



Proceedings of the Symposium on Sustainability in Vineyards and Wineries

Feb. 7-9, 2009
Midwest Grape and Wine Conference
Osage Beach, Missouri

Workshop Sponsors

Institute for Continental Climate Viticulture and Enology
College of Agriculture, Food and Natural Resources, University of Missouri
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University of Missouri Extension

Proceedings of the Symposium on Sustainability in Vineyards and Wineries

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**Midwest Grape and Wine Conference
Osage Beach, Mo.**

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On the Cover (clockwise from top left): 1) A pheromone-based grape berry moth (GBM) trap hangs in a tree on the vineyard's edge to detect the first emergence of GBM in the spring. The first trap catch sets the biofix date, from which the life cycle of the moth's multiple generations per season can be predicted; 2) A grower meeting held in a vineyard setting as part of the Institute for Continental Climate Viticulture and Enology's Vineyard Best Management Practices Project; 3) The use of petiole and soil samples to monitor vine nutrition status and guide vineyard fertilization programs can help prevent nutrient deficiencies before they occur or reduce excessive or unnecessary fertilizer applications; 4) A computerized vineyard weather station placed within the vine canopy to measure temperature, relative humidity and leaf wetness. Data from this station can be plugged into disease models to predict disease infection events.

Table of Contents

Symposium Agenda 4

Presentations

Sustainable Winegrowing: What is it and where does it come from? 7

Cliff Ohmart

Soil Biota in the Vineyard 25

Paul Schreiner

The “Greening” of Pacific Northwest Vineyards 27

Mercy Olmstead

VineBalance: Sustainable Viticulture for New York 34

Tim Martinson

**Vineyard Best Management Practices for Missouri and the Ozark Mountain Region:
Principles, Practices and Progress 41**

Keith Striegler, Donn Johnson, Andy Allen and Reid Smeda

**Marketing of Bio-Orgo-Carbon-Neutral-Enviro-Sustainable-Fair-
Trade-Dynamic Wine 49**

Larry Lockshin

**Lodi Rules: California’s First Third-Party-Certified Sustainable
Winegrowing Program 60**

Cliff Ohmart

Addendum

Nutrient Uptake and Use by Grapevines 79

Paul Schreiner

Symposium Agenda

Saturday, Feb. 7, 2009

Dr. R. Keith Striegler, Moderator

- 8:30 - 9:00 a.m.** **Sustainable Winegrowing: What is it and where did it come from?**
Dr. Cliff Ohmart, Research/IPM Director Lodi-Woodbridge Winegrape Commission, Lodi, CA
- 9:00 - 10:00 a.m.** **Soil Biota in the Vineyard**
Dr. Paul Schreiner, Plant Physiologist, USDA-ARS, Corvallis, OR
- 10:15 - 11:15 a.m.** **The “Greening” of Pacific Northwest Vineyards**
Dr. Mercy Olmstead, Extension Viticulture Specialist, Washington State University-IAREC
- 2:00 - 3:00 p.m.** **VineBalance: Sustainable Viticulture for New York**
Dr. Tim Martinson, Senior Extension Associate, Statewide Viticulture Extension Program, Cornell University, Geneva, NY
- 3:15 - 4:15 p.m.** **Sustainable Practices on the Central Coast: Vineyard Floor Management**
Dr. Keith Patterson, Professor of Viticulture, California Polytechnic State University
- 4:15 - 5:15 p.m.** **Vineyard Best Management Practices for Missouri and the Ozark Mountain Region: Principles, Practices and Progress**
Dr. Keith Striegler, Director and Viticulture Program Leader, ICCVE, University of Missouri

Sunday, February 8, 2009

Mr. Eli Bergmeier, Moderator

- 8:30 - 9:30 a.m.** **An Overview of Comprehensive Guide to Sustainable Management of Winery Water and Associated Energy**
Chris Savage, Senior Director, Global Environmental Affairs, E. & J. Gallo Winery
- 9:30 - 10:30 a.m.** **Marketing of Bio-Orgo-Carbon-Neutral-Enviro-Sustainable-Fair-Trade-Dynamic Wine**
Prof. Larry Lockshin, Head, Wine Marketing Group, University of South Australia, Adelaide, AU

11:00 a.m. - noon **Lodi Rules: California's First Third-Party-Certified Sustainable Winegrowing Program**
Dr. Cliff Ohmart, Research/IPM Director Lodi-Woodbridge Winegrape Commission, Lodi, CA

Addendum

10:45 - 11:45 a.m. **Nutrient Uptake and Use by Grapevines**
Dr. Paul Schreiner

Sustainable Winegrowing: What is it and Where Did it Come From?

Dr. Clifford P. Ohmart

Sustainable Winegrowing Director
Lodi Wine grape Commission
Lodi, Calif.

Abstract

Growers wishing to practice sustainable winegrowing are confronted with three challenges: 1) Defining sustainable winegrowing; 2) Figuring out how to implement it in their vineyards on a day-in-day-out basis; and 3) Measuring its impact on their farming operation. In an attempt to define sustainable winegrowing, I trace the history of organic farming, integrated pest management and sustainable agriculture to discover why they developed the way they did and put them into context with each other. I also briefly comment on Rudolf Steiner and the development of biodynamic farming and how it relates to sustainable agriculture, due to its current popularity among wine writers and others. I conclude the presentation with a detailed description of the *Lodi Winegrower's Workbook*, which the Lodi growers developed to meet challenge No. 2. Discussion of challenge No. 3 is left for a future presentation.

Introduction

Three important challenges exist when developing a sustainable winegrowing program: 1) Defining sustainable winegrowing; 2) Implementing it in the vineyard; and 3) Measuring its affects on wine grapes and wine, the vineyard and the surrounding environment. They are challenges because they are not easy to accomplish, and yet they are all very important to achieve.

If you cannot define sustainable winegrowing for yourself it will be impossible to implement it in your vineyard and on your farm. One of the difficulties in creating a definition is figuring out its boundaries. That is because sustainability involves everything you do on the farm, including economics, environmental impacts of everything done on the farm and all aspects of human resources, including not only you and your family but your employees and the surrounding community.

Once you have defined sustainable winegrowing for yourself, the next challenge is to figure out how to implement it in the vineyard on a daily basis. Some practices can readily be evaluated from a sustainability perspective if the right data are available. For example, take the use of a pesticide, either an organically approved one or one of conventional material. A decision on whether to apply it can be made by

considering its cost, its efficacy, its impact on the environment and its impact on workers. Some practices, on the other hand, are more difficult to evaluate from the perspective of sustainability. Consider the maintenance of your vineyard's irrigation system, for example. With a little thought, however, one realizes that an improperly maintained system will result in too much or too little water being applied, which affects not only water-use efficiency but also very likely wine grape quality. Because everything done on the farm can be evaluated from a sustainability perspective, the best tool I have encountered for a grower to use is one of several self-assessment workbooks available (e.g., Ackerman 1998; Dlott et al. 2002; Wise et al. 2008; Ohmart and Matthiasson 2000; Ohmart et al. 2008).

Finally, if you can define sustainable winegrowing for yourself and decide on which practices to implement using a sustainability yardstick, the next challenge is to be able to assess what impact they have on your finances, the quality of your crop, the environment, your workers and the surrounding community. This is just as daunting a challenge as the other two. Part of the problem is that measuring the impact your farming has on environmental indicators like air quality and water quality is extremely difficult. Measuring the affects of sustainable practices on other things, like yield and wine grape quality, is much more straightforward.

This paper will only tackle the first two challenges: defining sustainable winegrowing and implementing it in the vineyard.

Results and Discussion

Defining Sustainable Winegrowing

If I were to assemble 50 people in a room, including growers, environmentalists, scientists and government regulators, and ask them to define sustainable farming I would likely get 50 different definitions. One reason for this is that sustainability deals with all aspects of farming. Another reason is that for some, certain aspects of sustainable farming are value-based. And finally, some practices emphasize economics, others emphasize the environment, while others emphasize social issues.

When trying to come to grips with a complicated topic like sustainable winegrowing, I find it useful to study its evolution. Sustainable farming, organic farming and integrated pest management grew out of the same roots, so to speak. So let's examine how each developed over time and how they are related.

Evolution of Organic Farming

When defining sustainable agriculture we need to look at the history of organic farming because sustainable agriculture (and thus sustainable winegrowing) arose out of this movement. The present paradigm of organic farming began as a melding of several different schools of thought that were supported by European and English scientists active in the 1920s, '30s and '40s. As one would expect, opinions differ as to who really started the organic movement, with at least two people, both British, being bestowed the title of founder: Lady Eve Balfour and Sir Albert Howard. Both practitioners emphasized the role of a healthy, fertile soil in viable agriculture. Howard developed many of his ideas prior to World War II in India, where he was trying to meet the challenge of improving farmers' yields in order to feed a rapidly increasing population. He believed that the best way to increase food productivity at a moderate cost was to return the organic by-products of crop production as well as animal manures to the soil. Howard also had concerns about the changes in soil chemistry caused by the use of synthetic fertilizers and the use of chemical pesticides to solve all pest problems (Francis and Youngberg 1990; Rodale 1973).

In the 1980s and '90s, state and federal guidelines were developed for certification systems that growers must adhere to in order to sell their produce as "certified" organic. This certification entails many of the requirements familiar to all of us, such as prohibiting the use of synthetic pesticides and fertilizers.

The Emergence of Sustainable Agriculture

In the 1950s and 1960s another movement, labeled the green revolution, evolved to meet the challenge of providing food for a rapidly expanding world population. This movement met the challenge from a direction that was diametrically opposed to that of organic farming. It emphasized genetically enhanced plant varieties and high-energy off-farm inputs such as mechanization, synthetic fertilizers and pesticides. In time this movement became "conventional" agriculture and resulted in high food production at a low economic cost to the public, particularly in the United States. As this movement developed some people became concerned that this type of agriculture, high-energy off-farm inputs, could not be sustained in the long term. They felt that although the cost of food production was low, the dollar value of food produced with conventional agriculture did not reflect the true cost from an ecosystem and societal perspective. The true cost takes into consideration issues like air pollution from producing and using fossil fuels; soil degradation due to intense cultivation and use of synthetic fertilizers; habitat destruction; air and ground-water contamination with fertilizers and pesticides; and the steady decrease of the farmer population as

family farms were out-competed by corporate farms. These concerns over the long-term sustainability of conventional agriculture resulted in the continued development of the sustainable agriculture movement.

With the development of organic certification programs, organic farming became codified and easily distinguished from other farming strategies. However, sustainable agriculture is not so fortunate because no codified certification system has been developed. As a result, there is an active debate among academics, farmers, environmentalists and others as to what defines sustainable agriculture. Some consider it to be a philosophy, others consider it to be a guideline for determining farm practices, some view it as a management strategy, and others argue about whether it is strictly related to farm production or also encompasses sociological issues.

In 1989, the American Agronomy Society adopted the following definition for sustainable agriculture: “A sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole.” The Sustainable Agriculture Research and Education Program at University of California, Davis (UC SAREP) emphasizes that sustainable agriculture integrates three main goals — environmental health, economic profitability and social and economic equity. UC SAREP also points out that a systems perspective is essential to understanding sustainable agriculture. Farming does not operate in a vacuum. Each farmer’s field is part of a complex community ecosystem, which in turn can affect or be impacted by global economics and even global ecological processes (e.g., El Nino). A systems perspective involves viewing multiple factors when considering field- and farm-level decisions.

Where Does Integrated Pest Management Fit in?

Integrated pest management (IPM) was developed in the late 1950s to deal with some of the pest problems that in many ways can be attributed to the farming practices developed during the green revolution (Stern et al. 1959). The use of genetically enhanced plant varieties and over-reliance on pesticides to solve pest problems resulted in pesticide resistance in some of our most important crop pests, as well as secondary pest outbreaks and environmental contamination. It is important to note, however, that although a reduction in environmental contamination due to overuse of pesticides was a very important issue, IPM was initially developed more from a problem solving, economic imperative rather than from a need to reduce off-farm inputs and to protect the environment. The formalization of IPM occurred

several years before Rachel Carson's *Silent Spring*. IPM in the United States came about because there were several crops, particularly alfalfa and cotton that had developed unmanageable pest problems due to pesticide resistance and insecticide-induced secondary pest outbreaks. Scientists working in these crops realized that the overuse of pesticides had brought them to this point, and that the only way out was to integrate several control strategies and to reduce reliance on pesticides. Of course one of the many benefits of IPM is reduction in the use of high-risk pesticides and therefore reduced environmental impact. It turns out that IPM strategies fit right into the paradigm of sustainable agriculture and the environmental movement and thus have become an integral component of both.

Like sustainable agriculture, IPM has not been codified, and therefore it can mean many things to many people. A multitude of definitions has been proposed. I personally prefer this definition: "IPM is a sustainable approach to managing pests by combining biological, cultural and chemical tools in a way that minimizes economic, environmental and health risks." I like to think of IPM as a problem-solving tool. It is an approach to managing pest problems, just as sustainable agriculture is an approach to farming.

Definition of Sustainable Winegrowing

Although the concepts of sustainable agriculture, organic farming and IPM have been around for a long time, they are still often misunderstood or interpreted according to one's bias. For example, a farmer dedicated to organic farming may not have the same definition of sustainable farming or IPM as someone who does not restrict his or her farming to organic methods. On the other hand, in some farming circles sustainable agriculture, organic agriculture and IPM are still considered left-wing conspiracies. In any case, it is important to realize that pest problems may still arise, even when practicing sustainable or organic farming and/or using IPM for managing pests problems. That is because most crops are exotic (i.e., non-native) to the farms on which they are grown, and most pests on these crops are non-native, too. Moreover, many of the plant parts we harvest for food contain the highest concentration of nutrients and carbohydrates, which not only makes them very useful for us but extremely attractive to many other organisms. This creates a potentially unstable ecological situation regardless of the type of farming being practiced.

There are some crop/pest systems that are inherently unstable, and crop damage is unavoidable without some outside intervention. A good example is codling moth in many orchard crops. Despite

years of research in introducing natural enemies from its country of origin, developing mating disruption programs and using other sustainable techniques, it is still one of the major pests of many orchard crops. Pests can even get out of hand in some fairly undisturbed, “natural” ecosystems, as illustrated by periodic destructive epidemics of forest insects in certain forest ecosystems (e.g., Elliott et al. 1998).

How do I define sustainable winegrowing? I prefer to use the ideas formulated by the developers and practitioners of the sustainable agriculture and IPM movements. It is a systems view of wine grape growing that considers soil building as the foundation, minimizes off-farm inputs, emphasizes economic profitability and concerns itself with environmental health and social equity. The California wine industry, more than any other agriculture sector in the United States, has focused on developing an industry-wide sustainable farming program. During the process, the industry defined sustainable winegrowing as “growing and winemaking practices that are sensitive to the environment (environmentally sound), responsible to the needs and interests of society at large (socially equitable), and are economically feasible to implement and maintain (economically feasible)” (Dlott et al. 2002). This definition is often referred to as the “Three ‘E’s” of sustainability and is the one that I use in my presentations to growers and other groups.

It is sometimes difficult to use the Three E’s yardstick when evaluating the sustainability of an individual farming practice. For example, it is difficult to talk about the social ramifications of releasing a parasite to control vine mealybug or the environmental soundness of doing a team building exercise with your employees. However, the sustainability of a farm is measured by examining the sum total of all the practices implemented on the farm using the Three E’s.

And finally, economics is going to dictate what sustainable practices can be implemented. For example, the practices being implemented in a vineyard where the grapes are being sold at \$400 per ton are going to be quite different to those that can be implemented in a vineyard where the grapes are being sold for \$4,000 per ton.

A Snapshot of Biodynamic Farming (after Ohmart 2001)

Biodynamic farming is currently receiving a great deal of attention in the wine media, particularly with wine writers and chefs of high-end restaurants and caterers. Therefore I feel it is important to give my perspectives on the topic. Biodynamic farming is based on eight lectures presented by Austrian scientist and philosopher Dr. Rudolf Steiner. To understand the evolution of biodynamic farming, I think it is important to first know a little bit about the man.

Dr. Rudolf Steiner, “Spiritual” Scientist and Researcher

Rudolf Steiner was born in 1861 in a small town in what is now Croatia. He went to technical school as a youth and was well grounded in the natural sciences. Out of his own interests he began reading a great number of philosophy books. He became convinced that it was only through the philosophical method that the material and spiritual worlds would be bridged. Throughout his advanced studies in math, natural history and chemistry, he continued his keen interest in the work of contemporary philosophers. He saw a constant interplay between the material and spiritual worlds. He obtained a Ph.D. in 1891 and taught history, German literature and the history of science in Berlin for several years. In 1902, he declared in a lecture that his life’s aim was to found new methods of spiritual research based on science.

In a biography of Steiner, Gilbert Childs (1995) writes: “Steiner was an explorer of worlds closed to the ordinary powers of sense-perception, and few were capable of following him.” Childs develops Steiner’s idea that for spiritual perception we need to develop supersensory organs, and he claimed that Steiner had achieved such a perceptive ability. Nevertheless, because Steiner was trained as a scientist and dedicated to the investigative standards of scientific research, he strove constantly to apply corresponding rigor to his own investigations. Steiner referred to himself as a “spiritual researcher” and felt that the body of the knowledge he accumulated was genuine “spiritual science.” He coined the term “anthroposophy” as the name of this science. Steiner defined anthroposophy as “a path of knowledge that strives to lead the spiritual in man to the spiritual in the universe” (Koepf 1976).

Steiner’s views were considered by many of his contemporaries to be controversial, and there was strong opposition to them, to the point of threats being made on his life. Some felt he was associated with the occult. He began lecturing on diverse topics such as religion, education, social issues, history and human nature. Many sympathizers began to desert him. However, by January 1905, his depth of knowledge of the material and immaterial worlds was such that invitations to give lectures poured in and his life work had begun.

Around 1917, Steiner began another phase of his career, devoting his time to putting his spiritual-scientific principles and knowledge to practical use. For example, he was approached by the managing director of the Waldorf-Astoria cigarette factory in Stuttgart, Germany, to direct a school for children of factory employees. To accomplish this he started the Waldorf/Steiner school in 1919 and developed an educational system based on anthroposophy. There are now Waldorf schools all over the world. In 1920, he

was asked by a doctor to develop a series of lectures for doctors and medical students on various aspects of human anatomy, physiology and pathology, as well as diagnoses and appropriate remedies, including the development of some pharmaceuticals. Then in 1924, one year before his death, Steiner gave his series of eight lectures that became the basis for biodynamic farming.

The Foundations of Biodynamic Farming

Steiner took a holistic approach to farming. He felt that because plants germinate, grow and produce fruit and are dependent on the sun, earth, air and water to do so, then literally the whole universe is involved in these processes. Another way to put it is that the yield and quality of crops come about under the influence of two groups of environmental factors: earthly and cosmic. He saw each farm as an individual organism that should be as self-sufficient as possible. For example, a biodynamic farm should have a diversity of crops and a certain amount of livestock. Because a farm is a living organism, he reasoned that only life-endowed substances should be applied to it. “Dead” materials such as chemical fertilizers should not be used. By this same argument, synthetic pesticides should not be used either. Therefore only organically derived materials should be used in farming and it is in this aspect that biodynamic farming has a commonality with organic farming. It is interesting to note that Steiner developed these ideas before synthetic, carbon-based pesticides were invented and widely used.

When someone asked for his views about plant diseases Steiner responded by saying that plants could never be diseased in a primary sense, “since they are the products of a healthy etheric world.” He believed they are diseased as a result of diseased conditions in their environment, especially the soil (Koepf 1976).

