburn Valley Growers	6	2,3
12 March 2008	Pear follow up workshop, Adelaide Hills	Review of pruning theory and results in the orchard. Report on APFIP rootstock trial harvest results, APFIP variety presentation	Adelaide Hills Growers	18	2,3
13 March 2008	Pear follow up, Perth Hills	Review of pruning theory and results in the orchard. Report on APFIP rootstock trial harvest results,	Perth Hills Growers	20	2,3
March – May	Pear breeding selection evaluations	6-7 days Assisting with the evaluation of selections from the National Pear	NA	NA	4

		Breeding Program at DPI Tatura			
29 May 2008	Pear workshop at AFFCO Expo, Shepparton	Organisation of pear workshop at AFFCO expo, including field walk to APFIP rootstock trial site, visit to DPI Tatura to look at pear varieties from the Australian National Pear Breeding Program and hear about the outcomes of the pome fruit scoping study.	Growers	10	2,3
16 July 2008	Jef De Coster presentation and field walk, Shepparton	Organisation of visit to Shepparton to give presentation to growers followed by field walks	Shepparton Growers	20	2,3
17 July 2008	Jef De Coster presentation and field walk, Cobram	Organisation of visit to Cobram to give presentation to growers followed by field walks.	Cobram Growers	8	2,3
16-18 June 2009	Winter Pear School, Shepparton	Presentations on the latest pear research and development locally and internationally and field walks to demonstrate management techniques for pears.	Growers and Industry representatives from Vic, SA and WA	40	1,2,3

Table 2: Summary of publications from 2005-2009

Date	**Title**	**Description**	**Published**	**Strategy**
March 2006	Intensive Pear Production – Fate or Density?	Summary of the major trends seen on the 2005 study tour	Top Grower (VIC)	2

April 2006	Intensive Pear Production – Fate or Density?	Summary of the major trends seen on the 2005 study tour	Tree Fruit (National)	2
March 2007	Pear Production in Belgium and the Netherlands	Summary of trends in pear production in Belgium and the Netherlands seen on the 2006 study tour	Tree Fruit	2
May 2007	Regaining the Balance in Pear Trees	Summary of Jef De Coster's Pruning advice	Submitted to Australian Fruitgrower- Unpublished	2,3
August 2007	Expert Techniques For Pears	Summary of Jef De Coster's visit to the APFIP pear rootstock trial site	Tree Fruit	2,3
September 2007	Improving Fruit Set in Europe	Summary of research from 10th International Pear Symposium looking at controlling vigour and improving fruit set	Australian Fruitgrower	2
May 2008	Breaking the News When Pear Pruning	Outline of pruning techniques used in pear workshops	Australian Fruitgrower	2,3
June 2006	2005 Study Tour Report Europe	Summary of OS travel in 2005	DPI publication – Available on website	2
Oct 2007	2007 ISHS Pear Symposium report	Summary of ISHS pear symposium	DPI Publication – Available on website	2

January 2008	Can the pear industry exist without new rootstocks	Overview of our current understanding of rootstocks from around the world and in Australia	Submitted to Australian Fruitgrower and Tree Fruit	2
May 2007	'Status and Trends within the Pear Industries in New Zealand and Australia'	Paper for ISHS symposium co-authored with John Palmer from HortResearch New Zealand.	Acta Horticulturae 800	NA
May 2009	Intensivepear.com website	Central website to house project outputs as well as provide information about intensive pear production to the Australian industry.	www.intensivepear.com	1
June 2009	Intensive Pear Production Literature Review	Literature review was an ongoing publication throughout the life of the project. This publication was finalised for the completion of the project and used to develop the website	Unpublished (see Appendix 2)	1,2,3

4.0 Evaluation and Measurement of Outcomes – Impact and Adoption

An evaluation of the project was undertaken to understand the impact that the project had on the industry.

The objectives of the project were to develop expertise in intensive pear production and to increase the adoption of intensive pear production in Australia.

The initial adoption research for the project indicated that at any one time there would only be a small market for the adoption of intensive pear production. In addition to this, the lead time needed in planning orchard redevelopment would mean that any influence the project had on grower adoption may not be evident within the project life.

Therefore measuring intensive pear production adoption rates would not be an adequate reflection of the impact of the project. The real value of the project was seen to be in creating expertise and resources that could be readily accessed by growers when they were in the market for changing to intensive pear production.

Therefore the project evaluation was focussed on determining

- If growers considering replanting pears were engaged with the project and actively seeking information.
- If the project had improved growers' knowledge and skills in intensive production had provided information useful for their decision making.
- If valuable networks were created for the project and the industry.
- If the project was effective in communication with the industry.
- If expertise in intensive pear production has been increased and is available to the industry.
- Areas for further work.
- Project limitations and concerns.

A range of different methods were used for the evaluation. An independent evaluation group was employed to carry out in depth qualitative interviews with 10 people who had contact with the project, including steering committee members, industry representatives and growers. These contacts were chosen on the basis of their understanding of the project, the industry and the complexity surrounding intensive pear production. The interview process and detailed results can be found in Appendix 2. A survey of growers who attended the Winter Pear School was also carried out to provide further feedback from the perspective of people in the market for adopting intensive pear production. There were 11 surveys returned. Data collected during the project was also used in the evaluation process.

4.1 Results

<u>Grower engagement and information seeking</u>

During the project life, a range of activities were held to communicate outputs to the industry. Over this time there were 123 growers and industry representatives that attended activities (Table 1). This data does not distinguish between repeat attendees and new attendees.

There were also various grower enquiries over the life of the project that demonstrated growers were seeking information from the project. There were at least 15 major enquiries that were recorded and required further research and follow up. Many of these were a result of project activities and technical articles in industry publications. There were numerous other minor enquiries that were not recorded.

Often the engagement of the project with the overall industry was considered to be low. There was a perception amongst the evaluation interviewees that grower interest often did not convert into large turnouts to project events and this may be associated with timing and associated publicity (Fenton 2009). One interviewee was quoted as saying,

"We get criticised for not doing enough for the industry and we organise field days and get international guests out and get ten people turn up, and it is embarrassing".

These results however confirm the outcomes from the initial adoption research that indicated only a small proportion of the industry would be interested in the project outputs at any one time.

<u>Increase in grower skills and knowledge and use of project outputs in decision making</u>

The interview results indicated that the project had created useful outputs for the industry that improved growers' skills and knowledge and were useful in decision making. One participant stated:

"I think the project has created interest and recognition amongst those, certainly the growers that have participated, that there are opportunities to make the orchards that they currently have perform better, and to have a better idea about what they should be doing in planting new orchards."

'For one grower the project had helped them refocussed their business, commenting *"It has given me the confidence to actually go out and do pears"*, while another is planning to change his root stock and intensify his planting extensively' (Fenton 2009)

The evaluation of the 2009 Winter Pear School drew a range of responses from attendees that indicated that the information presented at that event had improved knowledge and skills in a number of areas and would be used in growers' decision making. Some of the quotes demonstrating this are listed below

'I have ordered for this winter and will try some of these (presented) systems'

'Times are changing and (I) have to keep up with the latest'

'Pruning and training techniques from other countries (is) similar to our practices on our farm. Helps to know what we are doing is similar to other areas''

The survey of growers at the winter pear school was also able to provide an understanding of how growers had made decisions when replanting pears and whether project outputs had been useful. Growers who had not replanted pears during the project had evaluated their options and felt that there was a lack of suitable varieties and rootstocks. Lack of water was also an issue. The growers who had replanted pears during the past four years had chosen plantings that would be considered low density but were still higher densities than traditional systems. Some of the reasons these systems were chosen included

- Continuity with current orchard systems.
- Good results with past experience.
- Consultant advice and personal discussion with project officer.
- Good cost vs. production.

All of these growers had accessed project outputs either through attending project activities, accessing articles or reports. This demonstrates that they were using expertise developed by the project to help with decisions. It was interesting to see that the some of the criteria that growers had used in their decision making were almost identical to the criteria initially outlined by the adoption strategy.

<u>Development of valuable networks</u>

At the beginning of the project the network needed for project implementation was identified, including key people and organisations and why they would be valuable for the project. This initial plan can be found in the Adoption Strategy Report (Grills and Mansfield 2006). There was a concerted effort within the project to develop and maintain this network.

The most important networks developed by the project were those with

- Major industry organisations such as APFIP, the Australian Fresh Fruit Company (AFFCO), APAL.
- State government horticultural representatives from NSW, Victoria, South Australia and Western Australia.
- Other pear projects including the APFIP National Pear Rootstock Trial, the National Pear Breeding Project and Integrated Management of Bacterial Diseases in Pome Fruit project.
- Key pear growers in local regions particularly in the Goulburn Valley and South Australia.
- Consultants in the pear industry.
- Key international pear expertise from Europe, USA and South Africa.

These networks were valuable for ensuring the project remained relevant to the industry and provided a channel for the communication of project outputs. The collaboration with other pear projects such as the rootstock trial and pear breeding resulted in accelerating the extension of those project results to the industry. This was important as rootstocks and varieties are key elements of an intensive pear production system. The networks with industry organisations, state government representatives, consultants and international expertise also provided valuable technical skills and knowledge and industry information. As a result the project was able to draw together the latest information around a number of key aspects of pear production and integrate them into resources for the industry such as technical articles and field days.

The evaluation interviews demonstrated the value of the network created by the project.

‘Some participants were particularly appreciative of the opportunity to access national and international pear experts who could argue the benefits of intensive pear production systems, but also suggest minor changes to improve existing production systems that could be immediately implemented. The rootstock trials were a clear benefit for many participants, where they could see and discuss the production techniques, and were far more valuable for growers than ‘watching a slide show’.’ (Fenton 2009)

Effective communication with the industry

Communication with the industry occurred through a variety of media. Technical articles were circulated through the two major industry publications Australian Fruitgrower (circulation to 1100 apple and pear growers nationally) and Tree Fruit (circulation to 1400 fruit growers nationally). These articles have also been placed on the project website (www.intensivepear.com). See Table 2 for more details.

In organising events for the project a range of media were used for publicity including direct SMS and emails to growers and articles and advertisements in newspapers, industry publications and on the radio. There was always at least two weeks notice prior to events occurring.

The evaluation interviews highlighted that project communications were effective.

‘The communication materials were well written appropriately targeted in terms of technical, honest, practical, interesting.’ (Fenton 2009)

A key aspect of the communication to the industry is the website developed for the project (www.intensivepear.com). This website will ensure growers can continue to access project outputs after the project ends. This website will be launched on completion of the project and has been funded for a further four years of hosting. Ownership will be transferred to APAL who can evaluate if it is still appropriate after the four years of hosting.

Increasing expertise within the project

The aim of the project was to increase local expertise in intensive pear production through the development of a local pear expert (project officer). The two international study tours, attendance at the 10th International Pear Symposium and the communication of the learnings to industry was integral to achieving this.

The evaluation interviews demonstrated that the industry felt the project had been successful in developing expertise

‘… they (interview participants) felt the project officer had built up a good level of understanding and a good reputation and credibility within the industry’ (Fenton 2009)

‘They (interview participants) felt that much time and resources had been invested skilling the project officer, who now has a good international understanding of the pear industry and intensive pear methods.’ (Fenton 2009)

Areas for further work

The evaluation interviews highlighted that the industry felt that there was a continued need for intensive pear production work.

‘While the project has created increased awareness amongst growers about the benefits of intensive production, there is still some work to do in encouraging many growers to change to intensive productions systems.

A range of barriers where mentioned in the interviews such as establishment costs, having the appropriate rootstocks available and seeing the economic and physical benefits through on-farm trial blocks may limit the change to intensive systems.
While some trials have been planted on existing rootstocks, the results aren’t always positive and therefore not a good advertisement for intensification. The availability of appropriate rootstocks, and alternative varieties, for trial plots is an important step in demonstrating the success and therefore the benefits of investment in intensive pear processes’ (Fenton 2009)

The evaluation of the 2009 Winter Pear School corroborated this with many participants indicating they wanted further information on rootstocks, varieties, planting systems and management requirements to ensure the best chances for a successful system.

Project limitations and concerns

The evaluation interviews were also useful in determining where the industry felt where the project’s limitations existed and what concerns may be held with the completion of the project.

The two main limitations highlighted were the lead time needed to develop expertise of the project officer and the tension between DPI corporate requirements and producing project outputs.

‘While they (interview participants) felt the project officer had built up a good level of understanding and a good reputation and credibility within the industry, they felt the lack of experience initially resulted in the project not getting up as fast as it could have with an experienced person’ (Fenton 2009)

‘There was also a tension around the competing demands of the project officer satisfying project requirements and DPI corporate requirements. Some (interview participants) felt that to begin with the project officer was always accessible, however in the last year there were increasing demands for other DPI work that limited the industry’s opportunity to utilise the project officers’ expertise. It was recognised this is a common tension with a number of projects, and not this project in particular.’ (Fenton 2009)

The concerns raised in the interviews after the completion of the project were associated with the perceived need for continued collaboration between various organisations and continued support of the pear industry.

‘The collaboration between DPI, consultants, scientists, industry and growers is crucial for the industry to grow. Some participants reflected that many experienced people have left the industry and the collaboration could be an uphill battle. They suggest while field days and visiting experts are good to introduce intensive pear management, growers need continued backup from accessible local experts for ongoing advice.’ (Fenton 2009)

‘A key issue for many participants is the continuity of support. They felt that much time and resources had been invested skilling the project officer, who now has a good international understanding of the pear industry and intensive pear methods. They question what will now happen since the project has ended.’ (Fenton 2009)

5.0 Discussion

Achievement of project aims and evaluation:

The aims of the project were to develop pear production expertise (within the project and the industry) and to increase adoption of intensive pear production. Adoption research indicated that the ability of the project to influence rates of adoption of intensive pear production in the short term would be limited. This was because adoption was determined by rates of redevelopment in orchards and the ability of intensive pear production to meet grower decision-making criteria for replanting. In the current operating context, redevelopment rates were low and growers were unlikely to choose intensive pear production as it was viewed as an unprofitable option by many due to low prices for pears.

