Victoria
The Place To Be

Australian Government
Grape and Wine Research and Development Corporation

Enhancing the uptake of wine industry innovations through the development of targeted extension programs

Project Number: **DPI 06/06**

Principal Investigators: **Megan Hill, Ben Rowbottom and Geoff Kaine**

Research Organisation: **Department of Primary Industries**

Date: **15 September 2008**

Published by the Victorian Government Department of Primary Industries

Tatura, September, 2008

Find more information about the Department of Primary Industries on the Internet at www.dpi.vic.gov.au or call the Customer Call Centre on 136 186

Authors:

Megan Hill, Ben Rowbottom and Geoff Kaine

Department of Primary Industries

Ferguson Rd

Tatura, Victoria 3616

Acknowledgments:

We are indebted to GWRDC, particularly John Harvey and Mark Krstic, for supporting this project. Thank you to all the wine grape growers, liaison officers and winemakers who generously shared their time and knowledge with us. Our thanks go to our colleagues in the Practice Change Portfolio who, through lively discussions, have contributed to the ideas in this paper. Special thanks to Roger Ashburner, Fiona Johnson, Jean Sandall and Guido Vazzoler for their contributions to this project.

Disclaimer:

If you would like to receive this information/publication in an accessible format (such as large print or audio) please call the Customer Service Centre on: 136 186, TTY: 1800 122 969, or email customer.service@dpi.vic.gov.au

Table of Contents

1 Abstract

Enhancing the uptake of wine industry innovations demonstrates the value of collecting and using market information to guide the design of targeted research and extension programs. Targeting research and extension to meet the needs of the grape growers and winemakers to whom it is relevant, will enhance their adoption of the innovations, supporting their response to challenges and change, and rewarding industry investment in research.

Market segments were identified, using a range of tools, for vine nutrition management, soil and petiole testing, and tannin-related innovations. The market segments described who the potential adopters were for these innovations, and why. This information enabled collaborating Department of Primary Industries project teams to identify additional research opportunities, confirm or refine existing research directions, assess the size of the market for the case study innovations and target extension to meet the markets needs.

A framework to enable agricultural innovations to be classified into types was developed and discussed. Potentially, this framework could be employed to help identify the extension processes best suited to promoting the adoption of different kinds of innovations.

2. Executive Summary

In order to meet environmental, business and market challenges, growers and wineries must change their businesses. This process of change is usually achieved through adopting innovations, or innovating with existing technologies and practices. In Australia, public sector agencies and industry bodies play a critical role in assisting the wine industry to adapt to change through their investment in research and development. It is through research and development that innovations in the form of novel information, products or technologies become available to the wine industry. Extension is used to communicate with industry, facilitating the adoption of these research innovations.

Traditionally extension has been designed on the premise that by generating and disseminating information about innovations all the potential users in an industry would benefit from the innovation and so adopt it. It has often been found that this does not always seem to be the case, with disappointingly low levels of adoption often being reported.

The objective for this project was to identify, adapt or develop frameworks for discovering who in the wine grape industry would benefit from a viticultural or processing innovation, and why. We identified and adapted three frameworks derived from the fields of marketing and organisational and business management. We used these frameworks to determine who in the industry an innovation would benefit, and why.

The Kaine (2004) framework was used to identify market segments for innovations relating to vine nutrition management and soil and petiole testing.

This framework is used when the innovations are adopted on-farm. The market segments were based on identifying the different benefits a range of grape growers sought from the innovations.

We used Porter's (1985) concept of competitive advantage to identify the potential adopters of some tannin-related innovations that are currently being developed. This framework was used as the innovations were relevant to businesses in the processing sector, such as wineries. We identified market segments for tannin-related innovations by categorising the problems winemakers were experiencing with tannins. These categories provided a basis for inferring the types of tannin-related innovations that could create a benefit for wineries, making them attractive to adopt.

By using these frameworks to identify and describe the potential market for these case study innovations, we demonstrated the value of market information in enabling;

- additional research opportunities to be identified,
- current research directions to be refined,
- the size of the market for an innovation to be assessed, and
- targeted extension to be designed for that market.

While valuable, the frameworks provided only partial guidance in relation to the design of extension programs to promote these innovations, in particular to choose the kinds of extension activities that would best promote the innovations. Consequently, we built on concepts proposed by Henderson and Clarke (1990) to create a framework that can be used to classify agricultural innovations into four types; incremental, modular, architectural or radical. Using illustrative examples we demonstrated that the adoption of each of these types of innovations required different information and skills. This provided insights into the extension processes best suited to meet those information and skill requirements.

Recommendations on using the findings and insights from the project, including the further refinement and application of the Henderson and Clark (1990) framework, were presented and discussed.

3. Project Background

Introduction

It is important to rural Australia that the wine industry performs well in domestic and global markets. In order to continue to achieve this, the industry must constantly change in response to the environmental, business and market challenges it faces.

Innovation facilitates the process of adaptation to change (Gopalakrishnan and Damanpour 1997), with growers and wineries changing their businesses, often through adopting innovations, or innovating with existing technologies and practices to meet challenges (Invest Australia 2005).

Through research and extension, public sector agencies and industry bodies play a critical role in supporting growers in this process of adapting to change. The Grape and Wine Research and Development Corporation (GWRDC) is one of the key providers of research and development in the Australian wine industry, facilitating the expenditure of $28.812 in 2006-07 (GWRDC 2007). GWRDC's program produces innovations in the form of novel information, products or technologies.

For GWRDC and the wine industry to realise the benefits of investment in research, the innovations produced must be adopted and used by the businesses and individuals within that industry. Some stakeholders suggest that this is the case with *"a sound foundation in technical excellence supported by world-class, commercially focused research organisations"* being one of the Australian wine industries key competitive advantages (Invest Australia 2005, pp 2).

Other stakeholders have suggested that the adoption rate of research innovations is not as high as it should be and suggest that there needs to be *"more effective extension to bridge the gap between research and practice"* (GWRDC 2008, pp 18).

Extension

Extension is the process used by public sector agencies and industry bodies to inform members of industry about research innovations. Extension has been defined as *"intervention programs that are planned, programmed, systematically designed and purposeful, and use communication strategies to encourage behavioural change"* (Nettle 2003, pp 3).

For members of an industry to adopt an innovation, the extension program must help create awareness of the existence and function of the innovation. The processes used to communicate information about innovations include training, participative research, group delivery, seminars, one on one discussion and technical articles.

While there is extensive literature on agricultural extension, that literature provides little guidance for systematically identifying which extension processes would be best employed to accelerate the adoption of any particular innovation. Fulton et al. 2003 (pp vii) suggest *"For the research and extension practitioner it is difficult for them to determine what processes are the most appropriate for their situation, and thus how they should design their extension effort to be more effective, and more efficient"*.

Traditionally extension programs have been designed based on the assumption that the innovation being extended is relevant to everyone facing a particular issue in an industry. Low rates or levels of adoption have been attributed to the target audience, the producers, not receiving enough information about the innovation (Kaine 2004). Hence the typical response to adoption rates or levels perceived to be low was to generate additional information, usually combined with the use of familiar extension processes based on past experience (Robert and Gillard, 2007).

The Kaine Framework

Kaine (2004) suggested that low rates of adoption may not be in response to the extension programs being used, but rather neglecting to first identify the population of potential adopters. In the absence of this information policy makers and extension staff do not have sound basis for making judgments about rates of adoption, or the success of extension programs (Kaine 2004).

Kaine (2004) has developed a framework with a conceptual structure and guidelines that can be used to identify the market, or potential adopters of an innovation. A framework is a conceptual structure that provides guidelines to enable the user to work through a complex process. For a complete description of this framework see Kaine (2004).

Kaine's framework is based on the assumption that the fundamental factor influencing the decision to adopt an innovation is the extent to which the innovation can contribute to better satisfying the needs of the purchaser (Kaine 2004). Using the Kaine Framework, market segments can be created based on differences in farm contexts, which define the potential benefits an innovation can provide in that farm situation. The farm context is the mix of practices and techniques used on the farm, the skill base of the farm manager and the biophysical and financial resources available to the farm business that influence the benefits and costs of adopting an innovation (Kaine 2004).

Similarities and differences among farm contexts translate into similarities and differences in how the innovation can be used on farm, and hence the benefits the innovation can provide. Therefore differences in farm contexts result in different market segments for an innovation (Kaine 2004).

The process outlined by Kaine (2004) has been successfully used for a variety of innovations across a number of agricultural industries in Australia and New Zealand. For examples see; (Kaine and Bewsell 2005; Kaine et al. 2005; Boland et al. 2006; Bewsell et al. 2008).

In viticulture Kaine and Bewsell (2001a; 2001b; 2002) used these methods to investigate the adoption of irrigation and soil moisture monitoring technology in the Australian grape industry. While Bewsell and Kaine (2003) studied the adoption of sustainable practices, relating to pest and irrigation management, and the adoption of soil moisture monitoring in New Zealand.

Porters' Framework

Porter (1985) also argues that the main motivation for adoption of an innovation is the adopter's perception that it will provide a benefit. Porter (1985) created his framework in the world of business, where rather than the potential benefit of an innovation being determined by the farm context, it was determined by an organisations' competitive strategy.

Porter (1985) suggests that to remain profitable a business must create a sustainable competitive advantage. A competitive advantage arises from combining activities that are valuable, rare or difficult to imitate and provide the basis for the creation of value for buyers. Generally speaking there are two basic types of competitive advantage - low cost and differentiation.

We used Porter's Framework to discover market segments for tannin-related innovations. Different wineries follow different competitive strategies based on their competitive advantage. Wine makers adopt innovations that improve their competitive advantage. They will not adopt innovations that will undermine their competitive advantage. The market segments we identified were based on the benefits winemakers were hoping to obtain from using exogenous tannin, which reflected problems they were having with the natural tannin content of the fruit they were processing. Again, by identifying where problems were occurring, opportunities for research and extension were highlighted.

Henderson and Clark and extension processes

Kaine (2004) has shown that identifying the population of potential adopters for an innovation is necessary to effectively design and evaluate extension programs. This information provides limited guidance on what processes to include in an extension program.

Hence, there was a need for a framework for classifying agricultural innovations to provide guidance on the qualitative differences in the extent and nature of learning necessary by grape growers to adopt innovations. Such a framework would assist in identifying the processes an extension program should contain in order to be effective in supporting the adoption of innovations.

We considered that the framework created by Henderson and Clark (1990) to classify architectural innovation in a manufacturing industry, could be modified to classify agricultural innovations. The Henderson and Clark (1990) framework uses changes in the components (physical parts) and the architecture (how those parts are arranged and linked) to classify innovations into types. These types of innovations are classified as incremental, modular, architectural or radical. Each of the four types of innovations present a continuum of change for the organisations that adopted them in regard to competencies, roles, responsibilities, processes, policies, organisational structure and culture (Abernathy and Clark 1985; Kaine and Higson 2006).

This project

In this project, three case studies were selected in order to explore the use of the Kaine (2004), Porter (1985) and Henderson and Clark (1990) frameworks to generate market information on research innovations in the wine industry. This objective of collecting and creating this market information is to enable industry research directions to be refined, and to inform the design of targeted extension programs.

Research and extension that is targeted to its market should logically be able to meet the needs of the grape growers and winemakers more effectively, enhancing their adoption of innovations. This in turn supports the wine industry in its response to challenges and change, and rewards its investment in research.

Two viticulture-related case studies were selected. In the first, the Kaine Framework was applied to the topic of vine nutrition management. Vine nutrition management is a broad topic and involves a range of innovations, products and practices. The aim of our study was to identify market segments based on current nutrition management practices, and to discover where problems were occurring, highlighting research and extension opportunities.

The second viticulture case study was on the topic of soil and petiole testing. Again, we used the Kaine Framework to identify market segments based on the benefits sought by grape growers using these innovations. The problems associated with the use of these innovations by grape growers were identified, suggesting additional opportunities for research and extension.

The aim of the third case study was to identify the potential market for some tannin-related innovations under development. When the tannin case study was selected it was anticipated that the market for the innovations were wine grape growers, and the innovations would be used in the vineyard. Hence, we had planned to use the Kaine framework for this case study. However, once the project commenced we discovered that winemakers presented the primary market for these innovations; hence the Porter framework was used for this case study.

In the final stage of this project we adapted Henderson and Clark's (1990) framework for classifying innovations into types and used illustrative examples to demonstrate its potential use for classifying viticultural innovations. We expected that each type of innovation had different requirements in regard to the information and skills that were needed by growers to adopt them. We anticipated that the results should provide insights into the extension processes that would best suit the information and skill needs of each type of innovation.

4. Project Objectives and Performance Targets

This project had two main objectives. First, to explore the market for selected viticultural innovations by applying the frameworks developed by Porter (1985) and Kaine (2004) to case studies in wine grape production and processing. The three case study reports were:

- Case Study One- The Management of Nutrition in Wine Grapes (**ATTACHMENT 1)**

- Case Study Two- The Use of Soil and Petiole Testing in Wine Grapes Viticulture **(ATTACHMENT 2**)

- Case Study Three- The Market Potential of Tannin-Related Innovations in the Wine Industry **(ATTACHMENT 3)**

The second project objective was to apply Henderson and Clark's (1990) framework to viticultural innovations, to classify them according to type and to explore this concept with the aim of providing insights for the design of extension programs. This report is:

- Types of agricultural innovations and the design of extension programs **(ATTACHMENT 4)**

The performance targets for project DPI 06/06 are listed in table 1. All of the outputs and performance targets have been met for this project (see Attachments 1, 2, 3, 4 and Appendix 1).

Table 1. Outputs and performance targets for project DPI 06/06

Outputs and Performance Targets 2006 – 07

Outputs	**Performance Targets**
1. A briefing document that shows the scope of methods and processes to be used on the two GWRDC/DPI pilot projects **(Relates to Objective 1 and 2)**	1. Scope the process for using the Kaine (2004) and Henderson and Clark (1985) frameworks for both pilot projects by 31st October 2006
2. Report on the market segments for the DPI 0501 Viticulture management of grape tannins and anthocyanin levels to achieve desired wine grape quality **(Relates to Objective 1, 2 and 3)**	1. Interviews completed with industry participants by 30th November 2006 2. Interviews completed with wine grape growers and/or wine makers by 28th February 2007 3. Interview results collated and analysed to identify market segments by 31st March 2007 4. Identification of the type of change the adoption of practices to increase tannins in wine grapes is to growers and the implication for extension programs by 30th April 2007 5. A document that provides insights into the type of change and its affect on the rate of adoption. 6. A report that documents the market segments for the GWRDC Tannins project by 30th June 2007
3. Documented strategy for extension program DPI 0501 Viticulture management of grape tannins and anthocyanin levels to achieve desired wine grape quality **(Relates to Objective 4)**	1. Workshop with project team and industry to verify results and gain feedback on potential extension program by 30th June 2007 2. Collaboration with relevant industry and extension staff to develop the components of the extension program identified in output 2 by 31st July 2007 3. Report on strategy for extension program for Tannins project by 31st July 2007

Outputs and Performance Targets 2007- 08

Outputs	Performance Targets
4. Report on the market segments for Review of nutrition requirements and the development of varietal based nutrition standards for Australia's major wine grape varieties **(Relates to Objective 1 and 2)**	1 Interviews completed with industry participants by 30th September 2007 2 Interviews completed with wine grape growers by 30th November 2007 3 Interview results collated and analysed to identify market segments by 31st December 2007 4 Identification of the type of change the adoption of practices to increase nutrition in wine grapes is to growers and the implication for extension programs by 31st December 2007 5 A report that documents the market segments for the GWRDC nutrients project by 28th February 2008
5. Documented extension program for Review of nutrition requirements and the development of varietal based nutrition standards for Australia's major wine grape varieties project **(Relates to Objective 3)**	1 Workshop with project team and industry to verify results and gain feedback on potential extension program by 31st March 2008 2 Collaboration with relevant industry and extension staff to develop the components of the extension program identified in output 2 by 31st May 2008 3 Report on strategy for extension program for Nutrients project by 30th June 2008
6. Workshops to develop capability in extension practitioners on Kaine Framework and types of change. **(Relates to Objective 4)**	1. Prepare a set of guidelines for developing the extension program associated with GWRDC projects by 31st July 2008. 2. Conduct two workshops to build capacity in extension practitioners in the use of the principles of the Kaine framework using the findings from this study as case studies by 31st July 2008 3. Present Seminar to GWRDC on findings and relevance to their extension portfolio by 31st July 2008
7. Refereed paper on the project produced	1. Paper written and submitted for peer review and presentation by 31st August 2008
8. Final Report **(Relates to Objective 5)**	1. Final report documenting the processes used, the products developed and recommendations for future work by 31st August 2008

5. Method

A comprehensive description of the methods used in each situation is provided in the individual case study reports (see attachments 1, 2, 3 and 4).

6. Results/ discussion

See attachments 1, 2, 3 and 4 for the results and discussion for each case study. These are summarised in the project conclusions.

7. Project Conclusions and Recommendations

In this project we have demonstrated the role the Kaine (2004), Porter (1985) and Henderson and Clark (1990) frameworks can play in generating market information towards directing the design of research and extension.

Kaine's (2004) framework was appropriate to use when the innovations were viticulture related, as was the case in the vine nutrition management and soil and petiole testing case studies. Both case studies demonstrated how differences in farm context led to different benefits being sought by the growers adopting the innovations.

Nutrition management

Wine grape growers have identified nutrition management as a key area for additional research and extension (Byrne and McGuire 2005). However, specific nutrition related problems have been difficult to identify, partly because nutrition management consists of a host of innovations, products and practices. Surveys, workshops and studies have resulted in a range of topics being generated (Atkinson and Dignan 2003; Byrne and McGuire 2005; Swinburn and Saris 2005), without information about who used different nutrition management practices and why, what aspects of nutrition management were important, how nutrition related to specific vineyard characteristics and how widespread the nutrition-related problems were. This lack of information makes it difficult to allocate research and extension funding.

The topic of nutrition management was complicated because:

- Nutrition management consists of a host of innovations, products and practices
- It could not be considered in isolation from topics such as soil properties, soil health and vine balance
- Some growers used a variety of different products and management techniques to address a problem
- Some growers also used one product or management technique to address a range of problems
- There is an extensive range of nutrition-related products and options available, often associated with conflicting advice.

We also found that nutrition management was not always a high involvement, or important decision to growers. This meant that they could not always describe their decision making process in regard to their nutrition management

Given these considerations we recommend that the market segments identified in this study be validated and quantified. This could include the use of spatial mapping technology, and would provide baseline data to the wine industry in regard to;

- current practice in relation to nutrition management
- evolving trends and issues
- adoption of relevant innovations and research findings, and
- selected practices with environmental implications such as the use of mulches and composts.

Quantifying market segments would also provide an industry-wide basis for research and extension efforts to be classified, prioritised and co-ordinated.

Soil and petiole testing

The market segments that emerged in regard to the benefits sought by grape growers through their use of soil and petiole testing were similar to those described in relation to soil moisture monitoring in wine grapes and soil testing for vegetable production (Bewsell and Kaine 2001).

These common themes may mean that different innovations providing information to support on-farm decision making may be used in three fundamental ways, for example;

- single use, when planting a new crop or identifying a problem
- short term analysis, to "get a handle on things" or evaluate a change or,
- long term monitoring, to check for emerging problems.

We recommend that these three fundamental dimensions of use be explored further and the characteristics of innovations in relation to these dimensions be identified. This would enable research and extension agencies to anticipate the use of emerging information innovations, and to design and market them accordingly.

Tannin-related innovations

Porter's (1985) framework was used when the innovation under study (tannin-related innovations) were relevant to processing industries, in this case wineries. The tannin-related innovations we studied were still under development, and hence not yet available to the industry. This meant that our work was timely in confirming and refining the research directions set by the tannin research team, while informing their future extension. This study also identified additional research opportunities in the area of green tannin or flavours and testing of exogenous tannin products (see Attachment 3).

We believe that there was considerable merit in using Porter's framework to understand the competitive advantage of wineries as a motivation for the adoption of innovations. We suggest that competitive advantage provides a useful basis on which to collect information and guide market segmentation. It would be valuable to further explore the potential for Porter's framework to guide investment in research on innovations for the wine industry.

The information generated in this project confirmed that the tannin-related innovations under development by the DPI research team at Irymple may provide benefits to the winemakers having problems achieving stable wine colour. Therefore the winemakers with unstable wine colour represent the potential market for these innovations.

We recommend that the DPI tannin research team consider exploring the additional research opportunities identified through this study. We recommend that the DPI tannin research team draw on the information generated in this study to design their extension program.

The Kaine and Porter Frameworks

This project has demonstrated the value of the Kaine (2004) framework in providing market information on the market for on-farm innovations. The application of the Porter framework has shown that this framework can be used to provide information on the market for innovations used in winemaking. Hence, we suggest these frameworks could be particularly useful for refining research directions, designing effective extension and setting realistic targets for adoption.

We recommend that resources are invested to build capacity in the application of the Kaine and Porter frameworks. We recommend that consideration be given to using these frameworks to guide GWRDC decision making in regard to the design of research and extension programs.

The Henderson and Clark Framework

The modification of Henderson and Clark's (1990) framework for use in classifying viticultural innovations was the first step in developing a tool which could be extremely useful in the design of extension programs. This framework could be employed to;

- make more informed judgements about the rate of adoption of innovations

- inform the selection of extension activities to promote adoption.

We recommend that work be directed towards testing the proposed relationships between the different types of innovation and the knowledge and skills required for their adoption.

The relationship between the different types of innovations and the complexity, observability, trialability and rates of diffusion of the innovations could also be explored in future work.

Appendix 1: Communication

Articles
"Managing the Nutrition of Grapevines"
Ben Rowbottom and Megan Hill.
Australian Viticulture, May/ June 2008. Vol 12 number 3.

"Who is interested in research on grape tannins…and why?"
Megan Hill, Ben Rowbottom and Geoff Kaine
The Australian and New Zealand Grapegrower and Winemaker, July 2008.

Presentations
Practice Change Research- Tatura Internal Seminar June 2007
Practice Change Research- Tatura Internal Seminar July 2008
Mark Krstic and Nicole Dimos June 2007
Mark Downey June 2007, May 2008
GWRDC Tannin workshop- Barossa July 2008
Australian Wine Research Institute- seminar September 2008.

Appendix 2: Intellectual Property

There are no intellectual property issues associated with this project. All project findings should be disseminated widely.

Appendix 3: References

Abernathy, W and Clark, KB (1985). Innovation: Mapping the winds of creative destruction. *Research Policy*, vol. 14 pp. 3-22.

Atkinson, I and Dignam, M 2003. Winegrape Grower Information Needs Survey, 2003. MD & Associates, prepared for Cooperative Research Centre for Viticulture, Glen Osmond, SA.

Bewsell D, Kaine G (2001) *Soil Monitoring, Irrigation Scheduling and Vegetable Production*. School of Marketing and Management, University of New England, Armidale.

Bewsell, D and Kaine, G (2003), 'Adoption of sustainable practices in the wine grape industry' Client Report. Prepared for New Zealand Winegrowers, AgResearch Ltd, Hamilton, New Zealand.

Bewsell, D, Clark, DA and Dalley, DE (2008). Understanding Motivations to Adopt Once-a-day Milking amongst New Zealand Dairy Farmers'. *The Journal of Agricultural Education and Extension*, vol. 14, no. 1, pp. 69-80.

Boland, A-M, Bewsell, D and Kaine, G (2006). Adoption of Sustainable Irrigation Management Practices by Stone and Pome Fruit Growers in the Goulburn/Murray Valleys, Australia. *Irrigation Science*, vol. 24, pp. 134-145.

Byrne, S and McGuire, L (2005). Nutrition in Focus. Final Report to Grape and Wine Research & Development Corporation, Murray Valley Winegrowers' Inc., Mildura.

Fulton A, Fulton D, Tabart T, Ball P, Champion S, Weatherley J (2003) *Summary of Relevant Research on Agricultural Extension, Learning and Change*. Tasmanian Institute of Agricultural Research.

Gopalakrishnan and Damanpour (1997). A Review of Innovation Research in Economics, Sociology and Technology Management. *Omega, International Journal of Management Science*. Vol 25:1 pp 15-28.

GWRDC (2007) Annual Report 2006-07. Available from: http://www.gwrdc.com.au/

GWRDC (2008) GWRDC Closes the Research Gap. *GWRDC Newsletter*, April 2008 pp. 19.

Henderson RM, Clark KB (1990) Architectural Innovation: the Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly* **35**, 1-12.

Hill, M, Murdoch, H and Linehan C (2004). Efficient Irrigation Technologies to Match Soils and Dairy Farming Systems. Project Report. Department of Primary Industries.

Invest Australia (2005) From Australian Wine Industry; A Fruitful Future, Wine Industry Overview. ISBN 0642 72339 7. Available from: http://www.investaustralia.gov.au/mediua/IS AB Wine.pdf

Kaine, G and Bewsell, D (2001a). Managing Irrigation for Grape Production. Interim Report, School of Marketing and Management. University of New England, Armidale. pp. 1-26.

Kaine, G and Bewsell, D (2001b). Managing Irrigation for Grape Production. Second Report. School of Marketing and Management. University of New England, Armidale. pp. 1-90.

Kaine, G and Bewsell, D (2002). Managing Irrigation for Grape Production. Third Report. School of Marketing and Management. University of New England, Armidale. pp. 1-39.

Kaine, G (2004). *Consumer Behaviour as a Theory of Innovation Adoption in Agriculture*. AgResearch Social Research Working Paper 01/04, Hamilton, New Zealand.

Kaine G, Bewsell D, Boland A-M, Linehan C (2005) Using Market Research to Understand the Adoption of Irrigation Management Strategies in the Stone and Pome Fruit Industry. *Australian Journal of Experimental Agriculture* **45**, 1181-1187.

Kaine, G and Bewsell, D (2005). An Innovative Approach to Irrigation Extension in Horticulture. *Acta Horiculturae*, vol. 672, pp. 177-183.

Kaine, G and Higson, M (2006). Policy Change as Innovation. Department of Primary Industries, Victoria. pp. 1-21.

Nettle, R (2003). The Development of a National Dairy Extension Strategy: A Literature Review. Institute of Melbourne School of Land and Environment, University of Melbourne, Parkville**:** pp. 77.

Porter, ME (1985) *Competitive Advantage: Creating and Sustaining Superior Performance*. (Free Press: London).

Roberts, G and Gillard, E (2007) Models and Strategies for Change. Paper presented at APEN national forum. Canberra.

Swinburn, G and Saris, S (2005). Results of a Survey to Identify the Issues Relating to Nutrition' Fertilizer Use and Soil Management for the Murray Valley Wine Industry. Scholefield and Robinson Mildura Pty Ltd, Mildura.