One important practice that sets biodynamic farming apart from other farming practices, particularly from organic farming, is the use of eight specific preparations of materials developed by Steiner to add to composts, to the soil or to spray on plants, depending on the preparation. The amount of the preparation applied is small because he felt that they worked “dynamically,” regulating and stimulating processes of growth. Putting it in present-day terms, their primary purpose is to stimulate the processes of nutrient and energy cycling. Steiner gave each preparation a number from 500 to 508, and they are divided into two groups. The first group consists of Nos. 500 and 501 and each is applied in spray form. No. 500 consists of dairy cow manure collected in early autumn, packed into a cow’s horn, buried in a pit in biologically active soil for the winter and dug up in the spring. No. 501 consists of ground quartz mixed

with rainwater to make a paste that is then packed into a cow's horn, ideally from a cow that has calved a number of times but is not more than 8 years old. The horn is then buried in the late spring in a sunny spot and dug up in late autumn. Both 500 and 501 are made into a spray by mixing the end materials with rainwater. No. 500 is sprayed onto the soil while 501 is sprayed onto plants (Sattler 1992).

Preparations 502 to 508 are made from the following plant substances, respectively: yarrow blossoms, chamomile blossoms, stinging nettle, oak bark, dandelion flowers, valerian flowers and horsetail. Each preparation is made in a very specific way. For example, No. 502 is made from yarrow flowers that are put in the bladder of a red deer stag, suspended in the sun throughout the summer and buried in the ground during the winter. The preparation is then added to a compost pile, along with some of the other preparations, to aid the composting process, resulting in biodynamic compost. Certain animal parts are used in the other preparations, such as bovine mesentery, bovine intestines and domestic animal skulls. For more detailed descriptions of Steiner's preparations and their uses, see Sattler 1992. Sattler emphasized in his book that little or no result can be expected if a preparation is used on its own. It needs to be used in concert with all of the other biodynamic principles, processes and preparations.

Rhythms are also an integral part of biodynamic farming. It is felt that biological rhythms are connected in some way to cosmic rhythms. For example, Steiner felt that sunspot activity, moon rhythms and the zodiac all have significant affects on the growth and health of plants. Space does not allow a detailed explanation here, but see Sattler's book for more details (Sattler 1992).

There has been little scientific research into the efficacy of biodynamic farming practices. The few studies that have been done have focused on the effectiveness of Steiner's preparations. The results have been mixed, but in some studies it was shown that biodynamic farming systems have better soil quality and lower crop yield when compared to conventional farming systems (Reganold 1995).

Because I was trained in the scientific method and my understanding of how biological systems work is based on ecological theories developed using this method, I have a hard time evaluating and acknowledging the efficacy of many of Steiner's ideas and recommendations. Not only did he develop his very unorthodox methods with little scientific justification, they cannot be tested in the normal sense because there is an inherent contradiction in his philosophy. Steiner developed his "spiritual" science as an alternative to the traditional scientific method, so traditional science cannot be used to test the efficacy of biodynamic farming.

Relating Organic, Biodynamic and Sustainable Farming

A big source of frustration for me is when I read or hear someone say that sustainable farming is something being practiced by a grower who is transitioning to either organic or biodynamic methods. Some authors have written that sustainable farming is done by growers who are not ready to make the commitment to organic or biodynamic farming. In my opinion, people who make these statements do not understand what sustainable farming is, or they are so passionate about organic and/or biodynamic farming that they are unwilling to consider farming in any other form.

Farming systems are influenced by the important issues of the time period in which they were established. Organic and biodynamic farming evolved during the 1920s -1950s, when there were great concerns about the environmental impact of farm inputs, such as pesticides and fertilizers, and a reduction in genetic diversity of crops as a result of breeding programs focused on high-yielding varieties. They developed as alternative farming paradigms to what many termed “industrial agriculture,” and recognized the farm as a living, dynamic system that needed to be treated as such. Synthetic inputs were viewed as much less desirable to naturally derived ones. To add credibility to these systems farming practices were codified and certification programs developed. While the requirements to achieve organic and biodynamic certification in the United States differ in some significant ways, both allow only the use of naturally derived materials that are approved by the National Organic Standards Board.

Sustainable agriculture traces its roots back to the same period as organic and biodynamic farming, but it has never been codified. Codification can be a good thing but can also have its downsides. One positive aspect is when a food or wine is labeled as organic or biodynamic one knows exactly what practices were used to produce it. Because sustainable farming has not been codified, if one buys food or wine labeled as produced with sustainable methods, one may not be certain of what methods were used. The exception is when a product bearing a sustainable label is certified by a third party and it has published the practices used, such as food or wine certified by Protected Harvest (protectedharvest.org), Food Alliance (foodalliance.org), and Oregon LIVE (liveinc.org).

One downside of codification is that as times change and new environmental and social issues emerge, rules do not exist in the system to address them. To add new farming standards to these systems to address new issues is extremely difficult.

There are many new issues impacting U.S. agriculture. While the environmental impact of inputs is still important, other issues have taken center stage. Climate change as a result of greenhouse gas production is probably the biggest. Not only how to respond to the changing climate in terms of long-term planning for the farm, but how to reduce greenhouse gas emissions to reduce the rate of climate change. Energy use has become a very important issue, particularly with the rapid increase in the price of oil. Water availability is a critical issue for some regions, such as California. Given the amount of specialty crops grown in this state such as lettuce, vegetables, fruits, nuts and wine, and table and raisin grapes, this is an important issue for America's food security. The impact of farming on air quality has also become a major issue in California and is the subject of new regulations. And finally, human resource issues have taken their rightful place as one of the most important issues of our time.

Because sustainable farming is not yet codified, it can focus on the new issues mentioned above because no governing body exists whose approval must be obtained to develop farming standards addressing them. As a result, the sustainable farming programs that have developed so far address issues like human resources, wildlife habitat, water use and energy consumption as well as inputs such as fertilizers and pesticides, whereas biodynamic and organic farming programs do not. It is for this reason that sustainable farming is not a transition to organic or biodynamic farming. Sustainable farming is able to address more issues than the other two systems.

Implementing Sustainable Winegrowing (after Ohmart 2008)

Although the title of this presentation is "Sustainable Winegrowing: What is it and Where Did it Come From?" I will take this opportunity to comment on meeting the second challenge to implementing sustainable winegrowing, which is to take the definition, such as the one stated above, and translate it into farming practices used to grow wine grapes: to put theory into practice. In 1998, LWWC growers concluded they needed a tool to help them increase the adoption of sustainable winegrowing practices and track the level of adoption over time. An industry-wide search was done to see how other grower groups were meeting this challenge. Two programs showed promise as models. One was the Positive Point System (PPS), developed by the Central Coast Vineyard Team (CCVT), a tool that wine grape growers could use to assess the level of sustainability in their vineyards (Akerman 1998). The other was a format developed through partnerships between Farm*A*Syst and producers in the United States, Canada and Australia, that develop self-assessment workbooks for dairy, cotton and other crops (Farm*A*Syst).

The Farm*A*Syst workbooks helped growers do several important things:

- Identify farming practices that were beneficial from an environmental perspective.
- Identify farming practices that were having a negative impact on the environment.
- Create action plans and a timetable to address the practices causing environmental concern.
- Provided information in the workbook to help develop and carry out the action plans.

Farm*A*Syst's approach to addressing environmental concerns on the farm is based on the Environmental Management Systems (EMS) model, a standard process used to develop goals, implement them, measure success and make improvements to ensure continuous improvement (World Comm. Environ. & Dev. 1987).

One of the components of the Farm*A*Syst workbook that sets it apart from other similar documents is the action plan. It is important to identify one's problems, but if these problems are not improved upon through actions then identifying them is of no help. The action plan is what puts a grower onto the path of continual improvement.

Adopting the EMS/Farm*A*Syst model, the first step Lodi growers took in the development of their sustainable winegrowing program was to establish goals and principles for the program (Ohmart and Matthiasson 2000). One of the most important reasons for growers to go through a goal-setting process is to give them ownership of the program. By doing this the reasons for developing and implementing the program come from within the grower community rather than from without. This seems critical for a program to be widely adopted by a grower community. Growers are much more likely to use a self-assessment workbook that was developed by growers and other stakeholders in their region than one that was developed by a group outside their region.

Writing the *Lodi Winegrower's Workbook*

There is no textbook devoted to sustainable winegrowing, and the most recent general viticulture text is almost 35 years old (i.e., Winkler et al. 1974). However, advances in wine grape growing have continued since then. They are reported in publications by University of California Davis and other institutions, such as Grape Pest Management (Flaherty et al. 1992), Grapevine and Nutrition Fertilization in the San Joaquin Valley (Christensen et al. 1978), Cover Cropping in Vineyards (Ingels et al. 1998), Sun-

light into Wine (Smart and Robinson 1992), Wine Grape Varieties in California (Christensen et al. 2003), California Vineyards and Wildlife Habitat (Adler 2002), and Deficit Irrigation of Quality Wine grapes Using Micro-irrigation Techniques (Prichard et al. 2004). There is also a substantial pool of knowledge about sustainable winegrowing in the collective experience of growers, farm advisors, research scientists and others. Therefore it was clear that not only would the above publications be needed to draft the most up-to-date workbook possible, but the pool of knowledge of the above groups would need to be drawn upon as well. To draft the workbook, a 17-member committee formed, made up of Lodi wine grape growers, vineyard consultants, University of California (UC) Davis scientists specializing in soils, pest management and viticulture, UC viticulture farm advisors, an NGO wildlife biologist, a U.S. EPA Region IX staff member, the regional Natural Resources Conservation Service agronomist, the director of Farm*A*Syst, and LWWC staff (Ohmart and Matthiasson 2000). For the second edition of the workbook a human resource expertise was added to the committee (Ohmart et al. 2008).

Following the Farm*A*Syst model, the next step in drafting the self-assessment workbook was to identify all of the issues that relate to growing wine grapes in the Lodi region based on the collective knowledge and experience of the committee members. Because sustainable winegrowing encompasses all aspects of farming these issues pertained to not just inputs, such as fertilizers and pesticides, but to everything related to growing wine grapes. One hundred-five issues were categorized in the following topic areas, which became chapters: Viticulture, Soil Management, Water Management, Pest Management, Habitat, Human Resources and Wine Quality (Ohmart and Matthiasson 2000). For the second edition of the workbook, the Viticulture chapter was separated into Vineyard Establishment and Viticulture, the Habitat chapter was greatly expanded and renamed Ecosystem Management, and a new chapter, Shop and Yard Management, was added, covering issues around the shop and office (Ohmart et al. 2008). The second edition added 55 new issues, bringing the total to 160.

Once the issues were identified, farming practices available to Lodi wine grape growers to address each of them were listed on worksheets by the committee, one worksheet for each issue. Each practice influences one or more of the Three E's of sustainability, either positively or negatively. In some cases a practice might be positive for one and negative for one or both of the others. For example, a pesticide might be very effective and cheap but highly toxic to workers and wildlife in and around vineyards. This illustrates one of the challenges encountered in sustainable winegrowing: deciding whether to use a practice if it has both positive and negative effects. As with farming in general, sustainable winegrowing involves a series of compromises.

After the practices were listed for each issue they were arranged into four categories on the worksheet with Category 1 listing the least sustainable practices, practices getting progressively more sustainable in Categories 2 and 3, ending with the most sustainable practices in Category 4. Figure 1 below provides an example worksheet for the issue on soil erosion from the Soil Management chapter (Ohmart and Matthiasson 2000). Decisions on what practices to list and the level of sustainability of each were based on research results in publications such as the ones listed above, as well as on the knowledge and experience of the workbook committee members.

Chapter 2. Soil Management

| Issue | Category 4 | Category 3 | Category 2 | Category 1 |
|------------------|--|---|---|--|
| 11. Soil Erosion | Permanent cover crop maintained <i>And</i> Permeability/run-off rates are known, and irrigation is applied accordingly <i>And</i> Water diversions are on the longer slopes to transport the run-off safely <i>And</i> No tillage is done. | Winter annual cover crop maintained <i>And</i> Water diversions are on the longer slopes to transport the run-off safely <i>And</i> No tillage is done. | Winter annual cover crop maintained <i>And</i> You have developed a tillage plan that minimizes the number of passes per season | No cover crop <i>And/or</i> There are visible signs of erosion on your property |

Figure 1. Worksheet for Issue No. 11 in the Soil Management chapter of the Lodi Winegrower's Workbook (Ohmart and Matthiasson 2000).

The layout of the worksheet is very important, i.e., with categories 4 to 1 going from left to right across the page. When filling out the workbook, growers are asked to read each worksheet and select the category listing the practices that most closely match what they do for that issue in their vineyard. People naturally read from left to right, so growers will read Category 4 first and continue reading until they get to the category that matches what they do. In this way they read the most desirable/sustainable set of practices addressing that issue first, i.e., Category 4. If the worksheet was laid out with Category 1 to 4

left to right across the page, the grower would read Category 1 first, the least desirable/sustainable set of practices. Furthermore, growers would likely stop at the one that matches what they do and never read Category 4, the most sustainable set of practices.

As mentioned earlier, sustainable winegrowing is best viewed as a continuum, from less sustainable farming on one end to most sustainable farming on the other end. The Farm*A*Syst workbook model puts each farming issue and each set of practices that address that issue onto a continuum. This does two things for growers. First, it helps them see where they are on the sustainability continuum with respect to a specific farming issue and set of practices. Second, it helps them see what practices to implement to become more sustainable on a particular issue. It is a road map of practices to move along the sustainability continuum.

The final step in writing the workbook was to add educational information about specific issues and practices. The workbook was not intended to be a textbook on wine grape growing, exhaustively covering all topics. However, the committee believed that certain scientific information that would be beneficial to the reader should be in the workbook, either as a stimulus for them to find out more about the topic with the resources referenced in the workbook, or useful for creating and carrying out action plans described below.

Implementing the Workbook Program

The workbook is most effective if a grower reads each worksheet in the entire workbook, evaluating all aspects of his or her vineyard management, and creating action plans to improve on issues of his or her choosing. It takes about three hours to complete the 105 worksheets in one sitting. A summary evaluation sheet is provided for each chapter on which a grower records the category checked for each workbook issue. Although it takes a considerable effort to complete the entire workbook, the most important part of the process has yet to be done, which is to review the evaluation sheets, pick out one or more issues where improvements can be made and create an action plan to make the improvements. The most serious concerns are where an issue was scored a one or two. The evaluation sheets are constructed in a way that makes them easy to scan and identify areas of concern.

It was readily recognized that, given that the *Lodi Winegrower's Workbook* was 145 pages long and takes three hours to complete, it was going to be a challenge to get growers to use it since they are very busy people. However, the workbook committee believed that if it created a workbook of real value, once

growers got part way through it they would recognize its value and fully utilize it. The key was to figure out how to get them to that point of discovery.

I suspected that if I handed a workbook out to each LWWC member to use, most would put it to rest on the bookshelf unused. It seemed the best way to get growers to look at the workbook in depth was to get small groups in a room, hand out the workbook and go through it with them. Therefore I asked key growers in the district to invite five to 10 of their neighbors over to their house or shop where I would bring workbooks and we would fill them out together. The hypothesis was that growers were more likely to attend if invited by another grower and the meeting was held at growers' homes or shops.

The plan was a great success. Two hundred sixty-five growers who manage about 60,000 acres of Lodi vineyards (about two thirds) each attended one of 36 workshops held during the first 18 months after the workbook was published in 2000. The workshop program took on a life of its own with growers taking their host role very seriously, in some cases trying to out-do other workshops they had heard about by serving snacks, wine and coffee. One workshop was held in a pizza parlor.

Conclusions

The paradigm of sustainable winegrowing continues to evolve. Because it encompasses all aspects of a farming operation and a wide range of practices, it is useful to think of it as a continuum from “not sustainable” on one end to “very sustainable” on the other. It is likely that no one will ever create a perfectly sustainable vineyard, in part because what is considered sustainable today may not be rigorous enough for tomorrow. Moreover, growing grapes leaves an environmental footprint and there will always be something that can be done to make the footprint smaller. It can be said that the world of sustainable agriculture is one where the horizon is always receding. I see this as a source of frustration for some wine grape growers because it is human nature to want to be at an end point rather than at some point along a continuum.

A Farm**A**Syst self-assessment workbook is well suited to dealing with the situation described above. First, it is suitable for most growers because it encompasses the complete range of practices for each farming issue, from less sustainable to most sustainable. Second, for every farming issue, it is a road map of practices showing growers exactly where they are in terms of the sustainability continuum and what they can do to improve to move along it. Third, it encourages them to create and carry out action plans to make improvements. And finally, it provides a form of objective measurement that will help

growers track themselves through time either individually or as a group. It is important to point out that in the future, metrics around sustainable winegrowing will need to move past simply tracking practices and include performance measures, such as energy expended and gallons of water used per ton of grapes produced, as well as balancing multiple factors along with farmgate income.

Implementing the workbook program by convening small workshops around the kitchen table in a grower's house or shop bench is unique and has had multiple positive effects. First, it got the growers to open the workbook and discover its value so they would use it. Second, as growers did the self assessment, they would ask the person next to them or across the table how they were dealing with certain farming issues. Invariably lively discussions would ensue with growers sharing valuable information with each other. And finally, the workbook program gave the Lodi growers a real sense of meeting the challenges of sustainable winegrowing as a community and led to increased adoption of IPM practices.

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Soil Biota in the Vineyard

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Abstract

The focus of this presentation is to highlight the variety of soil organisms present in most soils and the functions they perform, to briefly discuss principles of soil nutrient cycling and to review the biology of arbuscular mycorrhizal fungi (AMF) as it relates to grapevines. The sustainability of agriculture depends upon healthy soils that harbor a diverse and active biological community. A handful of soil may be home to a billion organisms (mostly microscopic) belonging to thousands of different species. The soil biological community consists of bacteria, fungi, protozoa, rotifers, nematodes, arthropods, earthworms and numerous other organisms. This vast diversity of organisms in the soil makes up a complex food web, which rivals any food web on the planet. Soil organisms perform the basic functions (decomposition of organic matter, formation of humus and nutrient cycling) that higher plants rely upon to get mineral nutrients needed for their growth. Of course, plants themselves contribute the vast majority of the fixed carbon (and hence food) to soil ecosystems, and plant roots are often the most abundant soil organism by weight. Bacteria and fungi are the next biggest contributors to soil biomass. A brief overview of the diversity and functions performed by prominent soil organisms will be presented.

The release of soluble nutrients (such as N) as organic matter is decomposed — and as the decomposers themselves become food for other organisms in the food web — occurs because each step up the food chain generally uses proportionally more of the ingested carbon (to fuel respiration, or energy demand) than the ingested minerals. However, the ease and rapidity of mineral-N release from decomposition (and the rate of decomposition itself) is dependent upon the C/N ratio of the source of organic matter. High C/N materials, such as straw, may actually sequester N from the soluble N pool as microbes decomposing it cannot get enough N to meet their needs. The release of root exudates in the rhizosphere can also drive nutrient cycling, but soil microbes that initially consume the root exudates can either compete with the root for soluble nutrients or release soluble nutrients depending on whether the exudates act as a primer to stimulate decomposition of existing soil organic matter. The activities of certain groups of soil organisms (or even a number of links in the food web) can occur in spatially separated niches in soil, resulting in “microsites” (or hot spots). For example, the rhizosphere may be spatially (and conceptually) separated from the detritosphere. However, the degree of overlap among different hot spots is largely unknown. Some soil organisms can consume similar types of prey associated with different food web pathways but cause very different responses. An experiment where I manipulated detritus (organic matter in the form of leaf litter) and fungal-feeding collembola in mycorrhizal pea plants illustrates this. The addition of collembola to potted pea plants without detritus caused a reduction in root colonization by AMF and reduced seed yield, but the addition of collembola to plants with detritus in the soil resulted in higher seed yield and no reduction in root colonization by AMF.