As a result of this the project direction focussed on creating Australian expertise and knowledge through technology transfer activities that

- Created resources on intensive production that could be readily accessed by growers when they were in the market to adopt to ensure informed decision making on the basis of accurate information.
- Provided information to the industry about intensive production systems and management requirements, trends from around the world and areas that the industry needed to focus efforts on (rootstocks, varieties and nursery trees) to ensure intensive production systems could be successful.
- Targeted practical activities towards management options for intensive production systems that could also be applied in existing systems to improve productivity.

The project did this through the development of key outputs including technical articles, international study tour reports, a literature review and technical field days and events. These outputs remain accessible to growers through the website developed for the project (www.intensivepear.com).

The evaluation of the project highlighted that the development of expertise and knowledge in intensive pear production was valuable for the industry. It also demonstrated that during the life of the project only a small proportion of the industry was in the market for this information, confirming the results of the initial adoption research.

Opportunities for future adoption of intensive pear production

Changes in external factors influencing redevelopment rates and the profitability of pear production could positively or negatively influence the rate of adoption of intensive pear production at any time. Prices for pears and other fruit as well as the costs of inputs such as water have the most potential to change rapidly over a short period of time.

Pear prices may increase through the release of new varieties or the development of export markets for existing varieties. This may result in pear production becoming more profitable and intensive pear production more likely to meet grower replanting criteria. The decrease in prices of other fruit crops due to over supply or loss of markets may also create more opportunities for growers to consider replanting pears intensively. Processing fruit varieties are the most likely to become less profitable in the near future as the major processor has indicated a reduction in processing intakes over the next few years.

In a future operating context where the rate of adoption of intensive pear production is accelerated, the findings of this project will provide a useful resource for growers to make informed decisions. The findings have also provided guidance on the key areas that the industry must continue to address to ensure productive and profitable systems are established. These are systems that can achieve sustained high yields of good quality fruit as early as possible and therefore early and high returns on capital. The key areas include:

- Using high quality nursery trees and suitable rootstocks to ensure maximum potential for canopy development and early cropping.
- Integrating tree density, training systems, rootstocks, cultivars and management regimes to suit site conditions.
- Carefully managing young tree growth to ensure the development of a good canopy structure for optimal light interception and distribution.
- Management of vigour in established trees to retain a balance between shoot growth and cropping and maintain a canopy structure that maximises light interception and distribution.

If the Australian industry believes that there is a future for pears and there is likely to be an increase in the adoption of intensive production it should continue to fund work in the areas listed above. It will also be valuable to further investigate the economics of intensive production systems and the impact redevelopment would have on an orchard. The impact of climate variability and longer term climate change on pear production and the risks for intensive production systems also needs to be incorporated into this work.

6.0 Recommendations

- Further research is undertaken to determine the economic impact of adopting intensive pear production in Australian orchards. This needs to include provision for:
    - Demonstrating the impact of changes in pear (and other fruit) prices and input costs on profitability.
    - Demonstrating the impacts of climate variability and potential long term climate change on production.
    - Demonstrating the influence of using high quality nursery trees, dwarfing rootstocks and optimal management on profitability.

- The pear industry needs to continue to invest in projects that ensure access to high quality nursery trees, dwarfing rootstocks and techniques for the optimal management of young and established orchards including:
    - Collaborative project between the industry and nurseries to improve quality of nursery material as well as grower tree ordering practices. In the short term this could encompass the implementation of clear industry specifications for nursery trees to suit particular planting systems (current APFIP Nursery tree specifications available from www.apfip.com.au would serve as an excellent starting point.) and a standard procedure for ordering. In the longer term a strategy is needed for the adoption by nurseries of a quality certification system for nursery trees (such as the APFIP certification program).
    - Continued development and maintenance of networks with international pear expertise to ensure Australian production remains up to date with the latest technologies.
    - Continued support of existing pear production projects including the National Pear Breeding Program and the National Pear Rootstock Trial with adequate provision for the extension of results to industry.

- Pear industry takes on ownership of the website developed by the project (www.intensivepear.com) to ensure it remains up-to-date and relevant to the industry.

7.0 Acknowledgements

The project team would like to acknowledge the support and input from all those who have contributed to the project including steering committee members, participating growers and representatives from industry organisations.

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9.0 Appendix 1 – Intensive Pear Production Literature Review

DEPARTMENT OF
PRIMARY INDUSTRIES

The thinking behind
our everyday essentia

Literature Review

Angie Grills
DPI Cobram

Victoria
The Place To Be

Intensive Pear Production

Angie Grills

Fruitcheque
Farm Services Victoria

Department of Primary Industries, June 2006

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1.0 Introduction

Globally pear growers are striving to achieve early returns on capital, produce consistent high yields of good quality fruit and economise on labour as a result of increasing competition and economic pressures. Over the years this has resulted in the trend for pear orchards to be planted more intensively (i.e. at higher densities).

Intensive pear production is seen as a vital way to improve the efficiency of Australian pear production and will become particularly important as existing orchards near redevelopment and new pear varieties with a specific marketing advantage become commercially available.

There are many integrated variables that make up an intensive system and careful consideration of each of these in the context of the growing environment is essential for success. Internationally there has been a plethora of research into optimising the performance of intensive pear systems and many good reviews of this work (Sansavini and Musacchi 2002; Wertheim *et al.* 2001 ; Wertheim and Wagenmakers 1993).

This review will focus specifically on the importance of planting material, choice of rootstock and planting system when developing intensive pear production systems (mainly for European pears). It will also look at management options to control vigour and improve fruit set. The particular focus will be on examining the work from around the world, the current trends in Australia and subsequently where the opportunities are for the future.

1.1 Australian Pear Production

Australian pear production represents 0.7% of world production (including China) (Belrose Inc 2008). Production of European pears has remained reasonably stable since 2001 with an average production of 140,000 tonnes, whilst 'Nashi' production has averaged just 3,300 tonnes (Table 1). In 2007, total pear production (134,800 tonnes) was just under half (49%) the apple production (ABS, 2007).

Pears are produced on approximately 700 orchards, with a total area of 5,600 ha (APAL, 2006). The state of Victoria is the largest pear producer, contributing between 80-90% of national production. Most of Victoria's pear production is situated in the Goulburn Valley with a smaller proportion in Southern Victoria. The other major pear production areas in Australia are based in the Adelaide Hills in South Australia and Perth Hills, Donnybrook and

Manjimup in Western Australia. There is limited production in Queensland, Tasmania and New South Wales.

The major European pear cultivars produced in Australia are 'William's Bon Chrétien' ('Williams' otherwise known as 'Bartlett' and 'Duchess') (48%) mainly for processing and 'Packham's Triumph' ('Packhams') (40%) for fresh market. Other important cultivars include 'Buerré Bosc' ('Bosc') (7%), 'Josephine' (1%) and 'Corella' (2%) for fresh market (ABS, 2007). This variety mix has remained reasonably static over the past 6 years (Table 1). 'Nashi' have been produced commercially since the early 1980's with Nijisseiki being the major variety. 'Nashi' are mainly produced for the fresh market.

In 2005, the non-bearing orchard area (trees less than 6 years of age) was 16% (ABS, 2006). ''Williams'', ''Packham's' and ''Corella'' constitute close to 30% each of these newer plantings (AFFCO 2006).

Table 1. Pear production in Australia by variety (fresh weight) (tonnes) 2002-2007 (Source: Australian Bureau of Statistics)

Cultivar	**Year**					
	2002	**2003**	**2004**	**2005**	**2006**	**2007**
Buerre 'Bosc'	10,600	9,600	10,500	10,300	9,400	9,700
'Corella'	700	600	700	1,200	1,500	1,500
Josephine	3,100	2,800	3,300	3,400	3,100	2,600
'Packham'	55,100	52,900	53,300	60,700	55,200	52,200
Red Anjou	300	300	400	400	400	300
Sensation	600	700	700	600	700	500
'Williams'	71,700	66,600	67,500	68,800	67,200	63,000
'Nashi'	2,600	3,800	3,500	3,800	3,400	2,900
All other European Pears	2,800	2,500	2,200	2,400	1,800	2,100
Total production (tonnes)	147,500	139,800	142,100	151,600	142,700	134,800

Generally 35-40% of total pear production is sent for processing, 5-10% is exported and the remainder is sold on the domestic market. Most of the pears produced for the fresh market are sold domestically. In recent years, the export of Australian pears has declined significantly and become quite variable from year to year. Increased competition in export markets from other Southern Hemisphere producers and higher prices for pears on the domestic market have discouraged exports. From 2000-2005 an average of approximately 14,500 tonnes of pears were exported from Australia (APAL 2006). This represents 10% of the average production during that period. In 2005 exports were well down on the average, only representing 6% of total production. The majority of exported pears are ''Packham's'. Asia, the Pacific region and Europe were the major destinations for exports.

Fresh pear imports into Australia have grown by almost 25% over the last 5 years to 4,200 tonnes in 2005-06 (Horticulture Australia Ltd, 2006). Pear imports have mainly consisted of Asian pears from China.

The processing industry in Australia is still largely based in the Goulburn Valley in Victoria where the majority of the ‘Williams’ production occurs. Pear processing in Australia involves the production of a range of canned products as well as pear juice. Since 2001 there has been a gradual decline in the amount of pears sent for processing. In contrast, imports of processed pears have significantly increased in the last 2 years, with just over 1,200 tonnes of processed pears imported in 2005-06 (Horticulture Australia Ltd, 2006). Processed pear imports are mainly from South Africa and China.

A large proportion of Australia's European pear production comes from low density planting systems (<1000 trees/ha). In the Goulburn Valley alone, close to 40% of the pear trees are planted at less than 400 trees/ha (Table 2). These trees are predominantly planted on the very vigorous seedling rootstock *Pyrus calleryana* D6 (D6) (until now the only commercially available rootstock), trained as a multi-leader tree and can reach heights of over 4 m. They are planted on the heavier soils to try to control their vigour. When planted in this way, it can take up to 10 years before a consistent commercial crop is produced. Many of these plantings are over 20 years old and the rate of redevelopment is generally low. Over one-third of the trees in production in the Goulburn Valley today were planted prior to 1987(Table 3) and are still considered by growers to be highly productive. Yields from these plantings can average between 40-60 tonnes/hectare. There are however many challenges associated with production from these trees including declining quality of fruit due to limb rub and russet (and therefore lower packouts), declining health and productivity of trees within blocks and high costs of labour for harvest and pruning very large trees.

Table 2: Planting density of pear trees (all varieties) in the Goulburn Valley, Victoria (Goulburn Valley Orchard Census-Preliminary Data 2007)

Density (trees/ha)	**Area (ha)**	**Tree Number**
<400	2 731	874 418
400-800	382	205 064
801-1200	113	100 824
1201-1600	75	671 808
1601-2000	41	64 280
2001-2400	63	341 786
>2400	1	4 394
Total	3 405	2 262 574

Table 3: Year of planting for existing pear trees (all varieties) in the Goulburn Valley (Goulburn Valley Orchard Census-Preliminary Data 2007)

Year of planting	Area (Ha)	Tree Numbers
Before 1967	2 187.4	636 967
1967-1976	308.8	93 903
1977-1986	267.9	100 624
1987-1996	282.6	441 372
1997-2005	358.4	989 708
Total	3 405.1	2 262 574

Plate 1: Common pear production system in the Goulburn Valley, Victoria

1.2 Intensive pear production in Australia

The adoption of intensive pear production has been reasonably limited in Australia to date. The reasons for this include the limited availability of precocious rootstocks, perceptions of low profitability in redeveloping pear orchards and the continued productivity of older orchards.

Growers remain interested in intensive systems for fresh market pear production and are seeking information on the most suitable systems for local conditions.

Plate 2: Intensive production of ‘Howell’ on D6 in the Goulburn Valley, Victoria

2.0 Planting Material

The profitability of an intensive pear orchard is dependent on how quickly after planting trees can be induced to set flowers and fruit, or in other terms the precocity of the trees. To realise the economic advantage of planting intensively, early cropping is essential. The quality of the planting material used when setting up an intensive production system and its subsequent management has a major influence on the ability to achieve this. It is therefore critical that growers plant nursery trees that are high quality. These are trees that are healthy (free of virus, pest and disease and physical injuries) and have a good structure (good height, stem diameter, feather size and distribution).

2.1 Types of nursery trees

There are various types of nursery trees that can be used when planting an orchard (Australian Pome Fruit Improvement Program 2005; Barritt 1989; Gardner 2006). Summer budded trees are produced over two seasons, with rootstocks planted in spring and budded in summer. These are headed at the bud in late winter, with the bud then growing into a tree in the next season. Sleeping eye trees are summer budded rootstocks that are cut above the dormant bud and stored for planting in a nursery or orchard.

One-year-old whips are produced through bench grafting of rootstocks in winter, planting in spring and then encouragement of a single bud to grow. One year old whips are generally shorter and have fewer feathers in comparison with summer budded trees (Barritt 1989).