Appendix 4: Staff

The staff from DPI Practice Change Research involved in this project were:
Megan Hill
Geoff Kaine
Ben Rowbottom
Chris Linehan

Collaborators were:
Mark Krstic (formerly DPI)
Nicole Dimos (formerly DPI)
Mark Downey (DPI).

Appendix 5- Attached Project Reports

ATTACHMENT 1- CASE STUDY ONE

Hill M, Rowbottom B, Kaine G, Dimos N (2007). *The Management of Nutrition in Wine Grapes*.
Milestone Report, Prepared for Grape and Wine Research Corporation.
Department of Primary Industries, Victoria. ISBN 978-1-74199-856-6

ATTACHMENT 2- CASE STUDY TWO

Hill M, Rowbottom B, Kaine G, Dimos N (2007). *The Use of Soil and Petiole Testing in Wine Grape Viticulture.*
Milestone Report. Prepared for Grape and Wine Research Corporation.
Department of Primary Industries, Victoria. ISBN 978-1-74199-976-1

ATTACHMENT 3- CASE STUDY THREE

Hill M, Rowbottom B, Kaine G, (2007). *The Market Potential of Tannin-Related Innovations in the Wine Industry.*
Milestone Report, Prepared for Grape and Wine Research Corporation.
Department of Primary Industries, Victoria. ISBN 978-1-74199-858-0

ATTACHMENT 4- WORKING PAPER

Kaine, G, Hill, M and Rowbottom, G (2008). *Types of Agricultural Innovations and the Design of Extension Programs*.
Working Paper 02/08. Department Of Primary Industries. September 2008.

Appendix 6: Budget Reconciliation

END OF PROJECT FINANCIAL STATEMENT
Statement of Receipts and Expenditure

At the conclusion of each Project, the GWRDC requires a Statement of Receipts and Expenditure of GWRDC funds received in relation to the Project.

Project Title:	**Enhancing the Uptake of Wine Industry Innovations Through the Development of Targeted Extension Programs**

GWRDC Project Number	Project Start Date	Project End Date
DPI 06/06	**1st September 2006**	**31st August 2008**

Financial Year (e.g. 2006/07)	(a) **Funds brought forward from previous year*	(b) #Approved GWRDC Budget (full year)	(c) Total budget available *(a)+(b)*	(d) Actual expenditure ($)	(e) Difference ($) *(c)-(d)*
Year 1: 2006/07	–	165,000	165,000.00	143,665.50	21,334.50
Year 2: 2007/08	21,334.50	165,000	186,334.50	161,988.11	24,346.39
Year 3: 2008/09	24,346.39	-	24,346.39	24,346.39	-
Year 4: 20__/__					
Year 5: 20__/__					
TOTAL	45,680.89	330,000	375,680.89	330,000	45,680.89

Note: Project commence 1 Sept 05 and finished 31 Aug 08.

Was funding expended as approved in the Project Agreement?

Yes ☒ No ☐

*If **NO**, please provide reasons:*

Has the cash and/or in-kind funding from Contributing Agencies been received and applied to the Project as approved in the Project Agreement?

Yes ☒ No ☐

*If **NO**, please provide reasons:*

I hereby certify that this statement is true and accurate.

Signature of duly authorised representative

……………………………………………………………

……………………………………………………………

Name: *Title:*

Date:

ATTACHMENT 1:

Enhancing the uptake of wine industry innovations.

GWRDC final report. Project: DPI 06/06

Practice Change Research

The Management of Nutrition in Wine Grapes

December 2007

Megan Hill, Ben Rowbottom, Geoff Kaine and Nicole Dimos
Department of Primary Industries, Victoria

Victoria The Place To Be

Australian Government
Grape and Wine Research and Development Corporation

ISBN 978-1-74199-856-6 (print)

ISBN 978-1-74199-857-3 (PDF)

Published by the Victorian Government Department of Primary Industries
Tatura, December 2007

Find more information about the Department of Primary Industries on the Internet at www.dpi.vic.gov.au

Authors:

Megan Hill, Ben Rowbottom and Geoff Kaine

Department of Primary Industries

Ferguson Rd

Tatura, Victoria 3610

Nicole Dimos

Department of Primary Industries

P.O Box 905

Mildura, Victoria 3502

Acknowledgments:
Thanks to the multitude of people we have interviewed for information. Thanks to GWRDC for funding this project and to Roger Ashburner, Fiona Johnson and Marg Watters for their contributions.

Table of Contents

Figures

Executive Summary

In this study we identified the factors that influence how wine grape growers manage vine nutrition, and where and why nutrition-related problems were occurring. This in turn highlighted research and extension opportunities. Based upon the Kaine Framework (Kaine 2004), forty-five wine grape growers from nine Australian wine regions were interviewed on a range of nutrition-related topics, including their objectives with regard to vine nutrition, choice of products, use of mulches, composts and soil additives and sources of nutrition related information. The growers were classified into market segments based on their current practice in regard to vine nutrition, and the benefits they were seeking from these practices. These segments were described and research and extension opportunities were identified for each segment.

Results

How wine grape growers manage vine nutrition is complex, but some general findings were that:

1. Nutrition could not be considered in isolation from topics such as soil types, soil health and vine balance, as they share a complex and dynamic relationship

2. Growers used a variety of products and management practices to address one specific problem. For example, a grower may increase fertiliser use (fertigate, broadcast and/ or foliar spray) or use mulch, compost, manures, organic or biodynamic products to increase wine grape quality. Sometimes the growers used one product to address a variety of problems, for example mulch was used to improve shallow soils, soil crusting, acidification, low vigour or nutrient deficiencies

3. There is an extensive range of nutrition related products and management options available to industry, sometimes coupled with confusing and conflicting advice on how to use them

Market segments

The growers we interviewed sought different benefits from their nutrition programs that were dependant on the age of the vines, and hence stage of vineyard establishment. Growers were therefore classified into segments depending on whether they were using nutrition inputs to:

- prepare a vineyard site for planting (Segment 1)
- optimise the growth of young vines (Segment 2) or,
- manage established vines (Segment 3).

There were a number of segments among growers managing established vines depending on the nutrition-related problems that arose. These problems related to the vineyard soils, and the growers' objectives in regard to fruit quality. Some growers said they used the same nutrition program each year and did not have any nutrition-related problems (Segment 3.1). Some growers had poor or shallow soils and were trying to increase the nutrient levels in these soils (Segment 3.2). Other growers had sufficient nutrition in their soils, but it was unavailable to the vine because of soil health issues (mainly acidification) or low soil water (Segment 3.3). Growers in Segment 3.4 did not have soil related problems as such, but they wished to increase the quality of their fruit through nutrition management. We also interviewed some growers who said they did not need to provide nutrition to their vines (Segment 4).

Most of the growers interviewed crossed a number of market segments due to the variable nature of vineyards, with most vineyards typically having blocks of vines of different ages and on a range of soil types. Growers may also change segments. For example, growers may have used the same nutrition program for ten years (Segment 3.1), however if their vineyard soils start to show acidification they will change their nutrition program to manage this problem (Segment 3.3).

Opportunities for research and/ or extension

The major issues that emerged, and hence opportunities for research and/or extension were:

- obtaining objective information about the effectiveness of fertilisers and organic products
- emerging soil health issues, particularly acidification
- methods of testing vine nutrition status, a lack of confidence in standards, interpretation and fertiliser recommendations (see "The use of soil and petiole testing in viticulture" report, by Hill et al. 2008)
- develop new products or application techniques that will provide the benefits *currently* being obtained, more cheaply, efficiently and/or reliably
- refine existing products to provide *additional* benefits, such as products that are more environmentally friendly, easier to apply, or safer to handle

Specific opportunities that arose were:

- ➢ clarifying pre-planting guidelines on nutrition-related inputs on different soil types (Segment 1)
- ➢ determining the effectiveness of foliar sprays in correcting micro-nutrient deficiencies (Segment 3.2)
- ➢ developing improved information, diagnostic and management practices and products in regard to soil health issues (Segment 3.3)
- ➢ information on the impact, and management of vine nutrition under conditions of low soil moisture (Segment 3.3)
- ➢ information on the impacts of nutrition, especially in regard to organic or biodynamic products on wine grape quality and production (Segment 3.4)

Future research

The area of vines and regional composition of the vineyards in each of the market segments described in this study could be determined using quantitative research methods, possibly in conjunction with spatial mapping technology. Such an activity would enable interested parties to determine how widespread the nutrition management practices and problems described are in the Australian wine industry, which in turn, would guide research and extension priorities and the allocation of resources. Quantifying the segments would also provide baseline data to the wine industry in regard to aspects of nutrition management such as; current practice, evolving trends and issues, adoption of relevant innovations and research findings, and selected practices with environmental implications such as use of mulches and composts.

Another option for future work would be to apply the Kaine Framework (Kaine 2004) to obtain a more in-depth understanding of some of the specific aspects of vine nutrition and soil management within the existing segments. For example, the use of mulches and composts, adoption of organic or biodynamic production practices or the use of sap or leaf testing in order to determine when, why and how they are being used and hence the market for emerging research findings and innovations in these areas.

Introduction

This work is the second case study of the "Enhancing the uptake of wine industry innovations through the development of targeted extension" project. It will inform aspects of "The review of and packaging of current viticultural nutritional management information for Australia's major wine grape varieties" project. A further report entitled "The use of soil and petiole testing in viticulture" is associated with this case study. These projects are supported by the Grape and Wine Research and Development Corporation.

The aims of this study are to identify the factors that influence wine grape growers management of vine nutrition, and where and why nutrition-related problems were occurring, which then highlights research and/ or extension opportunities. To achieve this we have used the Kaine Framework (Kaine 2004) which is a method for examining the adoption of agricultural innovations. This is the first time that the Kaine Framework has been applied to wine grape nutrition.

Background

Wine grape growers continually identify grapevine nutrition as a focus for additional research and extension, with it sometimes being their highest priority (Byrne and McGuire, 2005). Consequently, a number of surveys, workshops and studies have been conducted to identify the aspects of vine nutrition that present the greatest opportunities for research and extension (Atkinson and Dignam 2003; Byrne and McGuire 2005; Swinburn and Saris 2005).

While surveys, workshops and studies were successful in generating lists of nutrition-related topics, sometimes prioritised by workshop participants, little or no information was available in regard to who was using nutrition management and why, what aspects of the topics raised were important, how they were related to specific vineyard characteristics, and how widespread the nutrition-related problems were.

In this study we used the Kaine Framework (Kaine 2004) to identify the benefits the growers sought through different approaches to managing vine nutrition, assess if there were commonalities in the vineyard characteristics that led to similarities in the products and practices used, and explore any nutrition-related problems encountered. With this information we identified a number of opportunities for future research and extension.

The Kaine Framework

Kaine (2004) suggests that a market segmentation process, commonly used in market research for consumer products, in conjunction with farming systems theory (Crouch 1981), can be applied to understand the benefits sought through adoption of innovations and practices in agriculture and horticulture (Kaine 2004, Kaine et al. 2005). Kaine (2004) draws on the conceptual foundations of consumer behaviour theory (Assael 1998) to suggest that adoption of on-farm innovations and practices that are important to the business or producer is similar to high involvement purchasing. Therefore, the decision making process will be complex (Assael 1998) and will entail an extensive search for information and deliberate processing of the information and consideration of the options available before making a decision based on the extent to which the innovation is perceived to offer a benefit.

Drawing on farming systems theory, Kaine (2004) indicates the major driver to adoption of an innovation or practice is the belief of the grape growers that the innovation will provide a net benefit to their business by satisfying a *need*. This is determined by aspects of the growers' farm context. The farm context is the biophysical, human and financial resources and the mix of management practices available to the vineyard business that influence the benefits to be had from an innovation (Kaine 2004).

As not all farm contexts are the same, Kaine (2004) suggests that different farm contexts result in an innovation providing different benefits to different growers. By understanding these contexts and the benefits vineyard managers seek when adopting an innovation or practice, the vineyard managers can be classified into market segments based on their common features.

The implications of the adoption of an innovation or practice being similar to a high involvement purchase is that when interviewed, the vineyard manager can describe the search for information, and also the logic, reasoning and aspects of the farm context that led to the existing innovation or practice being used.

In this study, we have applied the Kaine Framework (Kaine 2004) to identify the benefits growers are seeking through their nutrition management and to use this information to create market segments. Once the market segments are created, it should be possible to assess how well the needs of a segment fit the characteristics of an innovation and where gaps exist that present opportunities for research and extension. Knowledge of market segments can also be used to set priorities with respect to targeting segments, forecasting the long term rate of adoption, and formulating extension programs (Kaine et al. 2005).

This approach could potentially be applied to obtain an in-depth understanding of other aspects of nutrition management such as adoption and use of sap or leaf testing methods, and use of mulch, or organic and biodynamic production systems.

Related Research

Despite there being a plethora of technical information on wine grape nutrition, our review of the literature did not reveal any other research on the adoption of nutrition management practices in viticulture. However, a number of studies exist in viticulture that illustrate how the work of Kaine developed to become the Kaine Framework (Kaine 2004), and how it can be used to highlight the factors that influence the wine grape growers propensity to adopt a research output or innovation.

Adoption of viticultural innovations

Kaine and Bewsell (2001a, 2001b, 2002a) investigated the adoption of irrigation and soil monitoring technologies in six Australian grape-growing regions, and developed recommendations for extension programs, using the same methodology employed in this study. Kaine and Bewsell (2001a, 2001b, 2002a) found that adoption of pressurised irrigation systems depended on the vineyards access to water on demand, the grape varieties and quality grown, and the system cost. Soil moisture monitoring was found to provide the most benefit to grape growers with pressurised systems who could use it to tailor their irrigation inputs to meet their grape quality objectives.

Bewsell and Kaine (2003) used the Kaine Framework (Kaine 2004) to study the adoption of sustainable practices, relating to pest and irrigation management, and the adoption of soil moisture monitoring in viticulture in New Zealand. They found that vineyard micro-climate, geographical isolation, availability of labour, chemical and biological control options and the reliability of monitoring techniques were the key factors influencing the adoption of sustainable pest management. Soil type and typography were the key influences on irrigation technology adoption, while soil type and the ability to control vine vigour using irrigation were the main factors influencing adoption of water monitoring technology (Bewsell and Kaine 2003).

Materials and Methods

This study consists of three parts:

1. Data collection to identify the factors that influence how wine grape growers manage vine nutrition, and where and why nutrition related problems were occurring
2. Analysis and interpretation of data to enable market segments to be formed
3. Identification of opportunities for nutrition-related research and extension

Data Collection

As recommended by Kaine (2004), convergent interviewing (Dick 1998) was used to collect the data. Convergent interviewing is unstructured in its content and also guides the sampling strategy. The key purpose of using convergent interviewing was to identify similar and contrasting patterns in the reasoning and logic underlying the decisions and actions of the wine grape growers in regard to their nutrition management. Interviews were conducted until any difference in reasoning was linked to differences in the context of the growers and no new contextual-based reasoning emerged. Interview responses were recorded manually by two interviewers and summarised.

Forty five interviews were conducted with grape growers from cool (Yarra Valley, McLaren Vale, Padthaway and Coonawarra), warm (Goulburn Valley, Bendigo, Heathcote and Barossa Valley) and hot (Sunraysia) wine grape producing regions. Growers were selected to represent large, medium, small, family and corporate businesses, and a cross section of wine quality grades and price points.

Initially, the following topics were explored in the interviews:

- the objectives, development, application, timing and evaluation of fertiliser programs
- the use of soil, petiole and other agronomic testing
- organic and biodynamic product choice and use
- the use of mulches, composts and soil additives
- identification and management of macro and micro nutrient deficiencies
- soil health, vine balance and grape quality
- sources and use of information
- industry factors influencing nutrition

As the study progressed the scope of the interviews was narrowed in order to collect detailed information with regards to the use of fertilisers (synthetic and organic), soil inputs (lime, gypsum, compost, manure and mulch), and testing methods (soil and petiole testing). These topics were selected after the initial round of interviews as they emerged as the major tools and techniques used in nutrition management. The soil and petiole testing results are presented in a separate report "The use of soil and petiole testing in viticulture".

Analysis and interpretation of data

The data was analysed using case and cross-case analysis (Patton 1990). Each interview represents a case. Each case must seem logical and make sense to the interview team before the data collection is complete. The cases are analysed individually to try to determine which information is relevant to the objectives of the study.

Cross-case analysis compares and contrasts the different cases, exploring the data for key information, similarities or differences, themes and patterns. This is an iterative process as the progress is made in clarifying and answering the research questions.

Identification of opportunities for research and extension

Once the market segments were identified, each of the segments were analysed to identify factors that might prevent segment members from realising the benefits they sought, that is, where problems were occurring. Where the problem was complex, the information collected was used to construct a problem tree (Mayeske 1994).

Where no known solutions to the problem exist, or existing solutions were not perceived by the growers as solving the problem, opportunities for future research or extension were identified.

Results

The vast majority of growers interviewed stated that nutrition management was one of the most important factors to consider when growing wine grapes. However understanding how wine grape growers manage vine nutrition was challenging for the following three reasons.

Firstly, vine nutrition cannot be considered in isolation from topics such as soil properties, soil health, and vine balance. Each of these factors depends on the other and the relationship between them is complex and dynamic. Consequently it is difficult to evaluate the effect of different nutrition-related inputs as the vineyard environment cannot be completely controlled, and the impact of the inputs may take months or years to become evident.

The second reason was that growers use a variety of different products and management techniques to address one particular problem. At the same time, they use one particular product or management technique to address a variety of different problems (see Appendix 1). This resulted in overlap in the products and practices used by each segment.

The third reason was that an extensive range of nutrition-related products and management options are available to industry, and these were sometimes associated with confusing and conflicting advice.

Vine Nutrition Based Market Segments

The growers interviewed said they managed their vine nutrition using nutrition-related inputs such as synthetic and organic fertilisers, lime, gypsum, compost, manure or mulch. The main factor that influenced this management was the age of the vines, that is, the stage of vine establishment (see Figure 1). Growers were therefore classified into segments depending on whether they were using nutrition inputs to: prepare a vineyard site for planting (Segment 1), optimise the growth of young vines (Segment 2) or manage established vines.

There were a number of segments among growers managing established vines depending on the nutrition-related problems that arose, which related to the vineyard soils, and the growers' objectives in regard to fruit quality. Some growers said they used the same nutrition program each year and did not have any nutrition-related problems (Segment 3.1). Some growers had poor or shallow soils and were trying to increase the nutrient levels in these soils (Segment 3.2). Other growers had sufficient nutrition in their soils, but it was unavailable to the vine because of soil health issues (mainly acidification) or low soil water (Segment 3.3). Growers in Segment 3.4 did not have soil related problems as such, but they wished to increase the quality of their fruit through their nutrition management. We also interviewed some growers who said they did not need to provide nutrition to their vines (Segment 4).

Most of the growers interviewed crossed a number of market segments due to the variable nature of vineyards, with most vineyards typically having blocks of vines of different ages and on a range of soil types. Growers may also change segments. For example a grower may have used the same nutrition program for ten years (Segment 3.1), however if the vineyard soils started to show acidification the grower will change their nutrition program to manage this problem (Segment 3.3).

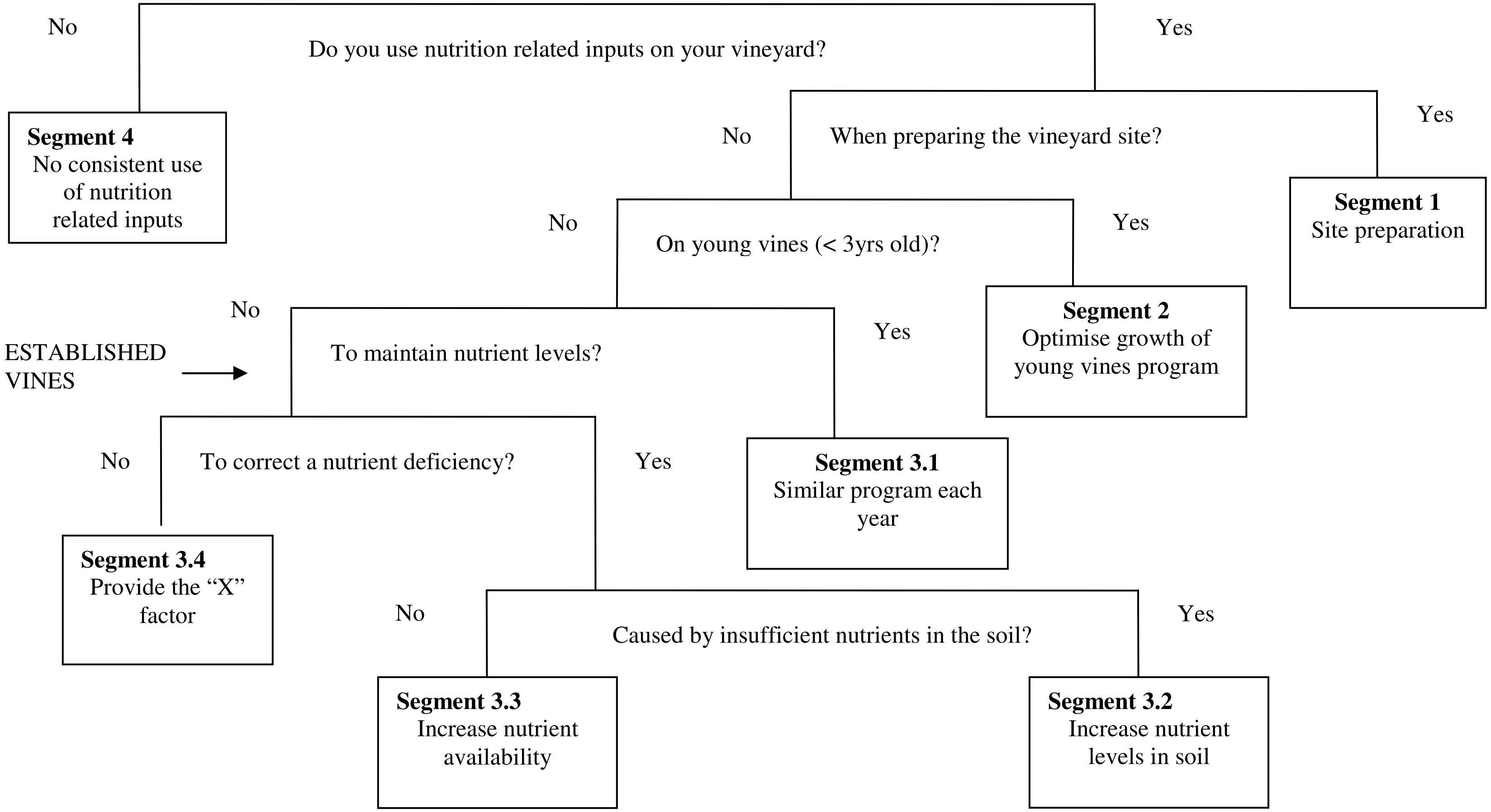

Figure 1: Market segments for growers using nutrition-related inputs on the vineyard.

Segment 1– Site preparation

The majority of growers interviewed prepared their vineyard site prior to planting the vines, by incorporating nutrition-related inputs into the soil, often by deep ripping or rotary hoeing them into the soil.

The growers said they used lime to modify the pH of the soil, gypsum to improve the soil structure, and fertiliser that would provide nutrients to the vines upon planting. By preparing the soil in this way, the growers were seeking to maximise the survival and growth of the young vines.

The majority of the growers interviewed based the amount and type of inputs they used on soil test results.

The growers interviewed said they thought that site preparation was extremely important as once the vines were planted it was difficult or impossible to get inputs where they were needed, near the root zone, without damaging the vine. The options available once the vines are planted are to broadcast the inputs on the soil surface, which is not as efficient because the nutrients have to be dissolved and leached to the root zone by rainfall or irrigation, or to apply the inputs using fertigation, however not all inputs can be applied this way and some product is lost through the nutrients leaching through the root zone.

As “George” a grower from Nagambie stated:

> *“We made sure the planting site was deep ripped, and we put lime and super phosphate down the rip lines. If you don’t get that stuff near the root zone before you have planted the vines, you have missed your chance.”*

Growers that did not add nutrition-related inputs prior to planting had either rich, deep soils, or a site with residual nutrition-related inputs from previous site use, such as growing pasture, cropping or horticulture (predominantly vegetable production).

Problems and opportunities

The majority of growers in this segment did not describe any nutrition-related problems when preparing their vineyard site, and overall they were happy that their site preparation had provided them with the anticipated benefits in regard to vine establishment and growth.

Any problems that did occur were related to incomplete or inaccurate information, recommendations or advice for preparing their individual vineyard site. Typically such inaccuracies occurred with fertiliser salesperson recommending what the growers perceived as, excessive inputs (for more detail see "The use of soil and petiole testing in viticulture" report) or, after some time, the growers wished they had added more lime and gypsum to the root zone during site preparation.

Therefore opportunities for research and extension in this segment lie in:

- clarifying pre-planting guidelines on nutrition-related inputs in relation to different soil types
- developing new products or application techniques that will provide the benefits currently being obtained, more cheaply, efficiently and/or reliably
- further development of existing products to provide additional benefits, for example making them more environmentally friendly, easier to apply, or safer to handle

Segment 2 – Optimise the growth of young vines

The majority of growers we interviewed said they had a nutrition program specifically for their young vines in order to increase their chances of survival and maximise their growth which would set up the vines' structure and get the vines cropping as quickly as possible.

"Alonso" a grower from Murchison succinctly summarised the views of many like-minded growers:

"It seems stupid to me to invest all that time and money in preparing the soil and planting and training the vines, only to not look after them properly at the most crucial stage of their development"

Most growers provided their young vines with frequent, small doses of nitrogen usually by applying Calcium Nitrate via fertigation.

Problems and opportunities

None of the growers we interviewed reported having nutrition related problems with their young vines. They were satisfied with the nutrition programs they followed, and problems they had encountered in relation to their young vines were usually due to hare (pest) damage, frost, watering or vine training.

Therefore opportunities for research and extension in this segment are limited to:

- developing new products or application techniques that will provide the benefits currently being obtained, more cheaply, efficiently and/or reliably
- further development of existing products to provide additional benefits, for example making them more environmentally friendly, easier to apply, or safer to handle

Segment 3 - The Management of Nutrition for Established Vines

Most growers we interviewed changed their nutrition management strategy once they believed their young vines were established. Typically once the vines were established the amount of nitrogen being applied to the vine was reduced otherwise the growers said they would get excessive leaf area, which led to shading, weak, sappy growth, disease problems and poor quality fruit.

We found that the nutrition management of established vines depended largely on the characteristics of the vineyard such as the soil type and location, for example if it was on a hillside or in a valley, and the fruit quality objectives of the grower. Therefore there are a number of segments within Segment 3.