The vast majority of higher plants form symbiotic associations with mycorrhizal fungi, and grapevines are no different. There are different types of mycorrhizal associations with different groups of plants; the two most common types are ectomycorrhizae (common with most temperate trees) and arbuscular mycorrhizae. AMF appear to have played a role in the evolution

and movement of early plants to the terrestrial environment. AMF have lost the ability to grow without their host plants and these fungi obtain their carbon from the plant. Plants benefit from the association with AMF by having greater access to soil nutrients (particularly those nutrients that have poor mobility in soil: P, Cu, Zn) and possibly soil water. Benefits from AMF become more important in low-input systems or whenever plants experience greater stress. In addition to the well-known effect on nutrient uptake, AMF can help plants better cope with water stress, suppress plant diseases and enhance the stability of soil aggregates. Different species of AMF can have different effects on plants and soils.

AMF have been known to colonize grape roots since the 1920s and all species examined in *Vitis* form arbuscular mycorrhizas. The fine roots of grapevines in the Pacific Northwest are heavily colonized by AMF and exceptionally high levels of arbuscules in roots are commonplace. Grapevines grown in Oregon's red hill soils are dependent on AMF in order to obtain enough phosphorus from these low-P soils. AMF have also been found to improve the uptake of N, K, Cu and Zn in grapevines. AMF are known to improve drought stress in many plant species under some circumstances and have been shown to improve drought tolerance of Cabernet Sauvignon. I have found higher levels of arbuscules in grapevine roots whenever water input was reduced to 35 percent FVET as compared to 70 percent FVET in a commercial vineyard in an arid region of eastern Washington. Deriving the maximal benefit from AMF in vineyards can be accomplished by enhancing the existing population in soil or by inoculating plants with fungi that have been produced on host plants grown in another location. The first option is most likely to have the greatest impact because inoculation is expensive and commercial products can be highly variable. Certain management practices are known to reduce AMF populations in soil or in roots, including fumigation, application of soil fungicides, high doses of fertilizers (particularly P) and tillage. However, not all species of AMF respond to these practices in the same manner. For example, fertilized plots in a native grassland system increased the number of spores of one AMF species. There is a clear trend in the loss of AMF species as we move from natural systems to high-input agricultural systems. Depending on the past land-use history, planting cover crops that are known hosts for AMF can probably have the greatest impact on subsequent AMF populations in soil.

The “Greening” of Pacific Northwest Vineyards

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Introduction

The Pacific Northwest (PNW) region has a reputation for being at the forefront of environmental policy, with cities like Portland, Ore., and Seattle, having pivotal roles in encouraging “green practices” of their citizens (e.g., mandatory curbside recycling). Recognition of the value placed on green practices by the public has been an impetus for change in the PNW grape and wine industry, resulting in greater environmental stewardship and enhanced social responsibility through improved agricultural practices and energy efficiency. Although the sustainability movement has its roots in the California wine industry, the PNW grape and wine industry has enthusiastically adopted these changes.

Wine Regions of the Pacific Northwest

In Washington, the wine and grape industry started in the mid-1800s in western regions of the state, with soldiers who brought grapevines with them while they were stationed at Fort Vancouver (Irvine and Clore 1997). Currently, there are more than 35,000 acres of wine grapes (*Vitis vinifera L.*) and 550 wineries in the state, with American Viticultural Areas (AVA) in both cool, maritime western areas and dry eastern locations (Figure 1). There are nine AVAs in Washington, with the first AVA established in 1982 (Columbia Valley), culminating with the most recently established Rattlesnake Hills AVA (2006). There are at least two others pending with the

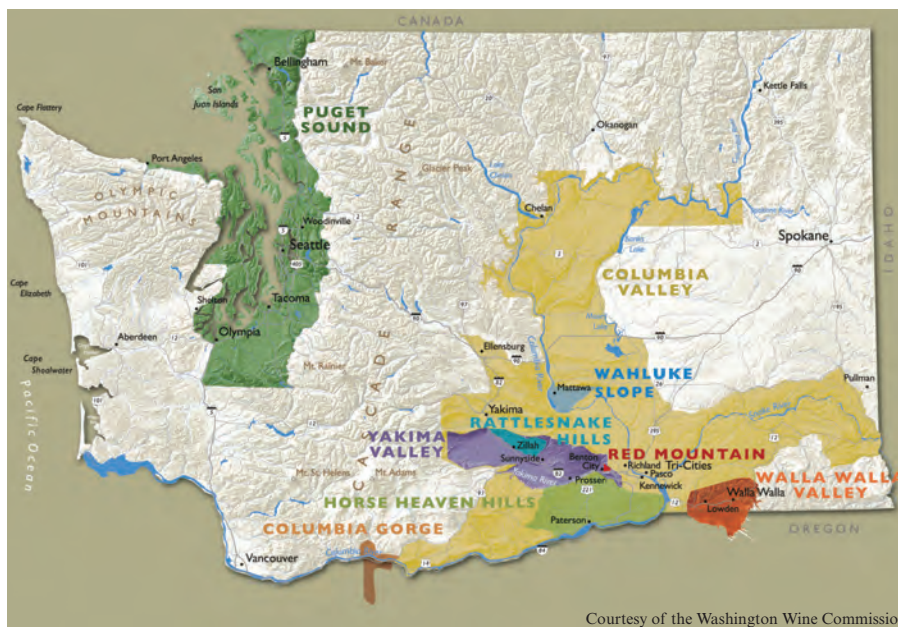


Figure 1. The state of Washington’s nine American Viticultural Areas (AVA).

Alcohol and Tobacco Tax and Trade Bureau (ttb.gov/wine): the Lake Chelan Area AVA, located in north central Washington, and Snipes Mountain in Sunnyside, Wash., located in south central Washington.

The Oregon wine industry has approximately 17,500 acres, with more than 400 wineries. The first vines were planted in the state around 1779 with the arrival of Franciscan missionaries. Planted vineyard acres rapidly expanded in the early to mid-1960s with the arrival of several California families searching for a new challenge. Today, there are 16 AVAs in Oregon, and the top five varieties are Pinot Noir, Pinot Gris, Chardonnay, Riesling and Gewürztraminer (Oregon Wine Board, oregonwine.org; Figure 2).



Figure 2. American Viticultural Areas in Oregon.

More recently, the Idaho wine industry has been garnering a reputation for its New World wines, with a total of 1,800 acres and one new AVA, the Snake River Valley AVA established in 2007 (Idaho Grape Growers and Wine Producers Commission, idahowines.org). Idaho was the first state in the Pacific Northwest to have multiple wineries around 1865, but the industry was devastated by Prohibition. Longtime research at the University of Idaho on vineyard site selection ceased; however, renewed interest in viticulture sparked plantings in the mid-1970s. Currently there are 32 wineries in the state, with several wineries winning awards for their wines. The top grape varieties grown are Riesling, Chardonnay, Merlot, Cabernet Sauvignon and Syrah.

Sustainable Production in the Pacific Northwest

Sustainable production practices started in the PNW region with the founding of a group known as Low Input Viticulture and Enology (LIVE; liveinc.org), focusing on sustainable viticulture education and certification. The original members of this group included university professors and industry members.

The main goals for this organization include:

- Viewing the vineyard as a whole system;
- Creating and maintaining a high level of quality fruit production;
- Implementing practices that reduce reliance on synthetic chemicals and fertilizers with the goal of protecting the farmer, the environment and the community at large;
- Encouraging responsible stewardship of the land, maintaining natural fertility and ecosystem stability;
- Promoting sustainable farming practices that maintain biological diversity in the whole farm.

Like a number of sustainable viticulture organizations around the world, LIVE uses a modification of the International Organization of Biological Control (IOBC), which sets out standard techniques with the goal of continued profitable production using minimal inputs (IOBC, 1999). The IOBC Commission allows for its standard set of techniques to be modified for each area to tailor these standards for specific regions. This organization is one of many in the PNW that emphasizes sustainable and/or organic practices, in addition to those like Salmon Safe (salmonsafe.org) and Oregon Tilth (tilth.org).

Soon after the publication of the *Lodi Winegrower's Workbook* in 2000 and subsequent *Code of Sustainable Winegrowing Practices* in California, a group of growers in conjunction with the Washington Association of Wine Grape Growers, the Washington Wine Industry Foundation and with the help of Washington State University professors authored a series of risk management checklists. These checklists became the basis for the creation of VineWise (vinewise.org), which is an online, interactive guide for growers to mitigate risk and increase their efforts to be more sustainable. Growers can anonymously compare their rankings to others who have completed the worksheets, giving them an idea of their sustainability ranking within the industry.

More recently, growers have expressed interest in organic practices. The oldest certified organic vineyard in the state of Washington is Badger Mountain Vineyard in Benton City, established in 1988. Various efforts such as recycling and composting its grape pomace, using biodiesel in its farming equipment, and consolidating herbicide and pesticide applications to reduce tractor passes are all incorporated into the vineyard's organic production practices. Its success at these efforts has offered an example to the

increased number of organic vineyards throughout the PNW region, inspiring an effort to create an entire AVA with organically and biodynamically farmed acreage in northwest central Washington.

Although organic production is most often used in conjunction with sustainability, it must be stated that organic practices are not always sustainable; for example, some organic-approved products are not as effective for pesticide and herbicide use as their synthetic counterparts and must be sprayed more often. This elevated spray schedule can increase fuel expenditures as a result of extra tractor passes through the vineyard. In addition, many of the organic compounds used in pesticide applications are not targeted for a specific insect and can result in decreases of both pest and beneficial insects.

Research and Extension Efforts for Sustainability

Enhancing the vineyard ecosystem by establishing native plant refuge islands, insectaries and ground covers within the vineyard rows is being increasingly integrated into several sets of guidelines for sustainable grape production (e.g., LIVE; Central Coast Vineyard Team, vineyardteam.org). Several U.S. wineries have established insectaries, which not only attract beneficial insects, but serve an aesthetic purpose as well. Native plant refuge islands and insectaries attract a range of beneficial insects and help to diversify a typical monoculture system of grapevines. In most commercial settings, a vineyard is managed only for its fruit crop and a secondary or tertiary cash crop is not planted. Monocultures are generally characterized by pest outbreaks, and increasing the biodiversity within these systems allows nature to keep diseases and pests in check. In many vineyards that have been farmed as monocultures, diversity in the ecosystem can be achieved simply by introducing some type of green cover crop, preferably one with an abundance of nectar and pollen to attract beneficial insects. A successful refuge island, insectary or flowering cover crop will reseed each year, providing a sustainable and reliable resource. Furthermore, this effort is enhanced if neighboring vineyards, orchards or other perennial cropping systems adopt this strategy to increase ecodiversity area-wide.

Native plant refugia within or near vineyards can serve as more than just reservoirs of biological control agents. They can also serve a broader purpose of helping to restore natural habitats and provide conservation zones for wildlife that existed prior to the establishment of vineyards and other cropping systems. This concept has been widely adopted in the Waipara Valley wine growing region of New Zealand with much success (waiparawine.co.nz/index.cfm/Research/GreeningWaipara) and is now being developed in Washington. The ecosystem approach to insect and mite management is a model that is cur-

rently garnering much favor among viticulturists as the industry moves quickly towards reducing pesticide inputs and improving sustainability. As a result, substantial decreases in pesticide use have been documented for grape production in Washington from 1995 to 2005 (Ferguson et al., 2007).

One caveat with the establishment of refuge islands and insectaries is that the beneficial insect populations within these areas do not necessarily suppress pests across an entire vineyard. Often, the impact of these beneficial insects is reflected only in vineyard rows immediately surrounding the refuge island or insectary. Thus, it is important that if refuge islands are used in the vineyard ecosystem they are distributed appropriately throughout the acreage for greatest effectiveness.

In 2005, a cover crop project located in the Columbia Valley of the state of Washington was initiated to improve the attraction and retention of beneficial insects in vineyards. While many viticultural areas are capable of sustaining a cover crop growing between vineyard rows, much of eastern Washington lies in the rain shadow of the Cascade Mountains and is arid. Vineyards in this area of the state receive an average of 250 mm of rain per year, with much of the precipitation falling between November and April, during the winter period. In the interest of water conservation and efficiency, the majority of vineyard acreage in eastern Washington is drip-irrigated with no additional water applied between the vineyard rows. Thus, cover crop choices must be made with this semi-arid climate in mind, and drought tolerance is of utmost importance.

Successful cover crop establishment is often achieved with autumn plantings between vineyard rows with protected seedlings (i.e., drilled into the ground or broadcast seeded and rolled into the ground). We looked at a number of cover crop species in previous research experiments (Olmstead et al. 2001); however, few of these had flowering sources that contained nectar and/or pollen to attract beneficial insects. Thus, in the 2005 experiment, we used several flowering species including California poppy (*Eschscholzia californica*), California bluebell (*Phacelia campanularia*), bachelor's button or cornflower ("dwarf blue"; *Centaurea cyanus*), sweet alyssum (*Lobularia maritima*), and dwarf candytuft (*Iberis umbellata*). To this flowering mix, we added additional treatments of an annual cereal rye (*Secale cereale*, a standard practice in many vineyards), a drought-tolerant medic mix (consisting of barrel medic, burr medic, and snail medic), and a control, which consisted of resident vegetation.

Throughout the first two growing seasons, fall-seeded establishment of the flowering mix was poor (less than 50 percent). In fact, there was such poor establishment of the drought-tolerant medic mix that

we dropped this treatment from the study. In addition, changes were made to the flowering mix by removing sweet alyssum and dwarf candytuft, and adding flowering buckwheat (*Fagopyrum esculentum*), which had shown some success in a separate beneficial insect study being conducted in south central Washington. Despite poor establishment, we observed an increase in the populations of some beneficial species (e.g., minute pirate bugs) in the flower plots in mid-June (Figure 3).

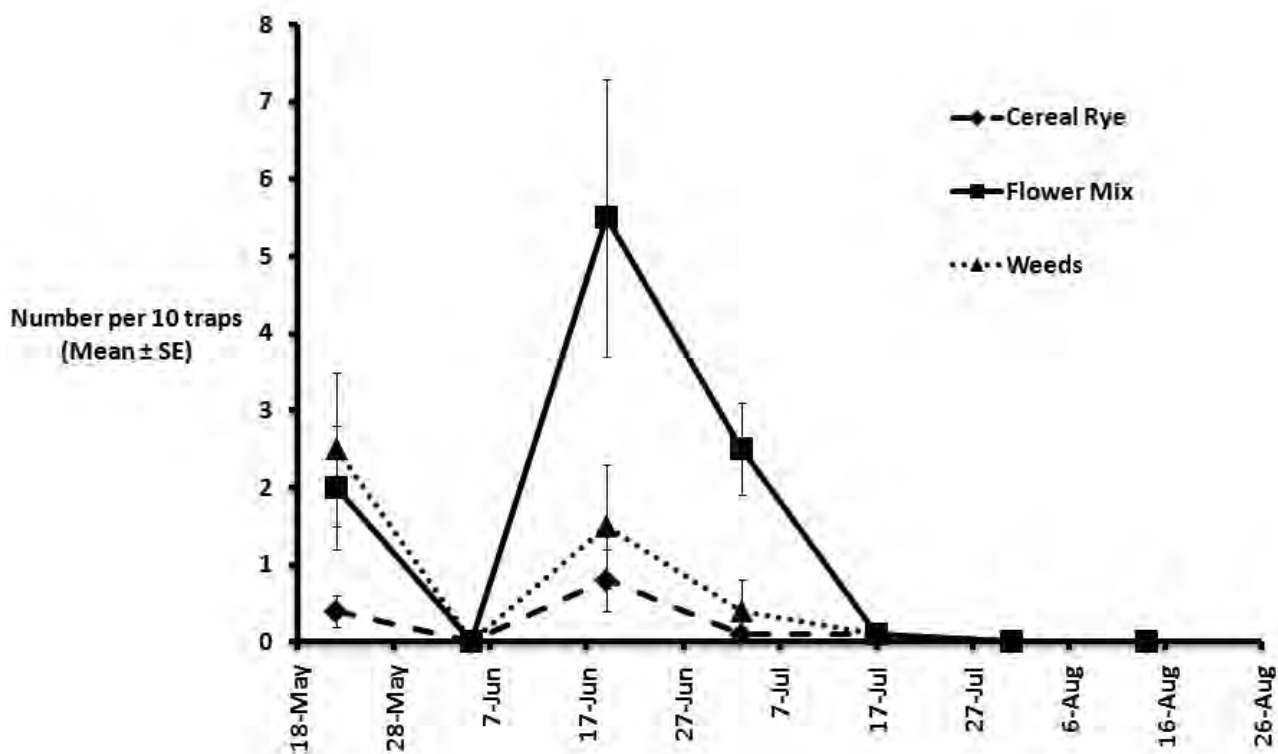


Figure 3. Predatory anthocorids (minute pirate bugs) found in an organic vineyard (2007) designed to enhance attraction and retention of beneficial insects using flower mixes between vineyard rows in Washington.

Population increases were also observed for big-eyed bugs (*Geocoris pallens*) and parasitic wasps in the flowering plots. All of these beneficial insects can reduce pest populations in eastern Washington vineyards. One caveat to the above experiment is that beneficial insects tended to stay in the ground cover rather than colonize the vine canopy. One solution might be to mow alternative rows of cover crop to force beneficial insects into the canopy.

There were no significant effects on grapevine shoot length, cluster number, berries per cluster, or Brix, pH and titratable acidity. This indicates that these cover crops were able to attract beneficial insects into the vineyard without the deleterious effects of increased competition for grapevine water and nu-

trients. Planting a cover crop with either nectar or pollen sources appeared to be successful in sustained increases of beneficial insects.

Research on this project is continuing and will focus on identifying native perennial flowering plants with better establishment and sustainability attributes under low irrigation conditions.

Concluding Remarks

The Pacific Northwest Region, along with the California wine industry, has been successful at implementing sustainability into everyday production practices. While there are several aspects to sustainability, enhancing biological diversity in the vineyard with the goal of attracting and retaining beneficial insect populations is a current focus of the Washington State Viticulture Extension Program.

Grape growers are now ready to adopt and exploit the ecosystem approaches and services described here to ensure that large pest outbreaks, typical of pesticide-damaged monocultures, do not return. Conservation biological control, the use of natural enemy services freely available in the environment, is now the foundation on which insect and mite management in Washington vineyards is based. Maximizing the potential and benefits from natural enemy services is the aim of ecological manipulations like the use of refugia, ground covers, floral resources and predator/parasitoid attractants. Much fine-tuning of these approaches and their utilization in vineyards remains, but the Washington grape industry is clearly at the forefront of low-input and sustainable production practices.

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VineBalance: Sustainable Viticulture for New York

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Abstract

New York's VineBalance sustainable viticulture project started in 2005, but is an outgrowth of earlier efforts from 1997 to 2000 to produce Agricultural Environmental Management (AEM) worksheets in the Finger Lakes region and a sustainable production workbook on Long Island. It is a joint project of an industry advisory board and Cornell regional grape extension programs. The project has produced the *New York Guide to Sustainable Viticulture Practices*, a grower workbook that rates specific production practices in vineyard establishment, soil conservation, integrated pest management, pesticide management and viticultural practices. Growers use the workbook to evaluate their production practices and develop action plans to address environmental issues identified through the workbook. To date, 83 growers, representing 15 percent of the grape acreage in New York, have participated in the workbook evaluations and developed action plans.

Sustainability Defined

Sustainable agriculture is defined by the California programs as the use of production and business practices that are environmentally sound, economically viable and socially equitable. These areas are referred to as the "Three E's of Sustainability." What this means is that growers and wineries strive to have their practices minimize environmental impacts, be affordable and enhance profitability of their vineyards and wineries, and to maintain standards with employees and suppliers that comply with applicable laws (e.g., worker protection standard) and economic well-being. In most cases, the "sustainable" practices are simply good viticulture and good business practices. Sustainable is not the same as organic. Although organic practices in general fall within the sustainable agriculture framework, sustainable agricultural programs are not focused exclusively on organic production methods.

Why Were Sustainable Viticulture Programs Developed?

