

POWDERY MILDEW COST COMPARISON

Presented to the
Faculty of the Agribusiness Department
California Polytechnic State University

In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Science

By
Natalie Lane Bazar

December 2009

ABSTRACT

This study was undertaken to see if using a powdery mildew prediction model combined with a JMS-Stylet oil based fungicide will incur less cost in preventing powdery mildew than a UC Davis standard recommendation sulfur based program.

To perform analysis, powdery mildew threat was predicted for Edna Valley using a temperature-triggering model, the Powdery Mildew Index. Two spray schedules were developed according the PMI and UC recommendations. Cost have compared for the two schedules using a partial budget.

It has been concluded that using the PMI to predict PM threat while using JMS-Stylet oil will incur less cost than the UC Davis standard recommendation program. This conclusion is based on the partial budget analysis that shows the posited recommendation cost to be 13% less than the UC Davis recommendation.

APPROVAL PAGE

TITLE: Powdery Mildew Cost Comparison

AUTHOR: Natalie Lane Bazar

DATE SUBMITTED: December 2009

Senior Project Advisor

Signature

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1
Statement of the Problem	2
Hypothesis	2
Objectives of the Study	2
Justification of the Study	2
II. LITERATURE REVIEW	4
Powdery Mildew <i>Erysiphe Necator</i>	4
Powdery Mildew Control	5
Optimal Economic Use	6
Comparing Cost	8
III. METHODOLOGY	9
Procedures for Data Collection	9
Procedures for Data Analysis	10
Assumptions and Limitations	12
IV. DEVELOPMENT OF STUDY	13
V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	19
Summary	19
Conclusion	19
Recommendations	20
References Cited	21
APPENDIX	22

LIST OF TABLES

Table	Page
--------------	-------------

1	Sample Powdery Mildew Index and Temperatures for April 25-28, 2008 for Edna Valley	14
2	Sample PMI and Temperatures for July 20, 2008 for Edna Valley	14
3	Sample Spray schedule April 13-May 1, 2008 Edna Valley vs UC Davis Standard	15
4	Partial Budget of Alternative Treatment Scenarios	17
5	Cost Aggregated by Activity per Acre	17
6	Calculations for Percentage Difference Between Programs	18
7	Spray Schedule March 9-September 1, 2009 Edna Valley PMI Stylet oil treatment V. UC Davis Standard	22

LIST OF TABLES

Figure		Page
1	Powdery Mildew Index 2008 Edna Valley Spray Program Versus UC Davis Standard	16

Chapter 1

INTRODUCTION

Powdery mildew (PM), *Erysiphe Necator*, is a fungus that attacks multiple crops such as tomatoes, roses, and fruit trees. It affects grapes in most places they are grown from California clear across the Atlantic to France. PM can be especially detrimental to the vines and become quite costly if the proper steps are not taken to control the fungi. Vineyards affected by PM see reduced yields, stunted vine growth and lower quality wine grapes (Chellemi and Marois 1992).

The most common practice in California to control PM is to spray sulfur every 10-21 days on the vines. While sulfur is low-cost, there are problems associated with frequent usage. PM spores can become desensitized when the same product is used to prevent the fungus so it is necessary to rotate between sulfur based fungicides. Also sulfur is hazardous to field worker's health when used frequently (Dell, *et al.*, 1996).

The powdery mildew index (PMI) is a treatment triggering predictive model developed by UC Davis agronomists to assess risk of powdery mildew infection. It uses hourly temperature data to delineate how often a fungicide should be applied (Gubler, *et al.*, 2006). Many spray programs require applications every two weeks, but integrating the PMI into a spray program should lower applications rates.

The type of treatment for PM result in varying costs for control. The UC Davis PMI model makes available to the public cost studies analyzing the different expenses associated with vineyard management. By comparing spray programs and their costs, vineyard managers can minimize expenses, thus earning better margins.

Problem Statement

Will predicting PM threat and evaluating associated cost of PM treatment reduce costs?

Hypothesis

A new spray program using PMI to predict risk will incur less than 5% less cost per acre for fungicidal applications compared to standard cost study recommendations.

Objectives

1. To assess Powdery Mildew threat for entire harvest season in Edna Valley using the PMI.
2. To estimate costs associated with new spray program to prevent powdery mildew.
3. To compare the costs of an Edna Valley PMI triggered spray program with the UC Davis cost study recommendations.