Segment 3.1– Similar program each year

Growers in this segment cropped their vines consistently once the vines were established and used the same or a similar nutrition program each year. These growers said that their individual nutrition programs worked for their vines on their sites, and they did not have any nutrition-related problems.

As "Nicole" who manages a vineyard in the Strathbogie Ranges said:

> *"I pretty much do the same thing each year regarding what fertilisers I use, and how much. The winery is happy with the fruit and the vines look good, so I am sticking with what I know works"*

Some of the growers based their nutrition program on calculations of nutrient removed from the vineyard through harvesting and pruning practices. Others relied on soil and petiole test recommendations. Others used advice obtained from a range of sources including local growers, vineyard liaison staff, fertiliser salespeople, consultants and literature when selecting or designing their nutrition program. All of the growers had some experience in growing and fertilising vines, which they used to guide their decision making.

Some of the growers interviewed used soil or plant tissue testing to check that their program was meeting the vines nutrient requirements, and might vary their program slightly, depending on test results. Others were happy that their visual assessment of the vines would reveal any emerging problems.

The distinguishing feature of this segment was that the growers were comfortable that their program met their needs and they did not have any nutrition related problems, hence they were not seeking information or thinking of making major changes to their nutrition program. Any changes they made were minor, such as changing fertiliser brands to minimise costs, or adjusting application rates.

Problems and opportunities

Growers in this segment said they did not have any nutrition related problems.

Therefore opportunities for research and extension in this segment are limited to:

- developing new products or application techniques that will provide the benefits currently being obtained, more cheaply, efficiently and/or reliably
- Further development of existing products to provide additional benefits, for example making them more environmentally friendly, easier to apply, or safer to handle

Segment 3.2– Increase nutrient levels in the soil

Growers in this segment said that their vines had nutrient deficiencies for one of two reasons. The first occurred if their vineyard soils were poor, weak or shallow, often in rocky areas or on hills. The second group of growers in this segment found that soil nutrient levels had become depleted over time, with a number of growers reporting that this occurred in vineyards that were 8- 10 years old.

The growers said that the low nutrient levels in the soil led to the vines losing vigour, showing deficiency symptoms and getting out of "balance", which is when the growth of the vine cannot support the optimal yield and desired quality of grapes.

The growers identified the problem of inadequate nutrient levels when visual symptoms started showing on the leaves, or in the fruit, when vine canopy growth was poor, or through soil or plant tissue test results.

Some growers were familiar with the deficiency symptoms and added additional inputs to solve the problem. Other growers used soil and/or plant tissue testing to confirm their suspicions, to determine how severe the deficiency was, and sometimes to get advice on products and rates of application to fix the problem. The growers said that soil and petiole testing achieved this, although there were some concerns about the tests (see "The use of soil and petiole testing in viticulture" report).

Macro-nutrient deficiencies were fairly common on hilly sites, or in some areas with poorer soils. For example "John" has two vineyards in Wrattonbully, of 24 and 48 hectares. His vines were planted between 1996 and 1999 into Terra Rossa soil over stone. He says:

> *"I alternate soil and petiole tests each year, and also keep my eyes open. I top up my fertiliser program depending on the results. I always have nutrient deficiencies where the soils are shallow. The soil test this year showed that the soil is low on P (phosphorus), K (potassium) and Mg (magnesium)."*

Some growers we interviewed said their vines had micro-nutrient deficiencies in particular zinc, boron, and molybdenum which they said lead to low rates of fruit set. A few growers mentioned that some of their grape had thin skins, which they blamed on a lack of calcium in the vine.

"Allister" grows grapes on his 25 hectare vineyard in the Yarra Valley, he told us:

> *"I have always had trouble getting reasonable levels of fruit set in Merlot. I had some petiole tests conducted which showed some micro-nutrient deficiencies. I now apply foliar sprays containing molydenum and boron as part of my fertiliser program, and I have not had trouble since.*

The growers said that it is relatively simple to increase the nutrient levels in their soil, as it is usually a matter of working out which nutrient/s were deficient and the fertilisers to apply to provide those nutrients. When a macro-nutrient was deficient the growers said they broadcast or fertigated additional fertiliser. If they thought the plant was lacking a micro-nutrient they usually applied foliar sprays.

Composts and mulches were also used by many growers to build up shallow or poor soils. Tom, a vineyard manager on a 1300 ha corporate vineyard in Padthaway said:

> *"We have sandy, deep soils in the east, red soils over limestone on the west, and a ridge with shallow soils through the middle. It is unfortunate that vines were planted on the shallow soils, so we use Plant Canopy Density maps to show the shallow, low vigour areas and we mulch them. This builds up the soil so it can hold onto the water and nutrients. We are hoping that this will increase vine vigour and reduce the variation in*

quality we are seeing due to those poorer soils. We would like to do more (mulching), but it is expensive".

Problems and Opportunities

Most growers in this segment did not report identification of deficiency symptoms or applying nutrition-related inputs as a problem. A few growers reported that obtaining mulch of reasonable quality in the quantities they required was difficult and expensive. Some growers had problems in regard to soil and petiole testing (see "The use of soil and petiole testing in viticulture" report for more detail).

The growers said the most difficult aspect of correcting nutrient deficiencies was in determining the "best" option for meeting their vines' nutrition needs, as they found it very difficult to get reliable information about the contents, use and effectiveness of individual fertiliser products from the resellers. The growers said they received conflicting advice and that comparing products was confusing and difficult, and there was rarely any reliable trial data that was relevant to their situation.

The effectiveness of applying foliar sprays to correct micro-nutrient deficiencies was questioned by some growers.

Therefore there are research and extension opportunities to:

- Independently evaluate the features and effectiveness of foliar application, fertilisers, mulches and composts
- Show growers how to set up trials or collect information to do their own evaluation of products, to enable them to select the best products to meet their needs

Segment 3.3- Increase nutrient availability

Growers in this segment reported that their vineyard soils had health problems or low soil moisture. These conditions meant that even though the nutrients were present in the soil, they were unavailable or difficult for the vine to absorb resulting in deficiency symptoms occurring, and reduced vine vigour. The growers in this segment were seeking information and making changes to their nutrition program to solve or manage these problems.

Soil Health Problems

Soil health problems can be divided into chemical, physical and/or biological problems. The major soil health problem raised by the growers interviewed was chemical, namely acidification of the soil, caused by long term use of conventional fertilisers, mainly ammonium nitrate and urea, which lowered the pH of the soil. The growers said that they found out the problem was soil acidification when test results showed sufficient nutrients were present in the soil, yet the vines still displayed deficiency symptoms. Testing the pH of the soil confirmed the presence of acidification.

Most of the growers who had found acidification in their vineyard soils were trying to reverse the process through the addition of lime to the soil, however they said that lime is not soluble so it does not move readily through the soil to the rootzone, and it can be hazardous for the grower to use. A dissolvable lime product has been developed which can be fertigated onto the vines, however the growers found this more expensive, and not always effective.

"Tim" a Strathbogie Ranges grower who produces both red and white grapes has noticed soil acidity problems occurring on his vineyard in the last few years:

> *"We have been using urea and super phosphate as a winter dressing for the vines, but we are trying to change that as our soil is becoming acidic, so the nutrients are not readily available to the vines. We think this is why we are starting to see deficiency symptoms show up on the leaves."*

Some growers had physical problems with their soil, such as compaction or the soil crusting and becoming impermeable to water. The growers attributed this to some of their viticultural practices, mainly driving along the vine row, particularly when the soil was wet, tilling the soil and/or removing the vegetation, leading to deterioration in soil structure. Deterioration in soil structure affects vine root development, resulting in reduced uptake of nutrients and water, and vine performance. The growers said they treated soil structural problems using inter-row planting or by increasing organic matter through the use of mulches, manures or composts (see Appendix 1).

A few growers said they did not have enough soil biota/microbial activity in their vineyard soil to break down organic matter and prevent nutrients from leaching out of the soil. The growers treated this problem by using composts or mulches, and a few were trialling commercial mixes of micro-organisms or humic acid. An example of this is Chris who has a 70 hectare vineyard in Coonawarra growing Shiraz, Merlot, Cabernet Sauvignon and Chardonnay in black clay over limestone soils. Chris said:

> *"I trialled compost with extra iron sulphate added. It worked well but I needed to redo it every two to three years, which became too expensive so I stopped doing it. I saw an improvement in vine health and it reduced the variability in the vineyard. I am now interested in trying humic acid, which should give me instant results as it has advantages for soil health and organic matter, and could solve a whole bucket load of problems."*

Many growers saw organic products as having the potential to solve or help them manage their soil health problems. When asked how these products worked, or what specific advantages they offered over other products the growers were not sure, but were convinced that organic products would help in some way, or at least provide some nutrition to the vines without exacerbating any existing problem.

Problems and Opportunities

There were a number of soil health diagnostic and treatment problems identified by the growers. These are shown in a problem tree in Figure 2. The opportunities that arise from these problems are to:

- develop tools to diagnose soil health problems
- provide objective advice about the causes and impacts of these problems
- conduct research and extension regarding how to solve or manage soil health problems

- evaluate and compare the effectiveness and economics of products being sold to solve or manage soil health problems

- develop superior products and practices to manage these problems

Why would a wine grape grower be encountering difficulties in addressing soil health issues?

Soil health issues can be difficult to diagnose

There is little or no information about the medium to long term implications of soil health issues on vineyard profitability

Growers often receive conflicting and/or confusing advice, due to a lack of:

- Objective information in regard to products
- Site specific information

It is difficult to evaluate the effectiveness of products or management practices because of:

- Vineyard variation
- Long lag time between application and results being visible
- Changing one aspect of a complex system

Some soil health issues cannot be solved in a cost effective manner using currently available materials and information

Figure 2: Problem tree to explore soil health issues

Low levels of soil moisture

Due to a series of dry years, some growers interviewed reported seeing visual symptoms of nutrient deficiencies for the first time on their vineyard. Most of the growers attributed this to low soil moisture levels reducing the availability of the nutrients to the vine.

Des from a large well established vineyard in the Sunraysia area summarised many growers' concerns:

> *"The drought is making grape growing harder, and so you have to be on the ball in regard to your vine nutrition. So I am taking more of an interest in nutrition at the moment."*

Some of these growers are rethinking their nutrition program, because the methods of application and products they have used in the past have depended on rainfall and soil moisture to carry the nutrients through the root zone. For example some growers have changed from broadcasting fertiliser to using products they can fertigate onto the vine, so that the irrigation water carries the nutrients to the root zone.

Problems and Opportunities

Many growers said they knew their nutrition program was not working well due to low levels of soil moisture but they lacked information on the short and long term impact of this on their vines. Some of the growers interviewed did not know if poor vines were suffering from other problems, perhaps plant health related, or if the changes they were seeing in the vines was due solely to the dry years.

There is an opportunity for research and/or extension on how to apply the water available to optimise fruit production and minimise long term implications on the vines health. There is also an opportunity to provide information on the impact of low soil moisture levels on vine nutrition, and the products and methods available to manage this.

Segment 3.4– Provide the "X" factor

The growers in all of the segments talked about vine balance and quality in relation to nutrition. Most growers said that if you met the vines' nutrition requirements, any changes in fruit quality beyond that would be achieved through changing vineyard practices such as canopy management and manipulation, and irrigation management.

The growers in Segment 3.4 differ as they believe that conventional nutrition management cannot provide the "X" factor that will grow happy, healthy vines, and superior fruit.

An example is "Eric" and "Maria" who are Sunraysia growers growing 20 hectares of vines. Eric and Maria reacted to falling fruit prices by trying to grow fruit that would meet the highest quality grade possible, in order to maximise the price they could sell the fruit for. They thought that changing their vine nutrition program would help them achieve that objective, so they switched from a conventional fertiliser program to BioAg, a commercial nutrition program which uses a mix of synthetic and organic products. "Eric" and "Maria" said:

> *"We are aiming for a higher quality grade than is normal for this area. We're targeting grade 3, semi-premium. So we have started using BioAg products, which are a combination of organics and synthetics. We are confident that the benefits we are seeing in the vineyard are due to the BioAg products, and I have faith in Franco, the consultant who designed the program. I can taste the difference in the fruit, and the vines look much healthier and even. This season coming should be better again as we had only been using BioAg for part of last season. This will give us an edge and help us as we strive for excellence".*

A few of the growers we interviewed were in the process of converting, or had converted their vineyard to organic or biodynamic. One of these growers is "Keith" who has a 10 hectare vineyard and an orchard near Heathcote. "Keith" said:

> *"I am a winemaker. I was at the London Wine Show five years ago, and I tasted a Riesling that gave me a feeling like I had angels dancing on my tongue. In all my years of*

winemaking it was the loveliest wine I had ever tasted. I talked to the man who grew the fruit for this wine, and now I have set up a biodynamic vineyard to try to achieve something that special myself".

Problems and Opportunities

The industry definition of "quality" varies and many characteristics of the wine grape that contribute to quality are poorly understood and cannot be measured. Hence it is difficult to determine the impact nutrition has on quality once the vines' basic nutrient requirements are satisfied. Once research has been conducted to answer some of the fundamental questions of what grape "quality" means, there may then be an opportunity to determine or develop products that can influence quality parameters.

Little is known about biodynamic and organic nutrition versus conventional nutrition. Any information generated on this topic would be of interest to this segment.

Segment 4- No nutrition-related inputs consistently used

During this study we did not find any commercial growers that had never used any nutrition related inputs on their vineyard, at least during site preparation or to help establish young vines. However, we did interview some growers that said they did not currently or consistently provide nutrition related inputs to their vines.

These growers said that they did not need to fertilise their vines as their vineyard soil had sufficient nutrients to support the vines and enable them to grow the tonnage and quality they required.

An example of a grower in this segment is "David". He has been managing his family's 33 hectare Barossa Valley vineyard for 25 years. The vineyard has been in his family for three generations, "David" said:

"Our vineyard was planted in the 1920's. We don't test it. We don't have any problems. We sow a cover crop which we fertilise with a bit of DAP (fertiliser) between the vine rows. We slash the cover crop and throw it under the vines. That's all we do. Our fruit

consistently goes into top of the range reserve wines every year. There is no reason to mess with it, and to force feed it to get a higher yield would be counter productive."

So even though "David" is using fertiliser in his vineyard, when asked he said he was not doing it as part of a vine nutrition management program, but seeking a different benefit, possibly in this case to grow a cover crop to maintain his vineyard soil structure.

Some of the other growers in this segment were growing vines on deep, rich soil, or their site was previously under pasture or crops and still had a high nutrient content. A few of the growers did not add fertiliser as their vineyards were young and their pre-planting applications had not yet been depleted.

As "Ed" who planted his 8.5 hectare vineyard in Colbinabbin seven years ago, on red and grey clay loam soils, said:

> *"I don't do a great deal of nutrition management. I put a bit of Calcium Nitrate through the drippers on the young vines, until they were 3 years old, then I stopped. This vineyard used to be an orchard. I did a soil test before I planted, and there were no pH or nutrient problems. The vines don't use much (nutrients). If I saw signs of a nutrition problem I would fix it."*

Some of the growers in this segment conducted regular soil or petiole tests to monitor their soil plant nutrient status.

Problems and Opportunities

The growers in this segment do not have any problems with nutrition or use of nutrition related inputs. Hence there does not appear to be any opportunity for research and extension to provide useful products for the growers in this segment.

Discussion

Our findings suggest that there are particular circumstances where growers will become highly involved in making decisions about their vine nutrition. That means they will seek information to determine and evaluate their options in order to decide on what they perceive to be the best course of action. This occurs when:

- growers are starting a nutrition program that is new to them, or in a new site (for example when pre-planting, or when their young vines become established vines) and/or
- something happens in the vineyard to indicate that there is a problem or a need to make a change. For example deficiency symptoms start to show, the vine is showing reduced vigour, or they become dissatisfied with the quality of fruit the vine is producing

The growers in Segment 3.1 said that they used the same nutrition management program each year as it met their needs, so why change? Hence they were not interested in nutrition management information *per se.* Yet they also said that if there was a better way of managing their nutrition, such as new cheaper, more efficient, safer and/or environmentally friendly products or application methods they would be interested.

While many of the growers that we interviewed were satisfied with their current nutrition management, in the course of the study we collected an extensive list of topics the growers said they would like more research and/or extension work conducted on (see Appendices 2 and 3).

Conclusion and Future Work

This study has identified the factors that influence how wine grape growers manage vine nutrition, where and why nutrition related problems are occurring, and some research and extension opportunities to address these problems.

To obtain maximum value from this work a quantitative study, possibly in conjunction with spatial mapping technology would be conducted to determine the area of vines and regional composition of the vineyards in each of the market segments. This would enable interested parties to determine how widespread the nutrition management practices and problems described are in the Australian wine industry, which in turn would guide research and extension priorities and the allocation of resources. Quantifying the segments would also provide baseline data to the wine industry in regard to aspects of nutrition management such as; current practice, evolving trends and issues, adoption of relevant innovations and research findings, and selected practices with environmental implications such as use of mulches and composts.

The Kaine Framework (Kaine 2004) used in this study should be applied again to obtain an in-depth understanding of some of the specific aspects of vine nutrition, such as the use of mulches and composts, adoption of organic or biodynamic production practices or the use of sap or leaf testing, or to determine the market for emerging research findings and innovations.

References

Assael, H. (1998). Consumer Behaviour and Marketing Action. South Western College Publishing, Cincinnati, Ohio.

Atkinson, I. and Dignam, M. (2003). Winegrape Grower Information Needs Survey, 2003: A research report from the conduct of qualitative and survey research with grape growers in the Riverland, Sunraysia and Riverina to determine their needs for information and training. Prepared for Cooperative Research Centre for Viticulture. Glen Osmond, SA.

Bewsell, D. and Kaine, G. (2003). Adoption of sustainable practices in the wine grape industry. Client Report, Prepared for New Zealand Winegrowers. AgResearch Ltd, NZ.

Byrne, S. and McGuire, L. (2005). Nutrition Focus. Final Report to Grape and Wine Research and Development Corporation. Murray Valley Winegrowers' Inc.

Crouch B (1981) Innovation and farm development: a multi-dimensional model. In: S. Chamala (ed) Extension Education and rural Development. Wiley and Sons, Brisbane.

Dick, B. (1998). Convergent Interviewing: a Technique for Qualitative Data Collection. Available at http://www.scu.edu.au/schools/gcm/ar/arp/iview.html

Hill, M., Rowbottom, B., Kaine, G., and Dimos, N. (2008) The use of soil and petiole testing in viticulture, Milestone Report, currently in preparation.

Kaine, G. (2004). Consumer Behaviour as a Theory of Innovation Adoption in Agriculture. Social Research Working Paper, 01/04. AgResearch, NZ.

Kaine, G. and Bewsell, D. (2001a). Managing Irrigation for Grape Production, Interim Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G. and Bewsell, D. (2001b). Managing Irrigation for Grape Production, Second Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G. and Bewsell, D. (2002a). Managing Irrigation for Grape Production, Third Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G. and Bewsell, D. (2002b). Soil Monitoring, Irrigation Scheduling and Fruit Production, Part Three. Armidale, N.S.W., School of Marketing and Management, University of New England.

Kaine, G, Bewsell, D, Boland A, Linehan, C. (2005). Using market research to understand the adoption of irrigation management strategies in the stone and pome fruit industry. Australian Journal of Experimental Agriculture 45(9):1181-1187.

Linehan, C. and Kaine, G. (2004). Methods used by the Rural Resources Development Team for qualitative interviews. Social Research Working Paper, Department of Primary Industries, Victoria.

Mayeske, G. W. (1994). Life Cycle Program Management and Evaluation: An Heuristic Approach, United States Department of Agriculture Extension Service, Washington.

Patton M, Q. (1990). Qualitative Evaluation and Research Methods 2nd Edition. Sage Publications; USA.

Swinburn, G. and Saris, S. (2005). Results of a Survey to Identify the Issues Relating to Nutrition, Fertilizer Use and Soil Management for the Murray Valley Wine Industry. Schoefield and Robinson Mildura Pty Ltd. Mildura.

Appendix 1– Problem areas, farm context, problem and possible responses

Problem Area	Farm Context	Problem	Conventional Fertiliser Application				Soil Amelioration			Organics				
			Fertigate	Broadcast	Band	Foliar	Deep Rip	Lime	Gypsum	Mulch	Compost	Manure	Liquid product eg seasol	Bio dynamic
Soil	Shallow soils	Water retention								√	√	√	√	
	Crusting	Water infiltration							√	√	√	√	√	
	Poor Infiltration	Water infiltration					√		√	√	√	√	√	
	Hard pan	Root growth, water holding capacity					√		√	√	√	√		
	Acidification	Low soil pH						√						
	Salinity/ sodicity	Increasing NaCl in soil or water leading to sodicity or salinity related soil problems							√					
Plant	Low vigour	Low vigour, unhealthy vines	√			√				√	√	√		
	Vine Yellows	Unhealthy yellow leaved vines	√			√				√	√	√		
	Inconsistent quality	Quality varies throughout vineyard block due to a number of factors								√	√	√	√	√
	Fruit set	Growers concerned about fruit set in reds				√								
	Unhealthy looking vines	Grower believes vines don't look healthy and balanced	√	√	√	√				√	√	√	√	√
Nutrition	P Deficiency	Low P detected by Petiole, soil of visual assessment	√	√	√	√								

Problem Area	Farm Context	Problem	Conventional Fertiliser Application				Soil Amelioration			Organics				
			Fertigate	Broadcast	Band	Foliar	Deep Rip	Lime	Gypsum	Mulch	Compost	Manure	Liquid product eg seasol	Bio dynamic
	Nutrient poor, dry or acidified soils	Magnesium deficiency	√			√								
	Nutrient poor, dry or acidified soils	Zinc deficiency	√			√								
	Nutrient poor, dry or acidified soils	Boron deficiency	√			√		√						
Management goals	Desire to increase quality grade	Higher quality fruit is required	√	√	√	√				√	√	√	√	√
	Market as clean/green/ natural/ organic/ biodynamic	Fruit that can be marketed as clean/green/natural/organic/biodynamic is required								√	√	√	√	√

Appendix 2- Topics for future research suggested by interviewees

	Topic	Description	Region/s
Testing	Improvement to Petiole standards	Re-assessing petiole standards in wine grapes. This could include creating different standards for different varieties, and/or regions, and determining the impact of variations in the taking, timing and transport of samples on the test results	Barossa, Coonawarra, Sunraysia
	Develop standards for sap testing and reporting	Growers suggested that lack of testing and reporting standards were a problem in regard to having confidence in sap testing techniques, reporting and recommendations	Coonawarra, Barossa, Heathcote
	Develop standards for leaf blade testing and reporting	Growers suggested that lack of testing and reporting standards were a problem in regard to having confidence in leaf blade testing techniques, reporting and recommendations	Barossa, Coonawarra, Sunraysia
Nutrient interactions	Regional responses of soil and grapes to nutrients	Research the response of the grapes to specific nutrients and soil types. Some growers felt that there is a large amount of general research and information on nutrition but when it comes to applying this knowledge to their individual vineyard site grower and consultant experience was still the only relevant knowledge.	Heathcote, Goulburn Valley, Coonawarra, Padthaway, Yarra Valley
	Interaction of nutrients, vines and soil	To research interaction between vine nutrients and soil. Mostly in relation to grape outputs, yield and quality	Heathcote, Padthaway, Coonawarra, Sunraysia
	Interaction of nutrients and microbes	To research the impact and importance of soil micro-organisms on nutrition status and availability	Padthaway, Strathbogie Ranges, Yarra Valley, Coonawarra, Sunraysia
	Influence of temperature on nutrient availability and uptake	There was a suggestion that grapes showed deficiency symptoms during colder months but once the temperature warmed up the symptoms disappeared. Therefore the grower was interested in research around soil temperature and nutritional availability/uptake	Padthaway
Specific Nutrient information	Nitrogen application at veraison	Research on the effectiveness of nitrogen application a veraison to help fermentation	Heathcote
	Micro-nutrients, yield and quality	Research into the specific effects of different micro nutrients on specific aspects of yield and quality, e.g. calcium and berry thickness, molybdenum and fruit set in Merlot	Heathcote, Sunraysia
Organic products	Effectiveness of organic products	To study the effectiveness of different organic products for addressing different nutritional and soil health problems, as limited scientific information exists in this field	Coonawarra, Padthaway, Strathbogie Ranges, Sunraysia, Yarra Valley
Product specific	Independent assessment of different fertilisers	To independently assess the contents and performance of conventional and alternative fertiliser products. Growers do not trust information provided by fertiliser company consultants, representatives or sales people.	Goulburn Valley, Coonawarra, Padthaway

	Topic	Description	Region/s
Fertigation	Effects of mixing fertilisers and other chemicals in spray tank	Effects of mixing different nutritional and pest management products together in the one spray tank to limit number of passes needed. Answer - What can and can't be mixed? Does mix alter the effectiveness of products?	Heathcote, Yarra Valley
	Fertigation products, systems and management	Cheaper, and easier to use fertigation products. Development of better automated and portable fertigation systems. More research on best management of applications through drippers e.g. timing etc.	Heathcote, Padthaway, Strathbogie Ranges
Soil Health	Avoiding, managing and reducing soil acidification	How to avoid, identify, manage and reduce soil acidification	Strathbogie Ranges, Yarra Valley, Bendigo

Appendix 3- Topics for extension suggested by interviewees

	Topic	Regions
Testing	How to interpret soil, petiole, sap and leaf blade tests	Barossa, Coonawarra, Heathcote, Sunraysia
	Differences between soil petiole, sap and leaf blade tests	
Nutrient interactions	Regional information on responses of soil and grapes to nutrients	Heathcote, Goulburn Valley, Coonawarra, Padthaway, Yarra Valley
	Information on the interaction of nutrients, vines and soil	Heathcote, Padthaway, Coonawarra, Sunraysia
	Information on the interaction of nutrients and microbes	Padthaway, Strathbogie Ranges, Yarra Valley
	Information on the influence of temperature on nutrient availability and uptake	Padthaway
Specific Nutrient information	Information on Nitrogen application at veraison	Heathcote
	Information on specific Micro-nutrients, on specific aspects of yield and quality. Such as Molybdenum on fruit set, and Calcium on berry skin thickness	Heathcote, Sunraysia
Organic products	Information on the effectiveness and use of organic products	Coonawarra, Padthaway, Strathbogie Ranges, Sunraysia, Yarra Valley
	Information on the effectiveness and use of microbial products	Coonawarra, Padthaway, Strathbogie Ranges, Sunraysia, Yarra Valley
Product specific	Independent assessment of different fertilisers conventional and otherwise	Goulburn Valley, Coonawarra, Padthaway
Fertigation	Information on effects of mixing fertilisers and other chemicals in spray tank	Heathcote, Yarra Valley
	Information on Fertigation products, systems and management	Heathcote, Padthaway, Strathbogie Ranges
Diseases and nutrition	Information on the effect of nutrition on Bunch Stem Necrosis (BSN). Note this is the only specific mention example however information on nutrition and other diseases may be quite relevant.	Coonawarra

ATTACHMENT 2:

Enhancing the uptake of wine industry innovations.

