Understanding the benefits sought from grapevine nutrition management by Australian wine grape growers

Megan Hill, Ben Rowbottom and Geoff Kaine

Department of Primary Industries, 255 Ferguson Road (Private Bag 1), Tatura, Victoria 3616
Email: megan.hill@dpi.vic.gov.au

Abstract. Previous studies regarding the need for viticultural research and extension in Australia have generally produced lists of research problems, without necessarily identifying why and for whom the research is important. In this study we used the Kaine Framework (2008) to identify opportunities and the target audience for research and extension in the field of wine grape nutrition. The framework uses a combination of consumer behaviour and farming systems theory to explain the adoption of agricultural innovations and identifies why growers adopt current practices, the context in which adoption occurs, who will adopt and difficulties growers have with adopting. Semi-structured, convergent interviews that used laddering to elicit the benefits growers sought from nutrition-related products where conducted with 45 Australian wine grape growers from 11 wine growing regions. We found that grape growers adopt nutrition-related products for two key reasons. The first was to optimise the establishment and growth of young vines. The second was to manage established vines to meet their vineyard production objectives. Growers considered current nutrition-related products and practices to be satisfactory for optimising the growth and establishment of young vines so we concluded there was little need for research into new products in this area. However, growers reported that they experienced a number of nutrition-related problems in regard to their established vineyards. These problems were in relation to nutrient availability, soil health and modifying wine grape quality. These problems present opportunities for research and extension on the use of nutrition products to achieve different vineyard production objectives. The findings of this study should help the Australian wine grape industry better target research and extension funding. The findings may also be relevant to international viticulture and related horticultural industries.

Key Learnings:

- Grape growers use nutrition-related products primarily to optimise the establishment and growth of young vines, and to manage established vines to meet production objectives.
- There are opportunities for research on nutrition-related products for managing established vines.
- Key problems to be addressed by research into nutrient products include managing nutrient deficiency and soil health problems, and modifying wine grape quality.

Introduction

Australian wine grape growers have repeatedly identified grapevine nutrition as a key area for research and extension. In a workshop held in 2003 growers rated nutrition as their highest priority for industry research, while horticultural advisers rated it their second highest research priority (Byrne and McGuire 2005).

Consequently many surveys, workshops and studies have been conducted to identify and prioritise nutrition-related topics for research and extension (Atkinson and Dignam 2003; Byrne and McGuire 2005; Swinburn and Saris 2005). However, these appear to have provided little information regarding the range of current nutrition practices, how nutrition was related to individual vineyard characteristics, specific nutrition-related problems and how widespread nutrition-related problems are. This lack of information makes allocating funding for nutrition research and extension difficult.

Kaine (2008) outlines a process to identify the benefits farmers seek from adopting innovations such as novel products, technologies and practices. Kaine (2008) suggests that it is the farm context—the biophysical characteristics, skills and knowledge and financial resources available to the farm, and the practices and technologies already in use on the farm—that determines the benefits an innovation can provide. Kaine (2008) further suggests that farmers can be categorised into groups or market segments based on the benefits they are seeking from an innovation, because their farm contexts are similar.

Knowledge of the attributes of farm context that lead to similarities and differences in the benefits an innovation offers producers can be used to identify:

- which producers are using an innovation
- why producers are using an innovation
- what features of the innovation are important in the creation of those benefits

- what features of the innovation or farm context create problems in regard to realising the benefits of the innovation (Kaine 2008).

Hence, the process described by Kaine (2008) can be used to identify priorities for research and extension. By applying this process to the issue of grapevine nutrition management we provide new information that will enable the Australian grape industry to more effectively allocate research and extension funding.