In more recent years there has been increased use of two-year-old well-feathered trees or ‘knip trees’. These trees originated in the Netherlands. One-year-old trees produced through either bench grafting or summer budding are held over in the nursery for another year and in the second winter are headed to the required height (50-75cm). A single shoot is then allowed to grow from the top bud and any laterals are removed. The shoot then grows very vigorously and produces branches on the current season’s growth (referred to as feathers).

Plate 3: Well feathered two year old nursery trees in the Netherlands

Plate 4: More detailed view of the feathering on two year old nursery trees in the Netherlands

There are marked differences in productivity between sleeping eye trees, one-year-old whips, summer budded trees and well feathered two year old trees. Generally it is accepted that the use of well-branched nursery trees contributes to early and high orchard yields.

When a 1 year old whip is planted, the productivity will be delayed by a period of 2 years during which the frame of the tree has to be developed (Deckers and Schoofs 2004). A number of studies have shown that the more lateral branches, the greater the yield in the second or third year. Iglesias *et al.* (2004) found that where two year old nursery trees were used, systems quickly 'filled' their within-row space and intercepted almost twice as much light as those where whips were planted. In the same experiment in the second leaf, a system planted with two year old nursery trees had reached production of 12 tonnes/ha whereas that which had used one year old whips had only reached 1.5 tonnes/ha (Asin *et al.* 2005). Lawes *et al.* (1997) found that in the first two years of an orchard, nursery tree grade was of great importance to achieving the ideal orchard tree – based on its size, complexity, form and precocity. Where they planted large well feathered trees they achieved the biggest tree with the most lateral shoots in the first two years after planting. These trees also produced a canopy nearest to the ideal with the most flowers at two years after planting. Balkhoven-Baart *et al.* (2000) also found that in apples, where two year old branched trees were planted, optimum light interception (70%) was achieved earlier than for one year old well feathered trees.

Sleeping eye trees are often used to keep costs down, particularly in very high density orchards. The risks of tree loss at planting can be higher when using sleeping eye trees and often this can counteract any advantages. Elkins *et al.* (2008) found that even though sleeping eye trees were cheaper than 'standard' nursery trees (similar to one year old whips) the cost of replacement and intensive training negated the benefit of the lower purchase price.

2.3 Nursery trees for Australian Pear Production

Well feathered two year old trees are often considered to be the best 'quality' trees to begin an intensive pear system with. However, growers' choice will also be influenced by availability of stock, the system they are going to plant and also the cost.

At present in Australia the cost of nursery trees can represent more than half the cost of establishing a high density orchard (Van Den Ende 2002). The most commonly planted nursery trees are one year old whips. It is not common practice for Australian nurseries to produce two year old well feathered trees. The extra cost associated with producing them provides a barrier both to the nursery and the grower. The lack of a rigorous nursery tree certification system in Australia also means that nursery tree quality can vary.

It is important that the industry works closely with nurseries to improve the quality of nursery material available. Nurseries need to be encouraged to adopt quality certification systems as well as produce trees that are aligned with grower specifications. APFIP is already currently working on a certification process and has published a list of nursery tree specifications (APFIP 2005) that can serve as a good starting point. The knowledge and skills of European nurserymen would also be valuable to extend to both growers and nurserymen.

Growers also need to be planning well in advance to allow nurseries to produce trees that meet their requirements. This means having a clear understanding of the variety, rootstock and system that they want to plant and setting out clear specifications for quality to the nursery.

2.3.1 Recommendations

- Collaborative approach needed between industry and nurseries to improve quality of nursery material available. In the short term this needs to encompass clear industry specifications for nursery trees to suit particular planting systems (current APFIP Nursery tree specifications available from www.apfip.com.au would serve as an excellent starting point.). In the longer term a strategy is needed for the adoption by nurseries of a quality certification system for nursery trees (such as the APFIP certification program)

- Continued education of growers regarding the importance of planning in advance for nursery trees that suit their variety/rootstock choice and planting system.

3.0 Rootstock Choice

The choice of rootstock in a planting system is important for many reasons. Rootstocks play an integral role in influencing vigour, growth habit and cropping of the scion cultivar, resistance to pest and diseases and tolerance to unfavourable conditions in the growing environment.

3.1 Rootstock effects on vigour and cropping

In terms of intensive production, the main interest in rootstocks is for their effect on scion vigour and cropping. Scion vigour is influenced by many factors (eg. climate, soil, and intrinsic scion vigour). In the most basic terms, the combination of rootstock and scion determines tree vigour and therefore tree density. Webster (1995) proposed that rootstocks effect scion vigour through influencing both rates of shoot extension and the timing of termination of active extension growth, however there is no clear understanding of the relationship. The development of dwarfing rootstocks that restrict tree height and spread have enabled fruit production systems to be planted at higher densities (Hoying and Robinson 2006). Rootstock and tree density are considered to be key factors for early cropping and high production levels (Wertheim and Wagenmakers 1993) and ultimately can determine profitability.

Rootstock effects on cropping are generally observed by measuring changes in yield precocity, productivity and yield efficiency. Yield precocity is dependent upon both precocity of flowering and the ability of those flowers to set, retain and size fruits (Webster 1995). Whilst there is no direct link between dwarfing rootstocks and increased yield precocity, Webster (2002) suggested that there were various ways through which rootstocks could influence floral abundance, flower quality and timing of flowering to result in an increased precocity.

In terms of productivity, dwarfing rootstocks generally result in lower yields per tree compared to larger trees; however this is compensated for by the ability to plant higher densities. What is most important when comparing rootstocks is their effect on scion yield efficiency, which is most usually expressed as yield (by fruit weight) per trunk cross-sectional area (Webster 1995). Rootstocks that produce smaller more precocious trees will result in better yield efficiency.

3.2 Rootstocks for pear production

Unlike for apples where there is a range of dwarfing and semi-dwarfing rootstocks available for producing high density orchards, there is still a shortage of efficient dwarfing pear rootstocks (Hoying and Robinson 2006; Jacob 2006; Webster 1998; Wertheim *et al.* 2001 ; Wertheim and Wagenmakers 1993; Wertheim 2002). There is still a need to develop pear rootstocks that offer:

- a range of vigour to meet the differences in growing environments,
- precocity,
- good fruit size and quality
- easy propagation
- cold hardiness
- tolerance to iron chlorosis and pear decline, and
- tolerance/ resistance to fireblight.

Most European pear species (*Pyrus communis)* are currently propagated on either clonal (vegetatively propagated) or seedling rootstocks of the *Pyrus* species (*Pyrus communis, P. calleryana, P.pyrifolia, P. betulaefolia)* or quince (*Cydonia oblonga*) (Rodriguez and Castro 2006; Smith 1996; Webster 1998). Almost all quince rootstocks are vegetatively propagated clones. Clonal rootsocks have the advantage over seedling rootstocks of uniformity, tree size control, precocity and resistance to soil borne pests and diseases (Palmer 2006).

3.2.1 <u>Pyrus species</u>

Most of the *Pyrus* rootstocks used commercially for the common pear (*Pyrus communis)* are seedlings. These rootstocks offer many advantages including good compatibility with scion varieties, good anchorage, tolerance to abiotic stresses such as drought, high soil pH and cold (Webster 1998). However, seedling rootstocks generally result in very vigorous growing trees that are slow to bear, an undesirable trait for intensive production. Trees grown on seedling rootstock can also be highly variable. In many of the world's pear growing areas, there has been a general move away from seedling rootstock and its use is limited to specific areas where the growing conditions are not suitable for less vigorous rootstocks.

In order to overcome the problems associated with using *Pyrus* seedlings as rootstock, some selection of clones of *P.communis* has occurred (Du Plooy *et al.* 2002). There are a number of these rootstocks available commercially world wide and substantial testing has occurred to identify their potential as dwarfing rootstocks. *Pyrus* rootstocks are generally considered to be more invigorating and have a lower yield efficiency than Quince rootstocks (Campbell 2003;

Webster 1998; Wertheim and Wagenmakers 1993; Wertheim 2002, Maas 2006) however results can vary. This is to be expected as various factors, such as climate, soil potential and management practices will significantly influence the performance of a scion/rootstock combination (Du Plooy *et al.* 2002).

3.2.1.1 OHF series

The OHF series of rootstocks are a result of crosses between the scion varieties 'Old Home' and 'Farmingdale' and originated in the United States (Hummer 1998). There are a number of rootstocks in this series with a varying range of vigour and yield efficiency. In Northern America the predominant selection planted is OHF 97 with lesser amounts of OHF 40, 69, 87, 217, 333 and 513 (Mielke 2008). OHF has replaced seedling rootstocks in the Pacific North West in environments where quinces suffer from poor winter hardiness (Palmer 2006).

OHF rootstocks are reported to be resistant to fireblight, woolly aphid and *Phytophthora* damage and tolerant of Pear Decline, high pH soils and drought (Hummer 1998; Webster 1998). Some of these rootstocks have been introduced into Australia, however no rigorous evaluation has yet occurred.

There are varying reports on the yield efficiency of scion cultivars on OHF rootstocks under intensive conditions. Whilst some clones such as OHF 87 have reportedly induced good yield efficiency (Carrera *et al.* 2005; Ing 2002; Johnson *et al.* 2005) others have not performed very well. In trials conducted with 'Conference' pear in Spain, OHF 69 and 333 had lower yield efficiencies than all of the Quince rootstocks (Iglesias and Asin 2005). This corresponds with trials by (Carrera *et al.* 2005), where yield efficiency for 'Conference' was highest on quince BA29 and Adams, intermediate on OHF 69, 87 and 40 and lowest on OHF 333 and seedling. In comparison, on trials with ''Williams'' in Spain, OHF333 induced highest yields, precocity and acceptable fruit quality compared to BA29 (Urbina *et al.* 2003).

Despite these varying results, it is generally considered that the OHF series is not satisfactory as a rootstock for intensive production(Campbell 2003; Jacob 1998; Wertheim 2002) as they are all more invigorating and less precocious than quince. They have however had some popularity in Europe due to their ability to adapt to certain conditions (eg. High lime tolerance) (Sansavini et al. 2008).

3.2.1.2 BP Series

The BP series of rootstocks BP1, BP2 and BP3 originated in South Africa and now, most pear orchards in South Africa are established on these rootstocks (Du Plooy *et al.* 2002). Trees on

BP1 reportedly have a vigour similar to Quince A and BA29 (75% of *Pyrus Calleryana*) and exhibit good yield efficiency (Webster 1998). BP2 and BP3 have vigour similar to ‘‘Williams’’ seedling, which is about 90% of *Pyrus Calleryana.* There are no reported compatibility issues with BP rootstocks and scion cultivars. These rootstocks are, however, highly susceptible to pear decline and fireblight (Campbell 2003; Du Plooy *et al.* 2002; Leis and Martinelli 2002) and are difficult to propagate. Susceptibility to pear decline has particularly limited the use of BP rootstocks in Europe.

In South African trials with various scion cultivars, under a range of growing conditions, generally Quince rootstocks resulted in smaller trees and higher yield efficiencies than BP1 rootstocks (Du Plooy *et al.* 2002). The smaller tree size (and therefore better light distribution within the tree) on Quince rootstocks was also associated with better blush development, fruit size and higher total soluble sugars (TSS) than those on BP1(Du Plooy and van Huyssteen 2000). This was confirmed by Roberts *et al.* 2008 who found that there was a general trend for fruit on Quince rootstocks to have better colour (greater percentage of blush) and slightly higher TSS than those grown on BP rootstocks.

The BP1 rootstock has been trialled in Australia in various orchards although no experimental data has been published. It is also currently planted in the APFIP rootstock trial site in the Goulburn Valley.

3.2.1.3 Pyrodwarf

Pyrodwarf originated from a crossing between Old Home and Bonne Luise d’Avranches. It reportedly has a vigour 50% lower than *Pyrus Calleryana D6.* It has good graft compatibility with European and some East-Asian pear varieties. Development of iron chlorosis on high pH soils is low, it is tolerant to waterlogging, has good winter hardiness and has a medium susceptibility to fireblight (much less than quince) (Du Plooy *et al.* 2002; Jacob 1998; Jacob 2006).

Whilst it is reported that Pyrodwarf does not show an inclination to grow suckers (Du Plooy *et al.* 2002; Jacob 1998; Jacob 2006), this was disputed by Spanish and Italian researchers (Grills 2006) who found that it suckered prominently. It is also regarded in these countries as still being too vigorous for high-density systems, although no corroborating experimental data was found in the literature. This rootstock has been introduced in Australia and will be included in future in the APFIP pear rootstock trial. This should yield information about its performance in local conditions.

3.2.1.4 Pyriam

Pyriam is a clonal rootstock developed by INRA in France through open pollination of ‘Old Home’. It is seen as a potential replacement for BA29 in south-east France. It has good graft compatibility with ‘‘Williams’’, a good ability to be propagated, low susceptibility to Fireblight and good growth and habit in the nursery. It induces slightly higher vigour than BA29 but has equal productivity and fruit sizes (Du Plooy *et al.* 2002; Simard and Michelesi 2002). No experimental data was found in the literature to compare the performance of Pyriam to other rootstocks.

3.2.1.5 BM2000

BM2000 originated in Australia as a result of open-pollination of likely parents ‘‘Williams’’ and ‘‘Packham’s’. It is described as having medium vigour compared to D6. There is no experimental data regarding precocity, productivity and yield efficiency in the literature. This rootstock is currently in the APFIP pear rootstock evaluation site and data should be available soon.

3.2.1.6 Fox Series

Fox 11 and Fox 16 are two of the fox series which have plant variety rights. According to a review by Wertheim (1998) Fox 11 has a vigour similar to BA29 and is recommended for tree densities between 2000-2500 trees/ha. It also has good compatibility and tolerates high alkalinity. Fox 16 has a vigour slightly greater than BA29 and it has drought tolerance but is less tolerant of high alkalinity than Fox 11. In trials with ‘Conference’ Massai *et al.* 2008 found that Fox 16 performed similarly to Quince A, BA29 and Sydo whereas Fox 11 was too vigorous.