There are a variety of motivations that led grower groups in California and Oregon to develop sustainable viticulture programs. The first reason is that agriculture by its nature involves altering the environment, with some potentially negative impacts. Sustainable practices can help minimize these impacts. Paying attention to the details of how and when inputs are applied can reduce impacts on soil and water resources and also can be a good business practice.

The second motivator in California is that grapes and wine are grown amidst a large and increasingly vocal group of suburban neighbors who are very interested in how agriculture in their neighborhoods affects them. They may perceive that grape production exposes them to health or nuisance risks, and they want reassurance that their home environment is safe. They need to be educated and also persuaded that the industry in their midst is addressing environmental issues and not simply exploiting the land resource.

Finally, growers and vintners feel that adopting sustainable viticulture practices can improve wine quality and serve as a selling point for consumers. The Oregon LIVE (Low Input Viticulture and Enology) program certifies growers and wineries, and allows producers to use a “LIVE certified” logo in their labeling and publicity. The Lodi-Woodbridge program has introduced, as a final step, a voluntary certification program called Lodi Rules for interested growers. These “eco-labeling” efforts are designed to signal to consumers that the products they buy were produced with low environmental impact practices. This is important to a small, but rapidly growing, number of consumers.

New York Motivators

In New York, the real and perceived need to protect water quality, the need to meet demands of major big-box juice retailers, and the need for wineries to be perceived as “green” have driven establishment of sustainable practices programs.

Neighbors. Grape production in the Finger Lakes region takes place within a mile or two of the major Finger Lakes — Canandaigua, Keuka, Seneca and Cayuga — which are the source of drinking water for numerous private lakeshore and municipal water supply systems. Active residential environmental groups, such as the Keuka Lake Association, promoted watershed-based inventory of environmental risks within the lake’s watershed. Along with agriculture, these inventories identified lakeshore septic systems, road salt storage and streambank erosion as potential sources of water pollution. The goal set by these orga-

nizations was to address and minimize environmental impact of all these activities within the watershed. Practices limiting runoff to surface waters were a high priority.

On Long Island, grape production occurs on sandy soils that overlay a shallow aquifer that is the single source of domestic water for more than 1 million suburban residents. Inputs (fertilizers, pesticides) associated with agricultural production are deemed to present major potential effects on water quality on the island. Practices limiting leaching of N and pesticides into groundwater were a higher priority than runoff.

Consumers and Buyers. Juice grape production comprises more than two-thirds of New York grape production, and most is marketed nationally through supermarkets and big-box retailers. Led by Wal-Mart's emphasis on sustainability, juice and major wine processors are feeling pressure from these major customers to adopt sustainable practices programs — or eventually lose shelf space. National Grape Cooperative and other processors view demonstrating sustainability as one of their most important issues that will drive juice sales in the next 10 years.

For small wineries, a common question in tasting rooms is: “Are you organic?” This reflects consumer interest in products that protect the environment and that are healthy to consume. Publicizing adoption of sustainable production practices — whether individually or as an industry goal — may provide a marketing advantage to environmentally conscious wine lovers.

New York Program

New York's sustainable viticulture program, established through a cooperative effort between industry groups and the Finger Lakes region, the Lake Erie area, and Long Island Grape Extension programs, is designed to both document sustainable grape growing practices already in use and promote sustainable practices throughout the industry.

The foundation of the program is the *New York Guide to Sustainable Viticulture Practices*, published in 2007 (Figure 1). This grower self-assessment workbook includes 140 questions in eight sections covering the multitude of management decisions faced by New York State grape growers. It was jointly developed by industry representatives and Cornell research and extension personnel, in a series of six meetings during the winter of 2006. Production issues addressed in the workbook are summarized in Table 1.

The workbook sections evolved from materials of two separate programs in New York: NYS Agricultural Environmental Management (AEM) worksheets and a similar workbook developed for Long Island growers by the Long Island grape program. A steering committee composed of extension, research, industry and grower representatives (from National Grape Cooperative, Centerra Wine Company (Constellation Brands), the New York State Wine Grape Growers, and Finger Lakes and Long Island wineries and vineyards), tackled the task of reviewing and developing questions that encompass the wide variety of practices used in the diverse growing regions of New York. The workbook serves as a roadmap for evaluating viticultural practices and addresses the diversity of the state's grape-growing industry with a broad range of questions.



Figure 1. New York Guide to Sustainable Viticulture Practices.

Continued outreach has been funded through a grant from the New York Farm Viability Institute. To date, more than 85 growers from the Finger Lakes region, Lake Erie region, Long Island and Hudson Valley (about 15 percent of New York grape acreage) have completed the workbook — most in one-on-one appointments with a regional cooperative extension specialist. Following completion of the workbook, growers develop and implement an action plan to address areas where current practices can be improved.

As part of this implementation plan, growers are referred to local Soil and Water Conservation District technicians, who administer the New York state Agricultural Environmental Management (AEM) program. The workbook has been adopted by the State Soil and Water Conservation Committee as the AEM worksheets for viticulture, and completion of the workbook assessment qualifies growers for access to cost-sharing funds to implement conservation plans in their vineyard. For example, Finger Lakes growers have received grants that have paid for up to 85 percent of the cost of installing pesticide mixing and loading facilities on their farms.

Complementing the workbook is the Sustainable Viticulture in the Northeast newsletter, which provides an in-depth examination of the economic, environmental and social implications of specific production practices. Three newsletters: *Optimizing Nitrogen Use in Vineyards*, *Soil and Water Conservation Practices for Vineyards*, and *Alternate Weed Management Practices for New York Vineyards*, have been published to date. Future topics will include IPM scouting and vineyard weed mapping, reduced-risk pesticides and biofuels, among others. These newsletters aim to provide guidance for growers seeking detailed, specific information on specific production practices.

The VineBalance Web site (vinebalance.com) includes an online version of the *New York Guide to Sustainable Viticulture Practices*, newsletters and information on program goals and adoption by growers in New York.

Tasting Room Information. As a final component of our project, we have been testing a point-of-sale brochure (Figure 2) aimed at tasting room customers. The goal is to provide a response to those customers who come into the tasting room and ask “Are you organic?” The brochure (Figure 3) provides a snapshot of the sustainable practices used to produce the grapes. We are working with six wineries to test consumer response to this sort of information. Will it help sell more wine or attract more loyal customers? We should know the answers to these questions by this summer.

Summary

Our VineBalance program has seen broad adoption by different segments of the New York industry, from bulk Concord producers marketing through major juice processors to high-end small wineries on Long Island. New York’s grape community is diverse, but different segments have expressed interest and have used the workbook as a tool to educate themselves and change practices on their farms. The benefits to participating growers have included:

- Cost-sharing opportunities for financing conservation needs through the Soil and Water Conservation districts;

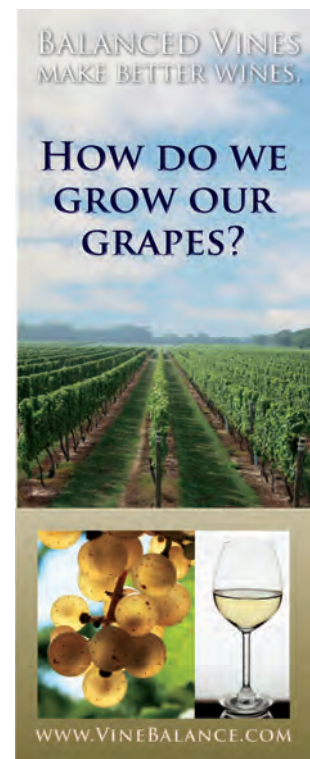


Figure 2. The cover of the point-of-sale VineBalance brochure for consumers.

- Increased product marketability for grapes and grape products;
- Economic and environmental savings through efficient use of fertilizers and agri-chemicals;
- Improved neighbor relations and industry reputation.

Wine production is a high-profile agricultural enterprise, and by making it an industry-wide goal to produce grapes, juice and wine utilizing practices that minimize environmental impacts and are economically viable and socially responsible, growers will reduce risks, improve profitability and stay competitive with other regions.

WHAT PRACTICES DOES THIS PROGRAM PROMOTE?

Sustainable Options for:









| | | | |
|---|---|---|--|
| <p>Protecting our soils...</p> <p>We use soil conservation and management techniques, including water diversion ditches, cover crops, straw mulch and grassed filter strips to reduce erosion, runoff and nutrient leaching. By limiting runoff and leaching, we help maintain and protect water quality of lakes, streams, and ground-water surrounding our vineyards.</p> |  | <p><i>Diversion ditches control erosion.</i></p> |  <p><i>Mulching adds organic matter and conserves moisture.</i></p> |
| <p>Managing nutrients...</p> <p>We limit excess nutrient inputs by maintaining organic matter, using soil and tissue testing to diagnose nutrient needs, and avoiding frequent tillage that leads to soil compaction and erosion. Limiting excess nitrogen protects ground and surface waters, and reduces excessive vine growth that limits wine quality.</p> |  | <p><i>Soil and tissue testing help diagnose nutrient deficiencies and allows growers to avoid excess fertilizer inputs.</i></p> |  |
| <p>Managing pests and diseases...</p> <p>Diseases, insects and weeds are a fact of life in our humid climate. We use weather-based disease forecasting, insect scouting, and weed identification mapping to guide our management of these pests. Cultural practices that minimize pest development are put in place first; sprays are applied only when needed to protect grape quality and yield.</p> |  | <p><i>Weather-based disease forecasting results in fewer sprays and better timing for disease control.</i></p> |  <p><i>Weeds are managed under the trellis to minimize competition with vines during key growth stages. Cover crops are often seeded between rows to reduce weed pressure and to minimize soil erosion.</i></p> |
| <p>Managing vine growth and crop levels...</p> <p>We use modern grapevine canopy management practices, including careful pruning, shoot positioning, shoot and cluster thinning techniques as appropriate to enhance fruit quality. Open grapevine canopies that expose grape clusters to sunlight promote flavor development and reduce disease pressure.</p> |  | <p><i>Leaf removal and shoot positioning promote light interception and reduces disease pressure.</i></p> |  |

Figure 3. Inside of point-of-sale brochure

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Table 1. Production Issues addressed in the New York Guide to Sustainable Viticulture Practices workbook.

| Workbook Section | Specific Issues Addressed |
|-------------------------|---|
| Vineyard Management | Canopy management practices Yield management |
| Nutrition Management | Nutrient use efficiency Tissue and soil sampling |
| Pest Management | Scouting and economic thresholds Weather, variety-driven disease management programs |
| Pesticide Management | Mixing, loading and storage practices Worker protection standards |
| Soil Management | Leaching and runoff potential Preplant site preparation |
| Weed Management | Post- versus pre-emergent herbicides Integrated tillage/ floor management |
| Irrigation Management | System design and maintenance Water-use efficiency |
| Continuing Education | Workshop enrollment Trade, technical and extension newsletters |

Vineyard Best Management Practices for Missouri and the Ozark Mountain Region: Principles, Practices and Progress

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Introduction

Wine grape growers in Missouri and Arkansas are increasingly interested in utilizing sustainable practices. This seemingly straightforward goal is not as easy to achieve as it might seem. Ohmart (2008) describes the challenges facing growers who desire to practice “sustainable winegrowing” as defining it, implementing it in the vineyard and measuring the impacts of implementation. Sustainable viticulture practices must first be identified; second, they must be integrated into farming operations; and finally, producers must implement these practices and document their impact. Important impacts to be measured include changes in vine health and productivity, fruit composition, wine quality, profitability, environmental quality, and worker safety and quality of life.

Two important meetings held in recent years addressed topics that helped identify key regional grape pests and gaps in knowledge related to use of sustainable viticulture practices in the Midwest. On July 15, 2003, a group of researchers, Extension specialists and producers met in Augusta, Mo., to work on the development of a Midwest Grape Pest Management Strategic Plan. The group identified key grape pests

as well as constraints to the regional grape industry's growth such as: a lack of monitoring to aid in making spray decisions for disease and insect control; cancellation of the use of older classes of pesticides; no management of canopy density, water and soil nutrition; and an inadequate quantity of good-quality cultivars to meet industry needs. A second meeting was held March 22-23, 2007, in Benton Harbor, Mich., and led to the development and publication of the *Grape Pest Management Strategic Plan* for the North Central region grape industry. This document can be accessed at grapes.msu.edu/grapeplan.htm and provides detailed information on grape pests addressed at this and the aforementioned 2003 meeting.

Information from these meetings was very useful as efforts were made to identify and implement sustainable viticulture practices appropriate for the region. Where gaps in the knowledge base exist, research from other regions must be tested and validated. However, this must be done with great care. Some viticulture techniques or innovations that potentially are of great benefit to the Ozark Mountain region grape industry have been investigated and/or used in other grape-producing areas of the country but have not been widely adopted locally. Often this is due to a lack of knowledge of the technique's existence or importance, or because of a lack of understanding of how to put the technique into practice. At the other extreme, recommendations or practices developed elsewhere may be blindly adopted locally without regard for the differences in soils, climates, species/varieties, and/or production systems that exist in the different locations. The Vineyard Best Management Practices project was initiated in 2005 to address the aforementioned concerns.

Project Objectives

Initial project objectives included the following:

1. To conduct surveys to establish a benchmark and quantify progress in adopting grape best management practices and to identify constraints to implementation in Arkansas and Missouri.
2. To demonstrate grape best management practices.
3. To disseminate grape management, pest and disease event information in a timely manner.
4. To produce a *Wine Grape Integrated Production Systems Workbook* for use in grower vineyard best management practices workshops.

Procedures and Major Accomplishments

Objective 1) To conduct surveys to establish a benchmark and quantify progress in adopting vineyard best management practices and to identify constraints to implementation in Arkansas and Missouri.

The vineyard best management practices (BMP) project began with a grower survey in 2005-2006 that established benchmarks to quantify progress in adopting grape best management practices and to identify constraints to BMP implementation in Arkansas and Missouri. A full account of the survey results are being submitted for publication. A follow-up survey to measure progress in adoption of best management practices will be completed and distributed in spring 2009.

Key findings from the benchmark survey include the following: Arkansas and Missouri are estimated to have about 14 (750 A) and 200 growers (1,500 A), respectively, and more than 59 percent of the responding growers intended to increase vineyard acreage. Most growers in the Ozarks select grape cultivars specifically for market potential rather than for high disease resistance, and many growers were planting European *Vitis vinifera* and hybrid cultivars with potential susceptibility to root and foliar grape phylloxera. Viticulture practices varied in adoption: 97 percent checked vineyard for disease damage, 93 percent controlled weeds, 80 percent employed balanced pruning, 80 percent tested soil for nutrients and applied fertilizer as needed, and 73 percent performed shoot positioning. Conversely, less than 31 percent collected petioles to assess plant nutrient status, protected graft unions from winter cold or applied mulch. Many pest management practices achieved only partial adoption: 97 percent scouted for insect damage, 57 percent identified weed species and 43 percent maintained scouting and treatment records. Additionally, only 13 percent of respondents utilized pheromone traps to monitor pest flight and degree-days models for timing pesticide applications, and very few removed alternate hosts such as wild grapes in adjacent woods.

Objective 2) To demonstrate grape best management practices.

A number of activities were undertaken to meet this project's objectives. Some were executed continuously throughout the project, while others were conducted at selected points in time as conditions allowed. However, best management practices were demonstrated each season through periodic tailgate meetings with grape producers.

Insect and Disease Management

A key foundation of this aspect of the project has been the use of Spectrum™ data logging weather stations in conjunction with insect and disease development models. One station was utilized in 2005, with additional stations deployed each of the years following to reach a total of six in Missouri and two in Arkansas in 2008.

For the Missouri vineyards in 2007, the number of disease model recommended fungicide sprays prior to disease events (assumed 10-day spray interval) was three to five for black rot, three to four for powdery mildew, three to five for downy mildew and zero to two for Botrytis. In 2008, the number of fungicide sprays predicted versus those actually applied by our cooperators (in parentheses) was five (5-8) for black rot, 10-15 (3-11) for powdery mildew, 7-10 (8-15) for downy mildew and three to five (2-7) for Botrytis.

The cumulative number of first-generation grape berry moths captured per trap in four vineyard sites in Missouri dropped from a range of 14 to 85 moths/trap in 2006 to a range of eight to 28 moths/trap in 2008 that remained below three moths/trap/week for the remainder of the season. Part of the drop in trap catch in 2008 was attributed to the freeze damage on April 7-9 in 2007. However, there is an obvious need to improve perimeter management of grape berry moth and to demonstrate timing and efficacy of low-risk insecticide applications against grape berry moth.

The green June beetle has been noted as a serious pest of ripening fruit in southwest Missouri and northwest Arkansas. In an efficacy study on this pest, more than 70 percent of green June beetle adults in screen cages died 72 hours after being dipped in solutions of Alverde, Ecotrol, Actara, Admire, Altacor, Battalion, Baythroid, Clutch, Danitol and Sevin (Johnson and Lewis 2009).

Grape root borer trapping efforts in five Ozark vineyards found this pest to be present at below economic levels in the region (< 5 percent of vine infested with larvae) in all but the Ste. Genevieve site (36 percent infested). Grape root borer mean trap captures in 2006 and 2008 in untreated Missouri vineyards were 0 and 0 moths/trap in Rocheport, 34 and 50 in St. James, 65 and 78 in Ste. Genevieve, and 130 and 21 in Hermann. Low population levels may not justify management by insecticide but hypothetically could be further reduced by mass trapping males of the species. Research will continue on this potential control tactic in 2009 and 2010.

We documented the spread of Japanese beetle (an invasive species) to many of our participating vineyard sites in northwest Arkansas and in Missouri. Japanese beetles were first detected near St. Louis in 1934 and in northwest Arkansas in 1997 (Johnson 2005). Recently, local populations of Japanese beetles increased to pest status, which required three or more foliar sprays by 2002 in northwest Arkansas and the same amount by 2007 in Purdy and Ste. Genevieve, Missouri. This pest will probably continue to increase toward damaging levels and require pest control in Hermann, Rocheport, St. James and other locations in Missouri. Johnson (unpublished data) reduced foliar damage from 22 percent to 5 percent in Concord grapes by applying Surround white kaolin clay particle film to the foliage and maintaining white foliage during the Japanese beetle flight period.

The majority of these and additional data were provided to participating growers and posted on the IPM Web site with recommendations (<http://comp.uark.edu/~dtjohnso/Current Pest Information.htm>).

Canopy Management

Four Missouri and two Arkansas canopy management research and demonstration plots were established for the BMP project in 2005. Changes in funding levels and priorities over the four years of the project required that this number be reduced in 2007. Results from these experiments were generally variable due to drought, disease pressure and the April 2007 freeze event that broadly impacted the industry.

While results from most of these experiments were non-significant, several important results were obtained from the Vignoles Cluster Architecture Modification Experiment in 2006 and 2008. This experiment consisted of an untreated control, foliage drench with Stylet oil (2 percent concentration), brushing the clusters to remove individual florets, and removal of eight basal leaves of all shoots at trace bloom in an effort to loosen the architecture of Vignoles grape clusters. In 2006, we were able to document the following: 1) severe leaf removal at bloom did not affect return bloom and yield of Vignoles in the following season, and 2) severe leaf removal at bloom was able to modify cluster architecture and reduce late-season bunch rots in some seasons. In 2008, leaf removal resulted in significantly lower yield due to smaller clusters with fewer berries per cluster and fewer berries per centimeter of rachis length than the other treatments, but it did not affect cluster number or fruit composition. There were no differences between the other treatments and the control vines.

Weed Management

A field trial at Les Bourgeois Vineyard in Rocheport, Mo., was established in fall 2007 to examine the influence of preemergence and postemergence herbicides on commonly found weeds. Prior to establishing the plots, the previous season's vine growth was measured and pruned. The herbicides included materials labeled for use in vineyards; glyphosate was also included in the initial application of some treatments to remove all emerged weeds. In a randomized complete block design with five replications, 11 herbicide combinations were applied (one on Nov. 20, 2007, and 10 on April 14, 2008). Most of the herbicide treatments included a soil-active herbicide to examine the length of residual activity. However, paraquat (non-selective contact herbicide) was also included to simulate repeated application of a non-residual herbicide. Following the April applications, visual control of herbicide efficacy was recorded 18, 39, and 60 days after treatment (DAT). Visual control was rated on a scale from 0 to 100 percent, where 0 percent indicates no control and 100 percent indicates complete plant death. An evaluation of 90 percent was considered acceptable control.