Kaine (2008) describes a market research like process involving qualitative dialectical methods and quantitative survey techniques developed over a number of years from numerous case studies. This process outlined by Kaine (2008) has been successfully used in a number of agricultural industries in Australia and New Zealand. Examples of this process can be seen in: Kaine and Bewsell (2005), Kaine et al. (2005), Boland et al. (2006) and Bewsell et al. (2008). In viticulture these methods have been applied by Kaine and Bewsell (2001b; 2001a; 2002) to investigate the adoption of irrigation and soil moisture monitoring technology in the Australian grape industry. These methods have also been used to study the adoption of sustainable viticultural practices in the New Zealand grape industry (Bewsell and Kaine 2003).

Previous applications of the process used by Kaine (2008) have concentrated on the adoption of distinct, individual innovations. This study represents a novel application of Kaine's (2008) process by using it to study the adoption of a product class (nutrition-related products). A product class is group of products that are, to some degree substitutable (Kotler and Armstrong 1999; Czinkota et al. 2000). In both economic and consumer behaviour theory a product can be defined as a bundle of functions, features, attributes or benefits (Czinkota et al. 2000; Lancaster 1966; Lancaster 1990; Widing et al. 2003). Products in the same product class are substitutable for each other because they provide the same core bundle of benefits or fulfil the same core need of the user. Hence although the products in a class may differ from each other in some way, they can be used for essentially the same reasons.

The topic of this study is nutrition-related products, yet Kaine's (2008) process is developed to study the adoption of an innovation. A number of definitions exist for what an innovation is, most of which include some reference to newness. Rogers (2003) defines an innovation as "… an idea, practice or object that is perceived as new by and individual or other unit of adoption." This concept of innovation may be embodied in new and improved products and process, organisational forms or applications of technologies (Niosi et al. 1993). Therefore innovations, as defined by Kaine (2008) can be viewed as new products or goods as perceived by the farmer according to the core benefit farmers receive from using the innovation.

In this study the innovations are a group of products (fertiliser, mulches etc) that can be employed to obtain benefits in regard to vineyard nutrition. These products are, to some degree substitutable; hence they can be viewed as a product class. In revealing the core benefits provided by an innovation, Kaine (2008) suggests that applying these methods to a product class should reveal the core benefits of that product class. Thus, in this study, we sought to understand the use of nutrition-related products as a product class using the methods proposed by Kaine (2008). In doing so we sought to identify opportunities for research and extension in the management of nutrition with regard to Australian wine grapes. We hope this information will allow the Australian wine industry to better target research and extension spending in the area of vineyard nutrition management.

Methods

We used the methods described by Kaine (2008) in a manner similar to Bewsell et al. (2008), Kaine and Bewsell (2005) and Kaine et al. (2005). This involved conducting a qualitative study of the management of vineyard nutrition and use of nutrition-related products by Australian grape growers.

Convergent interviewing (Dick 1998) and laddering (Grunert and Grunert 1995) were used to identify similar and contrasting patterns in the reasoning underlying the decisions of wine grape growers in regard to nutrition management. Convergent interviewing is unstructured in terms of content but structured in process, it starts with broad questions aimed to keep the interviewee talking, in which further more specific questions are asked to systematically explore common themes within and between interviews (Dick 1998). The process is continued until no new themes emerge from subsequent interviews (Dick 1998). Combined with laddering, a process of asking continually more focused questions (Grunert and Grunert 1995) the interviewer can elicit the reasoning underpinning the interviewee's adoption decision.

Interview responses were recorded manually by two interviewers, summarised, then analysed using case and cross-case analysis (Patton 1990). Growers were selected through purposive and

snowball sampling designed deliberately to seek cases where new themes and reasoning for adoption may exist. The growers were classified into market segments based on similarities in the benefits they sought (Assael 1998) from using nutrition-related products, which related to similarities in the grower's vineyard context (Crouch 1981). After the segments were identified, grower data was analysed to identify the nutrition-related problems for each segment. Opportunities for research were identified where there were no known solutions to problems. Opportunities for extension were identified where solutions existed, but the growers were unaware of them.