GWRDC final report. Project: DPI 06/06

Practice Change Research

The Use of Soil and Petiole Testing in Wine Grape Viticulture

March 2008

Megan Hill, Ben Rowbottom, Geoff Kaine and Nicole Dimos
Department of Primary Industries, Victoria

Victoria
The Place To Be

Australian Government
Grape and Wine Research and Development Corporation

ISBN 978-1-74199-976-1

Published by the Victorian Government Department of Primary Industries
Tatura, December 2007

Find more information about the Department of Primary Industries on the Internet at www.dpi.vic.gov.au

Authors:

Megan Hill, Ben Rowbottom and Geoff Kaine

Department of Primary Industries

Ferguson Rd

Tatura, Victoria 3610

Nicole Dimos

Department of Primary Industries

P.O Box 905

Mildura, Victoria 3502

Acknowledgments:
Thanks to the many people we have interviewed for this project. Thanks to GWRDC for funding this project and to Roger Ashburner, Fiona Johnson and Marg Watters for their contributions.

Table of Contents

Figures

Executive Summary

In this study we identified the benefits growers of wine grapes sought, and the problems they experienced with their use of soil and petiole testing. This knowledge was used to identify research and development opportunities. To collect this information we used methods proposed by Kaine (2004), and interviewed forty-five wine grape growers from nine Australian wine regions, on a range of nutrition-related topics including the use of soil and petiole testing. The results in regard to nutrition were described in Hill et al. (2007).

Results

The majority of wine grape growers interviewed had used, or were using either soil or petiole testing, or both, and regarded these tests as valuable tools to inform their management of soil and vine nutrition. The growers stated they used soil testing to see what nutrients were present in the soil, and petiole testing to see what nutrients the vines were actually taking up. The growers we interviewed were classified into market segments based on commonalities in their reasons for seeking the information obtained from the tests. The market segments were very similar for both soil and petiole tests. An individual grower could be in a number of market segments simultaneously, or could change market segments depending on the stage of their vineyard's development and circumstances in their vineyard.

Market segments

The growers interviewed were using soil tests to:

- Inform their pre-planting nutrition inputs (Segment 1)

Or they were using soil or petiole tests, or both, to:

- Understand a new vineyard (Segment 2)
- Evaluate changes in vineyard conditions or a new management practice (Segment 3)
- Diagnose a vine health problem (Segment 4)

- Monitor a problem in the vineyard (Segment 5)
- Monitoring for early detection of problems in the vineyard (Segment 6)

While most growers were satisfied that the tests provided the information they sought, a number of problems were raised with the testing which resulted in growers ceasing use of the tests and using other agronomic tests or changing service providers. The problems with soil testing related to varying methods of analysis being used, confusing presentation of test results, and inappropriate fertiliser recommendations being made based on the test results. Some growers stated that they had encountered similar problems when using petiole testing. Growers had additional problems with petiole testing, those being the short time frame in which petioles could be sampled (at vine flowering), the variability in test results, petiole test standards not being relevant to Australian conditions, and the length of time until the test results were received. These problems reduced the usefulness and accuracy of the petiole testing.

Opportunities for research, extension and future work

The problems growers had experienced with soil and petiole tests could provide opportunities for research and extension to improve the relevance and value to growers of soil and petiole tests in particular, and plant tissue tests generally. Specifically, there are opportunities for research and extension to improve:

- the relevance of petiole test standards to Australian conditions,
- the clarity and presentation of soil and petiole test results,
- the reliability of recommendations arising from soil and petiole tests,
- identify tissue tests that overcome the limited opportunities for conducting petiole tests

Further research could be conducted to estimate the size of the market segments we identified for soil and petiole tests and to determine why the use of tissue tests, such as sap tests and blade (leaf) analysis, is not more widespread.

Our findings also suggest that there may be common patterns in the reasons for using tools such as soil and petiole tests across horticultural industries. Therefore research and extension strategies used in relation to these tools in other industries may provide insights for the wine grape industry.

Introduction

Hill *et al.* (2007) found that soil and petiole tests were widely used by wine grape growers, and were considered to be valuable tools to assist in nutrition management. Yet some of these growers also stated that there were problems associated with the tests. In this study we investigated how and why these tests are used, and identified research and extension opportunities for improvement of the tests and their use. Other methods of agronomic testing, such as sap tests, were not within the scope of this study.

When conducting a soil test the grower or agronomist collects a number of soil samples at various depths and locations within the block, and sends them to a laboratory for analysis. The samples are analysed for micro-, macro-nutrients, pH, salt levels and possibly other characteristics, such as organic matter content, depending on the service provider and service purchased. The test results supplied to the grower contains information on these soil characteristics, and often information on the optimal ranges for these characteristics and recommendations on fertiliser applications, again depending on the service provided.

Petiole tests are conducted by collecting petioles (leaf stems) from the vines commonly at flowering. These petioles are then analysed to determine micro- and macro-nutrients levels present in the vine petioles. Again the results that are supplied to the grower usually include a range showing normal nutrient levels, and sometimes may include recommendations for fertiliser application.

Related Research

There have been a very few studies reporting on the adoption of soil testing in livestock and cropping industries[1] and none on the adoption of soil or petiole testing by viticulturists or horticulturalists in particular. However, Kaine (2004) has been applied to understand the adoption of soil testing in vegetable production (Bewsell and Kaine, 2001), soil moisture monitoring and sustainable practices in viticulture (Kaine and Bewsell 2001a, 2001b, 2002, Bewsell and Kaine, 2003), and soil moisture monitoring in pome and stone fruit (Kaine *et al*.

[1] The study by Kremer *et al.* (2001) into the adoption of the N-track self-administered soil nitrogen testing by farmers in Iowa is one of these.

2005). We will discuss these studies briefly as they are all related to technologies that test soil properties, and they are illustrating the use of Kaine's concepts (Kaine, 2004) in a range of horticultural industries.

Adoption of soil testing in vegetable production

As part of a study on the adoption of soil monitoring and irrigation scheduling practices in the Victorian vegetable industry, Bewsell and Kaine (2001) found that most vegetable growers in the regions they studied regularly used soil testing to determine the nutrient status of their soil so they could tailor their crop's fertiliser program. Bewsell and Kaine (2001) also found that these growers used soil testing when they had experienced, or anticipated that they may encounter a nutrition problem in a block. Bewsell and Kaine (2001) also found that the growers usually conducted soil tests when they were growing vegetables on a block new to them.

Adoption of soil moisture monitoring

Kaine and Bewsell (2001a, 2001b, and 2002) investigated the adoption of irrigation and soil moisture monitoring technologies in six Australian grape-growing regions, and developed recommendations for extension programs, again using a similar methodology to this study.

They found that soil moisture monitoring provided the most benefit to grape growers with pressurised systems who used it to tailor their irrigation inputs to meet their grape quality objectives. In particular growers with systems that applied smaller volumes of water, such as micro-spray and drip systems, had a greater need to monitor soil moisture than other grape growers. Growers also needed access to water on demand to be able to use soil moisture monitoring to meet grape quality objectives. The main benefits soil moisture monitoring provided to growers were in irrigation scheduling and controlling quality or vine vigour. Interestingly Kaine and Bewsell (2001a, 2001b, and 2002) did not identify water saving as a major factor motivating the adoption of soil moisture monitoring at that time.

Kaine and Bewsell (2001a, 2001b, and 2002) found some growers had adopted soil moisture monitoring but then ceased using the technology and concluded that these growers had used soil moisture monitoring to provide them with information while they were becoming familiar and confident with their new irrigation system. Once this was achieved growers no longer perceived that they needed to test soil moisture.

Bewsell and Kaine (2003) studied the adoption of sustainable pest and irrigation management practices, and the adoption of soil moisture monitoring in viticulture in New Zealand. Their findings regarding soil moisture monitoring adoption in New Zealand were similar to the findings for Australia. Soil type and the ability to control vine vigour and grape quality using irrigation were the main factors influencing adoption of water monitoring technology in New Zealand.

A study of the adoption of soil moisture monitoring techniques in the Goulburn Valley stone and pome fruit industry, found similar reasons for adoption to those found in New Zealand and other Australian industries (Kaine *et al.* 2005). Growers with pressurised irrigation systems and water on demand were found to be the highest adopters of soil moisture monitoring. The main benefits gained by growers of using soils moisture monitoring were controlling tree vigour, high water tables, salinity, or managing dwarf rootstocks (Kaine *et al.* 2005).

In short, these studies indicate that growers adopt techniques for testing soil characteristics when these created benefits by assisting:

- to solve problems in production (salinity, tree or vine vigour),
- in the management of constraints on production (limited water),
- in improving product quality (grape quality),
- in implementing new technologies or practices (changing irrigation systems).

Materials and Methods

This study consisted of four parts. These were:

1. Data collection to identify the factors that influenced the adoption of soil and petiole testing;

2. Data collection to identify problems associated with soil and petiole testing;

3. Analysis and interpretation of data to enable market segments to be identified based on the benefits growers were seeking from the tests; and

4. Identification of opportunities for research and extension in regard to soil and petiole testing

The theory and methods used in this study are reported in detail in Hill *et al.* (2007).

Results

Most of the growers interviewed had used soil and petiole testing at least once, and stated that they had found them a valuable tool when making decisions about vine nutrition. Growers offered a range of reasons for using the tests. The frequency of testing varied depending on the reason for testing. The growers we interviewed were classified into seven segments based on their reasons for using soil and petiole testing (see Figure 1).

Growers were initially partitioned into those that used testing and those that had not (segment 7). Growers that had used testing were first partitioned depending on whether they used soil tests to guide soil preparation prior to planting vines (segment 1). Those that were not using tests for pre-planting were then partitioned depending on whether they used testing to identify conditions in a new vineyard (segment 2). Growers were then sub-divided depending on whether they had changed management practices (segment 3), or had experienced a problem with vine health. The latter were partitioned into two segments

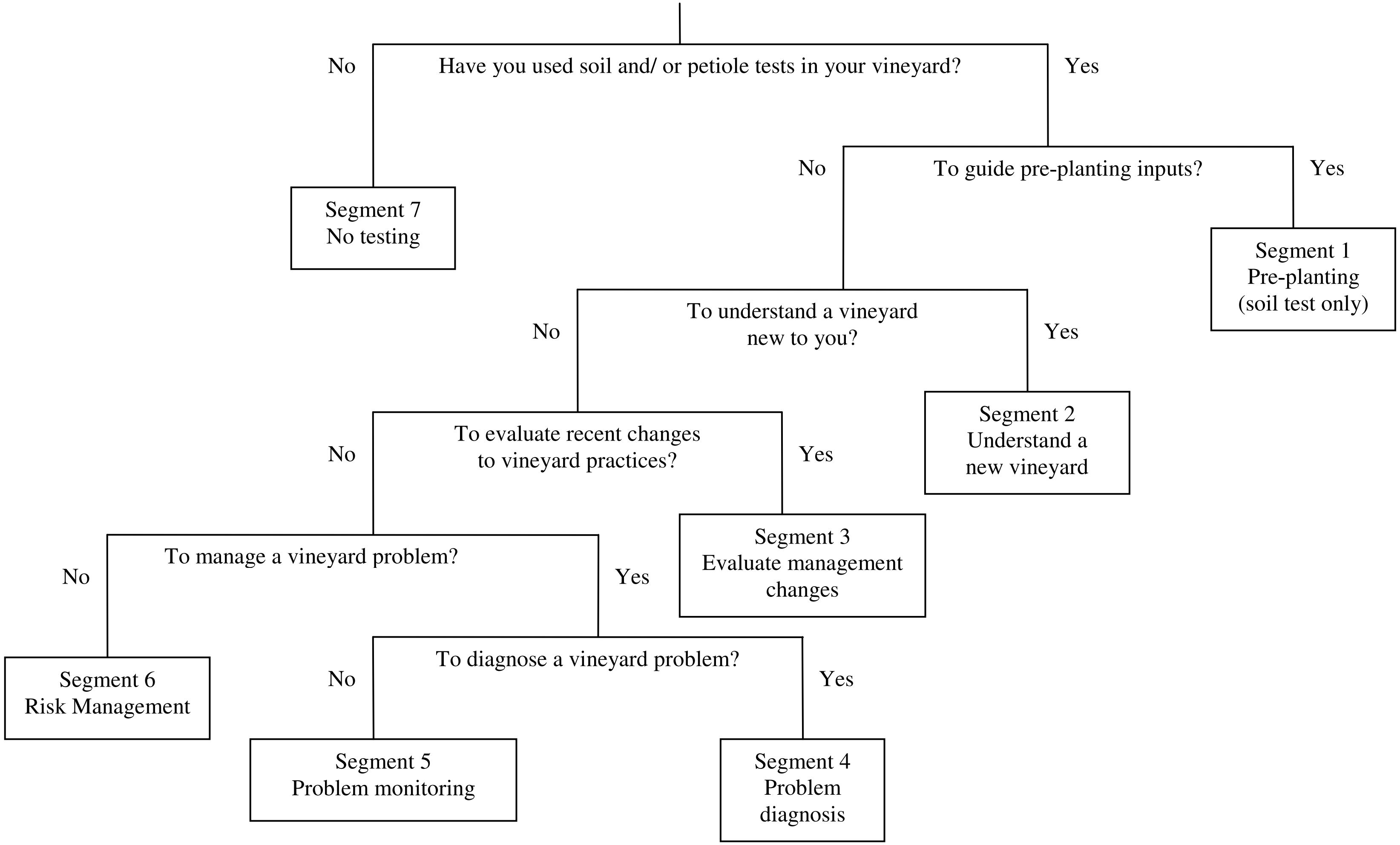

Figure 1: Market segments based on the benefits sought by growers by soil and/ or petiole testing.

depending on whether testing had been successfully used to diagnose and resolve the problem (segment 4) or testing was used to regularly monitor conditions in the vineyard to assist in the management of the problem (segment 5). The last segment consisted of growers that employed testing as a strategy to ensure early detection and correction of nutrition-related problems with vines (segment 6).

Individual growers may be members of two or more segments at the same time depending on their circumstances. For example, a grower could be a member of segment 1 (soil test pre-planting) while establishing a new block in their vineyard, and in segment 6 (petiole test annually to monitor nutrition) for established blocks in their vineyard.

Market Segments for Soil and Petiole Tests

Segment 1 – Pre-planting

Growers in this segment tested soil to determine the type and amount of inputs such as fertiliser, gypsum and lime they should incorporate, often by deep ripping, into the soil before planting new vines. The benefits growers in this segment sought from soil testing were to obtain information to plan their pre-planting nutrition program so as to maximise vine establishment and minimise nutrition problems in the future. Almost all of the growers we interviewed conducted soil tests at this stage, even if some of them conducted no further soil or petiole testing.

Laura, a grower from the Strathbogie Ranges said

> *"I had the whole vineyard site soil tested before I planted. I wanted to make sure that I got the right amounts of lime, gypsum and super phosphate down the rip lines to give the vines a strong start. If you miss that chance you will run into problems later, and are always trying to fix something up that you should have taken care of before."*

Similarly, a grower of super premium Merlot, Shiraz and Sauvignon Blanc in the Yarra Valley said

> *"I had a soil test done before planting the vines. I wanted to know if I had to add anything to the soil, or if I was going to run into problems. This land was under orchard before I planted vines.*

The test showed that there were no pH problems or nutrient deficiencies. I have dug an occasional hole to look at worm activity since, but I haven't done any more testing. If I saw a problem, I would do both soil and petiole tests"

Most of the growers interviewed said that they were satisfied that the soil tests provided them with the information they needed in this regard. A few growers reported that they had problems with preplanting though they indicated these were because of the misinterpretation of test results or incorrect recommendations they received based on the test results, rather than because of problems with the test itself.

The members of this segment correspond with the members of first segment in Hill *et al.* (2007).

Segment 2 – Understanding a new vineyard

Some of the growers we interviewed used soil and petiole testing for a few years "to get a handle on things", that is, to obtain information about the conditions in a vineyard that was new or unfamiliar to them.

The growers in this segment tended to use soil and petiole tests for three to five years, after which they said they understood the nutritional requirements of the vineyard and how the soil and vines responded to the fertilisers and products they were using. Testing over this period gave the growers the confidence that their nutrition program was working and they were not going to run into serious nutrition problems in the future.

Michael, a Bendigo grower managed a vineyard with Shiraz, Cabernet Sauvignon, Semillon and Riesling varieties. Michael used petiole testing while he was new to the vineyard:

"I've done petiole analysis in the past. It definitely helped us set our fertiliser program. We have got a handle on it now though, we were getting the same results all the time and the site has fairly well balanced vines, so it's not worth testing anymore".

Tony is a Sunraysia grower, with vineyards on three different properties. Tony said

"I used to monitor the water and do soil and petiole testing. It gives you the information to make sound, informed decisions. But with falling grape prices and rising costs I don't do it anymore.

The soil tests always came up good, and never identified any problems. I kept doing petiole tests until I saw the trends, until I got a good handle on it. You need to combine science with experience to be successful".

The growers in this segment said that testing provided them with the information they needed.

Segment 3 – Evaluate management changes

Growers in this segment used soil and petiole testing for a limited period to evaluate and understand the impact of management changes they had made in their vineyard, either on the soil characteristics (soil test), the vines nutrition status (petiole testing), or both (soil and petiole test). Examples of the management changes that were evaluated were; using a new nutrition product, changing the fertiliser rate, mulching the vineyard or installing drip irrigation. These growers used the tests for a few years until they felt that they "had a handle on things" and understood the implications of the changes they had made, then they ceased testing.

For example Bill, a grower in Sunraysia with wine grapes, told us

"When I installed drippers I had soil pits dug and the soil tested. I wanted to know if the new irrigation system would affect the nutrient availability of my soil. It turned out I've got uniform soils and the change to drippers didn't have enough effect (on nutrient availability) for me to need to change my fertiliser program".

Hayden manages vineyards in the Coonawarra region for a medium sized wine producer. In recent years organic sprays, mulches and manures have been included in his nutrition program and he was interested to know if these changes had improved soil health and nutrient status. Hayden said

"We are trying to go for softer options now, conventional (fertilisers) are not as good for soil, they kill off the bacteria and fungi in soil, which damages the soil structure and reduces nutrient uptake. I will do a soil test this year which will include a biological test because I haven't done one for a while and I want to know if these (organic) products are helping".

The growers in this segment said that they had not experienced any problems with soil and petiole testing.

Segment 4 – Problem diagnosis

Growers in this segment used the tests to try to determine why vines were looking unhealthy or weak, for example if vine growth was sparse or the leaves were discoloured. The growers said that when they found unhealthy vines, they first checked the vines roots for damage and then conducted soil and petiole tests to determine if the cause was nutrient or soil related. The growers conducted soil tests if they believed the cause was most likely soil related and petiole tests if they believed the cause was most likely related to the vines current nutritional status.

For instance Chas, who grows vines in the Goulburn Valley, said

> *"I had a soil test done because I had a problem in the vineyard and was trying to rule out a number of possibilities. I'd looked at the roots, water, soil and weeds, but there was no problem with these so I thought I'd better look at nutrition. I tested an area of healthy and an area of sick vines and the tests results all looked the same. This made me realise it may be a pest issue. It turned out that the sick vines were infested with phylloxera".*

Dave grows red wine varieties in the Barossa Valley, Dave said

> *"If I see an issue with my vines I get a petiole test done. I tested some Shiraz five years ago, the test showed the vines had a boron deficiency. I had a feeling that was the problem because the vines looked so ordinary. The test confirmed that that was the problem".*

The benefit growers in this segment sought from soil and petiole testing was identification of the cause of their vine health problem. If the problem was related to nutrition they wanted to know which nutrients would best solve the problem, in regard to the best fertiliser or soil treatment to apply.

The benefits this segment sought from soil or petiole testing were not realised if:

- There was more than one factor causing the problem with vines

- The cause was related to nutrition but the vines were not flowering, so petiole testing could not be conducted

- The test recommendations were inaccurate, incorrect or not suited to the site

Segment 5- Problem monitoring

Growers in this segment regularly used soil and petiole tests to monitor a problem they were experiencing such as soil salinity or nutrient deficiencies, or a situation they believed could develop into a problem such as acidity levels. The growers in this segment indicated that they had identified the source of the nutrient imbalance, hence they were not members of Segment 4, and while they may be adjusting their fertiliser program to address the nutrient imbalance they were not planning major management changes (Segment 3).

An example of a grower in this segment was Sarah who manages vines for a corporate Coonawarra vineyard. Sarah said

> *"We are worried about our soil salinity levels, so we soil test regularly. We also use soil tests in problem areas to confirm petiole test results, which we conduct every year. We use petiole tests mostly because they have standards and they give us a better indication of what the plant has taken up, rather than what is there (in soil) but not available. We just want to make sure things are not getting out of hand".*

Ken manages a large vineyard in the Strathbogie region. Ken said

> *"I have variable soils, with some of the patches of sandy loam being a bit acidic. I have had the soil tested in the past and am due to do it again this year. I also petiole test different blocks each year, especially targeting the problem areas. One of the reasons I got soil tests done was because I just wasn't getting enough yield and vigour in the vineyard. Some of this is probably due to the dry years, but not all of it. The soil tests showed increased acid levels, which decreases the nutrient availability. So I have stopped using urea and super phosphate, and have used chook manure, lime, rock phosphate and mulch for the last two years to improve soil health".*

Segment 6 – Risk management

Growers in this segment have tests done regularly to monitor conditions in their vineyard, even though they do not have any significant soil or nutrition-related problems. These growers indicated that they like to have tests conducted regularly as this gives them peace of mind that their vines nutrition needs are being met, desired production goals (yield and quality) will be achieved, and that problems will not emerge that will catch them unprepared. Other growers in this segment used soil and petiole test results when liaising with vineyard owners, chief viticulturists, finance managers or wineries about grape quality, vineyard planning or management or budgets. Essentially an unexpected nutrition problem poses a major risk for these growers and this risk can be easily and inexpensively managed by soil or petiole testing.

Kingsley runs a Managed Investment Scheme vineyard in Heathcote. Kingsley told us

> *"We base our rate of fertiliser application on soil and petiole tests, testing nine out of seventeen blocks each year. In April we soil test and put out any necessary ameliorations we need to meet our production targets. The tests help me to convince the finance people we're doing the right thing, and we need the test results to get the fertiliser allowance we need".*

Francis manages a vineyard in the Yarra Valley that sells most of its fruit to local wineries to make ultra-premium wines. Francis said

> *"Since the initial work (pre-planting lime and gypsum) I haven't done anything in regard to nutrition. This block was under pasture for beef cattle before it was developed as a vineyard, so it had been top dressed annually and has plenty of residual fertiliser. I soil and petiole test alternative blocks yearly. I'm building up a reference data bank because I want to make sound decisions about fertiliser applications based on information. Everything seems to be in the ideal ranges, and the pre-planting inputs are still holding up. It's important that the vines have enough nutrients, but not too much. The best way to get premium fruit is to monitor your vine nutrition and keep it spot on".*

Segment 7- No tests

The few growers we interviewed that had not used soil or petiole testing had either inherited established vineyards or had extensive experience in growing vines in their vineyard. These growers said that they use the same nutrition program each year, and, if any problems had occurred, they had been able to identify the cause of the problem and solve it. The growers in this segment were satisfied with the performance of their vineyards and said they did not require the information soil and petiole testing would provide.

Angello is a Sunraysia grower of both wine and dried fruit grapes. Angello said

> *"I don't soil or petiole test, I just look at the vines. If the vines start to look poor I fertilise with nitrogen. I don't seem to have any soil or nutrition problems, the vines usually look fine".*

Another example of a grower in this segment was Bill who has been growing wine grapes in the Barossa valley for 25 years. Bill said

> *"My grandfather started this vineyard in the 1920s, then my father ran it and I've run it for the last 25 years, I grew up working it so I've got a lot of experience and know this vineyard. We put in a cover crop and the rest takes care of itself, if the cover crop looks healthy then I assume the nutrients are all right. I don't see any nutrient deficiencies, so I don't do any tests. Our Shiraz is close to top of the range so there is no reason to mess with that".*

Problems associated with soil tests

A number of the growers we interviewed stated that they were not entirely satisfied with some aspect of their soil or petiole tests. In a few cases these concerns resulted in the growers either changing the type of test they used, changing their service provider, or ceasing use of the tests. The problems growers described with soil tests were as follows.

Analysis of the samples

A few growers said that they were confused by the results of their soil tests because different service providers use different methods of analysis. Different methods produce different results which can be confusing or even misleading. These growers sought to manage this problem by using the same service provider each year where possible.

What the test measures

A small number of growers were concerned that the standard soil tests did not reveal anything about important aspects of soil health, such as organic matter, microbial activity, acidity, salinity and soil structure.

Presentation and interpretation of the test results

Some of the growers interviewed said that they found the presentation of test results extremely difficult to understand or confusing. They stated that the results were often only presented as numbers without supporting information to enable the grower to determine the implications of these numbers. These growers then had to have the test results interpreted by another service provider such as an agronomist or fertiliser reseller. This added further expense to the testing procedure, and the grower had to trust that the service provider was correct in their interpretation.

Recommendations arising from test results

Growers indicated that they had experienced problems in regard to the recommendations arising from test results. Some of the growers interviewed said that the fertiliser recommendations written by some of the service providers, especially those linked with fertiliser companies, suggested applications of fertiliser were required that they, the grower, believed were excessive, were not appropriate to their vineyard, or did not include the product or brand best suited for their vineyard or their preferred methods of application. Rather the growers suggested that the recommendations favoured the resellers own products and brands. A small proportion of the growers we interviewed found that the nutrition needs of their vines had not been met by following the fertiliser recommendations.

Some growers dealt with these problems through gaining experience with fertiliser products on their vineyard and talking to other growers or experts who understood the specific characteristics of their location. Some growers used a consultant to design their nutrition program, while others used independent soil test service providers. Growers also spent time learning about tests results, vine nutrition and fertilisers.

Opportunities to improve soil tests

On the basis of the interviews with growers we concluded that soil tests would be more useful to grape growers if:

- common methods and units of analysis were used to test soils,
- tests and services were offered to evaluate aspects of soil health,
- guidelines were developed on interpreting soil tests results and the implications of these results in regard to product choices and product application rates.

Problems associated with petiole tests

Petioles are sampled for tests when the vines are flowering. Growers stated that this provided them with a narrow window of opportunity to conduct petiole tests and, if they missed this opportunity, they must wait a year before flowering occurs in the following season and there is another opportunity to petiole test.