Overall, residual herbicides provided acceptable levels of broadleaf control up to 60 DAT (late June), but grass suppression was only effective for metolachlor by 39 DAT. Much of the lack of residual activity on grasses results from the lack of grass activity among many soil-applied herbicides used in vineyards. In addition, rainfall was exceptional in 2008. Between April 1 and Sept. 1, rainfall occurred every five days or less, and total rainfall over that period was 85 percent greater than the most recent 20-year average. Future studies should consider the use of metolachlor applied mid-season to boost residual activity for suppressing grasses and small-seeded broadleaves (common waterhemp). There were no significant differences in any of the variables measured due to herbicide treatments.

Objective 3) To disseminate grape management, pest and disease event information in a timely manner.

Dissemination of information was a key objective of this project and was accomplished through the use of an electronic advisory, Web sites (iccve.missouri.edu and comp.uark.edu/~dtjohnso/) and the vineyard tailgate meetings. A wide array of topics were addressed at the tailgate meetings, including the following: demonstration of canopy and crop load management practices such as shoot thinning, shoot positioning, leaf thinning, and cluster thinning; petiole and soil sampling for vineyard nutrient management; irrigation; weed management; pesticide use and pre-harvest intervals; and demonstration of grape pest scouting and decision-making pest management program for grape berry moth, grape phylloxera,

grape root borer, grape scale, Japanese beetle and green June beetle. Although six sites were initially selected for tailgate meetings, the Altus, Ark., and St. James, Mo., sites were discontinued in 2007 due to funding constraints.

Objective 4) To produce a Wine Grape Integrated Production Systems Workbook for use in grower grape best management practices workshops.

The *Wine Grape Integrated Production Systems Workbook* is currently under development. Chapters on canopy management and insect pest management are complete. A first draft is expected to be completed by late winter 2009.

Future Directions

A new project has been established for the 2009 season. The goal of this project is to assist growers as they move along the pathway of increased adoption of sustainable practices in their vineyards. Emphasis will be placed on implementation and assessment of the impacts of implementation. In addition, several aspects of the project have been adjusted based upon lessons learned from the BMP project.

In the BMP project, we attempted to implement practices by training growers to scout and collect information. We achieved limited success with this approach. However, interest in accessing and utilizing information was very high. How can this apparent contradiction be explained? We believe that many growers are faced with constraints on the amount of time they have available to perform scouting and monitoring. Some are part-time growers with full-time jobs that consume the majority of their time. Others may be full-time, diversified farmers with limited time available for dedication to their vineyards, or individuals sharing time between the demands of grape growing, winemaking and wine marketing.

Our efforts to continue generating and distributing locally valid information are expanding. The canopy and crop load management, weed and insect pest management experiments will continue with distribution of this information through the aforementioned channels. The Integrated Production Systems Workbook will serve as an additional, valuable source of information. And beginning in 2009, we will begin efforts to model grape leaf wetness — the key to moving toward science-based prediction of grape disease infection events.

Finally, we will move toward aiding you — the grower — in assessing the impacts of adopting sustainable practices in your vineyards. We propose to achieve this through three principle means: 1) develop

the *Integrated Production Systems Workbook*, which will facilitate self-assessment; 2) offer a series of workshops during which we will assist you with the assessment process; and 3) develop a voluntary certification program that will document your progress on the path to achieving a high level of sustainable production. We look forward to making this journey with you in the coming years.

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Marketing of Bio-Orgo-Carbon-Enviro-Sustainable-Fair-Trade-Dynamic Wine

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Introduction

The winds of change have not only impacted our climate, they certainly have begun to impact our marketing as well. The high awareness of climate change, driven by the day-to-day reality of drought in Australia, has grown internationally as a result of the Stern report and Al Gore's documentary and recent Nobel Prize. The wine sector here and abroad has been aware of this issue longer than the average consumer, and many growers and wineries have implemented a range of practices to reduce the impact of their activities on the environment.

There have been long-standing practitioners of organic viticulture and winemaking in most countries, but most have focused on a limited market mainly through specialty organic shops. The South African wine industry started its biodiversity positioning about four years ago, to a "ho-hum" from media and consumers, but it was probably just a bit ahead of the curve. The New Zealanders have had sustainability registration for several years and are now awarding "pure" gold medals for top wines, which at the same time are from certified vineyards and wineries. Their positioning matches well the overall positioning of New Zealand as a clean, green and pure tourist destination. But this hasn't stopped some of the British wine press from criticizing the excess food miles New Zealand accumulates compared to European wines. Australia has been behind in trumpeting environmental credentials, although there has been a lot of activity in the vineyards and wineries (e.g., Banrock Station's positioning) and a biodynamic wine show for the last two years. The big question is: "What affect are these having on the purchasing habits of consumers?"

The short answer right now is "very little" and "we don't know." This hasn't stopped almost everyone from trumpeting his or her environmental credentials. However, this is how marketing works; there is often a group of early adopters, some of whom are opinion leaders, whose ability to be seen as role

models and to communicate their views helps new trends become established. Over time the early adoption becomes a fad, then a trend. So what do we know about what consumers think?

Background

We have to be careful about some of the recent press. A press release for the Sustainable Ag Expo in California trumpets that some consumers will pay more for sustainable products, just as some do for organic products. Where is the evidence? What it actually found is: “While ‘sustainability’ is not yet a household word, it is an umbrella term for six key values: healthier, local, social responsibility, environmental responsibility, simple living and control.” There is no evidence that consumers are willing to pay more for these products.

A few months ago, Wine Intelligence in the U.K. released a survey of 2,000 regular wine-drinking consumers concerning organic, biodynamic and fair-trade wines. It found that: “While 60 percent of respondents are aware of organic and fair-trade wine, only 11.9 percent claim to have bought organic or fair-trade wine in the last three months,” said Research Director Lulie Halstead. “This is compared to 60 to 70 percent who claimed to have bought organic and fair-trade food.” Few consumers understood the concepts and many assumed that all wine was organic. Virtually no one understood what biodynamic meant. However, we should realize that these same statements could have been made about organic and fair-trade food five years ago. One of the main issues for the wine industry claimed by Lulie Halstead is the existing confusion about wine labels in particular and the growing plethora of stickers for organic, biodynamic and sustainable practices.

In preparation for the certification of sustainable vineyard practices, the Central Coast Grape Growers in California hired me to help determine whether such certification would impact consumer buying behavior for wine. We conducted a small choice experiment of regular wine drinkers in the central coast area of Paso Robles and surrounding communities. Consumers were presented with different wine labels, with two regions, two types of sustainable labeling and four prices. We found that for wines priced less than \$20 there was little preference for sustainable compared to standard wines. There was a preference for “certified” sustainable compared to “sustainable” or no extra label for wines more than \$20. A somewhat surprising finding was that there was no major difference between low- and high-involvement wine buyers. The big finding was that wine buyers would pay \$5 to \$7 more for a certified sustainable wine, but only when it was from a well-known region and priced more than \$25. These findings show that although

there is some willingness to pay extra for these types of wines, it was only for those special high-priced wines in this research project.

Another recent study we conducted for the Riverland wine region showed that the regional association with wetlands and nature, or eco-friendliness were very weak. Currently we are conducting an expanded version of the California study for McLaren Vale with a large sample of Australian wine buyers. The results will be available in a month or so.

We reviewed more than 60 articles published about organic food consumers in the last two decades with the aim of better understanding their behavior, their motives and the willingness to pay (WTP) for such products. However, very few articles have focused on organic wine consumers and their WTP for organic wines, and these papers have some limitations. No academic studies were found focusing on bio-dynamic or carbon-neutral wine marketing.

Although the organic market is growing and environmental issues in the media are prevalent, there still exists confusion surrounding the term “organic” (Thogersen 2006). The meaning of “organic” changes depending on the country and its associated regulations. While many consumers have heard the term “organic,” many are unaware of its central features. This is similar to other food terms such as “cage free” and “natural,” which have shown a tendency toward consumer confusion (Hughner et al. 2007).

Various attitudinal studies indicate that the potential market for organic products is large, that is, people say that they intend to or want to buy organic products. However, attitudinal studies do not accurately predict consumer behavior, and many consumers have yet to link the benefits of organics with their behavior (Gribben and Gitsam 2007). Although people hold positive attitudes toward organic products, actual expenditure on the product category is quite small. However, some figures given by Dimitri and Oberholtzer (2005) indicate that annual growth forecasts for organic sales range from 1.5 percent for Denmark to 11 percent for the United Kingdom. The United States’ organic retail sales of organic products are predicted to grow 9 to 16 percent per year through 2010. Regarding the wine industry, it is quite difficult to estimate such a trend as reliable marketing and economic data are difficult to obtain. However, there are a growing number of wineries certified organic all around the world. For example in France, 1,639 wineries were organic in 2006 (up 10 percent compared to 2003, Viniflor 2004, 2007). In Australia, 44 wineries have been found producing organic wines in 2008.

Most studies attempt to differentiate the organic customer from the non-organic customer and then further define these two segments based on socio-demographic characteristics such as age, gender, education, household size and income. When reviewing results of these studies we have to keep in mind that segments solely based on sociodemographics and attitude-related variables have proven to be less stable and relevant to purchase behavior than segmentation based on the utility of product attributes (Wedel and Kamakura 1999).

Are people of a certain age more inclined to buy organic products? The papers we reviewed provide mixed evidence, but the conclusion seems to be that the purchasing of organic food does not differ across ages.

Women are more concerned with pesticide residues and the health of the environment, therefore, they are slightly more inclined to purchase organic products than men. Squires et al. (2001) support the notion that female consumers are more interested in organic products and are therefore more likely to buy them. In the four segments found by Gil et al. (2000) groups with a higher percentage of females tended to buy more organic foods and were more likely organic food consumers, while the younger group, dominated by male consumers, did not have as many likely organic consumers.

The evidence suggests that education does influence organic purchases. It was found that postgraduates and university graduates are more likely to buy organic products than people who have not attained a university education and or a high school level of learning (Krystallis et al. 2006).

Household size, especially whether there are children in the house, does seem to influence organic consumption (Tsakiridou et al. 2006; Chrysohoidis and Krystallis 2005). Families with young children are more likely to be concerned with the safety and nutrition of food they feed their young children and so tend to buy more organic foods — this being based on the assumption that organics are better for you (Kiesel and Villas-Boas 2007).

These findings partially vary across cultures, but the stereotypical organic customer emerging from previous studies can be described as following: She is female, has a higher income, is in a house with children, is aged between 30 and 40 years old, is concerned about the environment and her own health and is living a balanced lifestyle. On the other hand, the non-organic customer is predominantly male, is not overly concerned about the environment, does not live in a house with children, is younger than 20 years old or older than 55 and does not place high importance on healthy eating.

Most consumers have a positive attitude toward organic products and perceive them as healthier (Sirieix et al. 2005), better for the environment, of a higher quality and tastier than conventional alternatives (Gil et al. 2000; Kihlberg and Risvik 2007). Therefore, it could be assumed that these benefits determine a price premium compared to similar conventional products. We next discuss the only two studies that attempted to measure whether consumers will pay more for organic wines.

Brugarolas Molla-Bauza et al. (2005) used contingent valuation to determine consumers WTP for organic wine. Consumers were asked, “Are you willing to pay 10 percent, 25 percent, 50 percent, 100 percent more for an organic wine with respect to a conventional wine with similar characteristics?” Then, respondents also had the opportunity to write the maximum premium price that they would pay for an organic wine. The findings indicate that the average price premium that consumers are WTP for an organic wine is 16.92 percent. Using a cluster analysis based on lifestyle segmentation, the WTP for an organic wine varied from 20.9 percent (for the more environmentally concerned), 18.36 percent (for wine consumers worried about feeding and health, but not about environment) to 11.94 percent (for wine consumers worried by any of those factors). Findings of this study suffer from several limitations. Methods directly electing willingness to pay for attributes without forcing respondents to make trade-offs between product attributes (e.g., product price versus organic) are known to result in invalid and unrealistically high attribute importance (Louviere and Islam 2007). Also, the sample only represents a very limited sample, consumers of the city of Alicante in Spain, which cannot be assumed to be representative for Spanish consumers in general.

The primary purpose of Barreiro-Hurlé et al. (2007) was to estimate if a market does exist for functional wines — those with added health claims. They designed choice experiments and included regular versus resveratrol content-enhanced wines with various regions, brands and prices. Their findings indicated that the additional WTP for an organic wine on average is 1.53€. This price premium represents an extra 15 percent of the maximum price respondents declared they usually pay for a bottle of wine (10.11€).

Our Research

We used a discrete choice experiment (DCE) with visual product representations on the Internet to measure attribute importance for organic, sustainably grown and carbon-neutral wine. DCEs use experimental designs to combine attribute levels into bundles or product concepts. Respondents are forced to make trade-offs when choosing these product concepts (Louviere, Hensher and Swait, 2000).

To measure the influence of organic claims on consumers' wine choice we varied four extrinsic wine attributes: price, region of origin, environmental claim and organic claim (Table 1). The price levels were chosen to cover the medium- and higher-priced segment of Australian wines (\$12.50 to \$32) where products with organic claims will most likely be found. All regions were chosen to be known for Shiraz wines with varying levels of reputation. South eastern Australia and Heathcote have a comparable lower awareness than McLaren Vale and Barossa Valley, but Heathcote has a higher reputation among knowledgeable consumers. As environmental claims, we included the attribute levels "environmentally responsible" and "carbon neutral" and used two logos following the Australian Carbon Reduction Institute (noco2.com.au). For the organic claim, we used the logo of Australian Certified Organic (australianorganic.com.au). To avoid an overrepresentation of environmental and organic claims atypical for the real wine market, two and three levels, respectively, were chosen to contain no claim and were jointly used as a reference level in later analysis.

Because it was the aim to study if environmental claims are a viable marketing strategy, the brand name was held constant and the made-up name "Hook Hill Estate" was created. The Shiraz grape variety was also kept constant across the labels. Prices were assumed to represent a 750ml bottle as stated on all labels. For the visual label we used an off-white chateau-style label, which has shown to be widely accepted by Australian wine consumers (Mueller and Lockshin 2008).

The research survey was designed to simulate a real-life decision-making environment where the participant would imagine that they were going to purchase a bottle of wine for a special occasion. Respondents were asked to choose from the shelf the wine they most and least preferred and state whether they realistically would purchase their most preferred wine (see Figure 1 for an example of a choice set). Seven hundred fifty-six regular wine consumers living across Australia, recruited via a panel provider, completed the online experiment in November 2007. The sample is representative of Australian wine consumers.

Results

We used Latent GOLD Choice 4.0 (Vermunt and Magidson 2005) to estimate a latent class choice model. This is a means of producing a good-fitting segmentation (cluster) scheme where each cluster represents different factors in choosing a bottle of wine. A model with five latent classes including a random-choice cluster resulted in the best fit without producing classes with too few respondents (less than 10 percent). The choice behavior of respondents in the random class (19 percent) cannot be explained by

the attributes included in the experiment. Modeling a random-choice class significantly increases the explained variance in the remaining four classes and results in more accurate parameter estimates, which would otherwise be confounded by random-choice respondents (Cleaver and Wedel 2001). As also found in the real market place, the behavior of those respondents is either completely random (like giving the same choice each time) or determined by other attributes not included in the DCE.



Figure 1: Sample of a discrete choice set

Results of the DCE imply that, for the total sample, price was the most important attribute with almost two thirds (65 percent) of the importance (Table 2), followed by region (17 percent), and environmentally responsible claims (14 percent). The environmental claim was valued more than four times as much as the organic attribute, which on average accounted only for 3 percent of the importance for wine choice. However, the importance weights for each attribute differ greatly between the clusters. Two of the clusters carried all of the importance weight for organic wine, while the other two did not value this at all.

The four resulting clusters strongly deviate in the strength of their purchase-relevant characteristics. The first cluster is very price sensitive with a strong preference for the lowest price level (\$12.50). Region has only minor importance for this class with an almost equal preference for McLaren Vale or Barossa origin. Price and environmental responsible claims are the two most important characteristics for the second cluster, which compared to the first one prefers medium price level (\$19). The third cluster is the only consumer segment that places a noticeable importance of the organic claim, which accounts for 9 percent of the relative strength of all attributes analyzed. Region of origin is the most important cue for this class with a strong preference for Barossa wines. This third cluster is also the most environmentally influenced but least price sensitive. Region and price are the most important attributes for the fourth segment with a strong preference for the McLaren origin. Because cluster three was the main target segment for organic wine, we will focus on this consumer segment in the following discussion.

An analysis of variance of the significant differences of socio-demographic and wine behavior-related variables between all five clusters revealed the following significant differences for the third class. Firstly, this potential consumer segment has a significantly higher knowledge of what the organic claim means, cares more about how its food is grown, most often purchases other organic food, and claims to be an “environmentalist at heart.” Consumers in this class are more likely to be younger, female and have a higher-than-average willingness to pay for wine for a normal consumption occasion.

Discussion

The wine sector is in the early stages of consumer recognition of the environmental issues associated with wine making. Most consumers seem to be unaware of the large amount of waste products wineries produce. They seem to believe wine is a natural and environmentally benign product. Wine and food writers have been much more proactive in touting the credentials or, in the case of “food miles,” the damage that winemaking could have on the environment. Much of the debate has been uninformed, mainly because so little reliable information exists. So far, there is no way to compare the overall impact on the environment of a bottle of New Zealand or Australian wine grown under sustainable practices using a screw cap with one grown in Europe under standard practices using a cork. This won't stop writers or even some wineries from touting their environmental focus. A big issue is what is “standard” practice and what is the definition of “sustainable.” For example, biodynamic is a certified term pertaining to grape-growing practices, but it does not indicate what happens to the winery wastewater or its packaging. All of this is confusing to consumers, even well informed ones.

Our results demonstrate that there is a market for organic wines in Australia, albeit not a very large one. A small proportion of wine consumers (14 percent of the sample) are clearly environmentally conscious with eco-friendly claims accounting for almost 40 percent (30 percent + 9 percent) of the decision-making process, when making a purchase for a special occasion. Previous research shows this to be about 25 percent of wine consumption occasions in Australia (Oppenheim, Hall and Lockshin 2001).

The interesting but also sobering finding for the organic wine industry relates to the extent organic is less valued (9 percent) compared to an environmental claim (30 percent). Regarding organic wines, this situation might be explained by the physical availability of organic wines on the shelves. With a small production of organic wines, it is difficult for consumers to easily find some in stores. At present, the production and commercialization of organic wines is still relatively unknown in Australia. However, import-

ing and supplying organic wines to the Australian market is not an impossible task. Therefore, this low demand for organic wines reflects a low salience of these types of wines. Salience refers to the propensity of the product or brand to be noticed or thought of in buying situations (Romaniuk and Sharp 2004).

Indeed, awareness, which differs from salience, for organic products seems to be quite high with 80 percent of the respondents agreeing with the statement, “I know what organic (food) means” and 88 percent of the sample declaring that they have already eaten organic products. However, only 32 percent of the sample declared that they have already drunk an organic wine. In other words, “organic” may come to mind for food, but not for wine (as mentioned previously) and especially not during the purchase process (low salience). There is a strong need for more market information and education, especially as the term organic does not clearly signal the environmental aspect to many prospective consumers. That relates to the extent consumers were willing to value more an environmental claim (environmentally responsible), which has never been formally defined. But such a claim makes sense to consumers during their (simulated) purchase process. In other words, that claim increases the salience of eco-friendly wines compared to “organic” or “carbon neutral.”