Justification

In 1987 the California Department of Food and Agriculture reported 68% of pesticides sprayed on grapes were fungicides to control powdery mildew (Dell *et al.*, 1996). The findings of this study are not only pertinent to local growers, but wine grape growers around the world. This study emphasizes calculating the PMI using weather data close to the vineyard site, so the powdery mildew risk and spray schedule is different for every vineyard, thus the results of this study will be different for each area.

Chapter 2

LITERATURE REVIEW

PM is a fungus that affects nearly all vineyards and can limit crops loads. Effective protection of the fruit from fungal infection is important because there are many short and long term effects of PM that include reduction in yields, stunted vine growth, and unpalatable wine (Chellemi and Marois 1992). While there are many different treatments available to a vineyard manager, only a few fungicides can be used throughout the entire growing season because PM becomes decreasingly sensitive to many sprays (Dell, *et al.* 1998). Many spray programs require applications every 10 to 14 days, but by using a predictive model, the PMI, developed by UC Davis to assess risk of PM infection, application rates will be less each season (Bendek, *et al.* 2007). Also with the various types of treatments for PM, there are varying costs for each treatment. By comparing different spray programs and costs, vineyard managers can minimize expenses, thus earning a bigger profit margin.

Powdery Mildew *Erysiphe Necator*

PM is a fungus that can attack crops such as tomatoes, peaches, and barley (Dell, *et al.* 1998). In grapes the powdery mildew strain, *Erysiphe Necator*, stays dormant over winter as chasmothecia (spore structures). When moisture is plentiful and the weather is warm, chasmothecia burst and release ascospores. Asexual reproduction of fungi spores begins about 7 to 10 days after initial infection by the ascospores and will continue if temperatures stay between 70 and 85 degrees Fahrenheit (Gublar *et al.* 2006).

PM is capable of infecting all succulent tissue of the vine including berries, leaves and shoots. Early season infections can hinder fruit set and result in considerable crop loss; it can also cause berry splitting and scarring (Chellemi and Marois 1992). PM lowers the desirability of the fruit by reducing vine and fruit size, inhibits color development of the berry and just looks unpleasant. Calonnec *et al.* (2005) analyzed Cabernet Sauvignon and Sauvignon Blanc bunches infected with PM. The infected grapes reduced yields of 12-20% by weight, and as grapes are priced by weight, there is a revenue loss as well. Sugar content was not affected by PM, but acidity was higher by 14-20%. Anthocyanin (color pigment) levels decreased 0-91% in Cabernet Sauvignon (red varietal) and 0-66% in Sauvignon Blanc (white varietal). Flavor and aroma compounds found in wine first develop in the grape. Wines made from diseased berries were found least desirable when put through a blind tasting panel.

Powdery Mildew Control

There are many different fungicides to control PM. Dell *et al.* (1998) classified two groups that dominate chemical control of PM as inorganic sulfur in dust or wettable formulations and demethylation inhibitor (DMI) fungicides. The disadvantage to using sulfur include sulfur phytotoxicity, fear of H₂S production during fermentation, which leads to ruined wine and has led some winemakers to restrict the use of sulfur among growers, and increased sulfur dust restrictions. The advantage to using sulfur is availability and low expense.

Spraying with DMI fungicides can result in decreased sensitivity of the PM spores, making it harder to eradicate from the vineyards (Dell, *et al.* 1998). UC Davis “pest

management guidelines” recommend alternating treatments with a fungicide of different chemistry, to prevent pathogen populations from developing resistance to fungicides (Gubler, *et al* 2006).

Oils have long been known to have fungicidal properties, but are not widely used for plant disease control. JMS-Stylet oil¹ is refined parafinic oil that protects against PM, mites, Botrytis bunch rot, and white fly. When tested in the vineyards Dell *et al.* (1998) found JMS-Stylet oil disease control to be relatively similar to DMI based fungicides. The oil may be sprayed with the same regularity as a sulfur or DMI based fungicide. Stylet oil works by completely coating the shoots, leaves and fruit bunches, killing mildew spores on contact—thus it is extremely important that the vine gets complete coverage to eradicate the mildew spores (Dell *et al.* 1998). The biggest benefit with using Stylet oil is PM does not become resistant to it, so rotating spray regimes is not necessary. This means less equipment is needed for fungicidal applications, thus reducing costs.