Forty-five wine grape growers were interviewed from cool (Coonawarra, McLaren Vale, Padthaway, Yarra Valley and Wrattonbully), warm (Barossa Valley, Bendigo, Goulburn Valley, Heathcote and Strathbogie Ranges) and hot (Sunraysia) wine grape producing regions of Australia. Within each region growers were selected to represent large, medium, small, family and corporate businesses, and a cross-section of wine quality grades and price points.

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.

Results

General findings on vineyard nutrition management

We found that understanding how grape growers managed vine nutrition was challenging. Some growers used a variety of complementary and/or substitutable products and management techniques to address one particular problem. Hence, these products constitute a product class. For instance, some growers used foliar sprays, fertigation and mulch to improve vine vigour. Some growers also used one particular product or management technique to address a variety of different problems. For example manure may be used to improve low vine vigour, poor soil structure and inconsistent fruit quality. This resulted in an overlap between products and practices in product classes (Lancaster 1966; Lancaster 1990), and the products used by each segment.

The growers also said that grapevine nutrition interacts with (and could not be considered in isolation from) soil properties, soil health and vine balance. This interaction meant that the benefits of nutrition management were slow to become apparent, and difficult to evaluate. There is an extensive range of nutrition-related products and management options available to the industry, often associated with confusing and/or conflicting advice.

Market segments for vineyard nutrition management

The growers we interviewed managed vine nutrition using nutrition-related products such as synthetic and organic fertilisers, lime, gypsum, compost, manure and/or mulch. The main factor influencing the benefits sought by growers was the stage of vineyard establishment, which correlated with the age of vines (Figure 1). Therefore the growers were classified into market segments depending on whether they were using nutrition products to; prepare a vineyard site for planting, to optimise the growth of young vines, or to manage established vines. A number of market segments were identified among the growers managing established vines, depending if the growers were using nutrition-related products to try to improve their soil or change their fruit quality.

Many of the growers interviewed were members of a number of market segments as vineyards typically have blocks of vines of different ages, on a range of soil types. A summary of the benefits sought by growers in each segment is provided Table 1.