There is no doubt we are at the turn of a new era in winegrowing and marketing. Producers are reacting to the constraints now imposed, both locally and internationally. Consumers are also interested in “doing the right thing” in reducing their own footprint on environmental matters, but at this stage it isn’t clear what the right action is. We will see more confusion before we have any clarity. There will be a wide range of labels and stickers, and “holier than thou” promotions by companies, regions and countries. My own feeling is that environmental responsibility across a range of activities in the wine sector will become the standard; that no winery, region or country will gain much in the long run, because everyone will adapt. There may be some short-term gains for those who can prove their environmental credentials during the changeover. In the long term we will all gain by adapting our practices and our buying habits.

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Table 1: Attributes and levels

| Attribute | Levels | 1 | 2 | 3 | 4 |
|---------------------|---------------|-----------------------------|----------------|--------------|----------------|
| Price | 4 | \$12.50 | \$19 | \$25.50 | \$32 |
| Region of origin | 4 | South Eastern Australia | Heathcote | McLaren Vale | Barossa Valley |
| Environmental claim | 4 | Environmentally responsible | Carbon neutral | no claim | no claim |
| Organic claim | 4 | Certified organic | no claim | no claim | no claim |

Table 2. Attribute importance weights for classes and total sample

| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Total Sample |
|---------------------|----------------|----------------|----------------|----------------|----------------|---------------------|
| Class size | 34% | 22% | 14% | 11% | 19% | 100% |
| Price | 82% | 71% | 14% | 38% | — | 65% |
| Region | 11% | 7% | 47% | 58% | — | 17% |
| Environmental claim | 7% | 17% | 30% | 4% | — | 14% |
| Organic claim | 0% | 5% | 9% | 0% | — | 3% |

The Lodi Rules: California's First Third-Party-Certified Sustainable Winegrowing Program

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Abstract

In 2005, growers of the Lodi Wine grape Commission launched California's first third-party-certified sustainable winegrowing program, the Lodi Rules for Sustainable Winegrowing. Participation in the program has grown significantly each year with 27 growers certifying more than 10,000 acres in 2008, more than 10 percent of all the vineyard acres in the Lodi region. Nineteen wines from the 2005 and 2006 vintages made by six different wineries are currently in the marketplace bearing the Lodi Rules logo. Additional wineries will be using the logo for wines from the 2007 and 2008 vintages. Presented here is a history of the development of the program, some of its basic characteristics, the program's growth and specific practices used by three growers who have achieved certification of some of their vineyards.

Introduction

The global wine industry gets more competitive every day, and the ability to differentiate one's wine from others in the marketplace is a key to financial success. There are many ways to differentiate wines, such as by terroir, blends, pricing, clever packaging or regional origin. Building on their long history of implementing integrated pest management (IPM) and other sustainable farming practices in their vineyards, Lodi winegrowers have developed a program that will aid them in differentiating and adding value to their wines based on how the wine grapes are grown. The name of the program is The Lodi Rules for Sustainable Winegrowing (Lodi Rules). Differentiating a food or beverage from others in the marketplace based on how it is grown or produced is not new, organic and biodynamic farmers have done so for decades. However, the Lodi Rules is a new model, one promoted by Protected Harvest (see Table 1 for Web site address), a third-party non-profit organization that certifies farmers' use of stringent environmental farming standards.

What are The Lodi Rules for Sustainable Winegrowing? They are California's first sustainable winegrowing standards peer reviewed by scientists, academics and environmentalists, and they are accredited and certified by Protected Harvest. The Lodi Rules Program is open to all Lodi Wine grape Commission (LWC) growers on a voluntary basis and supports LWC's goals of improving Lodi's reputation for

producing quality wine grapes and wine. Growers who choose to participate in the program can get their vineyards certified as producing sustainably grown wine grapes. Wineries making wine from these grapes can then use the certification in their marketing programs. In 2009, Lodi Rules will be available for California growers outside of the Lodi region.

Materials and Methods

Review of Existing Certification Programs

In early 2000, LWC published the *Lodi Winegrower's Workbook: A self-assessment of integrated farming practices* (Ohmart and Matthiasson 2000). The workbook helps growers assess the level of implementation of sustainable farming practices in their vineyards and provides instructions on developing action plans to improve on specific practices where improvements are warranted. The workbook was used as the model for developing the *Code of Sustainable Winegrowing Practices* published in 2001 by the Wine Institute and California Association of Wine Grape Growers and was the primary source of material for the vineyard chapters in this workbook (Dlott et al. 2002). Since then others have used the workbook as a model for similar publications and programs (Wise et al. 2008).

While putting the Lodi workbook together, LWC growers realized that it could provide a foundation for developing a sustainable farming vineyard certification program. So in April 2001, after using it for a year and a half, the growers formed a planning committee to explore the possibility of developing a certification program for the sustainable production of Lodi wine grapes. The process was begun by the committee reviewing existing certification programs, particularly those dealing with wine grapes, of which there are several. The following programs were reviewed in detail: South Africa's Integrated Production of Wine, Oregon's Low Input Viticulture and Enology (Oregon LIVE), Salmon Safe, the Food Alliance and Fish Friendly Farming (see Table 1 for Web site addresses).

One certification program reviewed in detail by the committee that did not involve wine grapes was the Healthy Grown® program, which was conceived in the mid-1990's by a group of progressive Wisconsin potato growers facing serious environmental challenges (Table 1). One of the outcomes of the program was the creation of Protected Harvest to act as a non-profit, third-party certifier for the program. Like the certification programs listed above, the Healthy Grown program requires growers to meet stringent sustainable farming practices, particularly in the area of integrated pest management. Unlike other programs however, the Healthy Grower program emphasizes the fact that these standards have been peer

reviewed by scientists, academics and environmentalists. Another unique aspect of the certification program is the requirement that the environmental impact of pesticides used by the potato growers, whether synthetic or organically approved, be calculated by a multi-attribute pesticide impact model developed for the program. To qualify for certification, the pesticides used on a field during the year cannot exceed a threshold of environmental impact units.

After careful consideration, the LWC grower planning committee decided to design a certification program following the Healthy Grown model with Protected Harvest as the third-party certifier. This decision was made for several reasons. First, to achieve certification growers must meet not only stringent sustainable farming practices standards but also cannot exceed a measured level of environmental impact based on the pesticides used in each vineyard, regardless of whether these materials are synthetic or organically approved. Secondly, the farming practices standards and pesticide impact model are subjected to a peer review process involving scientists with expertise in the issues addressed by the practices standards as well as by environmentalists. And lastly, Protected Harvest has been given the highest rating by the Consumers Union Guide to Environmental Labels (Table 1).

Farming Standards Development

The next step was to form a certification committee to draft the farming practice standards. The 22-member committee was made up of 10 LWC growers, two Lodi winery representatives, two pest control advisors, a wildlife biologist, two University of California (UC) viticulture farm advisors, a UC irrigation specialist, and four LWC staff members. There were small, medium and large operation growers on the committee to ensure that all types of Lodi growers were represented. Moreover, more than 30 percent of the vineyard acres in the Lodi region are grown by those in the LWC. The committee met 14 times between November 2003 and February 2005 to draft the farming practices standards. The draft standards were submitted to Protected Harvest in April 2005 for peer review and Protected Harvest Board review. The standards were revised based on the reviews and given unanimous board endorsement in May 2005.

The Lodi Rules are made up of 75 farming practice standards divided into six chapters: Ecosystem Management; Education, Training and Team Building; Soil Management; Water Management; Vineyard Establishment; and Pest Management (Table 1). A farming practice had to meet three criteria to be included as a standard: 1) It must be measurable, in other words there must be physical evidence indicating the practice was carried out; 2) The practice must maintain or enhance one or more of the Three E's

of sustainability, those being economic viability, environmental soundness and social responsibility (social equity); 3) The practice must be technically and economically feasible, in other words it cannot be an unachievable standard. Some of the standards, such as nitrogen application in the Soil Management chapter, have two or more components to them. Some practices that are very important because they have multiple uses and effects in or around the vineyard, such as the planting of cover crops, appear in a standard in more than one chapter.

The Lodi Rules farming practice standards come in two basic forms. One form is a “Yes/No” question where if you answer “Yes” you get a specified number of points. If you answer “No” you get no points. There are 13 of this type of standard in the Lodi Rules and in all cases the requirement is a management plan that must contain specific components for the issue being addressed (see Table 2). The other form is a standard that deals with a specific farming practice or issue that has three or more levels with more points being awarded as one goes from the bottom level, for which one gets no points, to the top level, which requires the most to be done for that practice/issue and gets the maximum points. Table 3 contains an example of this type of standard from the Soil Management chapter.

There are many standards in the Lodi Rules with a “Fail Chapter” component where if growers are at the bottom level for that standard, they fail to get certified for that chapter regardless of what they score on the other standards for that chapter. Because growers must get at least half the points from every chapter to qualify for certification for each vineyard then, in effect, scoring the bottom level on any one of these “Fail Chapter” standards means they cannot get certified. The certification committee felt there were many farming practices where if a grower was not doing better than the minimum for any one of them then he or she should not be able to qualify for certification. Table 4 contains an example of a “Fail Chapter” standard from the Pest Management chapter.

The “Fail Chapter” standards highlight one of the foundations of the Healthy Grown/Protected Harvest certification model. To obtain certification, a grower must do a lot of different things. In other words, a grower cannot get certified by doing nothing. The Lodi Rules is much more than a “cause no harm” program. In order to qualify, a grower must be using practices that enhance the sustainability of his or her vineyards and farms.

Pesticide Environmental Impact Model

One of the unique aspects of the Healthy Grown/Protected Harvest certification model, and in our view one of its great strengths, is the use of a pesticide environmental impact model to determine whether a field/vineyard qualifies for certification. Environmental impact models have been developed as tools to quantify the environmental impact of pesticides. Because of the process used by EPA to register pesticides, there is a very large amount of data available on the toxicity and environmental impacts of the pesticide active ingredients commonly used in agriculture. However, the data is not readily available to most and cannot be directly applied to the process of selecting pesticides. Therefore, to make this data more useful to more people, several experts have taken these data and created pesticide environmental impact models. American Farmland Trust published a description and comparison of eight of these models (2004). Each model has strengths and weaknesses and must confront the pervasive lack of data needed to produce accurate estimates of risk to a given class of organism in a given setting, following a particular use of a pesticide.

A pesticide environmental impact model needs to strike a balance between complexity, accuracy and practicality. In general, models that are intended to measure or track pesticide risk levels across hundreds or thousands of growers at the scale of a state, province or country cannot be as field specific and sophisticated as models designed for use principally at the field level.

In order to determine which type of environmental impact model would be most appropriate for the Lodi Rules program, pesticide use data from Lodi vineyards were run through three of the eight models reviewed by American Farmland Trust. The models chosen were the Environmental Impact Quotient (EIQ), developed by Cornell University; the Environmental Yardstick for Pesticides (EYP), developed in Holland; and SYNOPS, developed in Germany. The pesticide use data were from LWC's Biologically Integrated Farming System's (BIFS) database, which contained eight years of farming data, including complete pesticide use, for 70 vineyards totalling 2,500 acres. These vineyards represent many wine grape varieties, trellis systems and soil types and are distributed throughout the Lodi region. A fourth environmental indicator model, the multi-attribute toxicity factor model (MATF) developed for the Healthy Grown certification program in Wisconsin, was also carefully reviewed, but it was not necessary to run Lodi data through the model to evaluate its utility for the Lodi region (Benbrook et al. 2002).

Each environmental indicator model differs in methodology. EIQ uses a ranking methodology that ranks toxicological data and chemical property information on a set scale and then multiplies that score by the application rate to arrive at an environmental impact score. EYP uses a groundwater-leaching program to calculate a predicted environmental concentration in groundwater. EYP also generates similar predicted environmental concentrations for surface-water and soil. These predicted environmental concentrations are then used in equations also considering toxicological effects and the Dutch drinking water standard to arrive at environmental impact points. SYNOPS also generates predicted environmental concentrations in soil and water and then uses those predicted environmental concentrations in equations that also consider toxicological effects to arrive at risk indices for soil and water. MATF uses a modified ranking methodology to calculate toxicity factor values for acute mammalian risk, chronic mammalian risk, ecological impacts and impacts on beneficial organisms. These toxicity factor values are based on human health risk data, toxicological data and chemical parameter information. Once calculated, these toxicity factor values are multiplied by the application rate of the pesticide's active ingredient to arrive at final toxicity units.

Models, such as MATF, whose output can be used to rank relative pesticide environmental impacts according to "toxicity units" or "Environmental Impact Units" (EIU) on a per-acre-treated, or per-hectare-treated basis have several advantages. Such indices are usually based on both pesticide toxicity and application rates. In addition, the MATF approach can be modified to include exposure adjustment factors that can be incorporated in the indices to take into account the likely impact of the timing and method of application, as well as formulation type. For example, an in-season, liquid foliar application is assumed to pose the highest potential exposure for workers and most non-target organisms, and corresponds to a use pattern adjustment factor (UPAF) value of one (i.e., no downward adjustment in expected exposure levels). A change in use pattern to, for example, a pre-plant soil-incorporated granular application, would result in a UPAF of 0.2, reflecting the lessened potential for exposure to workers. A new model, called the Pesticide Environmental Assessment System (PEAS), was developed to include UPAFs (Ohmart et al. 2006).

Differences in the environmental impact units per treated acre for various pesticides registered for the same use can be used directly in guiding pesticide selection and in determining the level of skill and scope of precautions that should be taken by applicators. Or this basic metric can easily be used to

estimate per acre environmental impact units, or units per field or farm, or across a watershed, region or country. Therefore, the Lodi Rules certification committee decided to use the PEAS model in its certification program so the environmental impact units on a per-acre basis for each vineyard to be certified could be calculated for all the pesticides used during the year.

The PEAS model was used to calculate pesticide impact units for each formulation of pesticide used in Lodi vineyards. The calculations were based on pesticide use in San Joaquin and Sacramento County vineyards obtained from the California Department of Pesticide Regulation's Pesticide Use Reporting database for 1999 to 2001. For those unfamiliar with this database, it is a full pesticide use reporting system. Furthermore, pesticide use data were also obtained from LWC's BIFS database. UPAFs were applied to the data based on formulation, treatment timing, method of application (e.g., soil applied, ground applied, aerially applied) and target (foliage, soil, etc.). The result was an environmental impact index for each unit of formulated pesticide. For example, the environmental impact unit for 1 pound of sulfur dust is 0.2, so the total number of environmental impact units for an application of 15 pounds of sulfur dust is 3.0. Table 5 presents the calculation of total environmental impact units for the pesticides applied to a representative vineyard in Lodi in 2004.

Developing an accurate system to track and manage pesticide risks is a major task that requires a long-term commitment. Any such system must be refined annually as new and more accurate toxicology data is released, and to encompass newly registered pesticides and new restrictions placed on existing products. In addition, much work is needed to sharpen the accuracy and relevance of PEAS risk indicators to specific circumstances. For example, LWC hopes to add a groundwater index and possibly a volatile organic compound (VOC) index to the PEAS model due to the importance of these issues in the Lodi region.

Market Research

While the farming standards were being developed, a task force of wine marketers, winery representatives, wine grape growers, LWC staff and a consultant carried out a year-long market research project. This involved identifying all the important segments of the wine industry, from the vineyard to the consumer, developing market messaging about the certification program for each segment and creating a plan to deliver this message to each one. The process involved more than 100 interviews with wine grape growers, winery representatives, wine wholesalers, retailers and specialty trade, restaurants, wine writers

and educators, international wine consultants, the media, as well as people involved in other environmental certification programs. Furthermore, focus groups of the wine-consuming public were convened in Sacramento, California, Chicago, Illinois, and the Washington, D.C., area. Participants were asked questions about their wine-purchasing behavior, their reactions to environmental messages associated with wine, environmental certification programs and their impressions of messages about Lodi wine and the growers' sustainable farming program. Analyses of these interviews and transcripts from the focus groups were used to develop plans on how to deliver information about the certification program to each industry segment.

Certification

A Lodi vineyard qualifies for certification if it meets two criteria. The farming practices used in the vineyard must achieve a score of 50 percent or better for each chapter of the Lodi Rules, and the environmental impact units for the pesticides used in that vineyard for the year, calculated using the Lodi Rules PEAS model, cannot exceed 50. The vineyard must qualify for certification each year. An independent auditor visits the farm and vineyard to ensure compliance with the Lodi Rules. A grower joining the Lodi Rules program pays an application fee, currently set at \$2,150. The grower is assigned a password to a secure, confidential Web site where he or she uses a sophisticated self-assessment to inform Protected Harvest of the specific practices being used in each vineyard. Upon completion of the self-assessment, Protected Harvest contracts with an independent auditor to visit the grower and each vineyard to verify that all the required practices have been executed. The grower pays a \$1 fee for each acre to be certified in addition to the application fee. The auditor submits the results of the audit to Protected Harvest, which then determines if a vineyard has qualified for certification. If it has, a certificate is then issued for the vineyard and sent to the grower.

Each vineyard must be certified every year. The application fee is reduced to \$1,300 dollars for the second and subsequent years of certification.

Results and Discussion

Program Growth

Six growers joined the program in 2005, the first year of the program, achieving certification on 1,455 vineyard acres. Twelve growers participated in 2006, the six original growers and six new growers,

certifying 5,424 acres. Eighteen growers participated in 2007 certifying 7,680 acres. In 2008, 27 growers achieved certification on 10,000 acres of vineyards, about 10 percent of all the wine grapes in the Lodi region.

Six wineries have received permission from the U.S. Department of Treasury Alcohol and Tobacco Tax and Trade Bureau to use the Lodi Rules logo on wine labels: Herzog Wine Cellars, Bokisch Vineyards and Winery, LangeTwins Wine Estates, St. Amant Winery, Lobo Loco Winery and Valhalla Cellars. There are currently 19 wines in the marketplace bearing the Lodi Rules logo (Figure 1) from the 2005 and 2006 vintages. Additional wineries will be using the logo on additional wine labels from the 2007 and 2008 vintages.

One of the most exciting developments is that Michael-David Winery began in 2007 to pay growers a \$50 per ton bonus for Lodi Rules certified wine grapes. We hope that other wineries will follow suit.

Examples of Lodi Rules Implementation (after Ohmart 2008)

While space does not allow for discussion of all the farming practices growers use to qualify for certification, to demonstrate what is required, below are some of the practices that three growers use. To be as comprehensive as possible, some practices are described from five sections of the Lodi Rules farming standards. No practices in the Vineyard Establishment section are reported because no growers have yet certified a vineyard starting from the date of its establishment.

Growers interviewed were: Markus Bokisch, Bokisch Vineyards & Winery; Aaron Lange, LangeTwins Wine Estates; and Bruce Fry, Mohr-Fry Ranches. Bokisch and Lange have their own wine labels and Fry's certified old vine Zinfandel vineyards provide grapes for several wineries, including St. Amant and Valhalla Cellars, which released Lodi Rules-labeled Zinfandels from the 2005, 2006 and 2007 vintages.

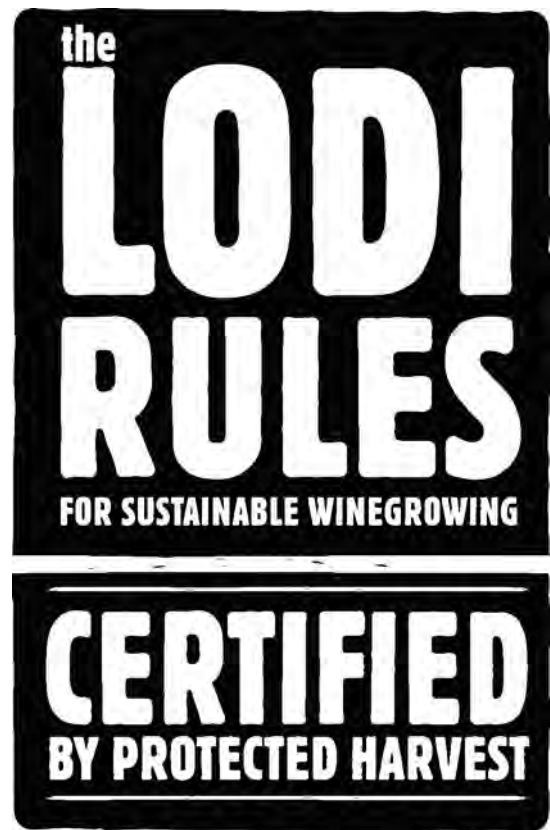


Figure 1. The Lodi Rules logo that appears on 19 wine brands currently in the marketplace from different wineries.