3.2.1.7 Horner Series

The Horner rootstocks were developed through open pollination of five ‘Old Home’ x ‘Farmingdale’ rootstocks (Mielke and Smith 2002). At 752 trees/ acre (approx 1800 trees/ha) ‘d’ Anjou’ on two of the selections (H4 and H10) out yielded and had a better yield efficiency than that of the control (OHF 97) (Mielke and Sugar 2004). These results have indicated potential for the Horner series of rootstocks to provide growers with rootstocks that are precocious and productive.

3.2.2 Quince rootstocks

Clonal quince (*Cydonia oblonga* L.) rootstocks are widely used in intensive pear production throughout Europe, particularly in countries such as the Netherlands, Belgium, Spain and Italy. Trees on quince rootstocks are reduced in vigour, precocious and productive in cropping and, in most cases bear fruits of good size and quality (Webster 1998). The quince rootstocks offer a range of vigour and in most cases have proven to be far more precocious, productive and efficient than any of the *Pyrus* clonal rootstocks (Carrera *et al.* 2005; Du Plooy *et al.* 2002; Iglesias and Asin 2005; Palmer 2006; Sansavini and Musacchi 2002; Wertheim 2002; Massai *et al*. 2008).

The Quince rootstocks most commonly used in intensive pear production are BA29, Quince MA (A), Sydo, Quince Adams and Quince MC (C). Quince A has been used for many years in Europe and has a vigour of 75% that of seedling. Quince Sydo and Quince A are similar in vigour and yield efficiency but Sydo is considered better than A in stool beds (Wertheim 1998). BA29 is slightly more vigorous but has a cropping efficiency equal to Quince A. BA29 is more tolerant to lime induced chlorosis and is therefore more suited to sites with calcareous soils and dry areas. Quince A, BA29 and Sydo are all recommended for densities between 1500-3000 trees/ha.

Quince C is the least vigorous of the Quince rootstocks approximately 10-20% more dwarfing than Quince A (Webster 1998). Quince Adams has vigour between Quince C and Quince A. Generally Quince C and Adams have better yield efficiency than MA and Sydo. Generally Quince C and Quince Adams are suited to densities above 3000 trees/ha.

More recently Quince EMH has been developed at East Malling. This induces scion vigour between C and A and is probably similar to Quince Adams in this respect. EMH has improved fruit size in comparison with Quince C in some cases, but has exhibited poorer yield precocity (Johnson *et al.* 2005; Webster 1998). There is further selection of quince rootstocks occurring at East Malling and some clones show promise of being more dwarfing than Quince C.

Plate 5: ‘Conference’ on Quince C (left) and Quince A (right) in Belgian nursery. The difference in vigour is noticeable.

Quince C132 and Eline ® are two other quince selections that have shown promise as rootstocks. Quince C132 is a quince selection raised at East Malling Research, from seed imported from the Caucasus region of Russia (Johnson *et al.* 2005). In trials with ‘Conference’ in the United Kingdom, C132 produced trees slightly more dwarfed than Quince C but with similar yield efficiencies (Johnson *et al.* 2005). This has been confirmed by Dutch trials that found C132 had similar control of tree vigour and production efficiency as Quince C (Maas 2006). In these trials C132 was found to induce bigger fruit size. Eline ® is a Romanian rootstock sourced from Flueren nurseries in the Netherlands. In Dutch trials Eline ® also displayed a similar control of tree vigour and production efficiency to Quince C but gave specific advantage of less russeted fruit (Maas 2006). Both Quince C132 and Eline ® are expected to give greater frost resistance due to their colder origins.

Whilst so far, quince rootstocks appear to be more suitable for intensive systems than *Pyrus* rootstocks, there are a number of inherent problems associated with them. The main problem is that they are incompatible with many European pear scion varieties. Trials in the Netherlands, using graft union breaking strength as a measure of compatibility have shown that cultivars such as ‘Williams’ are incompatible with Quince C and that others, such as ‘Conference’ are not fully compatible and fail under specific environmental conditions (Webster 1998). Generally most of the important varieties in Australia such as ‘Williams’, ‘Packhams’, ‘Buerre Bosc’ and ‘Corella’ are considered incompatible. This incompatibility of pear/quince can be overcome using interstems of compatible varieties such as ‘Buerre Hardy’ or ‘Comice’ however this would mean higher tree costs.

Quince rootstocks are also susceptible to lime induced chlorosis in soils where there is high pH and lime content. This can often rule out their use in otherwise suitable sites. Quince C, the weakest rootstock in terms of vigour is the most susceptible to these problems. This was noted as a particular problem in Belgium, Netherlands, Spain and Italy (Grills 2005). In Spain particularly, Quince C was of limited interest for pear orchards, because of its poor performance under their conditions of high pH soils. Quince C can also result in smaller fruit sizes, which makes it unfavourable for scion cultivars that naturally bear small fruit. Often more vigorous rootstocks such as BA29 are preferred in these areas.

Further problems with quince rootstocks include poor anchorage in comparison to *Pyrus* rootstocks, susceptibility to fireblight, drought stress and limited winter hardiness. The limited winter hardiness of quince has particularly prevented their use in areas with severe winters such as the US Pacific North West.

3.3 Rootstocks for Australian Pear Production

Since the mid 1950' *Pyrus calleryana D6* (D6) is the most commonly used rootstock for commercial pear production in Australia. D6 is a vigorous rootstock that produces very large trees. The advantages of D6 are that it is very productive (although slow to bear initially) and is compatible with most pear varieties. However, it is generally regarded that its vigour makes it unsuitable to modern systems of high-density pear production.

The lack of availability of the range of *pyrus* and Quince rootstocks that are found in other pear production regions around the world, and particularly in Europe, is the major limiting factor for intensive pear production in Australia. The semi-dwarfing *pyrus* rootstocks BP1 and BM2000 are currently available from nurseries but in limited numbers, whilst Quince is generally unavailable.

There is an opportunity to adopt both Quince and dwarfing *pyrus* rootstocks in Australia. It is difficult to draw solid conclusions from the literature as to which rootstock would most likely suit Australian conditions. Rootstock performance is influenced by a combination of the choice of scion, quality of testing material, systems of management and the growing environment (Johnson *et al.* 2005; Webster 1998) and therefore results from other areas may not directly translate to Australian conditions. It is obvious from the literature that Quince rootstocks are the most desirable for intensive production and results from areas with similar climatic challenges (South Africa and Spain) do suggest that these rootstocks should perform well in our conditions – given optimal management. The possibility for better blush development on Quince rootstocks is also interesting for ‘Corella’ pears in Australia and any potential new blushed variety.

The recent initiation by APFIP of a rootstock trial site in the Goulburn Valley, comparing BM2000, Quince A, BP1 and BM2000 should provide more information as to their performance under local conditions, however further rigorous long term trials need to be invested in by the industry.

It is estimated that a range of certified virus free dwarfing pear rootstocks (including Quince A and C) will be available to growers in the next three to five years, so it is important that growers develop the knowledge and skills to manage these rootstocks in advance.

3.3.1 Recommendations

- Further trialling of the range of *pyrus* and quince rootstocks under local conditions with current and potential new varieties (to expand on the current APFIP trials). Trials need to be replicated across pear production regions (including Vic, SA and WA) and have optimal management and monitoring from establishment through to full production to demonstrate maximum potential. Water use of rootstocks and the response to extreme heat events (such as those experienced in early 2009) are important factors that would need to be monitored. A rigorous extension program to educate growers on the rootstock characteristics and requirements would need to be built into the trials.

4.0 Planting system

The planting system is the integration of tree arrangement, planting density, support systems and training schemes. There is no one planting system to suit all situations. Factors such as soil, cultivar, rootstock, management regimes and socio-economic conditions will determine the optimal combination for each orchard.

The most important objective when choosing the planting system is to achieve optimal light interception and distribution whilst maintaining efficient orchard practices. Crop yield and quality are a function of the efficiency of light utilisation and distribution (Van Den Ende 2002). Differences in light interception could explain the reasons why yields among orchard systems and tree densities differ (Hoying and Robinson 2006; Robinson 1997). Intensive (or high density) production systems for apple and pear have been shown to allow for better light interception and distribution within the tree canopy (Balkhoven-Baart *et al.* 2000; Kappel and Brownlee 2001; Sansavini and Musacchi 2002). In particular, tree density and canopy shape (training system) interact in determining light interception and distribution.

4.1 Tree density

In the early years of the orchard, training system does not significantly affect productivity (Hampson *et al.* 1997; Sansavini and Musacchi 2002). Tree density and light interception is the major factor affecting early production.

Trees can be arranged as single rows, multiple rows or bed systems with occasional traffic lanes (Hoying and Robinson 2006). With increasing densities the need for a transition to multi-rows increase. The definition of density can vary. In most of the literature, low density is 1000 trees/ha, medium density 2000-3000 trees/ha and high density is 5000 trees/ha. Very high density is 6-8000 trees/ha and Ultra High density 10-12000 trees/ha. Increasing tree densities generally results in earlier production of fruit and increased yields. Increased densities have a negative influence on tree size due likely to two factors 1). inter-tree root competition for water and nutrients at high planting densities and 2). more intensive canopy management at higher tree densities (Robinson 2008). Higher planting densities whilst creating smaller trees, support a greater leaf area and usually intercept more light per unit area earlier in the life of the orchard than low density plantings (Balkhoven-Baart *et al.* 2000; Kappel and Brownlee 2001).

Musacchi *et al.* (2005) found that after 7 years, ‘Conference’, ‘Abate Fetel’ and ‘Comice’ grown on Quince Sydo at low densities (1984 trees/ha) were characterised by lower yields compared to those on Quince C at higher densities (≥3968 trees/ha). The results for ‘Conference’ are confirmed by Asin *et al.* (2005) who found that higher densities resulted in earlier production and higher yields. In the Netherlands, a multi site trial with slender spindles of ‘Conference’ showed that the average annual yield was 9 tonnes higher at 4000 trees/ha than at 2000 trees/ha. This was associated with an increase in light interception from 62-74% (Wertheim *et al.* 2001). In economic analyses of data derived from trials with ‘Golden Russet Bosc’ it was found that high density plantings (3073 trees/ha) came into production sooner demonstrating an estimated profit in year 6 compared to year 9 for standard density (598 trees/ha) (Elkins *et al.* 2008). High density plantings also demonstrated a yield of 56 tonnes/ha at full production compared to 45 tonnes for standard planting.

Increasing tree density only increases yields up to a certain level however. Balkhoven-Baart *et al.* (2000) showed this for apples where they found that in going from 6000 trees/ha to 10000 trees/ha the increase in fruit production was less than 15% as opposed to the 40% increase from 3000 trees/ha to 6000 trees/ha. When even higher densities were planted (20 000 trees/ha) there was little or no benefit to production. This was associated with light interception increasing past the optimum level and adversely effecting fruit quality. In apples Balkhoven-Baart *et al.* (2000) found that higher density systems which intercepted over 85% of light had reduced fruit quality compared with those that were intercepting 70% of light. Negative influences on fruit size and soluble solids are expected in ultra dense plantings above 8000 trees/ha (Van Den Ende 2002). There is also a risk with higher densities that fruit size can be reduced by over-cropping, something which requires improved cultural management techniques in these systems (Robinson 2008).

There are a number of factors that will determine the optimal tree density for an intensive pear orchard. Rootstock and scion vigour is generally one of the most critical. Where the scion and rootstock combination induce excessive vigour, increasing density can have no positive effect on yield (Wertheim and Wagenmakers 1993).

4.2 Training systems

The primary objective of pear tree training is to direct tree growth and develop a strong tree framework that will support quality fruit production. In particular, proper training of pear trees opens up the canopy to ensure maximum light interception and distribution. In mature orchards, canopy shape can affect light distribution within the tree canopy. If the intercepted light is not evenly distributed throughout the tree canopy, shading can occur which can inhibit flower bud development, fruit set and fruit colour. Tree designs that maximise exposure within the canopy generally have greater efficiency of conversion of light energy to fruit than canopy designs that allow heavy internal shading (Van Den Ende 2002).

Pear's vegetative and cropping habits and suitability to different pruning regimes mean that it can be trained to different systems (Sansavini and Musacchi 2002). The choice of training system is highly dependent on intra-row spacing (i.e. planting density) and is most important at very high densities. By exceeding densities of 3000 trees/ha and exceeding 60-70% intercepted light without controlling canopy leaf distribution, yield efficiency and fruit quality can be reduced (Sansavini and Musacchi 2002).

Traditional training systems for pear, particularly in Australia, focussed on widely spaced freestanding trees on vigorous seedling rootstock trained as open centre or vase shapes. If pruned correctly pears trained in this way can achieve high production levels. However, with the introduction of more dwarfing rootstocks and the move to higher densities, the focus has shifted to developing compact trees through using central leader systems such as the spindle bush and its variations or high-density hedgerows of trellised trees.

Around the world pears are trained in a variety of systems. It is possible to derive various training systems from the same pruning concepts or to apply various pruning methods to get, apparently, the same training system (Sansavini and Musacchi 1994). For the purpose of this review, systems have been reviewed as those derived from central leader, double leader, palmette and V Systems.