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

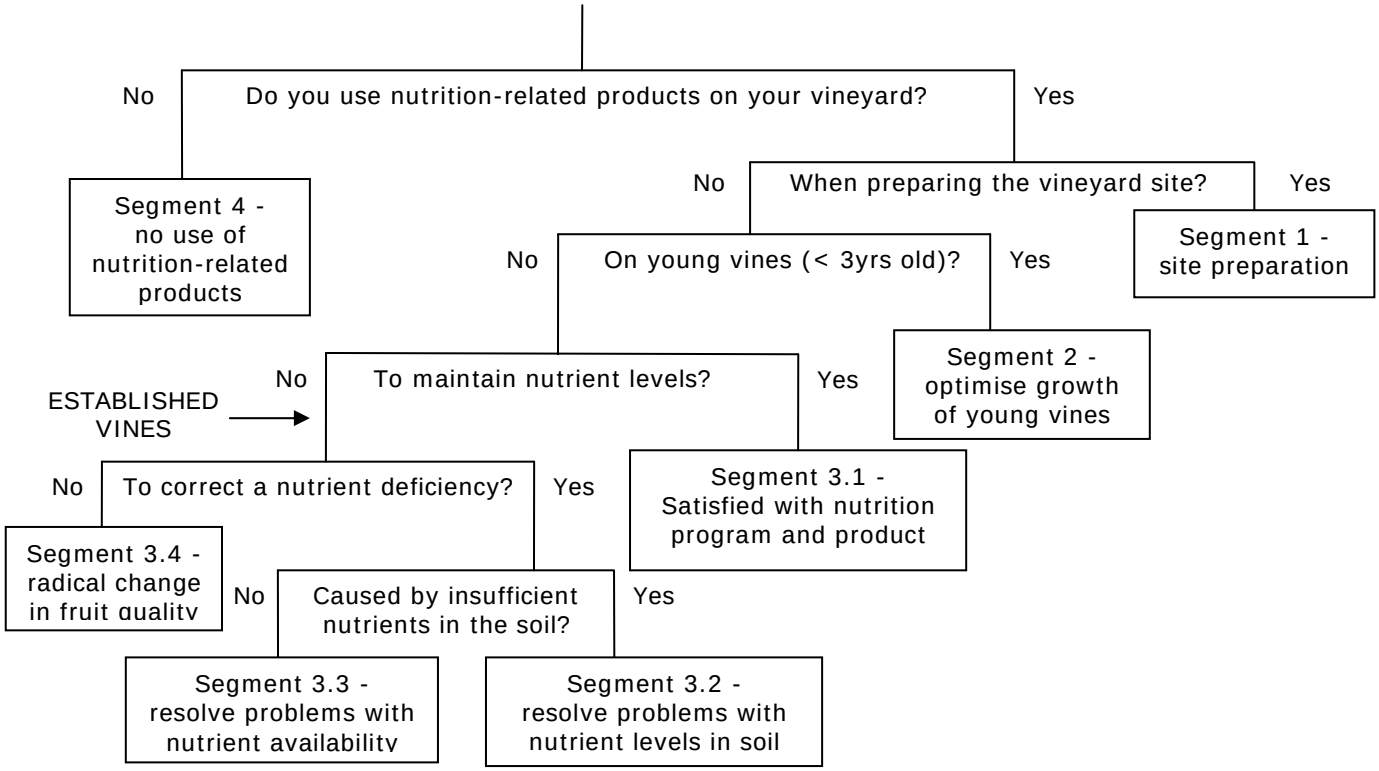

Table 1: Summary of the benefits sought by growers in each segment through nutrition management

Reason for using or not using nutrition-related products	Segment 1	Segment 2	Segment 3.1	Segment 3.2	Segment 3.3	Segment 3.4	Segment 4
Incorporate nutrient-related products into root zone	Yes	No	No	No	No	No	No
Maximise the survival of young vines	Yes	Yes	No	No	No	No	No
Maximise the growth of young vine	Yes	Yes	No	No	No	No	No
Manage establish vines	No	No	Yes	Yes	Yes	Yes	Yes
Increase nutrient levels in soil	No	No	No	Yes	No	No	No
Increase nutrient availability	No	No	No	No	Yes	No	No
Provide the 'X' factor/ improve fruit quality	No	No	No	No	No	Yes	No
Number of growers in segment for a section of their vineyard	31	35	29	29	18	4	12

Segment 1 - site preparation

Growers in this segment sought to maximise survival and growth of young vines through nutrition management. The majority of growers interviewed had prepared their vineyard site prior to planting vines by incorporating nutrition-related products, mainly gypsum to improve soil structure, lime to modify pH, and fertiliser to add nutrients, often by deep ripping or rotary hoeing. Growers said that site preparation was extremely important because once the vines were planted it was difficult or impossible to deliver nutrition products to the root zone, without damaging the vine. A Goulburn Valley grower 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 products prior to planting had either deep, fertile soils or a site with high residual fertiliser from previous use of the site.

Problems and opportunities The majority of growers in this segment were satisfied with their site preparation. The few problems that did occur were related to incomplete or inaccurate information, recommendations or advice for preparing the growers' individual vineyards. Therefore opportunities for research and extension in this segment are:

- clarifying pre-planting guidelines on nutrition-related products in relation to different soil types
- developing new products or application techniques that will provide the benefits currently being obtained, more cheaply, efficiently and reliably
- refinement 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 benefit the growers in this segment sought through nutrition management was to maximise the survival and growth of young vines to establish the vine structure required for cropping. The majority of growers interviewed had a specific nutrition program for young vines, which usually involved fertilising young vines regularly with small doses of nitrogen, often through applying calcium nitrate via fertigation.