Many growers said they felt the standards used to define deficient, optimum and toxic nutrient ranges in petiole tests were not always consistent, nor relevant to the grape varieties, and growing conditions found in Australia. Many of the growers believed that the current standards could only be used as a rough guide and therefore did not have complete confidence in the interpretation of petiole test results. Hence, recommendations based on the tests should be treated with caution.

Some growers dealt with this problem by collecting data from the tests over a number of years to identify trends in nutrient levels, rather than relying on the results of a single test.

Growers also said that when they use petiole testing the results and recommendations were not always returned to them in time for any nutrition management to be implemented that same season.

Other growers suggested that petiole tests only provide a snapshot of what is in the vine at that specific time, and that they had found that the results varied season to season, without any obvious explanation.

Growers said that these constraints limited the usefulness of petiole tests as a management tool, making it necessary to collect the petiole results over a number of years to build up sufficient data to identify trends in nutrition levels. Some growers had begun using sap or leaf blade tests to gather information on plant tissue nutrition levels at different times of the year. However industry standards have not yet been developed for these tests (Dimos pers.comm).

Opportunities to improve petiole tests

On the basis of the interviews with growers we concluded that there is a need for a plant tissue test that could be conducted any time during the growing season and that uses standards developed for Australian conditions. The usefulness of petiole tests could be improved if test results could be returned more promptly to growers and if the results were presented in a format that is easier to interpret.

Discussion

The findings of this study were that most of the growers we interviewed considered soil and petiole tests to be valuable management tools that assisted them to reach decisions in relation to determining nutrition requirements prior to planting vines, identifying the reasons for unhealthy vines, understanding conditions in vineyards, evaluating changes in management practices, and monitoring soil problems or monitoring for early detection of problems relating to soil and vine nutrition.

However, some of these growers also reported there were some major weaknesses associated with these tests. This suggests that, while growers do obtain useful information from soil and petiole testing, they would find tests that overcame these weaknesses attractive. In this regard it would be interesting to investigate the use of the other agronomic tests available, such as sap testing or leaf blade analysis, to determine why these tests are not as widely used as soil and petiole tests.

Our findings also suggest that there may be common patterns in the reasons for using tools such as soil and petiole tests across horticultural industries. Studies have shown that wine grape, fruit and vegetable growers all used soil moisture monitoring technology to identify problems, to detect the emergence of problems, to monitor problems, and to manage product quality (Kaine and Bewsell 2001a, 2001b, 2002, Bewsell and Kaine 2003, Kaine *et al*. 2005). These findings correspond closely to our findings in regard to the market segments for soil and petiole testing.

Interestingly, Bewsell and Kaine (2001) found that, similar to the wine grape growers in segment 1 in this study, vegetable growers usually conducted soil tests when they moved to a new lease. Bewsell and Kaine (2003) found that some grape growers in New Zealand reported they no longer used soil moisture monitoring after a few years as they had become familiar enough with conditions in their vineyards to confidently anticipate the results of monitoring. This is similar to the wine grape growers in segments 2 and 3 in the present study, which stopped using soil and petiole testing once they were sufficiently familiar with conditions in their vineyards.

Further, Kremer *et al.* (2003) found similar themes regarding the low adoption of the N-track self-administer soil nitrogen test amongst Iowa, farmers. Kremer *et al.* (2003) found that farmers who rejected, or initially adopted then discontinued use of the N-track test found it incompatible with their needs. Some of these farmers behaved very similar to segments 2 and 3, in that they stopped testing after a few years because they had developed a good understanding of their crop nitrogen requirements.

This suggests that experience in developing and promoting diagnostic and monitoring tests in one horticultural industry could be useful when planning research and extension programs for similar types of tests in other industries.

Conclusion and Future Work

Soil and petiole tests were widely used by wine grape growers to assist them in vine nutrition and soil management. However we found growers had experienced some problems with these tests. These could provide opportunities for research and extension to improve the relevance and value to growers of soil and petiole tests in particular, and plant tissue tests generally. Specifically, there are opportunities for research and extension to improve:

- the relevance of petiole test standards to Australian conditions
- the presentation and interpretation of the results of soil and petiole tests,
- the reliability of recommendations arising from soil and petiole tests,
- identify tissue tests that overcome the limited opportunities for conducting petiole tests

Further research should be conducted to estimate the size of the market segments we identified for soil and petiole tests and to determine why the use of tissue tests, such as sap tests and leaf analysis, is not more widespread.

References

Bewsell, D. and Kaine, G. (2001). Soil Monitoring, Irrigation Scheduling and Vegetable Production. Client Report, Prepared for New Zealand Winegrowers. AgResearch Ltd, NZ.

Bewsell, D. and Kaine, G. (2003). Adoption of Sustainable Practices in the Wine Grape Industry. Client Report, Prepared for New Zealand Winegrowers. AgResearch Ltd, NZ.

Dimos, Nicole Soil Scientist, Department of Primary Industries, Irymple.

Hill, M., Rowbottom, B., Kaine, G., and Dimos, N. (2007) The Management of Nutrition in Wine Grapes. Milestone Report, Prepared for Grape and Wine Research Corporation. Department of Primary Industries, Victoria.

Kaine, G. (2004). Consumer Behaviour as a Theory of Innovation Adoption in Agriculture. Social Research Working Paper, 01/04. AgResearch, NZ.

Kaine, G. and Bewsell, D. (2001a). Managing Irrigation for Grape Production, Interim Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G. and Bewsell, D. (2001b). Managing Irrigation for Grape Production, Second Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G. and Bewsell, D. (2002). Managing Irrigation for Grape Production, Third Report to the Victorian Department of Natural Resources and Environment, School of Marketing and Management, University of New England, Armidale.

Kaine, G., Bewsell, D., Boland, A. and Linehan, C. (2005). Using Market Research to Understand the Adoption of Irrigation Management Strategies in the Stone and Pome Fruit Industry. *Australian Journal of Experimental Agriculture.* 45 (9):1181-1187.

Kremer, K.S., Carolan, M., Gasteyer, S., Tirmizi S.N., Korsching, P.F., Peter, G. and Tong, P. (2001) Evolution of an agricultural innovation: the N-Trak soil nitrogen test – adopt and discontinue, or reject? *Technology in Society.* 23 (1):98-108.

ATTACHMENT 3:

Enhancing the uptake of wine industry innovations.

GWRDC final report. Project: DPI 06/06

Practice Change Research

The Market Potential of Tannin Related Innovations in the Wine Industry

June 2007

Megan Hill and Geoff Kaine
Department of Primary Industries, Victoria

Victoria
The Place To Be

Australian Government
Grape and Wine Research and Development Corporation

ISBN 978-1-74199-858-0 (print)
ISBN 978-1-74199-859-7 (PDF)

Published by the Victorian Government Department of Primary Industries
Tatura, June 2007

Find more information about the Department of Primary Industries on the Internet at www.dpi.vic.gov.au

Authors:

Megan Hill and Geoff Kaine

Department of Primary Industries

Ferguson Rd

Tatura, Victoria 3610

Acknowledgments:
Thanks Chris Linehan, Ben Rowbottom, Ruth Lourey, Guido Vazzoler and Roger Ashburner for assistance and input. Thanks to the multitude of people we have interviewed and pestered for information, including Mark Krstic and Mark Downey from the Winegrape Tannin Project research team. Thanks Vic Wright for editing and comments. Finally thanks to John Harvey from GWRDC for his support.

Table of Contents

Executive Summary

In this study we aimed to identify the market for innovations related to wine grape tannins. These innovations are currently under development as part of a research project funded by Grape and Wine Research and Development Corporation and the Department of Primary Industries. The innovations relate to the identification, measurement and modification of natural and exogenous tannins. Natural tannins are compounds which occur in the seeds, skins and stalks of grapes, and are an important component of red wine quality as they contribute to the structure, colour, complexity and mouth feel of the wine. Tannins can also be added in an exogenous form to grape juice in the winery to influence the characteristics of the resulting wine. Exogenous tannins are used in the winery in response to the natural tannin content of the grapes being processed and the quality and style of the wine being produced. Winemakers use oak to provide flavour but do not see oak as exogenous tannin.

We drew on Porter's (1985) framework for understanding competitive strategy to guide our research. Briefly, this framework characterises the purpose of commercial businesses as being the creation of profit. Businesses seek to establish a competitive advantage over competitors in order to remain profitable. There are two sources of competitive advantage – low cost and differentiation. Businesses will be most interested in adopting innovations that contribute to these sources of competitive advantage. Consequently, our approach was to understand the use of tannins by winemakers and how this contributes to the competitive advantage of wineries. This understanding then allowed us to draw inferences about the innovations in tannin measurement and management that may appeal to winemakers.

Data was collected by interviewing a range of wine grape growers, grower liaison officers and winemakers from selected Australian wine regions. Interview questions covered: current practice in managing natural tannin content when growing wine grapes, winemaking practices in regard to natural and exogenous tannins, and creating and maintaining competitive strategies in the wine industry. We also sought to identify problems related to tannins, or gaps in the information available on tannins.

We found that winemakers are the primary the market for tannin-related innovations. This is because tannins, both natural and exogenous, determine the characteristics of wine and the

winery processes required to achieve this. Should wineries commence paying for grapes on the basis of specific tannins, we envisage that innovations that provide vineyard protocols to modify tannins will become important to grape growers.

We classified winemakers were into six market segments depending on the benefits they were seeking from using exogenous tannins. Segment one consisted of winemakers that used exogenous tannins primarily to stabilise wine colour. Winemakers in segment one were mainly from hot wine-growing regions where, the winemakers said, the growing conditions can result in fruit that is poor or unstable in colour. Consumers view weak wine colour as indicating poor wine quality.

This segment of the wine industry is competing on a cost advantage so they are interested in innovations that allow them to reduce the costs of production. Therefore, tannin-related innovations that could potentially reduce costs through tailoring or reducing inputs and increasing the efficiency of winery processes would be of interest to these wineries.

Segment two consisted of winemakers that primarily used exogenous tannin to try to mask fruit faults. The major fruit fault was green flavours or tannins. These tend to occur in the cooler wine regions or when the growing season in cool. They give the wine astringent, bitter flavours which consumers often find too strong, or unpleasant.

Winemakers in segment two were seeking a differentiation advantage. Smaller wineries were following a focus differentiation strategy while larger wineries appeared to be following a broad differentiation strategy. Winemakers in this segment will be interested in innovations that support their point of differentiation. Innovations of interest to them may relate to the identification and measurement of green tannins, and vineyard protocols to manage green tannins. Exogenous tannins and winery processes to remove green tannin and characters may also be of value.

Winemakers in segment three followed a focus differentiation strategy by using exogenous tannins in conjunction with other wine-making processes to create wines with specialised characteristics, such as a European style in their wine. The winemakers in this segment will be interested in exogenous tannins that can add new features or deliver existing features to their wines more reliably.

The winemakers in segment four used the addition of exogenous tannins as a risk management strategy. These were small-to-medium wineries that were using relatively inexpensive exogenous tannins as a preventative measure to ensure problems with wine colour, complexity and flavour did not arise. These wineries followed a focus differentiation strategy if they were small or a broader differentiation focus if they were medium-sized. Their differentiation was based on a range of characteristics including aspects of their wine, site, region, heritage, and so on. This segment may be interested in innovations that allow them to reduce or cease their exogenous tannin inputs, or provide novel exogenous tannins that are even less expensive or more effective than those that are currently available.

Winemakers in segment five did not use exogenous tannins due to differentiating their wines on the basis of using minimal additives in the winery. This segment may be interested in vineyard protocols to modify natural tannins in the grapes as they have fewer alternatives than their conventional counterparts to manage tannins in the winery.

Winemakers in segment six did not use exogenous tannins either. These winemakers found that the grapes grown in their region had superior natural tannins. These wineries were following a focus differentiation strategy based on the natural quality of their wines and are unlikely to be interested in tannin-related innovations.

Introduction

In this paper we report on the first stage of study titled “Enhancing the uptake of wine industry innovations through the development of targeted extension programs”, to trial techniques for understanding the adoption of innovations in an agricultural context. These techniques include an approach developed by Kaine (2004) to identifying and quantifying the potential market for an agricultural innovation and techniques for identifying and quantifying the potential market for an agricultural processing innovation based on Porter (1985).

The objective for this first stage in the study was to identify the potential market for innovations concerning tannins in grape and wine production that are currently being developed as part of the Grape and Wine Research and Development Corporation-funded project “Viticultural management of grape tannin and anthocyanin levels to achieve desired wine quality specifications” (the “tannin project”). The innovations under development relate to the identification, measurement and modification of natural tannins in the vineyard.

Background

Australia's competitive advantage in the global wine market is due to its capacity to produce a wide variety of quality wines at competitive prices (Invest Australia 2005). To maintain this advantage in an ever-changing market place, it is essential that the Australian Wine Industry continues to raise wine quality in each price segment of the market (Krstic 2005). Given this context the development of techniques for improving the management of the compounds in wine that influence quality is of fundamental importance to the industry.

A complex group of phenolic compounds which occur in wine grapes, known as tannins, is a major contributor to wine quality. These compounds, combined with other compounds such as anthocyanins and organic acids, contribute to the flavour, aroma, structure, colour, mouth feel, and hence quality, of wine (Krstic 2005). Tannins occur naturally in the seeds, skin and stalks of grapes. The type, amount and structure of the tannins in grapes depends on a range of factors including vineyard site (climate, soil, water etc), vineyard practices (irrigation, canopy management, yield etc), and plant genetics (variety, clone, rootstock and scion).

Grapes are harvested and crushed in wineries. In Australia, the white wine juice is traditionally pressed off the skins and removed. As a result, Australian white wines are low in tannins. Red wine juice is left on the grape skins and seeds while it ferments. This process releases natural tannins and anthocyanins into the juice. Hence, red wines tend to be high in tannins and these give red wine its structure, flavour and colour.

Tannins can also be added to the wine in an exogenous form. These are added during the winemaking process, and can be divided into two groups, oak and "other" products. Oak barrels are traditionally used in winemaking. The wine is put in the barrels to imbue the wine with the oak flavour. However, oak barrels are expensive and modern wine makers now have access to a range of oak products such as powder, chips or planks. "Other" exogenous tannins are usually packaged in a powdered form and are derived from a range of sources, including grape seeds, chestnut tree wood or other types of wood.

Methods and materials

Preliminary interviews revealed that, at present, the composition of natural tannins in wine grapes cannot be reliably and precisely influenced by vineyard practices – largely because techniques for identifying and measuring tannins are yet to be developed. Consequently, the principal means of influencing wine quality by altering the composition of tannins in wine juice is through the addition of exogenous tannins during processing. This means that the primary interest in techniques for the identification, measurement and management of tannins would lie with wineries in the first instance.

The interest of wineries in such techniques would depend on the contribution of natural and exogenous tannins to their competitive advantage. As a result, we drew on Porter's (1985) concepts of competitive advantage and generic competitive strategies to identify market segments among winemakers in the use of exogenous tannins. We then used our knowledge of these segments to form inferences about the likely nature of their interest in techniques for the identification, measurement and management of tannins.

In the next section we describe Porter's (1985) competitive advantage and generic competitive strategy.

Competitive advantage and competitive strategy

Porter (1985) argued that to remain profitable in the longer term businesses must create a sustainable competitive advantage. A competitive advantage arises from combining activities that are valuable, rare, or difficult to imitate and provide the basis for the creation of value for buyers. Generally speaking, there are two basic types of competitive advantage – low cost and differentiation. These give rise to three types of generic competitive strategies depending on the scope of the business in terms of market coverage – cost leadership, differentiation and focus (see table 1).

Competitive scope		Competitive advantage: *Lower Cost*	Competitive advantage: *Differentiation*
	Broad Target	1. Cost Leadership	2. Differentiation
	Narrow Target	3A. Cost Focus	3B. Differentiation Focus

Table 1: Three generic competitive strategies (adapted from Porter, 1985).

The cost leadership and differentiation strategies seek competitive advantage with a single offer across all market segments, while a focus strategy aims at cost or differentiation advantage in one or a limited number of market segments. Porter (1985) observed that a critical influence on the adoption of a new technology by a business would be the potential contribution of a new technology to the competitive advantage and strategy of the business.

Cost leadership strategy

A winery seeking to follow a cost leadership strategy sets out to be the low cost producer in its industry, in a broad range of market segments and price points. To achieve this, a winery must be aware of, and make use of, all sources of cost advantage (Porter 1985). Typically, a cost leader sells a standard, no frills product focusing on economies of scale, processing efficiencies, or preferential access to materials. To be successful their customers must perceive the product as being adequately comparable in quality to rivals' products. A cost leader is most interested in innovations that lower production costs (refer to table 2).

Differentiation strategy

A winery following a differentiation strategy seeks to provide unique attributes or benefits that are valued by customers in a range of segments in the market. Differentiation can be based on the product itself, the delivery system by which it is sold, the marketing approach, and a broad range of other factors. The business aims to achieve a price premium for this uniqueness greater than the cost of differentiating, while maintaining cost parity or proximity to its competitors by reducing cost in all areas that do not affect differentiation (Porter 1985). To be effective a business must choose attributes that enable meaningful differentiation from rivals' products in the eyes of customers. Businesses adopting a differentiation strategy are attracted to innovations that lead to new features or enhancement of existing features, of products or services (refer to table 2).

	Cost Leadership	Differentiation	Cost Focus	Differentiation Focus
Aim of Product Innovation	To reduce product cost by: Lowering material content, Facilitating ease of manufacturing, Simplifying logistical requirements, etc.	Enhance product quality, features, deliverability, or switching costs (for customers to change supplier)	To design in only enough performance for the target segment's need	To meet the needs of a particular segment better than broadly-targeted competitors
Aim of Process Innovation	Reduce material usage or lower labour input Enhance economies of scale	Greater quality control, more reliable scheduling, faster response time to orders, and other dimensions that raise buyer value	To tune the value chain to a segment's needs in order to lower the cost of servicing the segment	To tune the value chain to segment needs in order to raise buyer value

Table 2: The aim of product and process innovations in relation to Porter's Generic Competitive Strategies (adapted from Porter 1985)

Focus strategy

Porter's third generic strategy is focus. Whereas cost leadership and differentiation present product offers that meet an average of the different preferences across distinct market segments, a winery following a focus strategy would select one or only a few segments within the market upon which to target their product. Within this target the business can seek either a cost or a differentiation advantage. By targeting a narrower range of customers the business seeks to service them more effectively and efficiently than its rivals (Porter 1985). A business following this strategy would be interested in innovations that support its basic strategy in the context of its specific targeted segment or segments and their preferences (refer to table 2).

The significance of these strategic alternatives is that they are, according to Porter (1985), mutually incompatible. Success in differentiation requires a prevailing concern in the business with understanding and meeting customer needs. With cost leadership the prevailing concern is to drive down costs. While a differentiator cannot completely ignore costs, and a cost leader cannot completely ignore changes in wines being offered in the market, the emphasis in the modus operandi of each will be defined by their strategy. Whenever a decision requires a choice between a focus on the customer or a focus on costs, it will be resolved according to the basic strategy. This includes consideration of innovations.

Competitive strategy, innovation and technology

Since technology is embodied in every activity in a business and is involved in creating linkages among activities it can have a powerful effect on the capacity for lowering cost and promoting differentiation. The technology adopted by a business must support its competitive strategy to be of benefit. Innovations vary in the potential improvement they offer in performance of activities that can create a competitive advantage. A technological innovation may offer cost reduction and/or differentiation possibilities. It may have positive, negative or neutral implications for differentiation and costs, respectively. Wineries would be expected to exhibit greatest interest in innovations which support their strategy as it is these that offer the greatest contribution to achieving competitive advantage. In effect, once their strategy is known, there is a predictable bias in their interest in any specific innovation.

Hence, whether innovations in the identification, measurement and management of tannins will be adopted by a winery will depend on how the innovation fits into their business and whether it enhances or creates a competitive advantage given the competitive strategy of the business.

A caveat to the above is the 'rising tide' effect of some innovations. An innovation that redefines the set of product features that all customers regard as the acceptable minimum may even force adoption by a cost leader. Alternatively, an innovation that drives costs down substantially may catch the attention of even a differentiator. The analyst has, as we have here, to be mindful of such second-round effects when considering specific innovations (Vic Wright pers.com).

Data Collection

Convergent interviewing techniques (Dick 1998) were used to collect the data. The convergent interviewing method is unstructured in its content. The interviewer employs laddering techniques (Grunert and Grunert 1995) to systematically explore the reasoning underlying the decisions and actions of the interviewee. The power of this interview process lies in identifying common and complementary patterns of reasoning among interviewees (Kaine et al. 2005). Interview responses were recorded manually by two interviewers, summarised and analysed using case and cross-case analysis (Patton 1990).

Twenty-seven interviews were conducted with grape growers, grower liaison officers, winery technical officers and wine makers. The interviewees were from cool (Coonawarra), warm (Nagambie, Colbinabbin and Rutherglen) and hot (Sunraysia) wine grape producing regions. They represented large, medium and small, family and corporate businesses, and all of the quality grades of wine (see appendix 2).

In the interviews the following matters were covered: current practice in managing natural tannin content when growing wine grapes, winemaking practices in regard to natural and exogenous tannin and creating and managing competitive strategies in the wine industry. We also sought to identify problems in relation to tannins and gaps in the information available on tannins.

Results

The market for innovations from the Tannin Project

Wine grape growers produce grapes to make wine, or to sell to wineries. The price the wineries pay for grapes is usually based on how well the fruit meets their quality requirements. During the interviews we did not find any growers being paid, or wineries paying for, grapes based on their tannin attributes. Consequently, the growers we interviewed said that understanding, measuring or modifying the tannin content of their grapes was not a priority for them.

This situation could change if wineries start including specific tannin attributes in their assessment of the quality of grapes when setting grape prices. If this occurs, innovations such as vineyard protocols to assist growers to modify their grapes and meet quality specifications, and obtain higher prices, would become attractive to growers.

While we did not find any growers receiving higher prices due to the tannin attributes of their grapes, we heard of growers being paid less. A winery representative who purchases grapes from cool regions told us that growers with otherwise high quality fruit sometimes miss out on bonuses due to the presence of green tannins in their fruit. It seems reasonable to suppose that growers experiencing these circumstances would be interested in vineyard protocols to minimise green tannins. None of the growers we interviewed had experienced these circumstances.

All the winemakers we interviewed expressed an interest in tannins. The winemakers said they tend to assess the natural tannins in the vineyard and use exogenous tannins to correct or complement natural tannins in the winemaking process (refer to appendix 1). Some of the winemakers had read articles or conference proceedings relating to tannins, and a few of the wineries were measuring fruit or wine tannin content, or both. Only one winery with a vineyard was experimenting with canopy management techniques to modify tannin attributes. The following section will provide a detailed break down of winemakers' interest in tannin related innovations.

Market segments for exogenous tannins

The winemakers we interviewed were classified into market segments based on their use of exogenous tannins in the winery and the contribution of tannins to their competitive advantage (refer to Figure 1). Briefly, winemakers in Segment 1 used exogenous tannins primarily but not exclusively to stabilise wine colour and this enabled them to pursue a focus cost strategy. Winemakers in Segment 2 used exogenous tannins primarily to mask fruit faults, mainly green tannins and flavours which assisted them in the pursuit of a differentiation strategy. The winemakers in Segment 3 pursue a focus differentiation strategy and used exogenous tannins primarily to try to create specialised characteristics in the wine. The winemakers in Segment 4 primarily used exogenous tannins as a form of risk management. We believe the winemakers in this segment were pursuing various focus differentiation strategies and the addition of exogenous tannins in the winery assured the quality of their product. The winemakers in Segments 5 and 6 did not use exogenous tannins. Those in Segment 5 were pursuing a focus differentiation strategy centred on avoiding additives. Finally, the winemakers in Segment 6 considered that fruit from their region has superior natural tannins that need no modification in the winery and so pursued a focus differentiation strategy based on the natural quality of wines from their region.

The market segments we have defined refer to the primary benefit winemakers are seeking from the exogenous tannins. Hence, membership of a segment does not mean that winemakers seek only that benefit from using exogenous tannins. Winemakers may also obtain other, secondary benefits from using tannins. For example, while a winemaker in Segment 1 may be using the tannins primarily to stabilise colour, winemakers from other segments may also be seeking this benefit as a secondary or additional aim. Likewise, a winemaker may be using exogenous tannins to correct a fruit fault and, if the wine shapes up to the quality they are seeking, they may use additional tannins to create the style of wine that will go in their ultra-premium label.

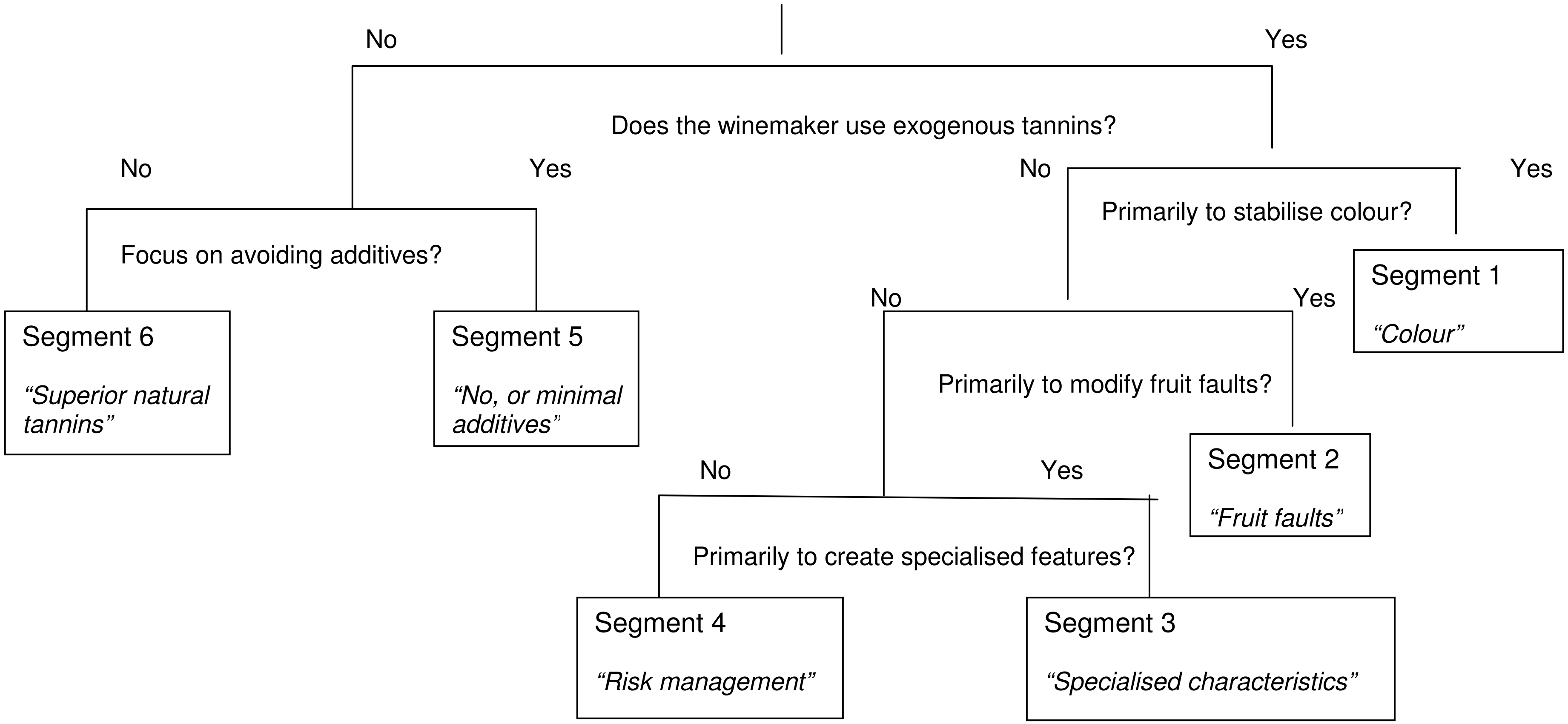

Figure 1: Typology of market segments based on the benefits sought by using exogenous tannins

It is clear from our interviews that the use of exogenous tannin depends on the natural tannins that are present in the grapes winemakers are processing. Hence, the segments reflect the natural tannin characters, a large contributor to quality, of wine grapes. As natural tannins are strongly influenced by climate and soil type, we found there was a link between region and typical exogenous tannin use. For example, all the winemakers interviewed that dealt with grapes from a hot region added exogenous tannins to stabilise colour. All of the winemakers that dealt with fruit from cool regions talked about green tannins. Hence, there is a link between region and segment membership.