4.2.1 Systems Derived from Central Leader

Pear trees are trained as central leader systems to develop a conical or pyramidal shaped tree which can be free standing or supported by a post or wire support system. This tree shape is one of the most efficient for light interception and crop production (Adem 2003). There are various systems that use the central leader concept. In general terms these consist of tiers of scaffold branches along a straight central axis (AgraPoint International Inc 2006). The major differences between central leader derived systems include tree density, height, leader management and whether or not permanent scaffold branches are retained.

4.2.1.1 Spindle Bush

The basic central leader forms, such as the spindle bush (or sometimes referred to as the free spindle) are generally suited to densities up to 2000 trees/ha and will vary from 2-3m in height. The planting distance is usually 1-2m x 3-4m. In Europe, spindle systems are usually planted using well feathered two-year old nursery trees. At planting a number of laterals are selected to form part of the permanent scaffolds in the bottom third of the tree. Competing laterals that develop at the end of the unpruned central leader have to be removed in a very early stage (Deckers and Schoofs 2004). As the leader grows more scaffolds are selected and spaced equally. Leader dominance is important and if it is lost will result in a reduced tree canopy, whereas if it becomes too strong lateral growth and development will be reduced. These systems can be free standing, however mostly utilise some form of support (either 2-3 wire trellis or individual supports).

Modified leader systems are the same as central leader initially; however the leader is removed, tied down, or cut to horizontally growing shoots at the desired tree height. This is mainly to reduce shading and loss of production in the centre of the tree (AgraPoint International Inc 2006).

As tree densities get higher and row spacing's get more restricted, variations on the spindle system such as the vertical axis, slender spindle and super spindle are favoured.

4.2.1.2 Vertical Axis

The vertical axis is similar to the spindle bush. A vertical central leader (axis) is developed with relatively 'weak' fruiting branches arising around the leader (Westwood 1993). Maintaining apical dominance is important in the vertical axis system particularly during early stages of development to ensure weak fruiting branches – therefore no heading of the leader occurs. Branches are systematically renewed to prevent them from becoming permanent scaffolds. Tree density is usually between 1000 – 2500 trees/ha at a spacing of 1-2m x 4-5m and height can reach up to 3m (Robinson *et al.* 2007). Support of 2-3 wire trellis is required. Similar to the spindle system, vertical axis systems are planted ideally using well feathered nursery trees.

4.2.1.3 Slender Spindle

The slender spindle system is involves more severe pruning than the vertical axis and is suited to densities of 2000-5000 trees/ha. The slender spindle is a more conical shaped tree with a distinct, supported, vertical central leader branch. At the base of the tree there is a permanent frame of a varying number of branches, above which exist more or less horizontal fruiting branches shorter in length than the frame branches (Wertheim 1978). Leader control is important and need to avoid strong leaders and lateral growth in the top of the tree (AgraPoint International Inc 2006). Generally the leader is headed back to a weaker lateral when it has become too dominant. Planting distances is 1-1.5m x 3-3.5m and tree height is usually restricted to 2-3m (Wertheim 1978). Well feathered nursery trees preferred for planting slender spindle systems.

4.2.1.4 Super Spindle

The super spindle system is utilised for super high-density orchards on weaker rootstocks such as Quince C. Generally there is a row spacing of $\leq$3m and a tree distance within the row of less than 0.8m, giving a density of more than 4000 trees/ha (Weber 2000). There are systems in Europe that can reach 12 000 trees/ha when trained as super spindle.

The main concept is to have closely spaced compact trees with short fruiting wood or spurs evenly spaced along the central leader. Tree height is generally maintained at 2-3m. Super spindles require a multi wire support system. The goal of this system is to achieve very high and early yields so that new varieties can be introduced as quickly as possible to meet market demands and low fruit cost per hour of labour (Robinson 2007.

Super spindle orchards do not usually use highly branched and relatively expensive trees used in slender spindle orchards but rather whips with a number of short feathers along the leader or even cheaper trees such as budded rootstocks (sleeping eye trees) (Robinson 2007).

4.2.2 Palmette

The palmette and its variations are generally limited to wide intra-row spacing’s (>2.0-2.5m) and by a taller tree which makes it best suited to medium-high planting densities (700-1500 trees/ha). There are a number of kinds of palmette training (Plate x) generally all comprising of a central leader with scaffolds in the plane of the row only. Tiers of scaffolds are chosen as the leader grows each season and are tied to wires to reduce vigour and promote spurring. The palmette, in many cases is considered a traditional system, however is still widely used in areas where the environment, species or the cultivar/rootstock combinations are conducive to vigorous growth (Corelli-Grappadelli 2000). These systems have been popular because the bending of branches on trellises controls growth and provides a balance of fruiting and vegetative growth (Westwood 1993).

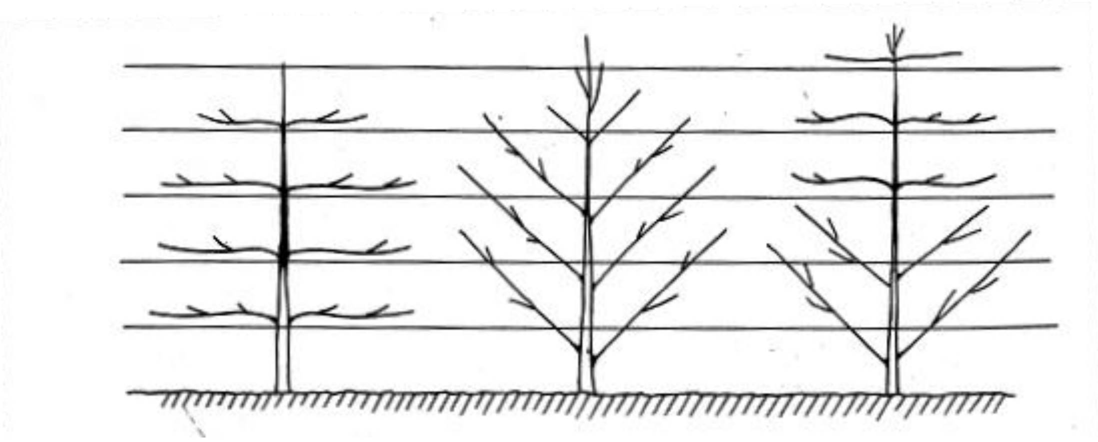


Plate 6: Three kinds of palmette training: (left) horizontal arms, (centre) oblique arms, and (right) a combination of the two (Westwood 1993)

Plate 7: 'Packham' on D6 trained as a palmette in the Perth Hills, WA.

Plate 8: 'Conference' on Quince BA29 trained as palmette in Spain

4.2.3 Double Leader Systems

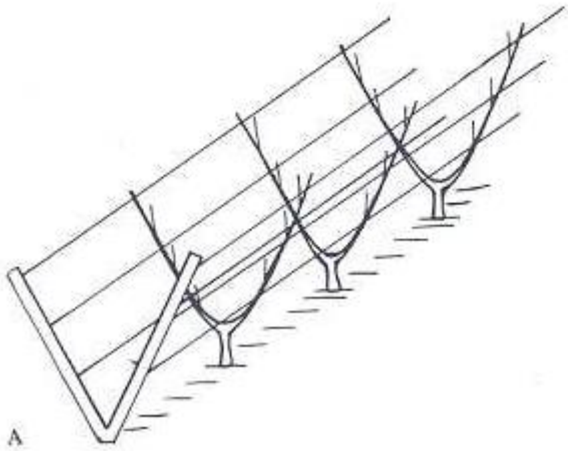
Double leader systems are trained with the aim of achieving high leader densities whilst keeping tree numbers (and cost) down. Trees are usually planted at approximately 3-4m x 1-1.2m equalling a tree density of around 3000 trees/ha. However, the development of double leaders mean that the leader density is 6000 trees/ha.

The Bibaum® system is a double leader system that was developed in Italy. This system involves planting Bibaum® nursery trees, which are preformed with 2 axes in the nursery. Trees are split at 25cm above the ground into 2 equally strong leaders (Musacchi 2008). Generally the trees are planted at 3.3m x 1-1.25m in a single row which equates to 3000 trees/ha but has a leader density of 6000/ha. The leaders are trained parallel to the row and are spaced at about 50-60cm apart. Musacchi (2008) found that 'Abate Fetel' on the Bibaum® system had a better yield efficiency than the spindle system and the candelabro. It also produced slightly larger fruit in one trial. Pruning time was reduced significantly for the Bibaum® system compared to both the spindle and candelabro.

Plate 9: 'Williams' trained as Bibaum® system in Italy.

4.2.4 <u>V Systems</u>

There are various V shaped orchard systems used in pear production. Generally there are 2 basic shapes of canopies – Y shaped trees which have a vertical trunk and two opposing arms of the tree trained to either side of the trellis and V shaped trees where the whole tree is leaned to one side of the trellis while the next tree in the row is leaned to the other (Robinson 2000). The two main V systems outlined here are the V hedge and Open Tatura Trellis.



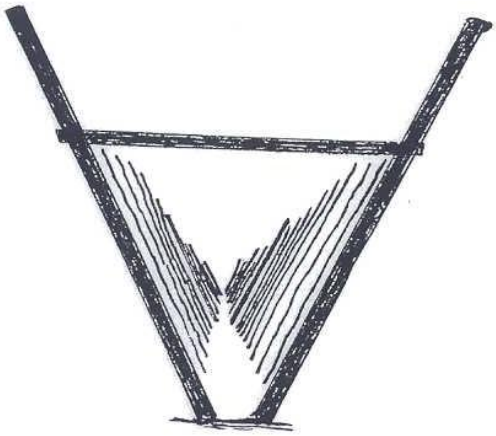


Plate 10: The two basic canopy shapes of V systems – The Y shaped canopy (left) (Westwood 1993) and the V shaped canopy (right) (Van Den Ende 1997)

4.2.4.1 <u>V Hedge</u>

The V hedge system is widely used in the Netherlands and Belgium and is a variation of a Y shaped system. The planting distance in the V Hedge is 3.5 x 1.25m which equals 2057 trees/ha (Deckers and Schoofs 2004). These systems are planted using well feathered 2 year old nursery trees. Four feathers are kept as fruiting branches and considered as four central leaders on one stem (Deckers and Schoofs 2004). Tree height is maintained at 2m with an opening of the V of 1.4m (Deckers and Schoofs 2004). These systems can be planted more intensively, however light interception can be inhibited. There is no pruning at planting.

Plate 11: Young 'Conference' orchard trained as V Hedge showing bamboo supports

Plate 12: Detail of V hedge showing the four fruiting units

Plate 13: 'Conference' on Quince Adams trained as V Hedge in ninth leaf. This orchard produced approximately 50t/ha.

4.2.4.2 Open Tatura Trellis

The open Tatura Trellis system is a modification of the original Tatura Trellis (a Y shaped system), developed in the 1970's. The Open Tatura Trellis is now more commonly planted in Australia than the Tatura Trellis. With the Open Tatura there is a narrow strip of about 0.5 meters that separates alternatively diagonally planted trees within each row (Van den Ende 2002). Open Tatura Trellis systems are generally planted 4-4.5m x 0.5-1m (2000-5000 trees/ha). Trees can be trained in a number of different ways in the Open Tatura Trellis System. Three of the most common are the Open Tatura with double leaders (similar to a Bibaum® system), Open Tatura with single leader and more recently the Open Tatura cordon (Plate 14).

The Open Tatura with double leaders involves training each tree with two leaders (approx 1m apart). This means that tree costs can be reduced whilst still maintaining a high density of fruiting units. The Open Tatura with single leader is similar to planting a slender spindle type system. With this system root systems are approx 0.5m apart but the leaders are 1m apart. (Van Den Ende 2002). The Open Tatura with cordon allows for a moderately dense orchard of around 2000 trees/ha with approx 8000 fruiting units growing up the wires (Van Den Ende 2005). Nursery trees (usually whips) are bent over at planting and trained to the horizontal. Fruiting units are then encouraged at regular intervals along the trunk. These fruiting units can be renewed regularly.

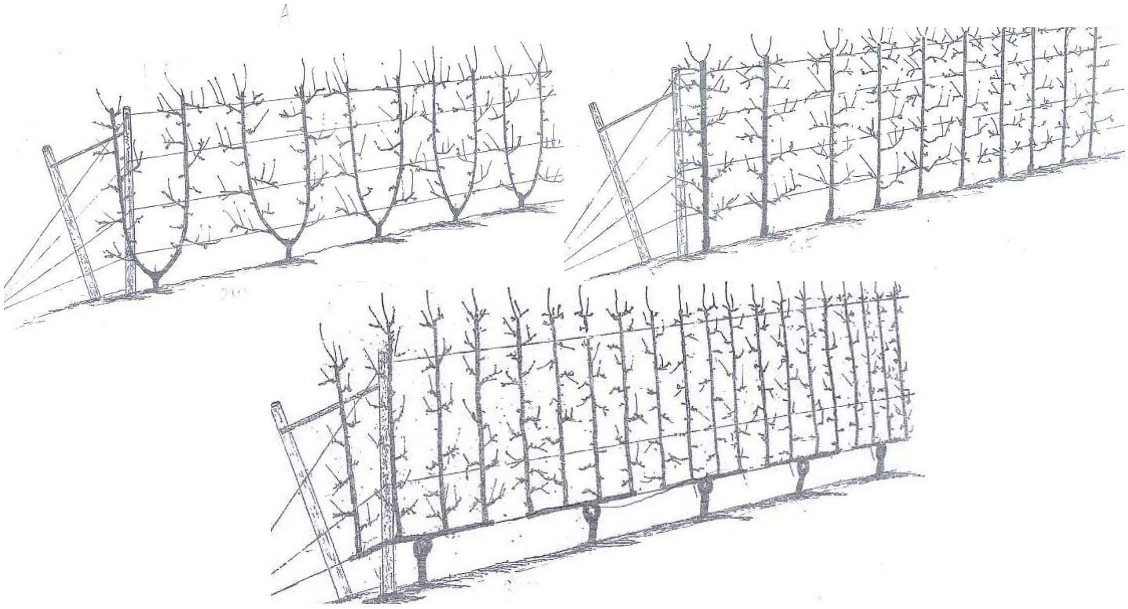


Plate 14: Training types for the Open Tatura Trellis system (only one side of the trellis is shown) – Double leader (top left), Single leader (top right) and Cordon (bottom) (Van Den Ende 2005)

The advantages of the Open Tatura trellis system is that it allows for early production and high yields at maturity which means early returns on investment. Elkins *et al.* 2008 found that the use of Tatura trellis and a compatible precocious rootstock (OHF 69) paid for the cost of investment in 10 years, 11 years sooner than for standard planting densities using the same rootstock. The Tatura trellis also reduces pruning and harvesting costs as the tree structure is simple and can mostly be done on the ground. However, the cost of establishment are often much higher than single row systems (such as central leader/palmette) due to both the trellis construction and the early training of the trees.