Creating a Sustainability Vision for the Farm

The first standard in the Lodi Rules requires each grower to write a sustainable vision for his or her farm. This vision provides the foundation for the grower's sustainable winegrowing program. Sustainable winegrowing is more than a laundry list of practices one uses in the vineyard. It is having a vision to ensure the long-term health (economic, environmental and social), biodiversity and productivity of the farm. Once written, each farming practice implemented in the vineyard can be evaluated as to whether it moves growers toward or away from their vision. However, because a specific practice does not move one toward the vision does not necessarily mean it should not be done. Just knowing where it fits into the sustainability vision for the farm is important for achieving the goals of the vision.

The process a grower goes through to develop a sustainability vision is important and challenging. One of the requirements for Lodi Rules certification is that the grower attends a half-day workshop to learn strategies for developing a vision. Through a facilitated process, growers are taken through a series of steps to create a vision, which includes defining their resource base and developing one or more sustainable goals. For each goal they develop objectives, strategies to achieve them and a monitoring scheme to determine if the goal has been met.

Ideally, a sustainability vision is developed collectively by key people in the farming operation and then shared with other family members and/or employees. A detailed guide for developing a sustainability vision for one's farm is available from the Lodi Rules Web site (Table 1). It is difficult for anyone who hasn't having experienced the vision-development process to appreciate its importance. I will try to convey this by describing how it has affected the operations of Bokisch Vineyards & Winery.

By developing a sustainability vision for his vineyards, Markus Bokisch realized that he held the keys to create buy-in from all the parties connected to his farming operation, from his family and employees to the financial partners in some of his jointly owned vineyards. He already had sustainability goals prior to joining the Lodi Rules program. However, the vision and the process he went through to create it as part of the program helped him bring all of the people involved in his farming operation together to achieve those goals. For example, by sharing his vision with the financial partners in some of his vineyards he was able to convince them of the importance of investing in improving wildlife habitat by putting up owl boxes, bat boxes, songbird boxes, wood duck boxes, and establishing hedgerows around vineyards and planting more oak trees.

Furthermore, by sharing his vision with his vineyard workers, he helped them appreciate their vital role in producing the highest quality wine grapes possible. He can trace the effects of the vision right down to the quality of the wine produced from the certified vineyards because the workers have taken added pride in the work they do, from leaf removal to shoot-thinning, knowing they are major contributors to the quality of the wine.

Ecosystem Management

As mentioned above, development of the sustainability vision has helped Bokisch justify to his investors the importance of improving the farm's ecosystem. During past and current vineyard development, existing oak trees have been left with large, unfarmed buffers around them. If trees are 75 feet apart or closer, they are left together with no vines in between them.

Large buffers are left around vernal pools and swales. In creating the farm's sustainable vision, Bokisch developed a reforestation plan to establish corridors of native trees and shrubs from local seed sources of blue oak, California buckeye, valley oaks, redbud and sycamore. Species will be planted in ecologically appropriate areas on the vineyard. He is also planting hedgerows in strategic locations to attract songbirds.

At LangeTwins Wine Estates, an important part of the Ecosystem Management component of the Lodi Rules is restoring riparian habitat along the rivers and creeks on its vineyards. It is also a vital part of its sustainable vision. Two important waterways cross through some of the property the Langes manage, the Mokelumne River and Gill Creek. Several years ago, they restored riparian habitat along a significant portion of Gill Creek, which is adjacent to a Chardonnay vineyard, and that was entered into the Lodi Rules program in 2006.

They are currently restoring riparian habitat on a section of the Lower Mokelumne River on their headquarters property. This work includes removing some vineyard acres and re-establishing native riparian plants. It also involves installing a bat "condominium" capable of housing 10,000 bats. In recognition for their past and current conservation work, Brad and Randy Lange were awarded the first Leopold Conservation Award for California in December 2006.

Ecosystem Management is made up of many small steps. After joining the Lodi Rules program, Bruce Fry installed owl boxes and bat boxes in all certified vineyards. Furthermore, since there are electrical power lines traversing one site where several of the certified old vine Zinfandel vineyards are located,

he convinced the power utility to put up perches on the power poles for red-tailed hawks. Since some birds were injuring themselves on the power lines, he had the company install measures to prevent these injuries from occurring.

Education, Training and Team Building

This section of the Lodi Rules farming standards has stimulated Bokisch to better engage and support his employees. For example, he has instigated regular meetings with employees in management positions to discuss why things are done, to better visualize what needs to be done and to then efficiently and effectively carry out the work.

Health care coverage is provided to key employees. Bokisch codified worker training meetings, making them more frequent and consistent, and recorded them for future reference. Developing a sustainability vision has inspired him to develop quantitative standards within his farming operation that help workers identify what skills they need to acquire in order to move to the next pay level. Furthermore, he began offering English classes for his workers and their families in 2008.

Bokisch has concluded that the human element is the single greatest factor in improving wine quality. Having employees share in the sustainability vision results in a more consistent carrying out of duties, whether it be shoot-thinning, leaf removal or pruning. Greater attention to detail is achieved through worker satisfaction.

One of the farming standards in the Education, Training and Team Building section of the Lodi Rules is the development of a human resources plan. The Langes have always recognized the importance of enhancing human resources as an integral part of a successful business, and participation in the Lodi Rules has increased this focus. For example, they will soon create a staff position devoted to human resources as a part of their human resources plan.

Mohr-Fry Ranches has also long recognized the importance of the human element in farming operations and the production of quality wine grapes. The Frys have striven to create an open communications environment where workers feel free to express their opinions on how things are done.

The Frys have paid particular attention to farm safety and are big supporters of and participants in Lodi Farm Safety Day. This event, sponsored by the Lodi Chamber of Commerce, is planned and carried out by the staff of many of the Lodi farming companies, including Mohr-Fry. Each year more than 500

workers are taken through a series of modules, each taught in English and Spanish, and devoted to one particular aspect of farm work, such as pesticide mixing and loading, personal protective equipment, etc. Bruce Fry also has two people designated to address human resource issues at Mohr-Fry Ranches.

Soil Management

Vineyard floor management is an important element of the Soil Management component in Lodi Rules vineyards. The specific strategies used depend on the wine grape variety, vine vigor, soil type and so forth. In the Bokisch Lodi Rules vineyards, the goal is to never expose more than 40 percent of the soil to discing in any given year. In some rows, an every-row permanent cover crop is maintained while in other vineyards, where the site is less vigorous, an alternate-row cover crop is maintained. Cover-cropped tractor rows are mowed twice per season and the tilled rows are disced two or three times, just enough to break up the soil, while minimizing dust creation.

Bokisch's primary motivation for using cover crops is to create a cleaner, healthier work environment for employees by minimizing the amount of dust generated as a result of farming practices. A secondary goal is maintaining good soil structure with healthy soil microbial communities, and maximizing soil organic matter, all of which are enhanced by permanent cover crops and minimal soil disturbance. The cover crop species are short-stem annual rye, subterranean clovers and California poppies for a bit of color. There are also permanent cover crops on vineyard headlands and avenues.

Some of Bokisch's Lodi Rules vineyards, which are also farmed organically, have wall-to-wall cover crops that are mowed twice per season in tractor rows and up to four times under the vine with a mower developed by the Bokisch mechanics. The challenge was to develop a mower that cuts cleanly around the base of the vine. The latest version of the mower, built in 2007, appears to have met this challenge.

LangeTwins Wine Estates maintains alternate tractor row cover crops in its Lodi Rules vineyards. Aaron Lange discovered that maintaining a permanent cover crop in every row was resulting in an unacceptable decline in vine vigor. As does Bokisch Vineyards, the Langes mow the cover-cropped tractor rows twice per season and disc the other tractor rows three times, at most.

Fry maintains an every-row permanent cover crop in all of his Lodi Rules-certified old vine Zinfandel vineyards. He has a particularly challenging situation in these vineyards because the vines are very old, from 60 to more than 100 years, and the vines are on their own roots. His primary reason for using no-till floor management is for dust control, but soil quality and better equipment access during winter

months is also important. He was able to move to no-till floor management in these vineyards when he installed underground drip irrigation systems (see below).

Water Management

From the perspective of sustainability, water management means minimizing water use. From a wine quality perspective, at least in the Lodi region, irrigation is one of the most important tools a grower can use to improve wine grape and wine quality. For example, in the Lange's Lodi Rules vineyards, irrigation management is the primary tool for achieving vine balance.

The Langes do very little leaf removal or shoot-thinning, choosing to manage the vine canopy vigor primarily through careful monitoring of vine water use with neutron probes, the pressure chamber, and in-vineyard weather stations. Using this information, they irrigate to achieve a 6- to 7-ton per acre crop with the proper fruit exposure. Mechanical pre-pruning was used in the Lodi Rules vineyards beginning after the 2007 harvest.

Bruce Fry has installed subsurface drip irrigation down the center of tractor rows in all his Lodi Rules old vine Zinfandel vineyards. Managing irrigation in this manner has had multiple positive effects. First, it has allowed the vineyards to grow a permanent cover crop that is mowed only three or four times per year, and the vineyards have not been disced since 1998. The cover crop adds organic matter to the soil and non-tillage results in improved soil structure and a healthier soil microbial community.

Second, no irrigation under the vines means that weed pressure has greatly decreased since the installation of the subsurface drip. This has allowed him to stop using environmentally problematic pre-emergent herbicides and switch to a contact herbicide program that requires only one winter and one in-season application and which has very low PEAS impact units. The presence of a permanent cover crop also allows much better vineyard access with equipment during the wet winter months.

All three growers have installed photovoltaic solar power systems to provide electricity not only for the pumps in their Lodi Rules vineyards, but also for the shops or houses present on the vineyard sites.

Pest Management

Pesticide use in Lodi Rules-certified vineyards is regulated through the PEAS model requirements. It ensures that only low-risk pesticides are used, whether organic or conventional, and that even a low-risk pesticide, such as sulfur dust, cannot be overused.

In some vineyards use of the PEAS model has not resulted in a change in pesticide use because growers were already using materials with very low environmental impact, such as sulfur dust and one or two low-risk contact herbicides. However, because the PEAS model provides a quantitative measure of a pesticide's environmental impact, some growers, like Bokisch, pick the materials with the lowest PEAS numbers even though they are under the required PEAS threshold because they want to lower their environmental impact as much as possible.

On the other hand, pesticide use in some vineyards has changed markedly as a result of joining the Lodi Rules program. For example, Bruce Fry was using Nematicur in his old vine Zinfandel vineyards prior to certifying them. Since these vines are on their own roots, nematodes are a significant problem. However, to qualify under the PEAS model requirements Bruce had to stop using Nematicur. He now manages the nematode problem through his vineyard nutrient management program. He has enrolled the vineyards in a crop monitoring program offered by the input supplier company from which he buys his fertilizers. It involves taking petiole samples from each vineyard up to six times a year, which are then analyzed for trends in all the important nutrient levels in the vine. From these trends the appropriate amounts of fertilizers are then applied at the correct time of year to have the optimum effect on vine health and wine grape quality. He also takes soil samples regularly to monitor the nematode populations. And finally, the vines are irrigated a bit more than younger vineyards, again to ensure optimum vine health.

LangeTwins Wine Estates has made a major investment in developing an electrostatic spraying system mounted as a modular unit on an over-the-row grape harvester. Recognizing that spraying for pests was always going to be a necessity in some vineyards, the Langes realized that sprayers could be developed that reduce the environmental impacts of spraying in many ways:

- The sprayer covers four rows per tractor pass, which reduces fuel consumption and dust in the air, particularly when compared to that produced by an air-blast sprayer.
- Soil compaction is reduced because the machine is traveling down every fourth row and the tires are in the middle of the tractor row.
- The per-acre rate of many pesticides can be reduced by more than half and still be effective because of better spray coverage.
- Water is applied at 17 gallons per acre so mixing and loading is dramatically reduced.

- The driver is riding in an enclosed cab with a carbon-filtered air conditioning system.
- The technology of the equipment requires a more highly trained operator, who can be paid a better wage to operate it.

Conclusions

The Lodi Rules program has the potential to benefit every part of the value chain from the vineyard to the consumer. It was developed by the Lodi growers in the hope of getting a premium for their grapes because of their high quality and the practices used to grow them. Wineries can add value to their wines by using high-quality certified grapes and marketing their wines using the Lodi Rules logo on their labels. Wine gatekeepers can increase wine sales by selling great wines with an interesting story behind them, and the consumers can enjoy great wine and feel good because their purchases help growers farm more sustainably.

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Table 1. Names and Web site addresses for certification programs reviewed by LWC's Certification Program Committee

| Program | Web site |
|--|-------------------------|
| Protected Harvest | protectedharvest.org |
| Integrated Production of Wines (IPW) | ipw.co.za |
| Oregon LIVE | liveinc.org |
| Salmon Safe | salmonsafe.org |
| Food Alliance | foodalliance.org |
| Fish Friendly Farming | fishfriendlyfarming.org |
| Healthy Grown | healthygrown.com |
| Consumers Union Ecolabel Evaluation | ecolabels.org |
| Lodi Rules for Sustainable Winegrowing | lodirules.com |

Table 2. Farming Standards Which are Yes/No Questions. The number indicates the chapter; 1) Ecosystem Management, 2) Education, Training and Team Building, 3) Soil Management, 6) Pest Management (lodirules.com).

| No. | Standard |
|------------|--|
| 1.1 | Sustainability Vision Plan for Farm |
| 1.3 | Environmental Survey and Monitoring Program for New or Existing Vineyard |
| 1.13 | Livestock Grazing Plan for Farm |
| 2.1 | Human Resources Plan for Farm |
| 3.1 | Nutrition Management Plan for Vineyard |
| 3.12 | Soil Erosion/Soil Conservation Plan |
| 6.2 | Economic Threshold Plan for Insect and Mite Pests |
| 6.11 | Powdery Mildew Management Plan |
| 6.15.1 | Soil-borne Pest Management Plan |
| 6.16.1 | Weed Management Plan |
| 6.17.1 | Vertebrate Management Plan |
| 6.18.1 | Sprayer/Duster Maintenance Plan |
| 6.18.4 | Spray/Dust Drift Management Plan for Vineyard |

Table 3. Farming standard from the Soil Management chapter with more than two levels and the points awarded for each level

3.4 Soil analysis for macronutrients

| | |
|---|----------|
| a. I sent a soil sample from the vineyard to a lab for macronutrient analysis within the last 12 months. | 3 |
| b. I sent a soil sample from the vineyard to a lab for macronutrient analysis within the last 3 years | 2 |
| c. I sent a soil sample from the vineyard to a lab for macronutrient analysis within the last five years. | 1 |
| d. I have never taken soil samples from my vineyard and had them analyzed. | 0 |

Table 4. A “Fail Chapter” farming standard from the Pest Management chapter. Notice that if a grower is at the bottom level he or she scores an “FC” and cannot certify that vineyard.

6.1 Vineyard monitoring for insect, mite and disease pests

| | |
|--|-----------|
| a. My PCA and/or I monitor(s) the vineyard for insect, mite and disease pests at least once every 10 days from bud break to harvest, and I keep a written record. | 6 |
| b. My PCA and/or I monitor(s) the vineyard for insect, mite, and disease pests at least once every 14 days during the growing season, and I keep a written record. | 4 |
| c. My PCA and/or I monitor(s) the vineyard for insect, mite, and disease pests at least once every 21 days, and I keep a written record. | 2 |
| d. My PCA and/or I monitor(s) the vineyard for insect, mite, and disease pests at least once a month, and I keep a written record. | 0 |
| e. I keep no vineyard monitoring records for insect, mite and disease pests. | FC |

Table 5. PEAS model environmental impact units calculation for a “typical” Lodi vineyard in 2004

| Input Date | Chemical Name | Rate/Acre | Units | Units/Acre | Impact Index | Impact Units |
|--------------------------------------|------------------------|------------------|--------------|-------------------|---------------------|---------------------|
| 4/13/2004 | Sulfur dust | 15 | lbs | 14.70 | 0.2 | 2.94 |
| 4/22/2004 | Sulfur dust | 15 | lbs | 14.70 | 0.2 | 2.94 |
| 5/3/2004 | Sulfur dust | 15 | lbs | 14.70 | 0.2 | 2.94 |
| 5/13/2004 | RoundUp Ultra Dry | 0.92 | lbs | 0.66 | 0.143 | 0.03 |
| 5/16/2004 | Sulfur dust | 14 | lbs | 13.72 | 0.2 | 2.74 |
| 5/29/2004 | Sulfur dust | 15 | lbs | 14.70 | 0.2 | 2.94 |
| 6/2/2004 | Rally 40W | 3.88 | ozs | 0.10 | 3.55 | 0.34 |
| 6/24/2004 | Provado Solupak 75% WP | 0.63 | ozs | 0.03 | 64.67 | 1.91 |
| 6/24/2004 | Acramite 50 WS | 0.87 | lbs | 0.44 | 1.5 | 0.65 |
| 6/24/2004 | Pristine | 11.49 | oz | 0.26 | 0.75 | 0.20 |
| 7/28/2004 | Gramoxone Max | 1 | pints | 0.52 | 0.58 | 0.09 |
| 7/31/2004 | RoundUp Ultra Dry | 0.63 | lbs | 0.45 | 0.143 | 0.02 |
| Total Impact Units for Season | | | | | | 17.75 |

Nutrient Uptake and Use in Grapevines

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Plant Nutrients

Plant nutrition is generally concerned with mineral elements that plants obtain from soil. These include the macroelements: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulfur (S); and the microelements: Iron (Fe), Manganese (Mn), Boron (B), Zinc (Zn) and Copper (Cu). Molybdenum (Mo), Nickel (Ni) and Silicon (Si) may also be required in even lower quantities (< ppm range) than the microelements. Table 1 lists the concentrations of nutrients that are typically present in grapevines and the primary physiological function of each nutrient in plants.

Nutrient Uptake by Roots

Plants normally obtain the elements above from soil, and have evolved rather complex and plastic root systems that allow for the acquisition of nutrients and water they need from a patchy environment. In much the same way that plants have developed complex organs to absorb and convert sunlight energy into food (carbohydrate), and to reproduce and disperse seeds, plants roots have numerous adaptations that allow them to grow within the soil matrix and capture nutrients needed for metabolism. These adaptations include the overall size and architecture of the root system (which determines the depth and length of roots and their distribution within the soil profile); morphological characters, such as the diameter of fine roots, the presence and length of root hairs, and the establishment of mycorrhizas (fungus roots); and chemical characters, such as the release of protons/organic acids/enzymes to increase the solubility of certain ions in the rhizosphere, and the kinetic properties of specific ion transporters in membranes. Because roots absorb nutrients that are dissolved in the soil solution, the fertility of soil is dictated by the quantity of nutrients that are in solution and the capacity of the soil to release ions back into solution as they are removed by roots. The concentration of most plant nutrients in the soil solution is very low (micro-molar range), but as nutrients are taken up by roots they can be replenished from exchange sites on soil particles or dissolved from the sparingly soluble minerals present. For example, the

quantity of P in the soil solution was found to be completely replenished 10 times each day (Stout and Overstreet 1950). Most nutrients required by plants are immobile within the soil matrix (although nitrate, borate and sulfate are mobile ions). Because of the low mobility and the low concentration of most nutrients in the soil solution, roots need to be in intimate contact with the soil to fulfill their primary function of obtaining nutrients. This is why root systems of most plants are so elaborate and ramifying throughout the soil profile.