We found that the large wine companies all have an extensive range of products that cover all the price points and quality grades in the market. To achieve this they obtain fruit from different regions and sometimes process it in different wineries, with a number of winemakers on staff. Hence, one company may have many winemakers and these may be placed in different segments depending on the grapes they are processing and the wine they are making.

Most of the winemakers we interviewed thought of exogenous tannins as powders or chips of non-oak products. Oak was not considered as exogenous tannin. Oak products were used for the flavour they contributed to the wine, with any tannins released being considered a bonus. Winemakers in each of the segments used oak in their wine.

Each of the segments will now be discussed in detail.

Segment one – colour stabilisation

The winemakers we placed in this segment used grapes from a warm-irrigated wine growing region, producing basic or premium grade wine. These winemakers said that the hot growing conditions that occur in this region, especially during certain stages of the grapes' development and ripening, tend to break down, or inhibit the development of, natural tannins and anthocyanins. This leads to weak and unstable fruit and wine colour. This was seen as a major quality issue as consumers equate strong wine colour with a good quality product. Hence, weak colour significantly reduces the value of the wine.

To manage this issue the winemakers indicated they employed a number of strategies to optimise colour, including buying grapes with high colour levels, adding exogenous tannins to most, if not all, parcels of fruit coming into the winery, and sometimes using other winemaking practices.

Some wineries measure wine grape colour and pay growers accordingly. However, the winemakers we interviewed stated that strongly-coloured grapes do not necessarily turn into strongly-coloured wine, as grape colour can be unstable and break down over time.

All of the wine makers interviewed in this segment said that they add exogenous tannin to the wine with the primary aim of stabilising the wine colour. Any complexity or mouth-feel characteristics the tannins provide is usually considered a bonus. As one winemaker in this segment stated:

> *The fruit from this area does not have much colour or complexity. We add 200 ppm of VR supra tannin at the crusher to try to preserve what colour there is.*

However, excessive levels of tannin in the wine are not desirable. These winemakers claimed that they aim to make a wine in a "soft, fruity and easy to drink" style that can be sold in the shortest possible time after production.

The addition of exogenous tannins increases input costs with one winemaker reporting that their company spends $200,000 per annum on exogenous tannins. Some winemakers reported that, even with the use of exogenous tannins, colour stabilisation was not always reliable with some wine still having weak colour, or the colour breaking down over time. As another winemaker said:

> *Even when we use exogenous tannins we only end up with the strong, stable colour we want 70% of the time.*

Another technique to extract and stabilise colour is to leave the grape juice on skins for longer, to maximise tannin and anthocyanin extraction. However, this has implications for winery logistics and costs as far as utilisation of valuable tank space and resources during harvest are concerned. A representative from a large winery said:

> *"Every extra day the grapes are on skins costs our business $1 million"*

Competitive advantage and strategy

The winemakers in Segment 1 compete largely on price. Descriptors of this wine include "excellent value and consistency, and quality for the price". The source of competitive advantage for these wineries is their capacity to offer consumers wine that meets certain quality standards at the same, or a lower, price than their competitors. These wines retail in the premium, or $5-$9.99 price range. In our view this suggests that these wineries follow a cost focus strategy. These winemakers have access to large volumes of low price grapes from warm-irrigated growing regions. They take advantage of economies of scale by processing the grapes in large quantities, at major wineries to produce wine at low cost.

These wineries are less likely to be interested in product development to provide additional product features, as they only require that the product meet the premium wine consumer's needs, the predominant feature of which is low cost. To achieve this, wineries need to reduce or keep production costs low. Therefore innovations that allow them to reduce input costs, improve winery efficiency, reduce the time taken to get the wine to market or create additional economy of scale advantages, will be of interest.

Relevant innovations

In Table 3 we have listed the characteristics of innovations in the identification, measurement and management of tannins, and their potential benefit to wineries in Segment 1. The primary theme is, given the reliance on cost advantage, on innovations that reduce costs and improve reliability in the preservation and stabilisation of colour. New exogenous tannins would have to be comparable in cost to those currently available, or be superior in reliability or performance.

Location	Purpose of the Innovation	Potential Benefit to the Winery
Vineyard or winery weighbridge	Measurement of colour related tannins in the grapes	To stream fruit so batches of like fruit can be processed together To pay for fruit in relation to colour stability
Vineyard	Protocols to modify tannins in the vineyard	Grapes can be purchased containing colour related natural tannins. This will minimise winery inputs and processes
Winery	Measurement of colour related tannins during processing	To reduce exogenous, and other inputs To tailor the time the juice spends on skins
Winery	Alternative stabilising technologies	Cheaper, more reliable methods for stabilising colour than existing practice
Winery	New exogenous tannins	Cheaper, more reliable methods for stabilising colour than existing practice

Table 3: Potential innovations, where they would be used, and winery benefits in regard to wine colour stabilisation

Segment two – green tannins and other fruit faults

The winemakers that we placed in this segment mainly used grapes from cooler wine regions to produce wine in the super or ultra premium quality grade (see appendix 2). Winemakers in this segment used exogenous tannins to mask or minimise the effect of faults in particular batches of fruit, the most prevalent of which were green tannins or flavours. Other fruit faults were Botrytis disease infection, which can taint the wine, or "poor" or "weak" fruit that lacked flavour or complexity.

Green tannin, flavour or character is a subjective term used to describe a range of problems around bitter, astringent, or vegetative flavours in grapes and resulting wines. It may or may not be tannin-related. This problem is more of an issue in cooler seasons, when grapes do not get the necessary warmth to ripen sufficiently, or when the vines are "out of balance" - which is when grape yield exceeds the vines' ripening capacity.

Green flavours and tannins have a major impact on wine quality as they can strongly influence that flavour of wine and consumers generally do not like these flavours. This can result in lost sales. Green characters can be a problem in both red and white wines. As a representative from a large wine company told us:

> *We recently missed a major overseas contract because the buyer didn't like the green characters in our Clare Riesling. That will impact on next year's grower contracts in that region.*

There are no winemaking techniques that are effective in removing green flavours, and as they are relatively strong they are difficult to disguise by blending with other batches of wine. For example, green characters can be minimised by reducing the time the juice spends on skins during fermentation. Less time on skins reduces the amount of tannins and other compounds that are removed from the grape seeds and skin. However, this can also result in reduced wine colour. Alternatively, micro-oxygenation of the wine is used to soften the tannins and other flavours. This creates additional steps in the wine making process and can have significant implications for wine quality, winery logistics and the cost of production. Consequently, winemakers are forced to use exogenous tannins to mask green characters as they provide other flavours, or soften the existing flavours, in the wine so that the green flavours are less obvious to the consumer.

Some wineries now go to considerable lengths to avoid green characters in their fruit. This may include numerous vineyard visits and tastings to monitor the development of the fruit and training growers and winery staff to identify green characters. Batches of fruit may be selectively harvested, and/or processed in the winery. Finally, by leaving grapes on the vine until the grapes ripen further so that all the green characters are gone, however this may compromise other components such as sugar levels, acid levels and flavour. Again this impacts on wine quality and cost of production.

Competitive advantage and strategy

The wineries in this segment are positioned at a higher price point than those in segment one because they are producing wines that are differentiated by style from the wines produced by winemakers in segment one, with more complexity, structure and tannins. Hence, we concluded differentiation was the source of competitive advantage for wineries in this segment.

We found that the while the wineries in this segment compete on a differentiation basis, they vary in scope. The small wineries tended to follow a focus differentiation strategy because they have limited capacity and resources. These wineries generally produced a small range of wines to meet one quality grade - often the ultra-premium grade. Larger wineries, with the capacity and resources to process, market and distribute a larger range of wine products, sometimes under different brands, tended to follow a classic broad, differentiation strategy.

Wineries pursue both types of differentiation strategies by growing or sourcing grapes from cool to warm region vineyards with the flavours, tannins and acids they seek. The grapes and other inputs are relatively expensive to purchase, and are processed in small-to-medium sized batches in smaller wineries than those found in hot regions. Also, more time and additional steps may be involved in the winemaking process.

Wineries in this segment will be interested in innovations that support product or process development that will enhance product quality, features, and reliability that are attractive to their customer segments (Porter 1985).

Relevant innovations

In Table 4 we have listed the characteristics of innovations in the identification, measurement and management of tannins, and their potential benefit to wineries in segment two. The primary theme is, given the reliance on differentiation advantage, on innovations that improve reliability in controlling or eliminating green tannins without substantially increasing production costs. New exogenous tannins would have to be comparable in cost to those currently available and superior in reliability or performance.

Other fruit faults

Winemakers in this segment also used exogenous tannins to compensate for other fruit faults such as Botrytis infection or weakness which usually means they are from overcropped or young vines, or have been grown in a poor site, and are low in colour, flavour and tannins. Exogenous tannins are used by winemakers to mask any undesirable flavours resulting from these faults. For example:

> *We add tannin to some weaker parcels of fruit that are going into the cheaper wines, or if it is a poor season.*
>
> *Poor red grapes are low in tannin or have unripe tannins and make a light and pissy wine, but oak chips will give it some flavour.*

Winemakers use a range of sources and types of exogenous tannin and oak products, to mask these faults depending on the value of the wine. High value wines were not made from fruit with faults.

Location	Purpose of the Innovations	Potential Advantage to the Winery
Vineyard	Measurement of compounds causing green characters in the grapes	Growers can identify and map areas of vines prone to produce green characters, for selective management and harvesting of grapes
Vineyard and/ or winery weighbridge	Measurement of compounds causing green characters in the grapes	Stream grapes to separate batches with green characters Determine grape price
Vineyard	Protocols to modify tannins in the vineyard	Growers will be able to grow fruit with minimal or no green characters Wineries will have access to better quality grapes
Winery	Measurement of green characters during processing	To reduce exogenous, and other inputs To tailor the time the juice spends on skins
Winery	Alternative processing technology to remove undesirable characteristics	Allow green characters to be extracted from the wine
Winery	New exogenous tannins	Cheaper, more reliable methods for masking or neutralising green characters

Table 4: Potential innovations and winery benefits in relation to green characters

We see limited opportunities for innovations in the identification, measurement and management of tannins among these winemakers at present. There are many causes of "poor fruit", most of which are well understood and relate to management practices or site selection. If the fruit does not meet the required quality standards, better fruit can be purchased or grown. None of the winemakers interviewed were unhappy with what they could achieve using the exogenous tannins, although they sometimes were uncertain about which commercial tannins best suited their objectives.

Botrytis is a viticultural problem and the wineries have protocols in place to minimise the infected fruit they receive. While exogenous tannins to neutralise Botrytis taint would probably be useful to the industry, this did not emerge as a high priority.

Segment three – specialised characteristics

The winemakers we placed in this segment were located in cool to warm regions and are targeting the ultra-premium or icon quality grades of the market by creating wines with specialised features such as oak characters, individual flavours, or flavour blends and styles in their wine. They do this through their selection of inputs, including exogenous, often finishing tannins, winery processes and marketing strategy. Consumers that purchase these wines may feel that they are getting something special and unique. Such wines may be described by winemakers as, for example:

> *This is a richly textured, intensely concentrated, complex, beguiling wine. It has a substantial palate of rich, dark berry flavours, and persistent chewy tannins.*

Another winemaker told us:

> *We have moved away from the Australian "fruit bomb", to a more European style of wine. We use small parcels of fruit. We leave the wine on skins to give a richer, more complex, tannic style. We enhance this by using finishing tannins and the best oak barrels.*

Competitive advantage and strategy

We believe winemakers in the third segment are following a focus differentiation strategy where their competitive advantage is based on creating complex wines with highly specialised characteristics that appeal to their customers.

Wineries in this segment will be interested in innovations that support product or process developments that will enhance product quality, features, and reliability that are attractive to their customer segments (Porter 1985). An example may be the development of exogenous tannins that could add new features, such as novel flavours, to the wine. Another would be tannins that could fine tune existing features or deliver existing features more reliably.

Relevant tannin innovations

In Table 5 we have listed our conclusions about the characteristics of innovations in the identification, measurement and management of tannins, and their potential benefit to wineries in segment three. The primary theme, given the reliance on differentiation advantage, is on innovations that enable wines with specialised characteristics to be created more reliably or innovations that enable wines with novel characteristics to be developed. New exogenous tannins would have to be comparable in cost to those currently available and superior in reliability or performance.

Location	Purpose of the Innovations	Potential Advantage to the Winery
Winery	Measurement of selected tannins during processing	To reduce exogenous tannins and other inputs To tailor the time the juice spends on skins
Winery	Alternative processing technology to remove undesirable characteristics	Allow undesirable characters to be extracted from the wine
Winery	New exogenous tannins	Enable new features, such as flavours to be added to the wine Fine tune existing features, or deliver them more reliably

Table 5: Potential innovations and winery benefits in relation to wines with specialised characteristics

Segment four – risk management

The winemakers we placed in this segment were generally from small-to-medium-sized wineries, in the warm regions, producing super to ultra premium wines. They used exogenous tannins as a form of risk management or an insurance policy. These winemakers are not sure exactly whether the addition of exogenous tannins definitively and regularly created benefits in terms of benefits colour stabilisation, wine complexity and mouth feel. However, they believed the risk of problems with colour stability, complexity and mouth feel justifies the cost of adding exogenous tannins during the winemaking process. Note that, in order to make an informed decision not to add tannins, winemakers require precise information on what limited benefits the tannins are providing for them. Gathering this information is too expensive for small to medium wineries as this requires extensive testing and experimentation. Hence, wineries in this segment were generally unable to monitor the benefits of using exogenous tannins, and hence cannot say for sure what impact exogenous tannins are having on their wine.

During the interviews with winemakers in this segment we found that they were satisfied with the wines they are producing using exogenous tannins and that they had been using exogenous tannins for some time. We also found that exogenous tannins were a minor component of input costs for these winemakers. As one winemaker in this segment said:

> *The tannins fall apart and may not do what they are supposed to, but we add them anyway as they don't hurt.*

Note that the wine makers in this segment do not consistently have any specific quality issues. If these winemakers were to begin experiencing consistent problems with poor colour or excessive green characters they would then be placed in segments one or two respectively.

Competitive advantage and strategy

Wineries in this segment are following a focus differentiation strategy. These wineries tend to be small and use their resources to focus on one market segment, usually the ultra premium ($15-$49.99) quality grade of the market. These wineries differentiate variously across a range of sources including characteristics of their wine as well as their site, region, heritage, and philosophy. These wineries often market themselves as providing a tourism experience.

Relevant tannin innovations

Wineries in this segment will be interested in innovations that allow them to better, more reliably or more cheaply meet the needs of their target market. For example tannin measurement technologies may allow them to reduce or stop using exogenous inputs, while still making wine of the same quality and style. Or new exogenous tannins may be developed that are less expensive or that allow winemakers to add new features or refine existing wine features. The primary interest here is on reducing costs while managing the risk of problems with colour stability, complexity and so on.

Segment five – no, or minimal additives

The winemakers in this segment stated they do not use exogenous tannins in wine production as they are following a focus differentiation strategy based on avoiding the use of additives. In using this strategy the wineries in this segment are marketing their wines as being more "natural" because they used minimal additives. Sometimes this strategy was pursued in conjunction with the use of traditional, old style winemaking practices or equipment, or organic production. These winemakers were from small wineries in warm regions and were producing ultra-premium quality wine. For example:

> *We are growing dry land and "natural" fruit. We don't add tannins because we are anti-additions in the winery, and because our yields are low we get enough natural tannin anyway.*

These winemakers could use this low additive approach as they were growing grapes in sites where the natural tannins were sufficient in themselves to allow them to make wine with quality characteristics that met their market needs.

Competitive advantage and strategy

These wineries were following a focus differentiation based on creating a competitive advantage founded on the limited use of additives and this was promoted through their marketing. Region and site selection were critical as this strategy depends on the grapes being used to produce wine being naturally free of colour or green character faults.

Relevant tannin innovations

The winemakers in this segment may be interested in vineyard protocols to modify naturally occurring tannins as they want to ensure that their grapes meet their wine needs as closely as possible. They may also be interested in measuring tannin levels on the vine for the same reason. Given their competitive strategy limits options for modifying wine by the addition of exogenous tannins in the winery we believe winegrowers in this segment will not be interested in innovations in relation to exogenous tannins.

Segment six – superior natural tannins

The winemakers in this segment were from small boutique wineries. These winemakers were producing ultra-premium to iconic wines from their own vineyards. They were located in warm regions. These winemakers did not use exogenous tannins as the grapes grown in their region had sufficient natural tannins to ensure stable colour, wine complexity and flavour. As one winemaker said:

> *The tannins from this region are naturally fine and smooth. They are palatable early, but can age a long time without deteriorating. Other areas either have to be drunk early or else they are unapproachable and have to be aged.*

These wineries were following a focus differentiation strategy based on their competitive advantage in growing grapes with superior natural tannins. This advantage derived from the soils and climate of the region.

This segment is unlikely to be interested in innovations produced by the Winegrape Tannin Research project. They perceive that they already have excellent natural tannins hence they are not interested in modifying them through vineyard protocols.

Consequently, they are unlikely to be strongly interested in techniques for measuring tannins on the vine or in the winery. Also, they are unlikely to be strongly interested in techniques for altering wine through the addition of exogenous tannins or innovations in the wine making processes.

In Table 5 we summarise the segments and our conclusions about innovations in the identification, measurement and management of tannins that will be of use to them.

	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Description of the segment	Weak or unstable wine colour	Green characters in the wine	Specialised features in the wine	Risk management	No, or minimal additives	Regional advantage
Source of competitive advantage	Inexpensive inputs, bulk processing	Cool climate fruit	Small parcels of selected cool climate fruit, winemaking processes, oak	Various- wine style, tourist experience, heritage, region	Winemaking practices, marketing	The regions superior natural tannins
Competitive strategy	Cost focus	Differentiation or differentiation focus	Differentiation focus	Differentiation focus	Differentiation focus	Differentiation focus
VINEYARD INNOVATIONS						
Measurement of selected tannins	√	√	–	–	√	–
Vineyard protocols	√	√	–	–	√	–
WINERY INNOVATIONS						
Measurement of selected tannins	√	√	√	√	–	–
Exogenous tannin	√	√	√	√	–	–
Processing technologies	√	√	√	√	√	–

Table 6: Summary table of the market segments, their competitive advantage, strategy and innovations of interest

Opportunities for additional research

An extensive range of exogenous tannins are commercially available to winemakers. In fact, so many tannins are available that many winemakers voiced confusion and frustration over the range. Winemakers indicated it was difficult to get reliable information on what materials were used in the production of the exogenous tannins, what their functions were in the wine, and how to evaluate and select the tannins best suited to their needs. For instance:

> *I spend half the time trying not to get excessive pip tannin, and then they try to sell it to you.*
>
> *The tannin options available to wine makers at the moment are overwhelming-so we do small trials. The manufacturers don't disclose if they are oak or skin derived. They give data, which may or may not be believed.*

Another observation that many winemakers made about tannins was that they did not precisely understand how tannins worked, with one winemaker describing tannin additions as a "dark science". Consequently, we found different winemakers using the same type or brand of tannin at different stages of the winemaking process to perform different tasks, such as stabilising colour or adding mouth feel. Conversely, different winemakers used different types and brands of tannins to perform the same task, such as colour stabilisation.

Consequently, we believe opportunities exist to provide impartial information to the winemaking industry regarding:

- Which exogenous tannins are best suited to meeting various winemaking objectives (i.e. colour stabilisation, adding complexity, filling the middle palate etc) and why.
- How to evaluate and select the best tannins depending on objectives.
- Information on the timing of tannin additions to optimise their effectiveness.

Discussion

Implications for research and extension

As the innovations to be developed in the Tannin Project are currently under development the opportunities for extension activity are limited at present. However, our results can assist in planning an extension program and identifying information to collect that would support the program.

Based on our results, we see the following opportunities for extension:

- Information could be provided to the wine industry to build an awareness of the project, its objectives, research staff and a point of contact for inquires. This is to maintain project profile and interest with industry, stakeholders and funding bodies.
- The level of technical knowledge among winemakers about exogenous tannins and how they work is fairly low. Winemakers are very interested in information regarding how to improve performance and reliability from the exogenous tannins. Therefore, an opportunity exists to provide technical articles presenting current knowledge on this topic.
- The research program could be expanded to include trials of exogenous tannins to determine which tannins are most effective in different circumstances, and how winemakers can maximise the benefits of using exogenous tannins through the selection and timing of applications.
- Further research may be worthwhile to understand the causes of green characters and protocols to manage or minimise them in the vineyard and the winery.

Extension processes

A range of extension processes are commonly used, including publications, action learning, discussion groups etc. However, as Fulton et al. (2003) suggest, it is difficult for the researcher or extension practitioner to determine what processes are most appropriate in a particular situation. This poses a challenge as to how they should design their extension effort to be more effective and more efficient. The classification of winemakers into segments in terms of their use of exogenous tannins provides a powerful means of improving the effectiveness of research and extension by enabling the targeting of efforts to specific segments and the tailoring of research products and extension messages to those segments.

In the next step of this project we will seek to develop methods that will assist in meeting this challenge. Our approach will be to adapt organisational behaviour literature on the competency and resource requirements of implementing different types of innovations and to apply this knowledge to understanding the competency and resource requirements associated with the adoption of innovations in grape production. The role of extension in facilitating producers to develop the requisite competences will be explored.

Conclusion

We have examined the role of natural and exogenous tannins in the production of wine and we have used this information to identify market segments amongst wineries in relation to innovations in the identification, measurement and management of tannins. These segments reflect the source of competitive advantage and competitive strategies, and therefore the appeal, of tannin-related innovations to the wineries in each segment. We believe that the wineries in segments one and two probably represent the major opportunities for these innovations. We anticipate this information will enable the Winegrape Tannin Research Team to tailor their research and extension efforts to better meet the needs of winemakers, thereby facilitating their adoption and enhancing the value of their research and extension efforts.

This project has required the novel application of Porter's (1985) strategic competitive framework to identify market segments in relation to innovations in tannins and has illustrated the value of this approach to understanding the market for a specific innovation in a horticultural context. We see further opportunities for exploration of these and other techniques in guiding the design of research and extension projects.

References

Assael, H. (1998). Consumer Behaviour and Marketing Action. South Western College Publishing, Cincinnati, Ohio.

Dick, B. (1998). Convergent Interviewing: a Technique for Qualitative Data Collection. Available at http://www.scu.edu.au/schools/gcm/ar/arp/iview.html

Fulton, A. Fulton, D. Tabart, T. Ball, P. Champion, S. Weatherley, J. and Heinjus, D. (2003). Agricultural Extension, Learning and Change. A report for the Rural Industries Research and Development Corporation. Publication No 03/032.

Grunert, K. and Grunert, S. (1995). Measuring Subjective Meaning Structures by the Laddering Method: Theoretical Considerations and Methodolical Problems. *International Journal of Research Marketing*. 12:209-225.

Invest Australia (2005). From Australian Wine Industry: A Fruitful Future. Wine Industry Overview. At http://www.investaustralia.gov.au/media/IS_AB_Wine.pdf

Kaine, G. (2004). Consumer Behaviour as a Theory of Innovation Adoption in Agriculture. Social Research Working Paper, 01/04. AgResearch, NZ.

Kaine, G and Lourey, R (2007). Understanding the Adoption of Innovations by Agribusiness Processors. Concept Paper. Department of Primary Industries, Tatura.

Krstic, M. (2005). Viticultural Management of Grape Tannin and Anthocyanin Levels to Achieve Desired Wine Quality Specifications. GWRDC Project Proposal.

Patton M, Q. (1990). Qualitative Evaluation and Research Methods 2nd Edition. Sage Publications; USA.

Porter, M, E. (1985). Competitive Advantage. Creating and Sustaining Superior Performance. The Free Press. ISBN 0-684-84146-0.

Appendix 1: Current practice of winemakers

Exogenous tannin use

Exogenous tannins can be added at any stage of the wine making process, depending on the characteristics the winemaker is seeking. Some examples are, adding tannins to:

- The grape crusher to stabilise colour
- To the fermenting grape juice to stabilise colour
- At racking (transferring juice or wine between tanks or barrels) to mop up free oxygen and prevent the wine browning
- At any stage of the wine making process to enhance wine structure and complexity
- Late in the wine making process (finishing tannins) to enhance mouth feel
- Any combination of the above.

The type and amount of tannin used varied, with many winemakers being unsure of exactly what they had in the winery and what they used.

Measuring natural tannins

The majority of winemakers talked about tasting the grapes and chewing the pips to assess tannins content and ripeness. Some winemakers said that green characters can be hard to pick up during tasting. Many of the growers in the Coonawarra Region had done a course on berry sensory assessment to better assess tannin ripeness and grape flavours.

One of the wineries sent samples of fruit to the Australian Wine Research Institute to have total tannin content tested. They found that *"we have lots of numbers, some anomalies, and no correlation between the winemakers and the assessments on quality"*. They found that both the high quality wines and the low quality wines made from pressings had high total tannin contents.