Plate 15: Open Tatura Trellis trained as a cordon in the Goulburn Valley, Vic

Plate 16: Open Tatura Trellis trained as a double leader in the Goulburn Valley, Vic

Plate 17: Open Tatura Trellis trained as a single leader in the Goulburn Valley, Vic

4.3 Planting Systems for Australian Pear Production

As previously mentioned, a large majority of Australian pear production occurs on older low density free standing systems. Across the pear production regions there have however been some commercial intensive plantings. These have mainly centred on fresh market ‘Packham’ and ‘Corella’ pears trained on Tatura Trellis (and its variations) or central leader systems with densities ranging from 1000-3000 trees/ha. The majority of these systems are on D6 rootstock with some smaller plantings using BP1 and BM2000. The performance of systems has varied, with some of the best producing close to 50 t/ha after 6-8 years. ‘Williams’ pears for processing are generally considered a low input crop and there is reluctance to plant intensively due to the lower returns received by growers for processing.

There is still a desire within the industry to refine systems that deliver yield and efficiency results similar to those achieved in intensive production systems internationally. Whilst a range of systems have been reviewed above, it is hard to draw conclusions on what will be the best for Australian conditions. Research trials can be useful in identifying the advantages of systems and comparing performance but if growers do not have the knowledge on how to correctly establish, train and manage systems for maximum potential these results can be irrelevant. Using good quality nursery trees that are developed to suit the chosen system, as well as rootstocks that will permit higher densities with manageable vigour control requirements are important factors for growers to consider when choosing planting systems. Given the lack of dwarfing quince and *pyrus* rootstock availability it may be more difficult to find systems that deliver good results. The financial commitment involved in establishing systems and the expected farm gate returns for the variety will also influence the suitability of a system for an orchard.

4.3.1 Recommendations

- Information provided to growers to understand the financial commitment of various growing systems – using current prices for inputs and expected returns.
- A systems trial (in conjunction with further rootstock trials recommended previously) that demonstrates a central leader type system and a V system and monitors establishment and ongoing management costs as well as yield performance (in terms of efficiency and fruit quality). Extension to growers built into the trial.

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5.0 Management methods to improve pear productivity

Pear productivity is dependent upon the successful achievement of a series of sequential processes: those associated with floral induction, flower development, pollination, and fruit set (flower fertilisation), fruitlet retention and fruit growth (Webster 2002).

Floral induction of pears usually occurs 60 days past full bloom (Westwood 1993) which is the equivalent of late December/early January in Australian conditions. During this time enough floral buds must be initiated to provide the potential for a large crop that meets quality requirements. The buds must then develop into flowers of high quality in terms of their ability to set, retain and size fruits through until harvest (Webster 2002). Furthermore flowers must have effective pollination, and once fruits are set enough must be retained to ensure a high yield of large, good quality pears.

The achievement of each of these processes is influenced by a combination of factors. These include genetics (rootstock and scion choice), tree age, tree growth (vigour), climate and also crop load at the time of floral induction. The effects on productivity by rootstock and nursery tree quality have already been covered in previous section. The following will review management techniques that attempt to manipulate vigour and fruit set for the maximum potential to produce quality pears.

5.1 Controlling tree vigour

Excessive tree vigour can have a major impact on the productivity of a pear orchard. Excessive shoot growth causes shading which has a negative effect on flower bud induction. The competition for the trees resources (nutrients and assimilates) between growing extension shoots and fruitlets impedes cell division is also the probable cause of fruitlet abscission on young trees and very vigorous trees (Webster 2002; Smit *et al.* 2005)

Any factor that reduces shoot growth of the tree is certain to change also the partitioning of assimilates, nutrients and hormones between the various sinks within the tree and will probably favour the production of floral primordia (Webster 2002)

Controlling vigour is particularly relevant to Australian pear production systems currently relying on vigorous seedling rootstock. Even where dwarfing rootstocks are being used around the world, vigour control is still an issue. There has been extensive research looking at the combination of physical and chemical vigour control methods, including root pruning, trunk incisions, Regulated Deficit Irrigation, and the use of plant growth retardants. These methods will be briefly outlined.

5.1.1 Girdling

Broadly speaking, girdling is a process that involves completely severing the phloem by a narrow incision or by the removal of a cylinder of bark from the trunk, with or without damage to the underlying tissue (Noel 1970). The severing of the phloem vascular vessels disrupts the transportation of photosynthates from source to sink, thereby reducing sink size and increasing photosynthate availability to fruits and other active meristems above the girdle (Mataa *et al.* 1998).

Pear growers can use trunk girdling at or shortly after full bloom in order to reduce vegetative growth on trees that are particularly vigorous (Ingels 2002). There are a number of variations on trunk girdling and often terminology can be confusing. In Australia girdling techniques tend to be variations on ring and double C ring girdling. Ring girdling involves removing a strip of bark (0.5 – 0.9 cm wide) from around the trunk, or simply cutting through the bark to the cambium layer with a handsaw or chain saw (Ingels 2002). A double 'C ring girdle uses two disconnected but overlapping cuts just over halfway around the trunk (separated vertically by several centimetres) (Ingels 2002). There have been references to guillotine girdling / notch girdling in the literature which describe techniques that cut deeper into the stem (Noel 1970; Hoying and Robinson 1992; Ingels 2002). For this review however, these processes are referred to as stem incisions and are covered under the stem incision section.

Ingels (2002) found that in 'Bartlett' trees on 'Winter Nelis' rootstocks, girdling two weeks after full bloom reduced pruning weights compared to control but there were no significant differences between girdling techniques. There was no significant difference in shoot lengths between girdled and non-girdled trees. Girdling also only slightly increased fruit set and yield but the increase was not significant. This is similar to results found by Smit *et al.* (2005) where girdling between full bloom and three/four petal drop was only effective in reducing shoot growth in 'Forelle'. However in this study girdled trees showed a consistent response of having the largest average fruit size. In 'Packham' it improved fruit colour and advanced maturity (increased sugars and decreased fruit firmness).

5.1.2 Stem Incisions

Stem incisions are often considered a more severe version of girdling, and can be referred to as 'guillotine girdling' (Noel 1970; Hoying and Robinson 1992; Ingels 2002). Generally stem incisions are made on both sides of the trunk with a saw/chainsaw to approximately one-third to a half of the trunk diameter, with no less than 30cm between the cuts. Stem incisions are best done in spring and should occur no later than 3-6 weeks before flowering.

The risks associated with stem incisions are mainly drought stress as a result of the disruption to water and nutrient transport in trees. There is also a risk of incisions being cut too deep and causing stems to break under heavy fruit loads or as a result of extreme weather events. In 'Conference' trees (Deckers, Schoofs *et al.* 2005)suggested that stem incisions could also increase the risk for silverleaf infections and it wasn't clear whether this was a fungal infection of *Stereum purpureum* on these trees or that it is only a physiological phenomenon linked with a physical stress situation in the trees.

Plate 18: Stem incision on 'Corella' in the Adelaide Hills SA.

5.1.3 <u>Rootpruning</u>

Rootpruning is a technique that became more widely used in European pear production systems as a result of the ban on the use of the chemical growth retardant chlormequat (CCC)(Deckers, Schoofs *et al.* 2005; Vercammen, van Daele *et al.* 2005; Maas 2007a; Maas 2007b). There has been limited use to date of rootpruning in Australian pear production, however, growers are becoming increasingly interested in the technique.

Rootpruning aims to cut both fine and large roots to reduce the absorption of water and nutrients whilst also changing the hormone balance – resulting in an overall reduction in shoot growth (Vercammen, van Daele *et al.* 2005). It is usually carried out no less than 4-6 weeks before full bloom as too close to blossoming can induce severe stress and result in poor fruit set. In Europe Rootpruning is also applied during the period of leaf and shoot growth after the June drop (equivalent of the November shed in Australia) if fruit set is poor.

The distance from the trunk and the depth of which to prune is dependant on the level of vigour in the tree and also the root distribution – key factors that growers need to assess when planning rootpruning. The need to understand root distribution prior to rootpruning was highlighted by Asin and Vilardell (2007) who found in one trial that the effect of rootpruning minimal due to the drip irrigation system confining the bulk of the root system to the central line of the row.

Rootpruning can either be carried out on one or both sides of a tree. Generally one sided pruning (alternating sides each year) is considered the least risky as the risk of drought stress is reduced and the tree is still able to absorb a sufficient quantity of nutrients (Vercammen, van Daele *et al.* 2005).

Whilst rootpruning is generally considered one of the easiest vigour control methods to apply, it still has a number of risks. These are mainly associated with the increased risk of drought stress and losses in internal fruit quality after rootpruning as a result of the reduced capacity of the tree to absorb water and nutrients (Deckers, Schoofs *et al.* 2005; Vercammen, van Daele *et al.* 2005). Rootpruning can also advance fruit maturity (Maas 2007a; Maas 2007b).

Plate 19: Rootpruning of 'Williams' in Open Tatura Trellis in the Goulburn Valley, Vic

5.1.4 Plant Growth Retardants

Plant growth retardants have been used in fruit production around the world for a number of years. Plant growth retardants are synthetic compounds which are used to reduce the shoot length of plants, primarily through reducing cell elongation but also by lowering the rate of cell division (Rademacher 2000). Cell elongation and cell division are controlled by auxins and gibberellins. Auxins are produced mainly in sub apical regions of actively growing shoots, young leaves and developing embryos whilst gibberellins are produced in very young leaves, young embryos, fruits and roots (Westwood 1993). Plant growth retardants disrupt the synthesis of these hormones. Two of the main plant growth retardants used in pear production around the world are Prohexadione-Calcium and Paclobutrazol. Neither of these chemicals is actually registered for use on pears in Australia at this stage.

5.1.4.1 Prohexadione-Calcium

One of the most important plant growth retardants available to orchardists in Australia at present is Prohexadione-Calcium (Pro-Ca). Pro-Ca works through interfering with the late steps of gibberellin biosynthesis (Rademacher 2000). In Australia it is registered under the trade name Regalis**®.** At present it is only registered for shoot growth reduction in Apples.

The application of Pro-Ca results in a reduction in shoot growth when applied to pears (Elfving *et al.* 2002; Theron, *et al.* 2002; Asin, *et al.* 2005; Deckers *et al.* 2005; Maas 2005; Smit *et al.* 2005; Asin *et al.* 2007; Asin and Vilardell 2007). However amongst cultivars there appears to be differences in sensitivity to Pro-Ca. Smit *et al.* (2005) found that cultivar response to the application of Pro-Ca fell into three groups

1. highly sensitive to Pro-Ca at low and medium application (50-150mg/L – ‘Rosemarie’ and Golden Russet ‘Bosc’)
2. responsive to high concentrations of Pro-Ca (250mg/L – this included ‘Packham’ and Early ‘Bon Chretin’) and
3. poor response to Pro-Ca, even at high concentrations (‘Forelle’).

Deckers, *et al.* (2005) also found different cultivar responses to Pro-Ca with ‘Comice’ being more sensitive to Pro-Ca application than ‘Conference’.

Elfving *et al.* (2002) suggested that the difference in the effectiveness of Pro-Ca to reduce shoot growth across varieties may be attributed to differences in shoot growth patterns. They found five distinct shoot growth patterns within untreated pears. Early season application of Pro-Ca was most effective where untreated trees produced a single prolonged phase of shoot extension growth (displayed by ‘Williams’, ‘Comice’ and ‘Bosc’). Where a second flush of shoot growth occurred, early Pro-Ca applications reduced growth in the first flush but were either ineffective or only modestly effective in suppressing overall shoot growth during the season. Applications of Pro-Ca later in the season were still unable to control the vigorous second flush.

Whilst Pro-Ca can successfully reduce shoot growth in pear trees, there has been hesitation with its widespread application due to the negative impact it has displayed on return bloom and cropping in some trials. Smit (2005) found that the use of Pro-Ca reduced fruit size in 'Early Bon Chretin' and 'Rosemarie' and reduced return bloom in 'Forelle' and 'Packham'. This was largely attributed to the direct effect of higher fruit set in these cultivars. Deckers *et al.* (2005) found that high concentrations of Pro-Ca (3 x 200g/ha) significantly reduced return bloom on 'Conference' and 'Comice'. Lower doses also impacted on flower bud formation but this did not seem to significantly impact on productivity. Asin *et al.* (2007) found that in 'Blanquilla' Pro-Ca produced similar return bloom levels to untreated trees.