Optimal Economic Use

Farmers looking to minimize the use of fungicides need to examine new approaches for management of grape PM. Chellemi and Marois (1992) examined the influence of leaf removal on incidence and severity of PM. They concluded that although basal leaf removal reduced PM on fruit bunches, it was not significant enough to stop fungicide spray programs. The most promising result came from three applications and basal leaf removal. One pre-

¹ JMS-Stylet oil is a highly refined white mineral oil. It is manufactured by JMS Flower Farms. The purity or unsulfonated residue of the white oil is about 99.1%, compared to 92% purity of non-white oils.

bloom and two (or three) fungicide applications controlled powdery mildew with the same effectiveness as a commercial spray program.

PM season-long control, (Gubler, *et al.* 2006), is dependent upon “reducing early-season inoculum and subsequent infection.” Gubler *et al.*, found prevention of PM must begin early in the growing season and be repeated regularly. Frequency of treatment depends on fungicide used, weather conditions and level of infection threat and can be determined using the Davis PMI.

The PMI assesses disease risk development by using weather data and indicates how often the vineyards need to be sprayed to protect the vines. Once initial infection occurs, ideal temperatures for growth of the fungus are between 70° and 85°F, but temperatures above 95°F for more than 12 hours can stop the fungus from growing, fungal stasis. Weather data is collected every day during the growing season and using the PMI, disease pressure can be calculated into three categories: low, medium, and high. Then by knowing what disease pressure the vineyard has, a spray program can be initiated (Gubler, *et al.* 2006).

Growers can calculate the PMI for their own vineyard by monitoring the weather using their own equipment, or if they are in Fresno, San Joaquin, or Madera counties, UC Davis has a PMI software program that calculates it for a growing area. Weather data for these counties are not similar to the central coast, so growers must calculate the risk on their own here.

Comparing Costs

To minimize vineyard costs growers often look at other growers' data to compare expenses, as well as make production decisions, determine potential returns, prepare budgets and evaluate production loans (McGourdy, *et al.* 2009). Cost and return studies can be found through UC Davis for wine grapes in counties throughout California with the exception of central coast counties. These studies include all the costs associated with a vineyard including cost per acre to produce wine grapes, hourly equipment costs, cultural practices and material inputs.

Partial budgeting helps managers calculate economic consequences that result from a change in a part of an operation. When a process is changed, the costs and returns change as well. The partial budget identifies all the returns and costs resulting from an adjustment in operations and compared against the original operations. Managers can then make decisions on whether a change in operations will benefit a company or not (Steward, *et al.* 2000).

Chapter 3

METHODOLOGY

Procedures for Data Collection

To predict whether a new PM spray program implemented in Edna Valley will incur less cost than an alternate standard spray program, define PM risk, which is calculated as PMI based on the number of hours per day the air temperature is between 70° and 85°F for every day during the grape growing season.

Hourly air temperature was collected using California Irrigation Management Information System (CIMIS) from station 52 in Edna Valley. The CIMIS network of 125 weather stations in California that records a variety of data including air temperature, soil temperature, solar radiation, vapor pressure and wind speed. Data is available online. Hourly air temperature will be recorded in Fahrenheit and collected from weather station 52, located in southern San Luis Obispo County, from 6 until 8, for March 1-November 1, 2008, the growing season. Normally, a grower would calculate the PMI each day as the growing season progresses, but this study's goal is to generate PMI for a growing season's application for cost implications and practical application.

Costs associated with the PM treatments are a result of interviews conducted with vineyard managers from Saunder's Vineyard. They were asked, fungicide application rate/cost per acre and equipment cost. Equipment includes a fungicide sprayer and fungicide mixing bins (Gubler, *et al.*, 2006).

UC Davis cost and return studies are available for many crops in California for a variety of counties, with the exception of San Luis Obispo County. The studies delineate costs associated with a vineyard per acre. UC Davis cost study (McGourdy, Klonsky, and De Moura, 2008) analyzing Cabernet Sauvignon in Lake County will be adapted to Edna Valley in San Luis Obispo County by using San Luis Obispo temperature data to predict sulfur spray timing.