In order for nutrients to be taken up by roots, they must come in contact with the root surface. Nutrients reach the surface of roots by the following processes: interception, bulk flow and diffusion. Interception is due to the direct displacement of nutrients contacted by the growing root tips. Bulk flow is the process of nutrient movement toward the root due to the action of water uptake by the root (which is driven by transpiration from the leaves above ground), although bulk flow can also carry nitrates deeper in the soil profile with rainfall events or irrigation. Diffusion is the movement of a nutrient toward the root due to kinetic activity (agitation) driven by the concentration gradient that develops near the root surface as a result of nutrient uptake (uptake exceeds what bulk flow can supply resulting in a depletion zone near the root surface). Experimentation and modeling has shown that the contribution of each of these different pathways to the root surface is unique for each element (Barber 1984). Interception usually accounts for a very small fraction of nutrient uptake for all nutrients. Nitrogen moves primarily to the root by bulk flow, while P and K arrive at the root surface primarily by diffusion. It is for this reason that many plants rely on arbuscular mycorrhizal fungi (AMF) to get enough P from soil, because the hyphae of these symbiotic fungi can reach beyond the depletion zone created by root P uptake.

Once at the root surface, nutrients can enter root cells by crossing the plasmamembrane through ion-selective channels or carriers (integral membrane proteins). This movement across the membrane is driven by an electrochemical gradient produced by pumping protons outside root cells. While entry of positively charged ions into the cell can be considered a passive process (for example, K^+ can passively enter the more negatively charged cell interior), this is an oversimplification. Energy is required not only to establish the electrochemical gradient by ATPase's, but energy is also needed to have initially grown the root in question and to build the elaborate membrane system in the first place. Nutrient uptake is very much an active process. And because the whole process is a biochemical process requiring metabolically active cells, nutrient uptake is affected by numerous environmental variables like temperature, pH, and oxygen availability.

The vast majority of nutrients are taken up by the smallest (non-woody) roots known as primary roots, fine roots or feeder roots. Woody roots only take up a small quantity of nutrients because of the existence of a waxy, suberized layer of cells that is designed to keep ions from escaping from the vascular tissues of these roots. The presence of woody roots at a particular location within the soil profile is not indicative of actual uptake of nutrients at that location. Quite often the fine roots that are actually doing the lion's share of work in nutrient uptake can be located in distal regions of the soil profile away from the large woody roots to which they are attached. The fine roots of grapevines are also the roots that are heavily colonized by AMF.

Mycorrhizal Fungi in Grapevines

It has been known for more than a century that grapevines (*Vitis spp.*) form symbiotic associations in their roots with AMF (Possingham and Obbink 1971). AMF co-evolved with higher plants approximately 400 million years ago and may be responsible for the movement of plants to the terrestrial environment (Pirozynski and Malloch 1975, Redecker et al. 2000). AMF are found in nearly all soils, although propagules of AMF and subsequent root colonization can be suppressed in some soil environments, including high input agricultural systems (Sieverding 1991, Kabir et al. 1997). Even so, more than 20 species of AMF have been identified in intensively managed agricultural soils (Ellis et al. 1992, An et al. 1993). Thirty-seven different species of AMF, representing a considerable proportion (ca. 25 percent) of the total AMF diversity known, have been identified from a single, abandoned agricultural field (Bever et al. 2001). While AMF are generally regarded as nonspecific symbionts (i.e., a single fungus species can form mycorrhizas with numerous host plant species), preferred associations between specific fungi and plant species occurs in various ecosystems (Johnson et al. 1992, Bever et al. 1996), including vineyards (Schreiner, unpublished data).

Different species of AMF have different responses (or tolerance) to agricultural practices such as tillage (Douds et al. 1995), fertilization (Hayman et al. 1975) and pesticide use (Schreiner and Bethlenfalvai 1997). Different species of AMF (and even isolates within a species) also differ in their ability to promote plant growth and nutrient uptake (Wilson 1988, Bethlenfalvai et al. 1989, Schreiner 2007). Differential responses among species of AMF to management practices (Douds et al. 1993, Galvez et al. 1995, Jacquot et al. 2000) may alter the benefit derived by the host plant because of shifts in the fungal species inhabiting its roots. Indeed, the enrichment of less effective species of AMF (in terms of plant growth

promotion) has been observed in corn and soybean fields that were successively monocropped (Johnson et al. 1992). Whether or not a buildup of less effective isolates of AMF will occur in vineyards over time is unknown, but the potential may be even greater than in annual cropping systems because grapevine roots are continually present. The vegetation between the grapevine rows, including cover crops and weeds, could play an important role in maintaining an effective, highly diverse community of AMF in vineyards (Baumgartner et al. 2005).

AMF are best known for their contribution to mineral uptake by plants, particularly those minerals that have limited mobility in soil, such as P, Zn, and Cu (Marschner 1995, Smith and Read 1997). AMF have been shown to increase P uptake by grapevines (Giovannetti et al. 1988; Karagiannidis et al. 1995; Schreiner 2007), but less is known about the role AMF play in the uptake of other plant nutrients by grapevines. AMF have been reported to increase N, K, Ca, Zn or Cu uptake in some studies (Biricolti et al. 1997; Petgen et al. 1998; Nikolaou et al. 2002), but it is unclear how universal these findings may be or whether uptake of these nutrients was due to improved P nutrition (Schreiner 2007). Nutrient uptake is enhanced by AMF primarily because of greater exploration of soil by the external hyphal network of these fungi. As a result, mycorrhizal roots are often more efficient than nonmycorrhizal roots in obtaining soil nutrients (Smith and Read 1997). AMF are completely dependent on plant-derived carbon for their growth and reproduction. Plants can benefit from AMF by acquiring greater quantities of soil nutrients at the cost of supporting the carbon requirements of the fungi.

Mycorrhizal fungi also benefit plants and soil ecosystems in ways that may be independent of enhanced nutrient uptake. AMF may play a role in protecting plants from soil-borne pathogens through either direct competition for root occupancy or by modifying the microbial community in the rhizosphere (Paulitz and Linderman 1991). AMF can improve the drought resistance of many plant species, although it is not always clear that the fungi affect plant-water relations independent from their role in plant nutrition (Augé 2001). AMF are also a primary determinant of soil aggregate stability in many soils (Schreiner and Bethlenfalvay 1995). Improved aggregate stability can arise from the physical entanglement of soil particles by the external hyphae of AMF (Tisdall and Oades 1982) and from the excretion of a recalcitrant, glycoprotein (glomalin) that binds soil particles together (Wright and Upadhyaya 1998). Indeed, the level of soil aggregation has been linked to the quantity of external AMF hyphae in soil under greenhouse conditions (Schreiner et al. 1997) and in the field (Miller and Jastrow 1990). Therefore, AMF can enhance both short-term nutrient uptake, by increasing nutrient availability to roots, and long-term nutri-

ent dynamics of soils, by enhancing aggregation and protecting soil organic matter from degradation. In turn, greater aggregate stability of soils improves infiltration rates, gas exchange with the atmosphere and resistance to erosion (Harris et al. 1966), which is of particular importance for hillside vineyards.

Managing Nutrition in Vineyards

Managing the nutritional health of vineyards should include the following components: 1) scouting blocks for the visible symptoms of both nutrient deficiency and toxicity; 2) routine testing of nutrient availability in soil and, more importantly, in plant tissues (leaves or petioles); and 3) modification of nutrient supply to vines through a variety of management practices.

Scouting fields for visible symptoms of nutrient deficiency can be useful because many nutrients will display unique foliar symptoms. These include symptoms such as: dull, yellow leaves indicative of low N; interveinal red spots at the margins of older leaves indicative of low P; and chlorosis, necrotic spots and wrinkled appearance occurring on leaf margins that may indicate low K. However, some symptoms can be similar for multiple nutrient deficiencies, such as interveinal chlorosis, which can be indicative of low Zn, Mn or B. In addition, other ailments including cold damage, virus infection and drought stress can be confused with foliar symptoms of nutrient stress. It is not clear whether all grape varieties display the same foliar symptoms of nutrient deficiency for each of the various nutrients required by grapevines, and symptoms may not show up until a nutrient is extremely low. It is best to confirm a perceived nutrient deficiency identified from foliar symptoms by conducting comparative tissue nutrient tests.

Tissue testing is the most accurate means to monitor vineyard nutrition (Christensen 2000). Soil testing is generally not useful in predicting vine nutrient status due to a variety of issues, such as differences in nutrient uptake or requirements of different varieties, clones and rootstocks, differing irrigation and soil management practices, and the plasticity of vine roots to explore soils in different environments. In addition, grapevines can store significant quantities of some nutrients to overcome short-term deficits of soil supply, and this ability increases with vine age (Schreiner et al. 2006). Soil analysis is useful in monitoring changes over multiple years, including measures of pH and soil organic matter that can impact nutrient supply in soil. Of course, soil analysis is useful in determining potential vineyard planting sites. Yearly soil tests are not recommended for perennial crops.

Plant tissue testing (leaf or petiole) is the preferred method of monitoring the nutritional health of your vineyard(s). Many wine grape growers collect petiole samples from their vineyards every year (or

two) and send them to a testing lab for analysis. Quite often the lab results end up in a desk drawer unless something appears alarming. Nutrient testing can be more useful if consistent, representative samples are collected year to year. It is also important to understand and correctly interpret tissue analysis data.

What do tissue nutrient test results tell you?

The data you receive in a plant tissue analysis report is nutrient concentration data; it is the amount of each nutrient per amount of petiole or leaf blade dry mass. Many assume that nutrient concentrations equate to nutrient uptake. This is not true. The only way to be sure about nutrient uptake is to monitor the content of nutrients (which equates to concentration \times mass and accounts for growth differences). Rapid growth can dilute the concentration of nutrients in leaves and petioles. Tissue tests are much more meaningful to you as a grower if you also have some measure of plant growth near the time of sample collection. This can be as simple as a rough estimate of how close shoots are to the top wire at bloom. Results from tissue analysis are most useful when combined with other information from your site such as previous and current season's growth, recent weather conditions, recent inputs to the vines (fertilizer, irrigation, tillage) and past experience with the particular vineyard or block.

Interpretation of tissue analysis results is not a simple process because plant mineral nutrition is complex. If an element appears to be deficient, closer inspection of the vines is warranted (looking carefully for signs of deficiency symptoms). If deficiency symptoms appear, detailed sampling and tissue analysis should be considered. Be sure to include samples from unaffected areas of the vineyard along with the samples from affected vines to confirm a nutrient deficiency. Tissue test results indicate nutrient status of vines, and they can be effective in identifying extremes whether at levels of deficiency or toxicity. When samples are systematically collected over a period of years, tissue test results can be a valuable tool to manage the nutritional status of your vines and indicate approaching problems.

Issues to Consider When Implementing a Tissue Analysis Program

- 1) Be as consistent as possible with respect to vine phenology (growth stage) when collecting tissue samples for nutrient analysis. Calendar-based sampling times are not as useful as phenology-based times. Nutrient concentrations in leaves and petioles can change rapidly during the growing season.
- 2) Monitor the same areas within specific vineyards or blocks. For example, designate and flag specific rows within a block that are revisited yearly. This can vastly improve the consistency of tissue analysis.

- 3) If you would like to monitor large blocks with a single sample, then collect petioles or leaf blades in systematic way and be consistent from year to year. For example, collect a petiole or leaf blade from a typical vine located every five posts from every 20th row, avoiding rows close to border of the block.
- 4) Collect and submit separate samples from problem areas where you suspect that vines are weak or otherwise lag behind (i.e., low-lying areas that may develop more slowly over the season due to cooler temperatures).
- 5) Determine at which times you will sample. Sampling is often done at bloom and/or véraison. Generally, petiole samples taken at bloom give a good indication of micronutrient status. However, véraison sampling is more indicative of the status of macronutrients (N, P, and K). In general, véraison or ripening samples are better to diagnose N, P and K problems because these elements are mobile within the plant and are at very high levels at bloom. Many people like collecting samples at bloom because they believe they can correct problems in the current year. This is not always possible as nutrient analysis takes time, and results need to be interpreted correctly to warrant fertilizer applications. Note: The whole-vine nutrient uptake study that was conducted in Oregon showed peak N and P uptake occurs near bloom and declines thereafter (Schreiner et al. 2006). Therefore, it is not likely that one can affect the macronutrients in the current season; however, micronutrient deficiencies can be amended with foliar sprays.
- 6) Determine which tissue to sample: leaf blade versus petiole. Generally, petiole samples give an indication of K, Cl and Na deficiencies/toxicities. Leaf blade samples give a much better indication of N than petiole samples, but also Mg, Zn, B, Ca, Cu and Mn deficiencies/toxicities. Petiole samples are easier to handle and collect in large quantities, which provide a good average for the block sampled. The leaf blade is the working organ of the plant and relates better to physiology of vines. Analyzing leaf blades and petioles simultaneously can be useful to diagnose specific deficiencies/toxicities.

Interpretation of Tissue Nutrient Test Results

Table 2 provides a guide for interpreting tissue-nutrient concentrations for grapevines grown in Oregon. The values in this table were derived from numerous sources and represent the current understanding for wine grapes. Remember — these values have not been determined for wine grapes grown at low yields.

Altering nutrient supply to vines is the last component of a nutrient management program. We know that many factors can alter the nutrient status of vines. These include preplant soil preparation (tillage, lime addition), the choice of variety and rootstocks planted, irrigation, fertilizer applications and canopy management choices. In addition, the inherent water holding capacity, organic matter content, and cation exchange capacity of the soil each have a large influence on nutrient supply to vines. However, while we know that these factors influence vine-nutrient status, it is exceptionally difficult to predict vine response at a particular site or in a particular growing region due to the interactions among these numerous biotic and abiotic factors. In addition, little information exists regarding the actual nutrient uptake of field-grown grapevines because the only way to confidently measure uptake involves destructive sampling of vines. This is relatively easy to do with young vines grown in pots (Schreiner 2007), but very difficult in the real world of a producing vineyards.

Whole-Vine Nutrient Uptake

Because little information regarding nutrient uptake by grapevines under actual field conditions was available, and because nearly all previous work was conducted on young vines, a study to examine whole-plant nutrient uptake by mature (22-year-old) Pinot Noir grapevines was initiated in Oregon. We were lucky that the research vineyard at Oregon State University had such a block of older vines consistently producing high quality fruit that we could destructively sample. The goals of this study were to quantify nutrient uptake (hence the nutrient requirements) of high quality Pinot Noir vines, determine what times during the season that different nutrients were taken up from soil, and to better understand nutrient cycling within the vine. We focused a great deal of effort on fine roots in this study because this was lacking in the previous whole-vine studies. In addition, this study is the only whole-vine nutrient uptake research project that examined all major nutrients in vines during two complete growing seasons, including the dormant period in winter. A comparison of this study from Oregon and the previous whole-vine studies were presented by Schreiner (2005) and the further details of the Oregon study can be found in Schreiner et al. (2006). The most important findings from this study were that: 1) the quantities of individual nutrients required by vines were generally low compared to many crops (see Table 3, below); 2) a large proportion of N (48-55 percent) and P (21-52 percent) that was required by the canopy was remobilized from stored reserves in the roots and trunk; 3) a much smaller proportion of K (7-15 percent), Ca (4-10 percent), and Mg (0-10 percent) that was required by the canopy came from stored reserves; 4) fruit clusters are a strong sink for K; 5) peak N and P uptake from soil occurred about the time of bloom, while K, Ca,

and Mg uptake peaked closer to véraison; 6) N was also taken up from soil after leaf fall in 2001, but not in 2002 when an early frost occurred; 7) a greater quantity of canopy N, K, and especially P was supplied from stored reserves in the drier 2002 growing season; and 8) replenishment of nutrient reserves occurs during the post-harvest period.

Preliminary results from a research project designed to better understand how N, P and K supply alters vine growth, physiology and fruit quality of Pinot Noir will be presented. A brief overview of a project that examined the use of foliar P fertilizers to improve P status of Pinot Noir, and the resulting impact on mycorrhizal fungi and fruit quality will also be discussed.

Conclusions

Uptake of nutrients by roots is an active process occurring primarily (if not exclusively) in the fine, feeder roots. Nutrient management in vineyards should include scouting, routine testing (tissue analysis), and careful record-keeping of vine growth, weather, crop load and management inputs. Grapevines generally require fewer nutrients than other crops (particularly wine grapes). More nutrients can be supplied from reserves as vines age and in drier years. The post-harvest period is an important time to replenish reserves, even in cool-climate regions such as Oregon. Foliar application is not an effective method to supply macro-elements (N P K Ca Mg S) to vines. Better tissue standards will be forthcoming for wine grapes (along with a better understanding of how mineral nutrition influences vine physiology and fruit quality), but we currently have to rely on existing standards. Field experimentation with nutrients in perennial systems is complex, labor intensive and expensive.

Note: Research Publications from Schreiner's work are available at ars.usda.gov/pandp/people/people.htm?personid=5018.

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Table 1. Concentrations of Mineral Elements in Riesling Grapevines grown in a slate soil (Gärtel, 1996).

| Group | Element | Dry Matter Concentration | Primary Functions |
|----------------------|---------|--------------------------|---|
| Macroelements | N | 1.2 % | Proteins/Nucleic Acids/Other Metabolites |
| | P | 0.2 % | Nucleic Acids/Lipids-Membranes/ATP |
| | K | 1.1 % | Osmoregulation/pH Control |
| | Ca | 1.4 % | Wall & Membrane Stability/Messenger |
| | Mg | 0.2 % | Protein & Chlorophyll Cofactor/Wall Stability |
| | S | 0.2 % | Protein Stabilization/Lipids/Redox Rxns |
| Microelements | Fe | 90 ppm | Redox Rxns/Electron Transport |
| | Mn | 14 ppm | Enzyme Co-factor – PS2, SOD |
| | B | 14 ppm | Wall & Membrane Stability/Cell Expansion |
| | Zn | 19 ppm | Enzyme Co-factor – Protein Synth., SOD |
| | Cu | 13 ppm | Enzyme Co-factor – PS1 (plastocyanin), SOD |
| | Mo | < 1 ppm | Enzyme Co-factor – Nitrate Reductase |

Table 2. Guide for grape tissue analysis at bloom or véraison (véraison values in parenthesis).

| Nutrient | Petioles | | Leaf Blades | |
|----------|-----------------|-----------|------------------|-------------|
| | Deficient | Excessive | Deficient | Excessive |
| N (%) | (0.5) | | 2.0-2.5 (1.5) | 4.25 |
| P (%) | 0.15-0.2 (0.10) | | 0.20-0.25 (0.12) | |
| K (%) | 1.0 (0.5) | 3.25 | 0.80-0.90 (0.60) | 1.50 (1.25) |
| Ca (%) | 1.0 | | 1.0 | |
| Mg (%) | 0.20 | | 0.20 | |
| Mn (ppm) | 20 | | 20 | |
| Zn (ppm) | 15-20 | | 20 | |
| B (ppm) | <25 | 125 | 20 | 250 |
| Cu (ppm) | 3-5 | 25-50 | 5 | |

Table 3. Nutrient demand and uptake from soil (in pounds per acre) for mature Pinot Noir grapevines over two years.

| Nutrient | 2001 | | 2002 | |
|-----------|---------------|------------------|---------------|------------------|
| | Canopy Demand | Uptake from Soil | Canopy Demand | Uptake from Soil |
| N | 28.9 | 15.1 | 35.3 | 15.8 |
| P | 3.3 | 2.6 | 3.6 | 1.9 |
| K | 32.0 | 29.7 | 34.9 | 29.8 |
| Ca | 23.0 | 20.7 | 22.4 | 21.5 |
| Mg | 8.4 | 7.5 | 10.5 | 10.8 |

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