The variation between trials indicates that if Pro-Ca is to be used for growth control in Australia there needs to be specific trials looking at rates and timing on different cultivars to determine application rates that can provide good shoot control without the adverse affects on productivity.

Whilst the major advantage of Pro-Ca is its ability to reduce shoot growth, it can also provide other advantages. These are mainly associated with improved control of pest and diseases, improvement of fruit quality and the reduction of fruit shedding.

Rademacher, (2004) reviewed the effects of Pro-Ca on Fire Blight (*Erwinia amylovora)*, highlighting that trees treated with Pro-Ca were less infected by Fire Blight. The mode of action of Pro-Ca in reducing Fire Blight susceptibility of pear trees was not clearly understood but could be attributed to both changes in tree morphology and metabolism. Paulson *et al.* (2005) also found that the application of Pro-Ca reduced incidence of Pear psylla (*Cacopsylla pyricoloa).* This was possibly due to the reduction in shoot growth making the shoot less attractive for developing pest populations and allowing for better penetration of pesticide applications.

In terms of improved fruit quality Smit *et al.* (2005) found that Pro-Ca application induced firmer fruit in Rosemarie, improved fruit colour in 'Forelle' and reduced cork spot in 'Packham'.

In Belgium trials have looked at using Pro-Ca to reduce fruit shedding during the June drop (equivalent to the November shed in Australia). The June drop is a natural final post-bloom shedding of fruits which happens in late May or June (Westwood 1993). It is thought that stress in the immediate period after full bloom can influence the severity of the June drop. When stress occurs, ethylene is produced which causes fruit abscission (Vercammen and A

2007). Vercammen and Gomand (2007) found that applying small amounts of Pro-Ca two and three weeks after full bloom reduced fruit drop, as Pro-Ca has an anti-ethylene effect.

5.1.4.2 <u>Paclobutrazol</u>

Paclobutrazol is another plant growth retardant that has had limited use in pear production systems around the world recently. It is also an inhibitor of Giberellin biosynthesis – inhibiting stem elongation and sometimes promoting flowering (Asin *et al.* 2007). Paclobutrazol is the active ingredient in a number of products registered in Australia – however none are registered for pears. The main issue with the use of Paclobutrazol is its extended persistence in trees and soil.

Asin *et al.* (2007) found that the application of Paclobutrazol on 'Blanquilla' pears resulted in effective reduction of vigour (shoot length reduction) and improved return bloom. This corresponds with results found in previous experiments on 'Blanquilla' and 'Conference' (Asin and Vilardell 2006).

5.1.5 <u>Regulated Deficit Irrigation</u>

Managing vigour in pear trees is also possible through the use of regulated deficit irrigation (RDI). RDI looks to restrict water during periods of slow fruit growth and rapid shoot growth to save water as well as reduce vegetative vigour.

In the most basic terms RDI scheduling involves applying less water at the same frequency during the period of vigorous shoot growth. During this period fruit growth is slow and less sensitive to water. In pears this is generally from the start of November until 6-8 weeks before harvest (Figure 1).

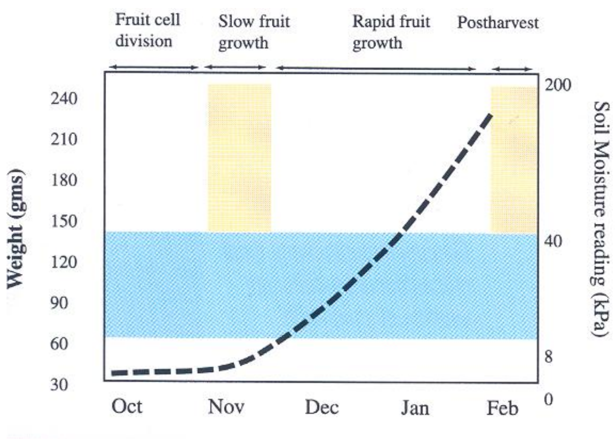

Figure 1: Pear Fruit Growth ((Boland, Ziehrl *et al.* 2002)

Irrigation requirements are generally calculated on the basis of tree water use (using crop factor and pan evaporation figures). During the RDI period, the crop factor is reduced when calculating irrigation requirements and it is recommended that soils are allowed to dry to 200kPa (Boland *et al.* 2002). It is essential however that full irrigation occurs before the onset of rapid fruit growth (Mitchell. *et al.* 1989).

Various studies have shown that applying RDI during the period of slow fruit growth can be successful in reducing shoot growth without negatively impacting on fruit production (Chalmers *et al.* 1986; Mitchell *et al.* 1986; Mitchell *et al.* 1989; Marsal *et al.* 2000; Marsal *et al.* 2002; Asin *et al.* 2007). However, Marsal *et al.* (2000) found that whilst shoot growth was decreased through RDI on 'Conference' pears, fruit growth was also reduced compared to control. This was possibly due to the growth conditions and the lack of competition for light among tree canopies. Mitchell *et al.* (1986) suggested that RDI is most effective at high tree density where competition amongst trees is already suppressing root growth.

The use of RDI has been investigated widely on moderate to low density orchards, and it can be assumed that the risk of water shortage inducing heavy stress (with reduction of fruit quality and flowering capacity for the next year) is higher in high density production systems and the water management strategy should be adjusted accordingly (Sansvani *et al.* 2008)

5.2 Improving Fruit set with Gibberellins

Gibberellins function in cell elongation, aid in breaking rest of seeds and dormant buds, prevent flower initiation and seem to interact with auxin to prevent abscission of young fruits (Westwood 1993). For a number of years the application of gibberellins to promote fruit set in pears has been common practice, particularly in European orchard systems. Different gibberellins can be applied : GA3, GA4/7 or mixtures of gibberellins with a cytokinin, such as GA4/7 + benzyladenine (promalin) (Deckers and Schoofs 2002). Generally they are applied at flowering.

The application of gibberellins (namely GA3 or GA4/7 or a combination of both at low doses) has been found to be a useful way of increasing the early yield productivity of young 'Conference' trees (Deckers and Schoofs 2002) as well as a measure for improving fruit set after frost damage (Deckers and Schoofs 2002; Vercammen and Gomand 2007; Yarushnykov and Blanke 2007; Ouma 2008).

Drawbacks to the use of gibberellins include the reduction in the following years fruit buds and return bloom, small fruit size (possibly due to over cropping) and malformations in fruit (eg. elongation) (Yarushnykov and Blanke 2007, Turner 1973).

5.3 Improving Pear Productivity in Australia

There has been extensive research into the use of physical and chemical methods to reduce tree vigour, improve set and ultimately optimise fruit production around the world. Whilst these have been outlined individually, in many cases the recommendations from many of the investigations have focussed on growers refining combinations of methods to achieve the best results on their individual orchards.

In Australian pear orchards the use of physical vigour control methods such as root pruning and trunk incisions has been limited to date. The lack of local trials has meant that there is still no clear indication of what impact these interventions would have particularly in our more stress-prone environments. The reviewed literature has highlighted that that fruit maturity could be advanced through trees suffering stress after root pruning or stem incisions and that there could be variable effects on vigour control and fruit production through a lack of precision and different orchard conditions. With adequate nutrition and irrigation and clear guidelines for depth of root pruning/trunk incision and timing of application, there is potential to further explore these options in Australian orchards.

Trials with plant growth regulators may also offer the potential to further fine tune pear production. Pro-Ca appears to be the most promising of plant growth retardants and trials investigating rates and timing under local conditions are required. This also applies to the use of Gibberellins, which may offer potential to both improve early production of our varieties as well as rectify frost damage.

5.3.1 Recommendations

- A program of trials over 3-5 years to investigate combinations of the management methods outlined above to improve productivity under local conditions. Trials could be performed on existing blocks with similar characteristics across pear production regions. This would also be appropriate to be involved with any further rootstock/systems trials in future.

6.0 Conclusions and Recommendations

This review has identified a number of key areas that are important to consider when establishing an intensive pear production system. It has also provided key recommendations for the Australian industry to look at for the future – a summary of which is provided at the end of this chapter.

Whilst a number of components of intensive pear production have been outlined in isolation within the review, it is important to recognise that a whole system approach is needed when planning and establishing a system. Rootstocks, varieties, planting systems and management options can not be chosen based on their individual merit or purely on research results. When planning an intensive system, growers need to have a good understanding of the importance of each of these components and how they interact. It is also important to understand the inherent site characteristics such as soil fertility and climate and how they may determine the most suitable combination for an intensive pear production system.

Currently the major limiting factor in Australia, identified in the review, is the availability of a range of Quince and *pyrus* rootstocks that can facilitate a more rapid move to intensive production by the industry. Not only does the industry need to ensure these rootstocks become widely available, but they also need to develop the skills and knowledge to manage them in advance.

Most of the recommendations to emerge from this literature review focus on developing knowledge and skills through local research/demonstrations trials. If the Australian industry is serious about maintaining a globally competitive and sustainable pear industry there needs to be a more directed effort to fund local trials that can refine planting systems and management to provide the maximum potential for future production. The support this provides to industry is evident in pear production regions such as in Belgium and the Netherlands where.

6.1 Summary of Recommendations

- Collaborative approach needed between industry and nurseries to improve quality of nursery material available. In the short term this needs to encompass clear industry specifications for nursery trees to suit particular planting systems (current APFIP Nursery tree specifications available from www.apfip.com.au would serve as an excellent starting point.). In the longer term a strategy is needed for the adoption by nurseries of a quality certification system for nursery trees (such as the APFIP certification program)

- Continued education of growers regarding the importance of planning in advance for nursery trees that suit their variety/rootstock choice and planting system.

- Further trialling of the range of *pyrus* and quince rootstocks under local conditions with current and potential new varieties (to expand on the current APFIP trials). Trials need to be replicated across pear production regions (including Vic, SA and WA) and have optimal management and monitoring from establishment through to full production to demonstrate maximum potential. A rigorous extension program to educate growers on the rootstock characteristics and requirements would need to be built into the trials.

- A program of trials over 3-5 years to investigate combinations of the management methods to improve productivity under local conditions. Trials could be performed on existing blocks with similar characteristics across pear production regions. This would also be appropriate to be involved with any further rootstock/systems trials in future.

- Information provided to growers to understand the financial commitment of various growing systems – using current prices for inputs and expected returns.

- A systems trial (in conjunction with further rootstock trials recommended previously) that demonstrates a central leader type system and a V system and monitors establishment and ongoing management costs as well as yield performance (in terms of efficiency and fruit quality). Extension to growers built into the trial.

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8.0 Appendix : Global Intensive Pear Production

Around the world, intensive pear production has taken on different meanings. Intensive pear production involves a variety of training and support systems, pear varieties and rootstocks and can range in tree densities from 1500 trees/ha to 11000 trees/ha. The following is a very brief review of pear production in selected areas, taken from the literature, study tours and personal communications.

8.1 South America

Argentina and Chile are the most important pear producing countries in South America making up 90% of the approximately 46000 hectares of production (Sanchez 2002).

In Argentina the most widely planted cultivar is ‘‘Williams’’ (with 50% planted area) followed by ‘‘Packham’ and 'Buerre D’Anjou' (Sanchez 2005). More than 99% of pear scions are propagated using seedling rootstocks such as *Pyrus Communis.* The trellis system with planting densities of 4 x 3m is popular and modern orchards are planted at 4 x 2m. Almost 40% of the total plantings are free-standing trees at 6 x 6m and over 40 years old, but highly productive (Sanchez 2005). Trials evaluating quince selections as rootstocks for 'Abbe Fetel' and ‘Conference’ pears in Argentina have been carried out in Argentina (Castro and Rodriguez 2002). During the first five years Quince combinations reduced vegetative growth and increased precocity, however incompatibility problems during the next four years which resulted in lower performance with seedling.

In Chile the main cultivar is ‘‘Packham’ followed by Buerre ‘Bosc’ (Sanchez 2005). Most of the old plantings are of low densities (400-500 trees/ha) while new ones are mainly of medium density (800-1200 trees/ha) (Sagredo and Cooper 2005). Quince A is the predominantly used rootstock, with Sydo and BA29 appearing in newer plantings of medium density orchards.

8.2 Belgium

The major variety currently grown in Belgium is ‘Conference’. ‘Comice’ is also widely produced, however it's popularity is declining. Systems are generally 1700-3000 trees/ha. The most common systems are the V hedge system on Quince Adams or Quince C (3.5m x 1.5m) and the free spindle system (3.75m x 1.5m) on Quince Adams. There are however some systems of 5000 trees/ha which are super spindle and spaced at 4-5m x 0.30-0.50cm on Quince C or Quince Adams. Vigour control in Belgium focuses on using rootpruning and trunk incisions. There is some use of Prohexadione-Calcium (Regalis®) for reducing fruit shed after the June Drop.

8.3 Netherlands

'Conference' is also the most important pear variety in the Netherlands. In the south west of Netherlands, systems generally were at tree densities ranging from 2500 trees/ha to 9000 trees/ha. Systems such as very high density super spindle (3-4m x 0.50m) and spindle with 2 leaders(3-4m x 1.20m). Rootstocks are predominantly Quince Adams and Quince C. Quince C is becoming more commonly planted. Rootpruning and trunk incisions are used for vigour control.

8.4 Spain

'Conference' and 'Blanquilla' are the most important varieties in Spain. Systems are generally between 1500-2000 trees/ha with very rarely ever passing 3000 trees/ha. Generally systems are either single axe (central leader) or double axis at 3.5-4 x 1-1.40m on Quince A or BA29 depending on the soil quality. Vigour control has relied more on chemical applications with combinations of Paclobutracol, Pro-Ca and Promalin.