Procedures for Data Analysis

The PMI is a risk assessment tool that calculates the threat and reproductive period for the mildew spores, replacing fixed period chemical applications with treatment correlated to likelihood of fungal problems using the temperature conductor knowledge of when to treat to prevent PM. To analyze the PMI, it is important to recognize how the weather data is translated into threat level for PM. To initiate the PMI, UC Davis Pest Management Guidelines (Gubler *et al.*, 2006) states:

1. Starting with the index at 0 on the first day, add 20 points for each day with 6 or more continuous hours of temperatures between 70° and 85°F. So three such days is an index of 60.
2. Until the index reaches 60, if a day has fewer than 6 continuous hours of temperatures between 70° and 85°F, reset the index to 0 and continue.
3. If the index reaches 60, an epidemic is likely under way. Begin using the spray-timing phase of the index.

Then to predict spray timing:

- If the index is already at 100, five days of six continuous hours of 70° and 85°F, do not add points.
- If the index is already at 0, do not subtract points.
- Do not add more than 20 points a day.

- Do not subtract more than 10 points a day for:
 1. If fewer than 6 continuous hours of temperatures between 70° and 85°F occurred, subtract 10 points.
 2. If 6 or more continuous hours of temperatures between 70° and 85°F occurred, add 20 points.
 3. If temperatures reached 95°F for more than 15 minutes, subtract 10 points.
 4. If there are 6 or more continuous hours with temperatures between 70° and 85°F AND the temperature rises to or above 95°F for at least 15 minutes, add 10 points. (This is the equivalent of combining points 2 and 3 above.)

Using the PMI

After the weather data has been analyzed using the PMI, a flow chart for the season was developed that delineated treatment frequency needed for the vineyard. The UC Pest Management Guidelines (Gubler *et al.*, 2006) states an index between 0-30 indicates a low disease pressure; mildew spores are present and sulfur should be sprayed every 14-21 days, DMI based fungicides should be sprayed every 21 days or label interval and JMS-Stylet Oil every 14-18 days. An index between 30-50 indicates intermediate disease pressure; mildew spores are reproducing every 15 days and sulfur should be sprayed every 10-17 days, DMI based fungicides should be sprayed every 21 days and JMS-Stylet Oil every 14-18 days. An index 60 or above indicates high disease pressure; mildew spores are reproducing every five days and sulfur should be sprayed every 7 days, DMI based fungicides should be sprayed every 10-14 and JMS-Stylet Oil every 14 days to break fungal life cycle.

To compare costs between treatment alternative budgets, each was expensed on cost per acre. The hypothesis will be accepted if total cost per acre for the new spray program is at least 5% less than the total cost per acre for the standard spray program from UC Davis. The

hypothesis will be rejected if total cost per acre for the new spray program is more than 95% of the total cost per acre for the spray program from UC Davis.

Assumptions

This study assumes the PM threat is the same year to year. Weather data from 2008 was assumed normal for the Edna Valley, but wasn't examined as such.

Limitations

PM threat varies from location to location, as does the weather. So while this study can compare costs for the year 2008, threat also varies year to year. Weather data was collected for a nearby weather station, not the specific location.

Chapter 4

DEVELOPMENT OF THE STUDY

The powdery mildew index was calculated from March 9 until September 1, 2008 using CIMIS weather data from a weather station in San Luis Obispo County Edna Valley. Table 1 shows the index being calculated from April 25-28, 2008. On April 25 there was seven consecutive hours of temperatures between 70-85°F and on the previous day, April 24 the index was zero, thus April 25, the PMI is 20. On April 26 there was again seven consecutive hours of temperatures between 70-85°F so the PMI is $20+20=40$. The next day was warmer with ten consecutive hours of temperatures between 70-85°F so on April 27 the PMI is $40+20=60$. On April 28 there were temperatures between 70-85°F, but not consecutively for six or more hours so 10 is subtracted from the PMI; $60-10=50$.