Another Goulburn Valley grower succinctly summarised the views of segment two growers:

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

Problems and opportunities Most growers in this segment were satisfied with the performance of nutrition programs for their young vines. Any problems encountered in relation to young vines were usually due to pests, frost, watering or vine training. Therefore opportunities for research and extension in regard to nutrition-related products in this segment were limited to:

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

Segment 3 - management of nutrition for established vines

Growers interviewed changed their nutrition management strategy once their young vines were established, which included reducing the amount of nitrogen being applied to prevent excessive growth and associated problems. We identified a number of sub-segments within segment three which depended on growers' soil types, vineyard location and fruit quality objectives.

Segment 3.1- satisfied with nutrition program and products

Growers in this segment cropped vines consistently once vines were established and used the same or a similar nutrition program each year. These growers' nutrition programs worked satisfactorily in that they did not have any nutrition-related problems. Growers in this segment achieved this through using the same nutrition program each year, or by changing fertiliser brands or adjusting application rates. These growers' did not report any nutrition-related problems. Some of the growers used soil or plant tissue testing to check that their management was meeting the vines' nutrition needs, others were happy that visual assessment of vines would reveal any emerging problems.

The manager of 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."*

Problems and opportunities Growers in this segment said they did not have any nutrition-related problems and were not thinking of making major changes to their nutrition program. Therefore opportunities for research and extension in this segment were limited to:

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

Segment 3.2 – resolve problems with nutrient levels in the soil

Growers this segment indicated they were using nutrition management to increase the nutrient levels of poor, weak, shallow or nutrient depleted soils

The growers said that low soil nutrient levels led to vines losing vigour, showing deficiency symptoms and getting out of "balance". That is when vine growth cannot support the desired yield and quality of grapes. Some growers were familiar with the visual symptoms of nutrient deficiencies and added additional products accordingly. Other growers used soil and plant tissue tests to confirm their suspicions, to determine how severe the deficiency was and to get advice on products and rates of application to fix the problem.

Macro-nutrient deficiencies were fairly common on hilly sites and areas with poorer soils. For example one grower had two vineyards in the Wrattonbully region. His vines were planted between 1996 and 1999 into Terra Rossa soil over stone. He said:

> *"I alternate soil and petiole tests each year, and also keep my eyes open. I top-up my fertiliser program depending on the test 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 reported micro-nutrient deficiencies—in particular zinc, boron and molybdenum—which they said led to low fruit set. A few growers mentioned having grapes with thin skins, which they attributed to low calcium levels. A grower with a 25 ha Yarra Valley vineyard 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 molybdenum and boron as part of my fertiliser program, and I have not had trouble since."*

Growers said they find it relatively easy to increase soil nutrient levels, as it was usually a matter of identifying which nutrient/s were in the soil and so which fertilisers to apply. For macro-nutrients growers usually broadcast or fertigate while foliar sprays are usually used to apply micro-nutrients.

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

> *"We have sandy, deep soils in the east, red soils over limestone in 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 difficulties in identifying deficiency symptoms or applying nutrition-related products. The growers said identifying the "best" product to meet their vines' nutrition needs was the most difficult part of correcting nutrient deficiencies. Growers reported finding it difficult to get reliable information about the content, use and effectiveness of fertiliser products from resellers. Growers said they received conflicting advice making comparing products confusing and difficult, and there was rarely any reliable trial data available. The effectiveness of applying foliar sprays to correct micro-nutrient deficiencies was questioned by some growers. Therefore there appeared to be opportunities for research and extension to:

- independently evaluate the features and effectiveness of foliar application, fertilisers, mulches and composts.

- instruct 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 – resolve problems with nutrient availability

Growers in this segment managed their nutrition to increase the availability of the nutrients to the vines. Soil health problems or low soil moisture made the nutrients present in the soil unavailable or difficult for the vine to absorb, which resulted in the vine showing deficiency symptoms. Growers in this segment were seeking information and changing their nutrition program to manage these problems.