While some of the larger wineries have full laboratory facilities and equipment, only one was regularly testing tannins to try to develop measurement techniques. Another winery reportedly provides their grape growers with information about the tannin profiles of their grapes, but these were not linked with payment, nor were vineyard protocols suggested.

Appendix 2: The quality grades of Australian wines

Quality	Price Range ($AUS)	Indicative Brands
Icon	> $50	Penfolds Grange Henschke Hill of Grace Leeuwin Chardonnay Petaluma Coonawarra
Ultra-Premium	$14 - 49.99	Wolf Blass Grey Label Orlando St Hugo De Bortoli Yarra Valley
Super-Premium	$10-14.99	Penfolds Koonunga Hill Jamieson's Run Rosemount Diamond Label
Premium	$5- 9.99	Banrock Station Jacob's Creek Lindemans Bin Range Yellow Tail
Basic	< $5	

From Australian Wine Industry A Fruitful Future. Wine Industry Overview.
At http://www.investaustralia.gov.au/media/IS_AB_Wine.pdf

ATTACHMENT 4:

Enhancing the uptake of wine industry innovations.

GWRDC final report. Project: DPI 06/06

Practice Change Research

Working Paper 02/08

Types of Agricultural Innovations and the Design of Extension Programs

September 2008

Geoff Kaine, Megan Hill and Ben Rowbottom
Department of Primary Industries, Victoria

Victoria
The Place To Be

Australian Government
Grape and Wine Research and Development Corporation

Published by the Victorian Government Department of Primary Industries

Tatura, September, 2008

Find more information about the Department of Primary Industries on the Internet at www.dpi.vic.gov.au or call the Customer Call Centre on 136 186.

Acknowledgments:

We are indebted to GWRDC, particularly John Harvey and Mark Krstic, for supporting this project. Thank you to all the wine grape growers, liaison officers and winemakers who generously shared their time and knowledge with us. Our thanks go to our colleagues in the Practice Change Portfolio who, through lively discussions, have contributed to the ideas in this paper. A special thank you goes to Roger Ashburner, Fiona Johnson, Jean Sandall and Guido Vazzoler.

If you would like to receive this information/publication in an accessible format (such as large print or audio) please call the Customer Service Centre on: 136 186, TTY:1800 122 969, or email customer.service@dpi.vic.gov.au

Table of Contents

List of Figures

List of Tables

Introduction

The Australian wine industry is constantly responding to environmental, business and market challenges, while striving to improve productivity and the management of natural resources (GWRDC 2007). To meet these challenges, growers and wineries adapt their businesses by adopting innovations or using existing technologies and practices in innovative ways (Invest Australia 2005). Through research and extension, public sector agencies and industry bodies play a critical role in supporting growers to adapt their businesses. Therefore effective extension to communicated inform growers about these research findings, and to enhance their adoption, becomes crucial in terms of justifying the investment in research and extension.

While there is an extensive literature on agricultural extension, it provides little guidance for systematically identifying which of those extension methods would be best employed to accelerate the adoption of any particular innovation. The extension literature on learning styles (Kilpatrick et al. 1999; Trompf and Sale 2001; Fulton et al. 2003; Kilpatrick and Johns 2003; Andrew et al. 2005; Coutts et al. 2005) suggests different types of extension methods are needed to deliver knowledge to people with different styles of learning. Although this literature draws on a variety of theories of learning such as action learning, adult learning, experiential learning, social learning and double loop learning (Argyris 1976; Bandura 1977; Kolb 1984), this literature does not suggest, in a systematic way, how different extension methods might suit the promotion of different innovations.

The extension literature on participatory approaches to research (Biggs and Clay 1981; Byerlee et al. 1982; Roling 1996; Black 2000; Norman 2002; Dorward et al. 2003; Sumberg and Reece 2003) highlights the importance of producer participation in refining research directions so that the innovations developed suit their needs. However, this literature is largely silent on the issue of the role of extension in promoting the resulting innovations among the wider population of producers (Douthwaite et al. 2002; Dorward et al. 2003).

The literature on the diffusion of innovations (Rogers 1995) provides criteria (based on the characteristics of innovations) for assessing the relative rates with which different innovations may be expected to diffuse through a population of potential adopters. While recognising that the differing characteristics of the innovations influence the ease of their adoption, this literature does not provide a systematic method for using these characteristics to identify which extension activities might be the most appropriate for promoting adoption.

Farming systems research (Norman 1980; Ruthenberg 1980; Byerlee et al. 1982; Norman 2002) focuses on identifying innovations to overcome critical constraints in selected farming systems. The issue of choosing methods to promote the dissemination of these solutions among producers with the selected farming systems is largely ignored (Dorward et al. 2003; Reece et al. 2004).

Kaine (2004) provides a method for identifying the population of potential adopters of an agricultural innovation and, in doing so, provides information on the benefits producers seek from innovations. While this information is necessary to design extension programs that will attract the attention of producers, this information provides only limited guidance on the extension methods to include in an extension program.

Hence, there is a need for a framework for classifying agricultural innovations in a way that provides guidance on the qualitative differences in the extent and nature of learning necessary to adopt them. Such a framework would assist in identifying the extension activities that would most effectively support that learning.

In this paper we describe Henderson and Clark's (1990) framework for classifying innovations. We then describe the adaptation of their framework so as to classify innovations in agricultural systems into the four generic types described by Henderson and Clark (1990). The application of the framework with implications for the design of extension programs is then illustrated using examples drawn from viticulture.

Conceptual Framework

Henderson and Clark (1990) argue that a product can be conceived of as a system – that is, a collection of components that are linked together. Henderson and Clark (1990) define the components of a product as the physically distinct parts of a product. Components embody a core design concept and perform a particular function. The architecture of the product describes how the components are linked together to enable the product to function as a whole.

Henderson and Clark (1990) describe how the creation, maintenance and management of a system requires knowledge in regard to the components of the system and the design concepts embodied in them. Architectural knowledge is also required, in regard to how components are linked together, the design concepts embodied in the architecture of those linkages and an understanding of how the components and linkages combine to influence the way in which the system functions and behaves in different environments (Baldwin and Clark 2000). This means, any change to the components of a system or the linkages between them involves, to some degree, the acquisition of new knowledge and the development of plans and procedures to implement the change. Consequently, the four types of innovations they identify present a continuum of change for organisations in regard to competencies, roles, responsibilities processes, policies, organisational structure and culture (Abernathy and Clark 1985; Kaine et al. 2006).

Henderson and Clark (1990) provide the example of a fan to illustrate these concepts. The components of a fan include blades, electric motor, stand and a fan guard. The motor embodies a core design concept which is the use of electricity to power the fan blades. Henderson and Clark (1990) describe how the components of the fan are linked together to create a system for moving air in a room. For example, the blades are secured to an axle which is linked to the motor. The motor and fan assembly are fixed to a stand. The linking of the blades, engine and stand is underpinned by a series of architectural principles resulting in a mobile room fan (Henderson and Clark 1990).

Consequently, product innovation can be conceptualised as changes to components, the linkages between them, or both. They then suggest that innovations can be categorised into four types: incremental, modular, architectural or radical, depending on the degree of change introduced into the components and the linkages between them (see Table 1 and Figure 1). The distinctions between these types of innovations are a matter of degree (Henderson and Clark 1990).

Incremental Innovations

Incremental innovations introduce relatively modest changes to existing products by refining and improving design concepts that exploit the potential of an established design (Henderson and Clark 1990). This is usually achieved by altering relatively few components and leaving the links between components, that is, the product architecture, largely unchanged (Henderson and Clark 1990). These incremental innovations increase the functional capacity of the product through small-scale, continuous improvements in product attributes such as performance, safety, quality and cost (Olofsson 2003). A change in the shape of the blades used in a fan might be an example of an incremental innovation.

Henderson and Clark (1990) suggest that incremental innovation may require new component knowledge and skills. However, incremental innovations are described as competence enhancing because they tend to build on, and extend existing skills, reinforcing the applicability of existing knowledge. Christensen and Overdorf (2000) suggest that incremental change also confirms that organisational processes and priorities are valid, entrenching them in the organisation's culture.

Modular Innovations

A modular innovation contains components that supersede the components they replace because they embody a new core design concept. Existing components become obsolete because the new components are based on novel design concepts rather than simply being improvements on established design concepts. The architecture linking the components of the product together remains largely unchanged with modular innovation (Henderson and Clark 1990).

Modular innovation may be competence enhancing or destroying, depending on the history of the specific organisation (Gatignon et al. 2002). Because the new modules are based on entirely new design concepts, the skills and practices that were required in the design and manufacture of the obsolete components may no longer be required. Entirely new skills, competencies and processes may be required to manufacture and install the new components. Some organisations purchase the expertise needed to deal with the demands for new knowledge and skills (Kaine and Higson 2006).

Since modular innovations may test or displace organisational competencies and knowledge that are specific to the components that are replaced, modular innovation may have disruptive effects across an organisation (Tushman and Anderson 1986) and require changes in roles and responsibilities within organisations (Kaine and Higson 2006).

A change in the materials used in the blades of a fan, such as the replacement of metal blades with plastic blades, might be an example of a modular innovation. The change from metal to plastic represents a new core design concept yet there is little or no change in the other components of the fan, or in the way the components are linked together.

Table 1: The characteristics of different types of innovation, adapted from Henderson and Clark (1990)

Type of innovation	Core design concept	Components	Architecture
Incremental	No change	Changed	No, or minor change
Modular	New	Major change or new	No, or minor change
Architectural	No change	No, or minor change	Major change or new
Radical	New	Major change or new	Major change or new

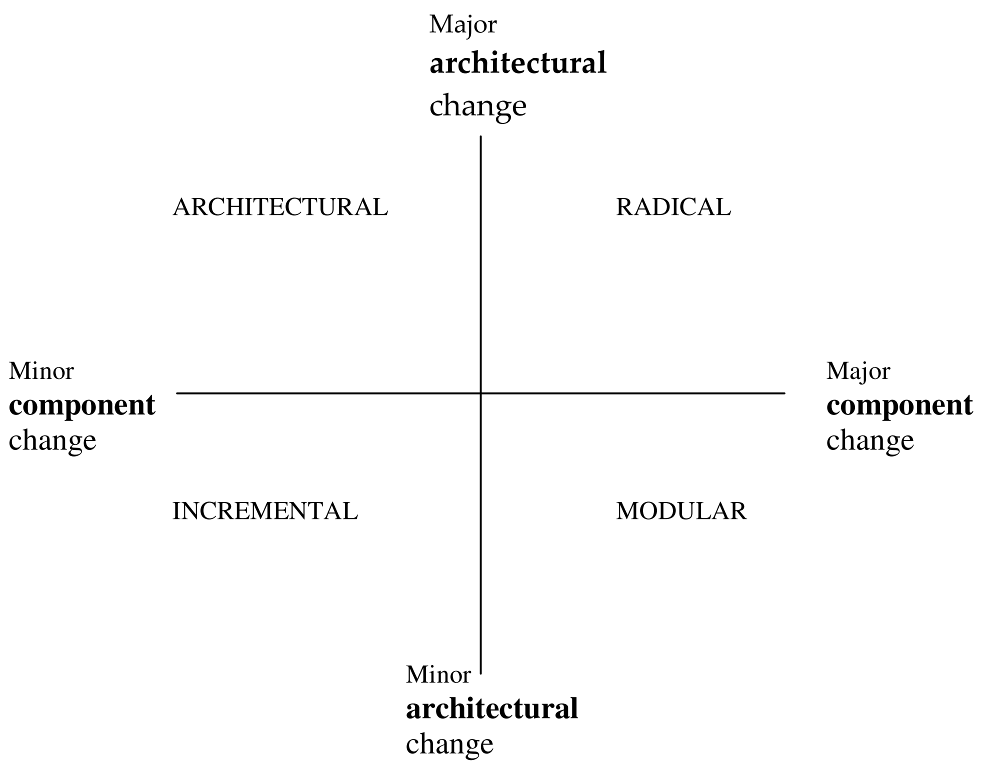

Figure 1: A classification of innovations, adapted from Henderson and Clark (1990)

Architectural Innovations

Henderson and Clark (1990) define an architectural innovation as "the reconfiguration of an established system to link together existing components in a new way". Generally speaking, architectural innovations entail relatively minor changes in the components. Abernathy and Clark (1985) suggest that architectural innovations are often triggered by changes in the size or design of component size that create new interactions and linkages between components in the established product. In short, the core design concepts that underpin the components in the system remain unchanged by architectural innovation, it is the changes to the linkages between components that characterises architectural innovation.

Architectural innovations may be difficult to identify because most of the components in the system and the core design concept that underpin them, remain the same. Yet architectural innovations have been shown to create serious disruptions in to organisations because areas of architectural knowledge are superseded, rendering the associated skills and competencies obsolete, even though much component knowledge remains useful (Henderson and Clark 1990; Kaine and Higson 2006). This is particularly disruptive for the organisation as architectural knowledge becomes embedded in the organisational procedures, processes and structures over time (Henderson and Clark 1990). Hence, architectural innovations in products not only require the acquisition of new skills and competencies, they may also require changes in the operating procedures, processes and structures of the organisations that manufacture them.

A change in the architecture of a fan, such as the development of the design for a ceiling fan from a design for a free-standing, portable fan, might be an example of an architectural innovation. A ceiling fan is manufactured from largely the same components as a portable, free-standing fan however the components are linked together in different ways using a different architecture based on fundamentally different design principles.

Radical Innovations

Radical innovations involve a new set of core design concepts embodied in new components that are linked together using a new architecture (Henderson and Clark 1990). Radical innovations are based on completely different scientific and engineering principles to the principles that were used in the products they supersede.

The magnitude of change entailed in radical innovations means that many areas of organisational knowledge and competence are rendered irrelevant, destroying the value of existing resources by making existing technologies, production systems and organisational structures obsolete (Henderson and Clark 1990; Gatignon et al. 2002; Kaine and Higson 2006). Consequently, to adopt a radical product innovation an organisation must acquire completely new component and architectural knowledge, develop new organisational processes and procedures, implement new organisational structures and may even have to consider new ways of thinking that may challenge organisational values (Smith 2000). In short, radical innovations are the most disruptive type of innovations.

The switch from producing a ceiling fan to an air conditioner is an example of a radical innovation. Both products are used to change the temperature of air in a room. While a ceiling fan achieves this by using rotating blades to circulate air, an air conditioner changes air temperature by refrigeration. The air conditioner is composed of many components that are based on design principles that are fundamentally different from those used in a fan. Furthermore, the components in an air conditioner are linked together using a different architecture based on fundamentally different design principles to the architectural principles used to create fans.

Types of Agricultural Innovations

Henderson and Clark (1990) developed their framework to identify different types of product innovation and argued that each of these types of innovation had different consequences for the manufacturing organisation in relation to organisational skills, competencies, procedures, structures and culture. In essence their framework identifies different generic types of system innovations. Given that agricultural enterprises are systems, we should be able to adapt and use their framework to classify agricultural innovations into these generic types.

Henderson and Clark (1990) argued that changes (innovations) in the components or architecture of a system require, to some degree, the acquisition of new knowledge and the development of plans for implementation. The greater the degree of change in the components and architecture of the system an innovation poses, the greater the effort involved in learning the knowledge, skills and competencies necessary to adopt the innovation. So, if agricultural innovations can be classified into the generic types proposed by Henderson and Clark (1990), there should be qualitatively important differences in the learning required to implement each type.

We expected that, as a result of these differences in learning, different kinds of extension activities would be required to support the adoption of each type of innovation. Given this purpose, we were interested in identifying different types of innovations in the production system rather than the output of the system. In other words, unlike Henderson and Clark (1990), we wished to identify different types of innovations in the organisation producing the product, rather than the product itself.

As our purpose was to classify agricultural innovations into types so that there were important differences in the learning involved in implement each type, we chose farm sub-systems as the unit of analysis for applying the concepts used by Henderson and Clark (1990). We found that if the farm as a whole was treated as the unit for analysis, then this would mean that radical innovations would be restricted to those innovations where the design concept underpinning most of the components and the architecture of the farm were replaced by fundamentally different design concepts. In other words, radical innovation would be restricted to instances where the farm system itself was completely transformed. The analysis of such transformations, such as conversion of a beef enterprise from an extensive grazing system to an intensive feedlot system, was not our intent. Consequently, we chose farm sub-systems as the unit of analysis for this paper. This choice is consistent with the systems theory which recognises that the boundaries of any systems or subsystems of interest must be established depending on the topic of interest and are rarely clear cut (Weinberg 2001; Packham et al. 2007).

Fundamental Elements

Having selected farm sub-systems as the unit of analysis, innovations to sub-systems can be categorised into types on the basis of the extent to which the design concept or design principles underpinning the components and architecture of a sub-system are changed by an innovation (see Table 2).

A 'sub-system concept' is a generic description of the function of the sub-system and the way that the sub-system performs this function. Different sub-systems are designed to perform fundamentally different functions in specific ways. For example, a pressurised irrigation system is a generic description of a sub-system that distributes water to plants using mechanical energy. In contrast, integrated pest management is a generic description of a sub-system for managing pests and diseases based on the use of beneficial insects and species-specific chemicals. Therefore, pressure irrigation and integrated pest management are examples of two sub-system concepts; other sub-system concepts include animal health, feed management and breeding management.

Table 2 Fundamental elements of a farm sub-system

Sub-system Concept	A generic description of the function of a sub-system and the way this function is performed
Components	The individual technologies, techniques, practices and procedures that form the sub-system
Component Principles	The fundamental principles that guide the design and functioning of a component
Architecture	The way that the components are arranged or integrated to form the sub-system
Architectural Principles	The fundamental principles that underpin the arrangement and combined functioning of the components that form the sub-system

Adapting Henderson and Clark's 1990 framework, we defined the 'components' of a farm sub-system as physically distinct elements of the sub-system that perform a particular function. The components of a farm sub-system may include technology, techniques and practices. They embody a core design concept which consists of one or more component principles.

'Component principles' are the fundamental principles that guide the design and functioning of a component. For example, the design of irrigation bays in a flood irrigation sub-system is governed by principles in relation to controlling the direction and rate of flow of water. Other components of an irrigation sub-system might include dams for storing water and devices for monitoring water flow (see Table 3).

The 'architecture' of the sub-system describes how the components are arranged or linked together to enable the sub-system to function and consist of one or more architectural principles that describe how two or more components link together. Architectural principles are the fundamental principles that underpin the arrangement and combined functioning of the components that form the sub-system. For example, in a flood irrigation sub-system the layout of channels, bays and dams is governed by the principle that water moves from higher to lower areas. Similarly, the scheduling of irrigations is governed by principles including plant physiology.

Different sub-system concepts have different architectures and so are underpinned by different architectural principles. For example, the principle that water moves downhill under the influence of gravity underpins the arrangement and combined functioning of the components (bays, channels, gates) that form a flood irrigation sub-system. In contrast, the principle that water moves from an area of high to low pressure underpins the arrangement and combined functioning of the components (pumps, pipes, valves) that form a sprinkler irrigation sub-system.

These fundamental elements provide a basis for classifying innovations in farm sub-systems into four types of innovation: incremental, modular, architectural and radical. These four types of innovation are distinguished by the dimensions of change the innovation introduces to the component principles and architectural principles of the original sub-system.

Given that farms consist of hierarchies of inter-related sub-sub-systems (Packham et al. 2007) farm managers require procedures, policies and strategies to co-ordinate the behaviour of these sub-systems and manage the interactions between them. Hence, implementation of changes to a farm sub-system (such as the incorporation of an innovation) may require not only the acquisition of knowledge about the change to the sub-system, but also the acquisition of knowledge about how to realign sub-systems to accommodate any changes in the behaviour of sub-system that has been changed.

Different types of innovation are expected to have differential effects on the linkages between sub-systems and their interactions, with architectural and radical innovations having greater effects than incremental or modular innovations (Henderson and Clark 1990; Gatignon et al. 2002).

Therefore, if innovation in farm sub-systems can be classified into the generic types proposed by Henderson and Clark (1990), then the adoption of each type could be expected to differ in:

- the new skills and competencies needed with respect to the sub-system itself,
- the skills and competencies needed to manage changes in the interactions between sub-systems
- the skills and competencies needed to plan the implementation of the innovation.

In the next section we explore the application of the Henderson and Clark (1990) framework using illustrative applications from viticulture.

Table 3 Fundamental elements of overhead sprinkler irrigation

Overhead sprinkler irrigation	
Component	**Component Principles**
Pump	A mechanism for compressing water
Valve	A mechanism to control the flow of water through a pipe
Timer	A mechanism to open or close valves at a pre-set time
Sprinkler	Water outlet that emits water at relatively high volume
Pipe	Round, sealed receptacle used to store and transport water
Dam	Installation for storing water
Tensiometer	Mechanism for measuring water content of soil
Architecture	**Architectural Principles**
Sprinkler irrigation	Irrigation system is a fixed structure
	Water moves through system from high to low pressure
	Irrigation scheduling based on satisfying physiological requirement of plants for water optimises plant growth and crop production

Illustrative Applications

To demonstrate the application of the Henderson and Clark (1990) framework to a vineyard system, we considered the adoption of four different types of irrigation system innovations.

Kaine and Bewsell (2001a; 2001b; 2002) conducted a study on the adoption of irrigation systems in Southern Australia. They created market segments to describe the irrigation systems adopted and the benefits sought from adoption. Kaine and Bewsell (2001a; 2001b; 2002) found that the growers they sampled in Victoria and New South Wales were either:

- using either conventional gravity fed, pipe and riser irrigation systems or laser graded furrow irrigation systems
- installing pressurised irrigation on new vineyard sites
- removing furrow irrigation and installing pressurised irrigation systems when redeveloping the vineyard
- replacing outdated with new pressurised irrigation systems.

Some of the following examples represent changes made by grape growers when adopting the irrigation systems described in the Kaine and Bewsell (2001a; 2001b; 2002) study. Supporting information was obtained from a range of personal communication and technical information (Cornish et al. 1990).

These examples assume that service providers will be employed to plan, design and install the irrigation systems, as these tasks require specialised skills and technology.

Incremental Innovation

The conversion of an irrigation sub-system from overhead sprinkler to drip irrigation is an example of an incremental innovation. The key components, component principles and architectural principles for overhead sprinkler irrigation are reported in Table 4. The components and component principles that are changed by the conversion to drip irrigation are also reported in the table. Table 4 reveals that most of the components in the irrigation sub-system, except for the sprinkler heads which are replaced by drippers, are unchanged. The architectural principles of the sub-system are unaffected by the conversion. Hence, as a type of innovation, the conversion from sprinkler to drip irrigation is incremental.

The innovation requires the acquisition of some new knowledge about the components in the sub-system. For instance, drippers emit water through holes of 0.5-1.0 mm in diameter and, as a consequence, a 150 mesh water filtration system is required to prevent impurities in the water blocking these holes (Cornish et al. 1990). However, for the most part, the components in the system and the design principles that underpin them are unchanged. This means the knowledge the grower has accumulated about these components remains relevant and useful.

The architectural principles underpinning the linkages between the components in sprinkler and drip irrigation systems are largely the same. Consequently, the majority of the grower's knowledge associated with the management of the sprinkler system will apply to the management of the drip system. Some experimentation may be required to adjust irrigation schedules that were designed for relatively high volume system to suit a low volume system. In short, most of the knowledge, competencies and skills the grower already possesses from operating spray irrigation remains useful and relatively little additional knowledge is needed to install and operate drip irrigation.

These considerations suggest that the adoption of drip irrigation is, at least in this instance, competency enhancing. Nieuwenhuis (2002) suggests that reading journals and talking to other growers would be sufficient for most growers to obtain straight-forward technical information. Hence, the role for extension may be limited to the provision of technical information on the new components and guidelines on irrigation scheduling (Rogers 1995; Czinkota et al. 2000).

Table 4 Incremental innovation – conversion from overhead sprinkler irrigation to drip irrigation

Overhead sprinkler irrigation		**Drip irrigation**	
Component	**Component Principle**	**Component**	**Component Principle**
Pump	A mechanism for compressing water		Unchanged
Valve	A mechanism to control the flow of water through a pipe		Unchanged
Timer	A mechanism to open or close valves at a pre-set time		Unchanged
Sprinklers	Water outlet that emits water at relatively high volume	Drippers	Water outlet that emits water at particularly low volume
Pipes	Round, sealed receptacle used to contain water		Unchanged
		Filter	Mechanism for removing impurities from water
Tensiometer	Mechanism for measuring water content of soil		Unchanged
Architecture	**Architectural Principle**	**Architecture**	**Architectural Principle**
Sprinkler irrigation	Irrigation system is a fixed structure		Unchanged
	Water moves through system from high to low pressure		Unchanged
	Irrigation scheduling based on satisfying physiological requirement of plants for water optimises plant growth and crop production		Unchanged

Modular Innovation

The replacement of a travelling irrigator with mini-sprinkler irrigation is an example of a modular innovation. A travelling irrigator has relatively high volume sprinklers mounted on a carriage that is pulled along a cable by hydraulic pressure, the traveller irrigates a crop as the carriage moves along the cable. Mini-sprinkler irrigation is a system with many low volume sprinklers that are attached to pipes which are fixed to vineyard trellises. Both are pressurised methods of irrigation. The key components, component principles and architectural principles for travelling irrigators are reported in Table 5. The components and component principles that are changed by the replacement with mini-sprinkler irrigation are also reported in the table.

Table 5 reveals that many of the components in the irrigation sub-system and the principles underpinning them, are changed. However, only one of the architectural principles of the sub-system is affected by the innovation. Hence, as a type of innovation, the conversion from travel irrigation to mini-sprinkler irrigation is modular.

The replacement of many of the components of the travelling irrigator with new components underpinned by different principles or core design concepts means that much of the knowledge accumulated by growers about the operation of travelling irrigation would not be relevant to the operation of mini-sprinkler irrigation. Hence, much of the component knowledge growers with travel irrigators possess would be obsolescent. Consequently, the replacement of travel irrigation with mini-sprinkler irrigation is competence destroying.

In short, modular innovations require new component knowledge and may make existing competencies obsolete (Tushman and Anderson 1986; Kaine and Higson 2006). These considerations suggest that the adoption of mini-sprinkler irrigation would, at least in this instance, require learning a relatively large body of technical knowledge. Furthermore, the process of replacing travelling irrigators with mini-sprinklers may involve some degree of problem solving and planning to fit the particular circumstances of growers, and experimentation with irrigation scheduling. This suggests that some experiential learning may be involved (Nieuwenhuis 2002).