Table 1: Sample Powdery Mildew Index and Temperatures for April 25-28, 2008 for Edna Valley

4/25/08 Hour	Air Temp(°F)	4/26/08Hour	Air Temp(°F)	4/27/08Hour	Air Temp(°F)	4/28/08Hour	Air Temp(°F)
600	56.1	600	60.1	600	73.5	600	72.1
700	58.8	700	63.7	700	73.2	700	73.3
800	64	800	69.1	800	73.3	800	75.9
900	67.2	900	73.7	900	76.2	900	71.7
1000	70.6	1000	76.9	1000	80.5	1000	69.3
1100	74	1100	80.3	1100	82.7	1100	70.6
1200	76.1	1200	83.1	1200	83.6	1200	69.7
1300	78.2	1300	84.5	1300	84	1300	70.3
1400	75.9	1400	79.1	1400	84.5	1400	71.8
1500	74	1500	77.8	1500	83.1	1500	66.4
1600	70.7	1600	78.4	1600	84.3	1600	62
1700	68.3	1700	73.6	1700	81.6	1700	59.6
1800	61.6	1800	72.7	1800	80.1	1800	57.7
index=20		index=40		index=60		index=50	

Table two shows the PMI for July 20, 2008. Temperatures exceeded 95°F so 10 was subtracted from the previous day's index. The previous day's index was 70 so the index for the 20th is 70-10=60.

Table 2: Sample PMI and Temperatures for July 20, 2008 for Edna Valley

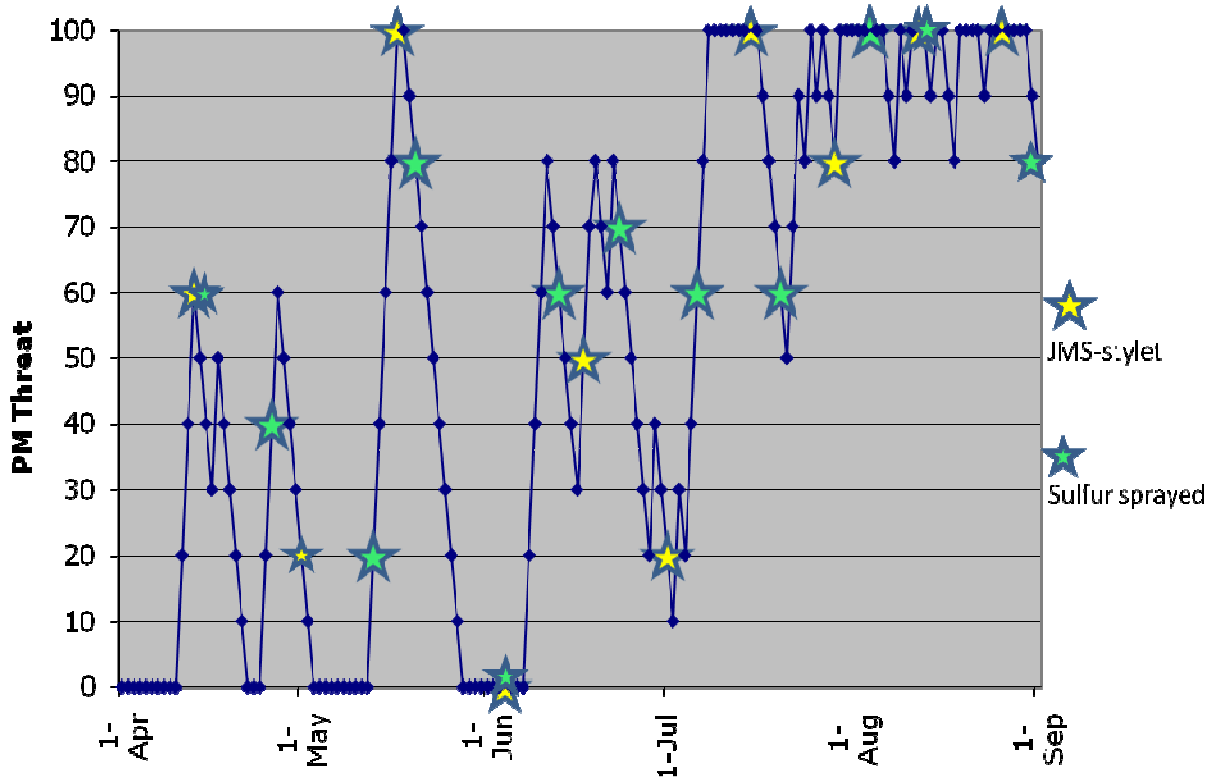
7/20/08 Hour	Air Temp(°F)
600	64.8
700	74.6
800	81.2
900	85
1000	98
1100	97.8
1200	97
1300	95
1400	94.9
1500	95.1
1600	79.8
1700	76
1800	74
index=60	