Soil health problems Soil health problems can be chemical, physical or biological. Chemical soil acidification associated with long-term use of conventional fertilisers—mainly ammonium nitrate and urea—was the major soil health problem raised by growers in this segment. These growers were trying to reverse the acidification process by applying lime to the soil. However, growers said that lime is not soluble so it does not move readily to the root zone and it can be hazardous to apply. A soluble lime product has been developed for fertigation, however growers found this more expensive and not always effective. A Strathbogie Ranges grower who produces both red and white grapes has noticed soil acidity problems occurring 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 soil problems, such as compaction and soil crusting. The growers attributed this to some of their viticultural practices, mainly driving along the vine row, tilling the soil or removing vegetation. Deterioration in soil structure affects root development, reducing vine performance, nutrient and water uptake. Growers treated soil structure problems by using inter-row plantings or increasing organic matter by applying mulches, manure or composts. A few growers said they did not have enough microbial activity in their soil to breakdown organic matter and prevent nutrient leaching. Growers treated this by using composts or mulches. A few were trialling commercial mixes of micro-organisms or humic acid. The manager of a 70 ha Coonawarra vineyard growing Shiraz, Merlot, Cabernet Sauvignon and Chardonnay in black clay over limestone soils 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. 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 resolve their problems with soil health. Many of these growers were unsure how organic products worked, or what relative advantage organics offered, but they were convinced that organics would improve soils without exacerbating existing problems.

Problems and opportunities A number of soil health diagnostic and treatment problems were identified by the growers in this segment. The opportunities that arise from these problems include:

- developing tools to diagnose soil health problems
- providing objective advice about the causes and impacts of soil health problems
- conducting research and extension regarding how to solve or manage soil health problems
- evaluating and comparing the effectiveness and economics of soil health management products
- developing superior products and practices to manage soil health problems.

Low levels of soil moisture Due to a series of below average rainfall years, some growers were experiencing symptoms of nutrient deficiencies for the first time. Many growers attributed this to low soil moisture reducing nutrient availability. The manager of a large well established Sunraysia vineyard, summarised many growers' concerns:

> *"The drought is making grape growing harder and 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 were rethinking their nutrition program, because products they have used in the past have depended on rainfall and soil moisture to transport nutrients to the root

zone. Some growers had switched from broadcasting fertiliser to using fertigation in order to use irrigation water to transport nutrients.

Problems and opportunities In short these growers believed their nutrition program was not working due to low soil moisture but lacked information on the implications of this for selection of nutrition-related products. Some growers were unsure if the symptoms exhibited by their vines were due solely to dry years. Opportunities for research and extension may be to:

- disseminate information on products to optimise fruit production from limited water while minimising long-term impacts
- inform growers about nutrition management and product options for low soil moisture.

Segment 3.4 – radical change in fruit quality

The growers in this segment were seeking to change the quality of their fruit through their nutrition management. Growers from all segments talked about vine balance and fruit quality in relation to nutrition. Most growers from other segments said that if you met the vines' nutritional requirements, any changes in fruit quality beyond that would be achieved through changing other vineyard practices. In contrast, growers in this segment believed they could change fruit quality by using nutrition-related products.

A Sunraysia couple, who own a 20 ha vineyard, reacted to falling fruit prices by deciding to grow the highest quality fruit possible in order to maximise their fruit price. They changed their nutrition management to help them achieve this objective. They said:

> *"We are aiming for a higher quality grade than is normal for this area. We're targeting grade 3, semi-premium quality. So we have started using […] 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 […] products, and I have faith in […], 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 […] for part of last season. This will give us an edge and help us as we strive for excellence."*

A few growers were in the process of converting, to organic or biodynamic systems. The owner of a 10 ha vineyard and an orchard near Heathcote 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 definition of grape 'quality' varies and the many grape characteristics that contribute to quality are poorly understood. Consequently it is difficult to determine the impact nutrition has on grape quality. Establishing the link between grape characteristics and quality could inform the design of product that could influence grape quality. Little is known about biodynamic and organic nutrition versus conventional nutrition. Any information generated on these topics would be of interest to growers in this segment.