Hence, the role for extension may be to provide technical information on the new components and guidelines on irrigation scheduling, support for experiential learning and experimentation through farm demonstrations, and maybe support for business and development planning possibly through formal training (Kilpatrick and Johns 2003). Hence, a mix of printed information and personally conveyed information using formal or informal, group or individual processes may be appropriate (Rogers 1995; Czinkota et al. 2000; Shields et al. 2003).

Architectural Innovation

The adoption of Reduced Deficit Irrigation (RDI) is an example of an architectural innovation. Conventional irrigation is based on the principle of meeting any shortfall between the water available to plants from the soil and their requirements for growth, as any shortfall will create physiological stress in plants and reduce plant growth (Goodwin 2000). RDI is based on the principle that limited water stress induces a hormonal response in plants that results in an increased yield (Goodwin 2000). Hence, RDI involves under-watering compared to standard irrigation practice and its adoption entails changing the principles that underpin the timing and duration of irrigations. RDI may be employed with all types of irrigation sub-systems and does not require any change to the components of irrigation sub-systems.

In Table 6 the key components, component principles and architectural principles for mini-sprinkler irrigation are reported together with the architectural principles that are changed by the adoption of RDI. Table 6 reveals that only the architectural principles of the sub-system are affected by the innovation. In other words, adopting RDI does not involve changing the irrigation sub-system as such, it involves changing the way the irrigation sub-system is managed. Hence, as a type of innovation, the adoption of RDI is architectural.

Table 5 Modular innovation – conversion from travelling irrigator to mini-sprinkler irrigation

Travelling irrigator		**Mini-sprinkler irrigation**	
Component	**Component Principles**	**Component**	**Component Principles**
Pump	A mechanism for compressing water		Unchanged
Valve	A mechanism to control the flow of water through a pipe		Unchanged
Timer	A mechanism to open or close valves at a pre-set time		Unchanged
Sprinklers	Water outlet that emits water at relatively high volume	Mini-sprinklers	Water outlet that emits water at relatively low volume
Carriage	Travelling structure with wheels and a rotating pipe		Not required
Hose	Flexible, round, sealed receptacle used to contain water that attaches to carriage	Pipes	Fixed, round, sealed receptacle used to contain water
Cable	A strong wire rope that guides the carriage		Not required
		Filter	Mechanism for removing impurities from water
Tensiometer	Mechanism for measuring water content of soil		Unchanged
Architecture	**Architectural Principles**	**Architecture**	**Architectural Principles**
Mobile sprinkler irrigation	Irrigation system is a moveable structure	Fixed sprinkler irrigation	Irrigation system is a fixed structure
	Water moves through system from high to low pressure		Unchanged
	Irrigation scheduling based on satisfying physiological requirement of plants for water optimises plant growth and crop production		Unchanged

Architectural innovations such as RDI can appear misleadingly simple to adopt because the differences between them and the practices they supersede can be subtle. Yet they can create unexpectedly disruptive consequences (Henderson and Clark 1990). The adoption of RDI illustrates this proposition. A comparison of Tables 5 and 6 reveals that, at first glance, the extent of change associated with the adoption of a modular innovation is greater than for the adoption of an architectural innovation. However, the differences in the tables are deceptive. The replacement of travelling irrigators with mini-sprinklers involves learning new technical knowledge, experimentation with irrigation scheduling and some degree of planning and problem solving. The adoption of RDI involves all this and much more.

The adoption of RDI requires learning and applying new knowledge in relation to:

- the response of vines to water stress
- the growth cycle of vines and stages of berry development through the season
- the water requirements of vines water through the season
- experimenting with the timing and rate of application of irrigations
- changing exposure to climatic risk.

This knowledge challenges and may even supersede long-held beliefs about best practice in irrigation management and associated competencies. This means that to adopt RDI, the grower may have to acquire new analytical, evaluation and monitoring skills in order to accurately assess the state of their soil and vines, draw appropriate conclusions about the need for management intervention and make appropriate decisions about when and how much to irrigate.

This suggests that the adoption of RDI may entail considerable problem solving and experiential learning as well as learning new technical information (Nieuwenhuis 2002; Shields et al. 2003). Hence, the adoption of RDI is competence destroying and therefore requires learning and practising new skills and competences.

Hence, the role for extension may be to provide technical information on principles of RDI and guidelines on irrigation scheduling, support for acquisition of analytical, evaluative and monitoring skills, and support for experiential learning and experimentation (Rogers 1995; Czinkota et al. 2000; Nieuwenhuis 2002). This may involve growers attending courses and demonstrations, visiting other growers and employing agronomic consultants. Hence, a mix of printed information and personally conveyed information using formal or informal, group or individual processes may be appropriate (Rogers 1995; Czinkota et al. 2000; Shields et al. 2003).

The adoption of RDI irrigation also highlights that architectural innovations can have profound implications for the operation of other farm-sub-systems. The higher degree of stress placed on vines may increase the susceptibility of vines to pests, requiring changes in pest and disease management. In addition, the adoption of RDI also requires growers have the capacity to source and deliver irrigation water quickly to vines in response to unexpectedly high temperatures. This may require additional investments in plant and infrastructure to ensure reliable water supplies.

These considerations increase the likelihood that producers may need to make a substantial investment in anticipating and evaluating the benefits and costs of architectural innovations, and planning their implementation. This reinforces the conclusion that the adoption of RDI is likely to entail considerable problem solving and experiential learning as well as learning new technical information.

Radical Innovation

Conversion from furrow irrigation to mini-sprinkler irrigation is an example of a radical innovation. Furrow irrigation involves the watering of plants using a series of narrow channels dug into soil to distribute water. Differences in the elevation of the furrows enable water to flow through the channels under the influence of gravity. Mini-sprinkler irrigation is a system with many low volume sprinklers that are attached to pipes which are fixed to vineyard trellises.

Table 6 Architectural innovation – adoption of Reduced Deficit Irrigation (RDI)

Conventional irrigation with mini-sprinklers		Reduced Deficit Irrigation with mini-sprinklers	
Component	**Component Principles**	**Component**	**Component Principles**
Pump	A mechanism for compressing water		Unchanged
Valve	A mechanism to control the flow of water through a pipe		Unchanged
Timer	A mechanism to open or close valves at a pre-set time		Unchanged
Mini-sprinklers	Water outlet that emits water at relatively low volume		Unchanged
Pipes	Fixed, round, sealed receptacle used to contain water		Unchanged
Filter	Mechanism for removing impurities from water		Unchanged
Tensiometer	Mechanism for measuring water content of soil		Unchanged
Architecture	**Architectural Principles**	**Architecture**	**Architectural Principles**
Conventional irrigation	Irrigation system is a fixed structure	Reduced deficit irrigation	Unchanged
	Water moves through system from high to low pressure		Unchanged
	Irrigation scheduling based on satisfying physiological requirement of plants for water optimises plant growth and crop production		By limiting water during specific stages of crop development the physiological processes of the vine can be influenced to modify crop characteristics

A pump creates pressure and the difference in water pressure between the pump and the sprinklers forces water to flow through the pipes. The key components, component principles and architectural principles for furrow and mini-sprinkler irrigation are reported in Table 7.

Table 7 reveals that many of the components in the irrigation sub-system and the principles underpinning them are changed. In addition, the architectural principles of the sub-system are also changed. Hence, as a type of innovation, the conversion from furrow to mini-sprinkler irrigation is radical.

The replacement of all of the components of furrow irrigation with new components underpinned by different principles or core design concepts means that much of the knowledge accumulated by growers about the operation of furrow irrigation would not be relevant to the operation of mini-sprinkler irrigation. Hence, much of the component knowledge growers with furrow irrigation possess regarding irrigation layout, laser grading and the timing and duration of irrigations would be obsolescent. Consequently, the replacement of furrow irrigation with mini-sprinkler irrigation is competence destroying. Growers must acquire new skills in the operation, service and repair of pumps, valves, pipes and mini-sprinklers.

The changes in architectural principles may require growers to understand the consequences of differences in wetting patterns and flow rates and to learn new skills in the frequency and duration of irrigation. This may entail the acquisition of new skills in monitoring, evaluation and analysis in order to accurately assess the state of their soil and vines, draw appropriate conclusions about the need for management intervention and make appropriate decisions about irrigation scheduling. Furthermore, the process of replacing furrow irrigation with mini-sprinklers may involve some degree of problem solving and planning to fit the particular circumstances of growers. These changes may require new management procedures, the replacement of old equipment and the establishment of new relationships with suppliers (Abernathy and Clark 1985).

Table 7 Radical innovation – conversion from furrow irrigation to mini-sprinkler irrigation

Furrow irrigation		**Mini-sprinkler irrigation**	
Component	**Component Principles**	**Component**	**Component Principles**
Gate	Mechanism for releasing water into channel		
Furrow	Narrow channel in soil for directing water		
Siphon	Mechanism for directing water into furrows from channel		
		Pump	A mechanism for compressing water
		Valve	A mechanism to control the flow of water through a pipe
		Timer	A mechanism to open or close valves at a pre-set time
		Mini-sprinklers	Water outlet that emits water at relatively low volume
		Pipes	Round, sealed receptacle used to contain and transport water
		Filter	Mechanism for removing impurities from water
Spade	Mechanism for subjectively assessing water content of soil	Tensiometer	Mechanism for measuring water content of soil
Architecture	**Architectural Principles**	**Architecture**	**Architectural Principles**
Gravity irrigation	Irrigation system is a fixed structure	Pressurised irrigation	Irrigation system is a fixed structure
	Under the influence of gravity water moves through system from high to low elevation		Water moves through system from high to low pressure
	Irrigation scheduling based on satisfying physiological requirement of plants for water optimises plant growth and crop production		

In short, the conversion from furrow irrigation to mini-sprinkler irrigation is likely to entail considerable problem solving and experiential learning as well as learning new technical information (Nieuwenhuis 2002; Shields et al. 2003). Hence, the role for extension may be to include the provision of technical information on principles of mini-sprinkler irrigation, the provision of information on maintenance and management, guidelines on irrigation scheduling, support for acquisition of analytical, evaluative and monitoring skills, and support for experiential learning and experimentation (Rogers 1995; Czinkota et al. 2000; Nieuwenhuis 2002).

Assistance in planning and installation may also be required. This may involve growers in attending courses and demonstrations, visiting other growers and employing agronomic consultants. Hence, a mix of printed information and personally conveyed information using formal and informal, group and individual processes may be appropriate (Rogers 1995; Czinkota et al. 2000; Shields et al. 2003).

The conversion to mini-sprinklers may also have profound implications for the operation of other farm sub-systems. With furrow irrigation, a relatively high proportion of the vineyard floor is watered. This restricts the potential to carry out other activities in the vineyard during irrigation. Furthermore, furrow irrigation requires relatively constant monitoring to ensure appropriate rate of flow is achieved along the furrow. In contrast, with mini-sprinklers a relatively low proportion of the vineyard floor is watered. Also, relatively little time is required monitoring mini-sprinkler irrigation. Consequently, the conversion from furrow to mini-sprinkler means that other activities such as inter-row management, pest and disease management and harvesting can be undertaken while irrigating. Also, the labour effort involved in irrigating is substantially reduced.

In short, as an example of radical innovation, the conversion from furrow to mini-sprinkler irrigation can have profound implications for the operation of other farm-sub-systems. This suggests that substantial effort may need to be invested in anticipating and evaluating the benefits and costs of radical innovations, and planning their implementation. This reinforces the conclusion that the conversion from furrow irrigation to mini-sprinkler irrigation is likely to entail considerable problem solving and experiential learning as well as learning new technical information.

Discussion

The classification of agricultural innovations according to extent of innovation in the components and architecture of farm sub-systems seems consistent with concepts in diffusion theory like relative advantage, complexity, trialability and observability. 'Complexity' concerns the degree of effort needed to understand and use an innovation (Rogers 1995). The more complex an innovation is, the more difficult will be the tasks of understanding their underpinning principles, implementing them and anticipating the consequences of adopting them. Hence, more complex innovations place greater demands on the learning and implementation skills of decision-makers (Rogers 1995). Given this characterisation of complexity, it seems reasonable to propose that incremental, modular, architectural and radical innovations are progressively more complex kinds of innovations. This suggests that the rate of diffusion would tend to be fastest for incremental innovations, slower for modular and architectural innovation, and slowest for radical innovations.

'Observability' is the ease with which the results of the innovation can be seen and evaluated, while 'trialability' is the degree to which an innovation can be tested or sampled before being fully adopted (Rogers 1995; Pannell et al. 2006). Given these definitions, we expect that incremental and modular innovations to farm sub-systems are likely to be easier to trial and the results easier to observe, than would be the case with architectural and radical innovations to farm sub-systems. Hence, the classification of innovations to farm sub-systems presented here may assist investors in research and extension to make assessments about the likely rate of adoption of innovations, as well as the kinds of extension activities that would accelerate adoption.

These considerations suggest that the classification of innovations presented here complements diffusion theory and that this proposition could be empirically tested using appropriate measurement scales.

The approach taken here to classifying agricultural innovations also seems consistent with farming systems research. Farming systems research treats agricultural enterprises as managed systems that consist of hierarchical networks of complicated, interdependent sub-systems that are open to biophysical, economic and social influences (Norman 1980; Ruthenberg 1980; Byerlee et al. 1982; Norman 2002). The objective of farming systems research is to find solutions to critical constraints within farm sub-systems that limit the operation of farm systems as a whole (Ruthenberg 1980; Byerlee et al. 1982; Norman 2002). These solutions often take the form of innovations in technology or management practices. Hence, the approach taken here of interpreting agricultural innovations as a type of innovation in the sub-systems of farms is entirely consistent with farming systems research.

The innovations that emerge from farming systems research are expected to diffuse among the population of agricultural enterprises with the appropriate type of farm system because the innovations are designed to integrate precisely with that type of farm system (Byerlee et al. 1982; Dorward et al. 2003; Kobrich and Khan 2003). Consequently, the approach taken here complements farming systems research, in that it provides a framework for assessing the relative rate at which innovations that are the product of farming systems research may diffuse through the relevant population of farm enterprises. The framework also provides insights into the kinds of extension activities that may be necessary to support that diffusion.

The approach taken here to classifying agricultural innovations complements participatory approaches to agricultural research and extension. Participatory approaches to research and extension lack systematic methods for promoting the dissemination of innovations on a broad scale (Douthwaite et al. 2002; Dorward et al. 2003). Hence, the approach presented here to classifying innovations into different types complements participatory research and extension programs by providing a means for identifying the kinds of extension activities that may be necessary to promote the dissemination of innovations through the wider population of producers.

The approach taken here to classifying agricultural innovations also complements the concept of farm context proposed by Kaine (2004). Kaine (2004) and others (Rogers 1995; Roling 1996; Pannell et al. 2006) propose that agricultural innovations will only be adopted if they create net benefits for producers, that is, they will only be adopted if they offer a relative advantage (Rogers 1995). Kaine (2004) draws on faming systems theory to suggest a method for identifying those producers for whom an innovation has the potential to create a net benefit. These producers represent the market for an innovation and this market can be classified into segments based on differences in their farm systems that influence the kinds of benefits to be had from an innovation. The identification of benefit segments provides a basis for designing extension messages to communicate the benefits of an innovation to producers. These messages provide the basis for producers to self-select in seeking information on innovations and choosing to attend extension activities. Hence, the approach presented here to classifying innovations into different types, by providing a means for identifying the kinds of extension activities that may be necessary to support the adoption of agricultural innovations, complements the identification of benefit segments.

The distinction Henderson and Clark (1990) have made between changes in the components of a system and changes in the architecture of a system appears to provide a method for classifying innovations that discriminates between the critical qualitative differences in the learning that is required to adopt them. This raises the possibility that their approach to classifying innovations may be used by extension professionals and policy makers to make decisions more systematically about the incorporation of different extension methods into the design of extension programs.

For example, Henderson and Clark (1990) suggest that architectural and radical innovations have greater disruptive effects on organisational systems than incremental and modular innovations. The corollary here is that architectural and radical innovations have greater disruptive effects on other farm sub-systems than incremental and modular innovations. The results of the applications presented here support this proposition. This suggests that, even though architectural innovations can have profound impacts on the operation of farm systems, they can appear deceptively simple to disseminate. Consequently, investors in research and extension may find extension programs intended to promote architectural innovations may produce unexpectedly disappointing results. On the other hand, if similar results were produced by a program promoting the adoption of a radical innovation, that program may well be regarded as a model of success. Hence, distinguishing between different types of innovations is fundamental important to making accurate assessments of the performance of extension programs.

We have argued that different kinds of extension activities suit the promotion of different types of innovations. An important consequence of this argument is that similar programs should not be employed to promote different types of innovations. This suggests that great care should be taken in using apparently successful extension programs as models for the design of programs to promote the adoption of other innovations. Similarly, great care should be taken in designing a single extension program to promote a variety of innovations.

Finally, we have focussed on applying Henderson and Clark's (1990) approach to classifying innovations in agricultural technologies and practices. In principle this approach could be extended to any change in farm sub-systems. This raises the possibility that other interventions in farm systems, such as the regulation of farm activities by government policy and legislation, could be classified in a similar fashion thereby providing insights into the degree of disruption such changes may introduce into farm systems. Such insights could be used to guide the design of extension programs aimed at supporting compliance by producers.

Conclusion

Applying the framework developed by Henderson and Clark (1990) to the agricultural innovations appears to provide insights into the kinds of information and knowledge that producers may require to successfully incorporate different types of innovations into their farm systems. As a consequence, the framework offers the promise of a systematic method for identifying the kinds of extension activities that might be necessary to promote the adoption of different types of innovations. Such a method would assist investors in research and extension to formulate expectations about the rate of diffusion of innovations in a more methodical manner, and would allow them to make decisions about investing in extension programs and activities in a more logical manner.

We have argued the use of the framework developed by Henderson and Clark (1990) is consistent with current thinking in extension including farming systems theory and research, diffusion theory, benefit segmentation and participatory approaches. As a consequence this framework provides insights that complement those obtained from these theories and approaches.

In principle, the framework could be extended beyond the adoption of agricultural innovations to classify other interventions in farm systems, such as regulatory interventions. This would offer insights into the selection of extension activities to support compliance programs.

Future work will be directed towards testing the proposed relationships between the different type of innovation and the knowledge and skills required for their adoption. For example, a series of case studies may be used to explore how producers have acquired component and architectural knowledge when adopting innovations and to determine if different extension processes were required for each.

The proposed relationship between the different types of innovations and the complexity, observability and trialability of innovations may also be explored in future work. Differences in the rate of diffusion of each type of innovation could also be investigated.

Finally, the application of the framework to compliance issues in agriculture could be explored in the future.

References

Abernathy, W and Clark, KB 1985, 'Innovation: Mapping the Winds of Creative Destruction', Research Policy, vol. 14, pp. 3-22.

Andrew, J, Breckwoldt, R, Crombie, A, Aslin, H, Kelly, D and Holmes, T 2005, 'Fostering Involvement—How to Improve Participation in Learning', Rural Industries Research and Development Corporation.

Argyris, C 1976, 'Single-Loop and Double-Loop Models in Research on Decision Making', Administrative Science Quarterly, vol. 21, no. 3, pp. 363-375.

Baldwin, CY and Clark Kim, B 2000, Design Rules: the Power of Modularity, MIT Press, Cambridge, MA.

Bandura, A 1977, 'Self-efficacy: Toward a Unifying Theory of Behavioural Change', Psychological review, vol. 84, no. 2, pp. 191-215.

Biggs, SD and Clay, EJ 1981, 'Sources of Innovation in Agricultural Technology"', World Development, vol. 9, no. 4, pp. 321-336.

Black, AW 2000, 'Extension Theory and Practice: A Review', Australian Journal of Experimental Agriculture, vol. 40 pp. 493-502.

Byerlee, D, Harrington, L and Winkleman, DL 1982, 'Farming Systems Research: Issues in Research Strategy and Technology Design', American Journal of Agricultural Economics, vol. 64, no. 5, pp. 897-904.

Christensen, CM and Overdorf, M 2000, 'Meeting the Challenge of Disruptive Change', Harvard Business Review, vol. March-April., no. 1-10.

Cornish, JB, Murphy, JP and Fowler, CA 1990, 'Irrigation for Profit', Water Force Victoria, Irrigation Association of Australia.

Coutts, JR, K. Frost, F. Coutts, A. 2005, 'The Role of Extension in Building Capacity. What Works and Why?' Rural Industries Research and Development Corporation.

Czinkota, MR, Dickson, PR, Dunne, P, Griffin, A, Hoffman, KD, Hutt, MD, Lindgren, JH, Jr., Lusch, RF, Ronkainen, IA, Rosenbloom, B, Sheth, JN, Shimp, TA, Siguaw, JA, Simpson, PM, Speh, TW and Urbany, JE 2000, Marketing Best Practices, The Dryden Press, Orlando.

Dorward, P, Galpin, M and Shepard, D 2003, 'Participatory Farm Management Methods for Assessing the Suitability of Potential Innovations. A Case Study on Green Manuring Options for Tomato Producers in Ghana', Agricultural Systems, vol. 75, pp. 97-117.

Douthwaite, B, Keatinge, JDH and Park, JR 2002, 'Learning Selection: An Evolutionary Model for Understanding, Implementing and Evaluating Participatory Technology Development', Agricultural Systems, vol. 72, pp. 109-131.

Fulton, A, Fulton, D, Tabart, T, Ball, P, Champion, S, Weatherly, J and Heinjus, D 2003, 'Agricultural Extension, Learning and Change', Rural Industries Research and Development Corporation.

Gatignon, H, Tushman Michael, L, Smith, W and Anderson, P 2002, 'A Structural Approach to Assessing Innovation: Construct Development of Innovation Locus, Type, and Characteristics', Management Science 2002 INFORMS, vol. 48 no. 9, pp. 1103-1122.

Goodwin, I 2000, 'Irrigation Scheduling for Regulated Deficit Irrigation (RDI)'. State of Victoria, Department of Primary Industries.

GWRDC 2007, 'Annual Report 2006-07', Grape and Wine Research Development Corporation.

Henderson, RM and Clark, KB 1990, 'Architectural Innovation: the Reconfiguration of Existing Product Technologies and the Failure of Established Firms', Administrative Science Quarterly, vol. 35, no. 1, pp. 9-27.

Invest Australia 2005, 'From Australian Wine Industry; A Fruitful Future, Wine Industry Overview'.

Kaine, G 2004, 'Consumer Behaviour as a Theory of Innovation Adoption in Agriculture', Social Research Working Paper 01/04, AgResearch, Hamilton, New Zealand.

Kaine, G and Bewsell, D 2001a, 'Managing Irrigation for Grape Production, Interim Report' School of Marketing and Management, Interim Report, University of New England, Armidale. pp. 1-26.

Kaine, G and Bewsell, D 2001b, 'Managing Irrigation for Grape Production, Second Report' School of Marketing and Management, Second Report, University of New England, Armidale. pp. 1-90.

Kaine, G and Bewsell, D 2002, 'Managing Irrigation for Grape Production, Third Report' School of Marketing and Management, Third Report, University of New England, Armidale. pp. 1-39.

Kaine, G and Higson, M 2006, 'Policy Change as Innovation', Department of Primary Industries Victoria. pp. 1-21.

Kaine, G, Higson, M, Sandall, J and Lourey, R 2006, 'Policy as an Innovation: Case Studies in Australia and New Zealand', Practice Change Research 07/06 Department of Primary Industries Victoria. pp. 1-70.

Kilpatrick, S and Johns, S 2003, 'How Farmers Learn: Different Approaches to Change', The Journal of Agricultural Education and Extension, vol. 9, no. 4, pp. 151-164.

Kilpatrick, S, Johns, S, Murray-Prior, R and Hart, D 1999, 'Managing Farming How Farmers Learn', Rural Industries Research and Development Corporation.

Kobrich, CR, T. Khan, M. 2003, 'Typification of Farming Systems for Constructing Representative Farm Models: Two Illustrations of the Applications of Multi-Variate Analyses in Chile and Pakistan', Agricultural Systems, vol. 76, pp. 141-157.

Kolb, DA 1984, Experiential Learning, Experience as the Source of Learning and Development, Prentice-Hall, New Jersey

Nieuwenhuis, LFM 2002, 'Innovation and Learning in Agriculture', Journal of European Industrial Training, vol. 26, no. 6, pp. 283-291.

Norman, DW 1980, 'The Farming Systems Approach: Relevancy for the Small Farmer', MSU Rural Development, vol. Paper No.5.

Norman, DW 2002, 'The Farming Systems Approach: A Historical Perspective'.

Olofsson, D 2003, 'Radical Product Innovations', Malardalens Hogshola.

Packham, R, Petheram, J and Murray-Prior, R 2007, 'A Farming Systems Research (FSR) As a Platform for RD&E in Agriculture and NRM', In APEN Forum'07, Capture, Consolidate and Communicate......the Changing Nature of Extension, Canberra, 13-14 November, 2007, Australasia-Pacific Extension Network.

Pannell, DJ, Marshall, GR, Barr, N, Curtis, AL, Vanclay, F and Wilkinson, RL 2006, 'Understanding and Promoting Adoption of Conservation Practices by Rural Landholders', Australian Journal of Experimental Agriculture, vol. 46 no. 11 pp. 1407-1424.

Reece, JD, Sumberg, J and Pommier, L 2004, 'Matching Technologies with Potential End Users: A Knowledge Engineering Approach for Agricultural Research Management', Journal of Agricultural Economics, vol. 55, no. 1, pp. 25-40.

Rogers, EM 1995, Diffusion of Innovations, 4th edn, Free Press, New York.

Roling, N 1996, 'Towards an Interactive Agricultural Science',' Journal of Agricultural Education and Extension, vol. 2, no. 4, pp. 35-48.

Ruthenberg, H 1980, 'Farming Systems in the Tropics', in, Farming Systems in the Tropics, Oxford University Press, New York.

Shields, RW, Aaron, D and Wall, S 2003, 'What is Kolb's Model of Experiential Education, and Where Does It Come From?' Ontario Institute for Studies in Education of the University of Toronto, Toronto

Smith, K 2000, 'Innovation as a Systemic Phenomenon: Rethinking the Role of Policy', Enterprise and Innovation Management, vol. 1, no. 1, pp. 73-702.

Sumberg, JO, C. Reece, D. 2003, 'Agricultural Research in the Face of Diversity, Local Knowledge and the Participation Imperative: Theoretical Considerations', Agricultural Systems, vol. 76, pp. 739-753.

Trompf, JP and Sale, PWG 2001, 'Adult Learning Principles Embodied in the Pair-Paddock Model', Australian Journal of Experimental Agriculture, vol. 41, pp. 195-204.

Tushman, ML and Anderson, P 1986, 'Technological Discontinuities and Organisational Environments', Administrative Science Quarterly, vol. 31, pp. 439-465.

Weinberg, GM 2001, An Introduction to General Systems Thinking, Silver Anniversary edn, Dorset House Publishing, New York.