Once all the weather data was put into the PMI “risk” index, two spray schedules were assembled based on treatment group JMS-stylet oil and the UC Davis sulfur based program (see Table 3). The first spray was initiated on April 13 and continued based on index and what treatment (JMS-stylet oil or Sulfur) was used. Sulfur was sprayed ten days later and the stylet oil was sprayed 17 days later. The entire spray schedule is located in the Appendix and charts the PMI from April 1-September 1, 2008 with both spray schedules marked. For the 2008 grape growing season the JMS-stylet oil should be sprayed ten times- marked by the yellow star. Alternatively the UC Davis standard recommendation (sulfur rotated with Ralley and Flint) would have been sprayed 12 times- marked by the green star.

Figure 3. PMI Spray Schedule April 13-May 1, 2008

	PMI	Edna Valley	UC Davis Standard
13-Apr	60	JMS-stylet	Sulfur
14-Apr	50		
15-Apr	40		
16-Apr	30		
17-Apr	50		
18-Apr	40		
19-Apr	30		
20-Apr	20		
21-Apr	10		
22-Apr	0		
23-Apr	0		
24-Apr	0		
25-Apr	20		
26-Apr	40		
27-Apr	60		
28-Apr	50		
29-Apr	40		
30-Apr	30		
1-May	20		

Figure 1: Powdery Mildew Index 2008 Edna Valley Spray Program (yellow star) V. UC Davis Standard (green star)



A partial budget, Table 4, was then drawn up to compare costs between the two spray programs. Variables include cost per acre of: chemical treatment, labor and equipment. These variables were then added together and then multiplied by the number of times the treatment was sprayed. The result is total cost per acre for each spray program. The UC Davis standard recommendation cost per acre for 2008 is \$393.54. The posited recommendation cost per acre for 2008 is \$343.50.

Table 4: Partial Budget of Alternative Treatment Scenarios

Chemical Treatment	Chemicals				Labor		Cost per Acre	
	# Applications	\$/Unit	units/acre	\$/acre	Hr/acre	Labor\$/Hr	Equipment\$/Acre	Total \$/acre
UC Davis Standard								
Dusting sulfur	5	\$0.50	15 lbs	\$7.50	1.42	\$11.00	\$4.54	\$138.30
Rally 40W	3	\$4.92	4 lbs	\$19.68	0.86	\$8.00	\$5.72	\$96.84
Flint	4	\$13.50	2 lbs	\$27.00	0.86	\$8.00	\$5.72	\$158.40
								\$393.54
PMI Stylet-oil								
JMS-Stylet Oil	10	\$14.50	1.5 gal	\$21.75	0.86	\$8.00	\$5.72	\$343.50

Source: UC Davis (McGourdy *et al.* 2008); Aribico Organics, Tucson, AZ, 2009

Note: Example Flint cost= 4(27) + 4(8 x .86) + 4(5.72)= \$158.40

Costs were then viewed on a percentage basis in Table 5. In the standard recommendation 52% of costs were chemical related, compared to 63% in the posited recommendation. Alternatively, labor was 12% higher in the UC Davis standard recommendation than the posited. Equipment percentages were about the same.

Table 5 Cost Aggregated by Activity perAcre

Chemical Treatment	Chemical	Labor	Equipment	Total
UC Davis Standard				
Dusting sulfur	\$37.50	\$78.10	\$22.70	\$138.30
Rally 40W	\$59.04	\$20.64	\$17.16	\$96.84
Flint	\$108	\$27.54	\$22.88	\$158.40
Subtotal	\$204.54	\$126.26	\$62.74	\$393.54
Percentage	52%	32%	16%	100%
PMI Stylet-oil				
	\$217.50	\$68.80	\$57.20	\$343.50
Percentage	63%	20%	17%	100%

To delineate the cost per acre on a percentage basis (Table 6) the posited recommendation was subtracted UC Davis standard recommendation. This number was then divided by the UC Davis standard recommendation. Thus the posited recommendation incurs **13% less** cost per acre than the UC Davis standard recommendations.