Segment 4 – no use of nutrition-related products

In this study we did not find any commercial growers that had *never* used any nutrition-related products. However, we did interview some growers who did not currently or consistently apply nutrition-related products, either because their soil was deep and fertile or their vineyard was previously under pasture or crops and had a high residual nutrient content. Some of these growers had younger established vines and their pre-planting fertiliser had not yet been depleted. Many growers in this segment regularly monitored their soil or plant nutrient status.

One grower had planted an 8.5 ha vineyard in Heathcote seven years ago on clay loam soils:

> *"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."*

Problems and opportunities Growers in this segment do not have any problems with nutrition or use of nutrition-related products. Opportunities for nutrition research and extension in this segment were not evident.

Discussion

In this study we have identified factors that influence how wine grape growers manage nutrition, where and why nutrition problems are occurring, and have identified opportunities for research and extension. The advantage of this study over previous surveys and workshops is that the cause of problems and opportunities are explained and linked to specific groups of growers. Our findings suggest that there were particular circumstances where growers were strongly motivated to seek specific information about nutrition-related products to inform their nutrition management decisions. This occurred when:

- growers were starting a nutrition program that was new to them, or on a new site
- symptoms appeared in the vineyard to indicate that there was a nutrition-related problem
- growers were seeking to change their grape quality.

We suggest that outside these circumstances, growers would not be seriously interested in reconsidering their nutrition management programs and changing the nutrition-related products they purchase. This is exemplified by the growers in segment three point one, who used the same nutrition management program each year as it met their needs. They were not interested in searching for new information and changing their nutrition management. However, these growers did suggest that they were interested in cheaper, more efficient, environmentally friendly or safer products and application methods.

Grouping some nutrition-related products into product classes has enabled us to avoid the confusion and complexity created by farmers using complementary and substitutable products to solve one problem, or one product to solve a number of problems. The confusion created by this product substitution we believe has confounded results of previous research. One of the details that previous research has not been clear about is that these substitutable products are actually providing the same core benefit to the grape growers. Hence research and extension should focus on how growers can best achieve the core benefit (e.g. increased nutrient availability) of the substitutable products. For example, a grower suggesting research on mulch, compost and lime may actually be requesting research on soil health.

By aggregating a number of innovations into product classes we have been unable to identify specific purchase criteria for each particular innovation or product. This is an area for further research if we are to assist growers to make more informed decisions about nutrition-related products. For example studies on the use of mulches and composts, adoption of organic products or the use of sap and leaf testing would provide valuable information on the market for these products; and how research and extension may contribute to the efficient operation of these markets.

To obtain maximum value from this work a quantitative study similar to Kaine et al. (2005), possibly in conjunction with spatial mapping, would be desirable to determine the numbers, area and location of vineyards in each market segment. The results of such a study would indicate how widespread nutrition management practices and the problems we have identified are, which would guide the allocation of research and extension resources. Quantifying segments could also provide baseline data regarding aspects of nutrition management such as current practice, evolving trends and issues, adoption of relevant innovations and research findings, and environmentally important practices.

Conclusion

Australian grape growers see vineyard nutrition management as an important aspect of their business. Grape growers use nutrition-related products primarily to optimise the establishment and growth of young vines, and then manage establish vines to meet their vineyard objectives given their vineyard context. Growers consider their vineyard nutrition management in conjunction with information about their soil type, health and vine balance. Depending on the circumstances growers may use one nutrition product to address many nutrition problems, or use many products to address a single problem. While extensive information, and much advice, is available on vine nutrition it is not easy for growers to identify the best nutrition practices for their vineyard.

In this project we have classified growers into market segments based on the benefits they sought through using nutrition-related products. We have identified opportunities for research and extension for growers in each segment. We suggest that future work should aim to validate, describe in more detail and quantify these market segments. The information generated by this study should help the Australian wine grape industry better target research and extension funding. The approach used in this study could also be to determine the benefits sought by farmers when adopting innovations from other classes of products in other industries.

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