8.5 Italy

Abate Fetel is the most important variety in Italy, followed by 'Conference' and ''Comice''. The systems in Italy range from 3000 trees/ha to 12000 trees/ha. Systems such as super spindle (3.5 x 0.5), double axe (3.3 x 1.0) and based on rootstocks Sydo, Quince C, BA29, Quince MH. Vigour control methods include rootpruning and trunk incisions. There is a reluctance to rely on chemical control due to ever increasing restrictions in the European Union.

8.6 South Africa

Up to the mid 1980's most pear orchards were established on pear seedling rootstocks, however clonal rootstocks BP1 and BP3 have dominated since then (Ferrandi and Huyasamer 2005). Most of the plantings since the late 1980's/early 90's on BP rootstocks are fairly intensive at approximately 4 X 1.5m or (1666 trees/ha) and some at 4.5 x 2-2.5m . This is evident when comparing the average tree density in 1980 (740 trees/ha) with the average in 1995 (1746 trees/ha) (Ferrandi and Huyasamer 2005). These are still predominantly freestanding central leader or spindle. With a renewed interest in Quince and other more dwarfing rootstocks used in conjunction with a support system, growers are moving to higher densities (Hugh Campbell-pers comm.)

The major varieties in South Africa are 'Packham's Triumph', 'Bon Chretien' and 'Forelle'. There has been a move towards more blushed cultivars like 'Forelle' and plantings of 'Abate Fetel' have also increased (Theron *et al* 2008).

8.7 North America

There has been a 5% reduction in pear production in North America since 2002(Mielke 2008). The US has 80% of the production area (240 000 ha) and produces 630 000 tonnes(Mielke 2008). 'Packham', 'Anjou', 'Buerre Bosc', 'Comice' and 'Williams' (both green and red) are the most common varieties. Approximately 50% is from trees on seedling rootstocks with densities ranging from 850-2200 trees/ha(Mielke 2008). OHF 97 and 87 are also used. In the Pacific North-West where the majority of pear production occurs there is a problem with using quince rootstocks as they are not cold hardy (Mielke 2008).

8.8 New Zealand

New Zealand fresh export production relies on three cultivars 'Buerre Bosc', 'Comice' and its russeted sport 'Taylors Gold', whilst domestically 'Winter Cole' and 'Winter Nelis' are also sold (Brewer and Hilton 2005). In New Zealand European pears have been planted 5 x 3m on Quince BA29 or *Pyrus* seedlings and grown as a large central leader tree (Palmer 2002). There have been some high density plantings with up to 1800 trees/ha (3.7 x 1.5m) on Quince C rootstocks with 'Buerre Hardy' interstocks (Brewer and Hilton 2005). Growers in the Nelson region have also successfully used divided canopies on a mini-Tatura trellis system (Palmer and Grills 2008)

9.0 Asia

Pear production has generally increased in Asia. China's pear production area has risen to 1.6 million hectares, producing 9.8 million tonnes of mainly Asian pears. Korea has 30 000 ha and produces 450 000 tonnes of Asian pears. Japan is experiencing a decline in Asian pear production but European pear production is on the increase (30 000 tonnes) (Gemma 2008).

10.0 Appendix 2 – Evaluation Interviews

Intensive Pear Project

Key Contact Interviews

May-June 2009

Prepared by the FSV Practice Change
Evaluation Unit for the Intensive Pear Project

Table of Contents

1. Introduction

The Intensive Pear project aims to improve industry adoption of intensive pear production, increase local knowledge and skills in intensive pear production systems, and contribute to a more adaptable and competitive pear industry. This report was commissioned by the Intensive Pear project team in May/June 2009 as a component of the evaluation focussing on key contacts who have had regular involvement and interaction with the project.

2. Acknowledgements

The Evaluation Unit would like to acknowledge Liz Curran, DPI Rutherglen, for conducting the interviews.

We also are grateful to the participants for the willingness and candour of participants in the Intensive Pear Project and this evaluation. Their participation is greatly appreciated.

3. Method

Semi-structured interviews were held with 5 pear growers and 5 pear consultants by telephone during June 2009. The participants were purposefully selected by the project team as they had an increased level of involvement or interest in the project.

The questions were guided by an interview schedule (appendix 1) which covered their role in the project, their views of the project and future opportunities. The interviews were taped and then transcribed.

The interviews were held in accordance with the Australasian Evaluation Society (AES) Code of Conduct, available at www.aes.asn.au.

4. Analysis

The interview transcripts were aggregated and sorted by key emerging themes. This was done using NVivo – a qualitative analysis software package. The report is structured by these key themes.

5. Findings

5.1 Benefits of the project

Many participants felt that the intensive pear project was a 'kick start' that the industry needed to refocus the attention on the pear industry, and the potential benefits for the pear industry by moving to intensive processes. Some felt that pears have suffered in the past as the 'poor cousins' of the apple industry, so having a pear-focussed project was refreshing and invigorating. One participant suggests:

> *"I think the project has created interest and recognition amongst those, certainly the growers that have participated, that there are opportunities to make the orchards that they currently have perform better, and to have a better idea about what they should be doing in planting new orchards."*

For one grower the project has refocussed their business, commenting: *"It has given me the confidence to actually go out and do pears"*, while another is planning to change his root stock and intensify their planning extensively.

The project approach of showing growers different production techniques and options, and encouraging them to adapt them to their growing systems, rather than telling growers how to do it, was well received by growers.

5.2 Access to International experts

Some participants were particularly appreciative of the opportunity to access national and international pear experts who could discuss the benefits of intensive pear production systems, but also suggest minor changes to improve existing production systems that could be immediately implemented. While there were some issues with timing and the interest in field days not converting to large turnouts, the access to international experts was considered a valuable opportunity. One participant vents their frustration:

> *"We get criticised for not doing enough for the industry and we organise field days and get international guests out and get ten people turn up, and it is embarrassing".*

Some participants suggested that longer notice of events would allow time to promote the event via several sources, or incorporate it into a quarterly calendar to let growers know it's planned so they can schedule it in, and keep an eye out for further details closer to the date. Incorporating several topics into one field day could also be beneficial as growers are more likely to attend if they can cover a number of interest topics, and feel that the day will be useful for them. Another suggestion was to have personalised sessions where a ‘host’ farmer invites five neighbours or friends to an hour’s discussion, repeated at several ‘host farms’ throughout the day. It was felt more farmers might commit to attending if they were personally invited and also provide a supportive environment where farmers may discuss issues they wouldn’t necessarily raise in a group environment.

5.3 Rootstocks

A clear issue to emerge from the project is the rootstocks currently available in Australia are not sufficient to support intensive pear production. Some commented that the pears don’t come into production quick enough – but through the project they could see the way forward in sourcing the right rootstocks and pear varieties.

Some trials have been planted on existing rootstocks, however the results aren’t always positive and therefore not a good advertisement for intensification. The availability of appropriate rootstocks, and alternative varieties, for trial plots is an important step in demonstrating the success and therefore the benefits of investment in intensive pear processes. The benefit of overseas rootstocks is that production occurs after 5 years, rather than the usual 10 years that is currently the lag in existing pear management systems. The environment in Australia is believed to be suitable for quality intensive pear production, yet some feel we don’t make the most of that potential.

One participant suggested that industry could better partner with growers to establish focus orchards, where each party commits 50% of the inputs. The grower can then establish intensive pear systems, and industry can use the data and the orchard for demonstrations.

5.4 Communication materials

Articles in the industry magazines were well received, with participants commenting that the articles published by the project were well written, appropriately targeted in terms of technical content, and were honest, practical and interesting.

The website is expected to be a useful resource in the future, however one participant commented that they don’t believe it has gained much of a profile as yet – and while it may increase grower’s awareness that doesn’t necessarily result in changed activities.

5.5 Limitations of the project

A trial plot would have been beneficial in the long-term as an output of the project, and a good opportunity to physically show growers the benefits of intensive production systems.

It was recognised that the benefits would not occur until well after the project had finished, however many felt that farmers make decisions *"based on what they see"* and *"to convert them it needs to be proven that it does work and that it can be done"*.

Some believe that outcomes need to be considered on a longer term perspective rather than the project life perspective, and explicitly recognise that changes within the pear industry can't happen overnight.

5.6 DPI's involvement in the pear industry

Some participants reflected that many experienced people have left the industry and the collaboration could be an uphill battle. The collaboration between DPI, consultants, scientists, industry and growers is crucial for the industry to grow. They suggest while field days and visiting experts are good to introduce intensive pear management, growers need continued backup from accessible local experts for ongoing advice.

The ongoing role of DPI in the industry was questioned by several participants. The benefit of having DPI involved as a research and development was well recognised, however several felt the level of engagement from managers, and support of the pear industry was lacking.

The approach to initially employ a staff member with little experience in the industry was also mentioned by most participants. While they felt the project officer had built up a good level of understanding and a good reputation and credibility within the industry, they felt the lack of experience initially resulted in the project not getting up as fast as it could have with an experienced person.

A key issue for many participants is the continuity of support. They felt that much time and resources had been invested skilling the project officer, who now has a good international understanding of the pear industry and intensive pear methods. They question what will now happen since the project has ended.

There was also a tension around the competing demands of the project officer satisfying project requirements and DPI corporate requirements. Some felt that to begin with the project officer was always accessible, however in the last year there were increasing demands for other DPI work that limited the industry's opportunity to utilise the project officer's expertise. It was recognised this is a common tension with a number of projects, and not this project in particular. Some also commented that DPI is good at getting projects up, but not necessarily finishing off and disseminating the information effectively.

5.7 The future

Some participants suggest that the pear industry is in a unique position in that Australia has the market available to export pears successfully and profitably, but needs to increase the amount of production – which is a turn-around on many other products. The focus away from fruit grown for cannery, and more for fresh production, has challenged some growers to reassess how they approach their thinking – by considering consumer requirements rather than focussing on the dollar per cannery tonne and managing production input costs to ensure a return. One participant comments:

> *"The pear industry is growing, processing doesn't have a fresh fruit focus and therefore their understanding and their focus on economics is all wrong. Growers who grow for fresh fruit have the opportunity to look at the economics for the industry a little bit differently."*

While the project has created increased awareness amongst growers about the benefits of intensive production, there is still some work to do in encouraging many growers to change to intensive productions systems.

Barriers of cost in setting up the system, having the appropriate rootstocks available and seeing the economic and physical benefits through on-farm trial blocks are still limiting the change to intensive systems. The uncertainty of water availability, and impacts of climate change were raised as potential barriers to adoption, given the large costs of establishment of intensive systems may take a substantial time to be recouped.

The difficulty in getting wider involvement of the industry was discussed, with some suggesting that those growers showing interest in the project are already involved in industry changes, so there was a sense of *"preaching to the converted"*. However, it was also recognised that if the benefits of intensive production systems could be shown, the interest of non-participating growers would most likely occur by *"looking at what their neighbours are doing"*.

6. Discussion

The project was well received by the participants we interviewed. There was a general feeling that it helped invigorate the pear industry, which was in need of a ‘kick start’. The access to international experts, and local experts with international experience was beneficial to growers and the industry, however sometimes the interest did not convert to actual attendance at events due to a variety of factors including timing and topics. Having several topics of interest at an event may draw larger crowds than those focussed on a single, particular topic.

The development and continuity of expert support in the industry was a concern for many participants, as the support, leadership and expertise is crucial to maintain and further develop the industry and the uptake of intensive pear management systems.

Greater involvement of growers in the industry, access to new rootstocks and varieties, trial plots and data from intensive management systems, and a focus away from cannery pears and towards fresh fruit production will result in a vibrant and successful pear industry.

7. Appendix 1

Interview Schedule

Intensive Pear Project 2009

Thanks for taking the time to talk to me today. Just before we start I wanted to let you know that anything you say today will be confidential and kept in accordance with the Privacy Act 2000. Your responses will be collated with other interview participants, and a report will be given to the Intensive Pear Project – so no-one will be directly identified. Sometimes because of your role you might be identifiable, so if there's anything you don't want included let me know and I'll ensure that it isn't reported.

I would like to tape today's interview so I can focus more on talking with you than taking copious notes, is that okay with you? (again, these will be kept in accordance with the Privacy Act 2000 – eg. won't be circulated, kept secure).

Firstly I wanted to focus on your interaction with the Intensive pear project, then we will discuss the pear industry and future opportunities.

The Project

Interaction with the project

Can you tell me about your involvement in the project?

Prompting questions:

- What interaction did you have with Angie?
- did you attend any events?

What are two key things you have taken away from your involvement?

Have you read any articles about intensive pear production written by the project? What did you think of them?

Successes

What do you think the key successes of the project have been?
Prompting questions:
- Has anything been beneficial to you? To industry?

What sort of long term benefits might the project have?

Limitations/weaknesses

On reflection, what would you have changed (or suggest be changed) about the project?

What could've been included, or focused on more, in the project (what was missing)?

The Industry

What do you think will need to change for more adoption of intensive pear production in the pear industry?
Prompting question:
- what are the barriers to adoption? (eg. within farm – cost of infrastructure, externally – eg. market access, fruit prices)

In what ways do you think this project has benefited the industry?

The future

If you were in control of the APAL (apple and pear Aust. Ltd.)/Government funding, would you fund any further work in this area?
- Yes, what would the focus be?
- No, why not? What would you focus on instead

What is the one key thing that needs further work to improve pear production methods generally?
(focus on generally, not just intensive methods)
Prompting question:
- either by research or industry?

Anything else?

Wind up

Thankyou for your time today, it was great to talk to you. From here we will present a report to the Intensive Pear Project Team. If you're interested in the findings or the report I suggest you talk to Angie, her number is xx.