Calculations for Percentage Based Cost per Acre:

\$393.54	\$50.04
	÷
-343.50	393.54
\$50.04	13%

The hypothesis states: new spray program using PMI to predict risk will incur **>5%** less cost per acre for fungicidal applications compared to standard cost study recommendations. **13% > 5%**. We can reject the null hypothesis and accept the alternative hypothesis.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The posited recommendation fungicide spray program, JMS-stylet oil, was compared to the UC grape standard recommendation, a sulfur based program. The posited recommendation PMI approach with stylet oil, a white mineral oil, was found to have less cost per acre than the alternative for the harvest year 2008 in Edna Valley triggered by cumulative temperature readings. By using JMS-stylet oil to prevent PM compared to a sulfur based program, less fungicide was needed to be sprayed in the vineyard. This lead to less labor and chemical cost- as well as keeping labor crews away from potentially harmful sulfur exposure. When using the PMI to predict PM threat, unnecessary fungicidal applications in the vineyard can be avoided.

Conclusion

When developing a fungicidal spray program it is important to know two things, PM index threat level in “the specific vineyard” and the regularity the fungicide needs to be sprayed. As the weather is never the same day to day, year to year, PM threat level is in constant flux. When temperatures sit at a consistent warm temperature for days on end,

powdery mildew threat is luminous and sulfur needs to be sprayed with twice the regularity than JMS-stylet oil. The oil creates a continuous barrier over the grapevines, stopping PM infection. Knowing the PMI and using it can prevent over spraying and thus spending more capital than necessary on chemicals and labor.

Recommendations

This study's findings show that by using an alternative fungicide to sulfur and predicting the powdery mildew threat level, labor and fungicide costs can be lowered and fewer chemicals can be applied in the vineyard. But it is important to note that these numbers and figures supporting the hypothesis are only valid for the 2008 growing season in Edna Valley, San Luis Obispo County. Weather conditions vary with each year and location- which means fungicidal applications may be more or less. It is this study's recommendation that each vineyard manager keep track of the PMI for their vineyard on a day to day basis.

This study's fungicidal applications in the vineyard are purely "theoretical", meaning no chemicals were actually sprayed in the vineyard. It would be beneficial to recreate this study in the field; recording the PMI on a daily basis and physically spraying the fungicides.

Referances Cited

- Bendek, C. E., P. A. Campbell, R. Torres, A. Donoso, and B. A. Latorre. 2007 "The Risk Assessment Index in Grape Powdery Mildew Control Decisions and the Effect of Temperature and Humidity on Conidial Germination of *Erysiphe Necator*" *Spanish Journal of Agricultural Research*. 5(4), 522-532
- California Winegrape Work Group. 2004. *A Pest Management Strategic Plan for Winegrape Production in California*. California Association of Winegrape Growers. Sacramento, CA. (69-72)
- Calonnec, A., P. Cartolaro , C. Poupot, D. Dubourdieu, and P. Darriet. 2004 "Effects of *Uncinula Necator* on the Yield and Quality of grapes (*Vitis Vinifera*) and Wine." *Plant Pathology*. 53(February): 434-445.
- Chellemi, Daniel O. and J. J. Marois. 1992. "Influence of Leaf Removal, Fungicide Applications, and Fruit Maturity on Incidence and Severity of Grape Powdery Mildew." *American Journal of Enology and Viticulture*. 43(March):53-57.
- Dell, K.J., W. D. Gubler, R. Krueger, M. Sanger, and L. J. Bettiga. 1996 "The Efficacy of JMS Stylet-Oil on Grape Powdery Mildew and Botrytis Bunch Rot and Effects on Fermentation" *American Journal of Enology and Viticulture*. 49(March):11-16.
- Gubler, W.D., R. J. Smith, L. G. Varela, S. Vasquez, J. J. Stapleton, A. H. Purcell, and G. M. Leavitt. 2006. "*UC IPM Pest Management Guidelines: Grape Powdery Mildew*." UC ANR Publication 3448
- McGourdy, Glen T., Karen M. Klonsky, and Richard L. De Moura. 2008. " *Sample Costs to Establish a Vineyard and Produce Winegrapes, North Coast, Lake County*." University of California Cooperative Extension: (1-23). GR-VN-08.
- Stapleton, J.J., Charles G. Summers, and Beth L. Teviotdale. 1992. "Combining Leaf Removal and Fungicides to Manage Grape Powdery Mildew in the San Joaquin Valley" *UC Plant Protection Quarterly*. 2(October):8-10
- Steward, Jim, Raleigh Jobes, James E. Casey, and Wayne D. Purcell. 2000. *Farm and Ranch Business Management*. East Moline: John Deere Publishing,

APPENDIX

Table 7: Spray Schedule March 9-September 1, 2009 Edna Valley PMI Stylet oil treatment Versus UC Davis Standard

			Sulfur
			Ralley
Date	PMI	JMS-Stylet oil	Flint
9-Mar	0		
10-Mar	20		
11-Mar	10		
12-Mar	0		
13-Mar	0		
14-Mar	0		
15-Mar	0		
16-Mar	0		
17-Mar	0		
18-Mar	0		
19-Mar	0		
20-Mar	0		
21-Mar	0		
22-Mar	0		
23-Mar	0		
24-Mar	0		
25-Mar	0		
26-Mar	0		
27-Mar	0		
28-Mar	0		
29-Mar	0		
30-Mar	0		
31-Mar	0		
1-Apr	0		
2-Apr	0		
3-Apr	0		
4-Apr	0		
5-Apr	0		
6-Apr	0		
7-Apr	0		
8-Apr	0		
9-Apr	0		
10-Apr	0		
11-Apr	20		
12-Apr	40		
13-Apr	60		
14-Apr	50		

15-Apr	40		
16-Apr	30		
17-Apr	50		
18-Apr	40		
19-Apr	30		
20-Apr	20		
21-Apr	10		
22-Apr	0		
23-Apr	0		
24-Apr	0		
25-Apr	20		
26-Apr	40		
27-Apr	60		
28-Apr	50		
29-Apr	40		
30-Apr	30		
1-May	20		
2-May	10		
3-May	0		
4-May	0		
5-May	0		
6-May	0		
7-May	0		
8-May	0		
9-May	0		
10-May	0		
11-May	0		
12-May	0		
13-May	20		
14-May	40		
15-May	60		
16-May	80		
17-May	100		
18-May	100		
19-May	90		
20-May	80		
21-May	70		
22-May	60		
23-May	50		
24-May	40		
25-May	30		
26-May	20		
27-May	10		
28-May	0		
29-May	0		
30-May	0		
31-May	0		

1-Jun	0		
2-Jun	0		
3-Jun	0		
4-Jun	0		
5-Jun	0		
6-Jun	0		
7-Jun	0		
8-Jun	20		
9-Jun	40		
10-Jun	60		
11-Jun	80		
12-Jun	70		
13-Jun	60		
14-Jun	50		
15-Jun	40		
16-Jun	30		
17-Jun	50		
18-Jun	70		
19-Jun	80		
20-Jun	70		
21-Jun	60		
22-Jun	80		
23-Jun	70		
24-Jun	60		
25-Jun	50		
26-Jun	40		
27-Jun	30		
28-Jun	20		
29-Jun	40		
30-Jun	30		
1-Jul	20		
2-Jul	10		
3-Jul	30		
4-Jul	20		
5-Jul	40		
6-Jul	60		
7-Jul	80		
8-Jul	100		
9-Jul	100		
10-Jul	100		
11-Jul	100		
12-Jul	100		
13-Jul	100		
14-Jul	100		
15-Jul	100		
16-Jul	100		
17-Jul	90		

18-Jul	80		
19-Jul	70		
20-Jul	60		
21-Jul	50		
22-Jul	70		
23-Jul	90		
24-Jul	80		
25-Jul	100		
26-Jul	90		
27-Jul	100		
28-Jul	90		
29-Jul	80		
30-Jul	100		
31-Jul	100		
1-Aug	100		
2-Aug	100		
3-Aug	100		
4-Aug	100		
5-Aug	100		
6-Aug	100		
7-Aug	90		
8-Aug	80		
9-Aug	100		
10-Aug	90		
11-Aug	100		
12-Aug	100		
13-Aug	100		
14-Aug	90		
15-Aug	100		
16-Aug	100		
17-Aug	90		
18-Aug	80		
19-Aug	100		
20-Aug	100		
21-Aug	100		
22-Aug	100		
23-Aug	90		
24-Aug	100		
25-Aug	100		
26-Aug	100		
27-Aug	100		
28-Aug	100		
29-Aug	100		
30-Aug	100		
31-Aug	90		
1-Sep	80		

		10	5
			3
			4
Total Applications		10	12