California Wine Grape Growers' Use of Powdery Mildew Forecasts

Travis J. Lybbert and W. Douglas Gubler

Powdery mildew poses a major disease threat to grape growers. While disease forecasts can be a valuable tool, many growers do not use them. We explore forecast adoption and use patterns among California wine grape growers.

Growers face several potential costs and benefits when using the Powdery Mildew Index.

Grape growers in California spend more to control powdery mildew each year than other diseases or pests, yet it still causes considerable crop loss. Growers' only real hope in the annual battle with powdery mildew is proper preventative management. This task is complicated by the explosive episodes of powdery mildew growth that are possible when optimal temperature and humidity conditions prevail. These growth explosions pose substantial production risks to growers; an entire season can be lost with a poorly timed treatment. While powdery mildew forecasts seem to be an especially promising tool in this context, many growers choose not to use them. In this paper, we discuss the economics of using powdery mildew forecasts and use survey data to explore forecast adoption and use patterns among California wine grape growers.

In the early 1990s, plant pathologists worldwide began to develop powdery mildew growth models that could provide growers with forecasts and help them foresee outbreaks in order to time more precisely their preventative powdery mildew treatments. One such model has attracted the attention of growers worldwide: the Gubler-Thomas Powdery Mildew Index (PMI). The PMI, a simple risk index that ranges from 0 (low disease potential) to 100 (high disease pressure), is founded on the observation that powdery mildew growth, sporulation, and infection are largely a function of length of exposure to different temperature ranges. The PMI can be computed using onsite weather stations linked to specialized software and is available for broad areas throughout California's grape growing regions from a variety of external sources.

The PMI has proven to be a useful tool for improving treatment timing and intervals. Field trials have shown that structuring spray application programs according to the PMI reduced fungicides "by two to three applications over the course of the growing season with equal or better disease control" (Gubler et al. 2003, p.10). It is estimated that growers using the index eliminated three and two applications in 2003 and 2004, respectively. The human and environmental benefits of this reduction in fungicide use could be substantial: by one estimate, sulfur applications on raisin grapes would have decreased by one million pounds (an eight percent reduction) if 25 percent of raisin growers used the PMI in 2003.

Despite these favorable trials and grower experiences, PMI adopters are still in the minority among Californian grape growers. This raises questions about adoption constraints. Are growers slow to adopt because they are still learning about the PMI? Or are there structural constraints that discourage the adoption of a flexible spraying regimen? What distinguishes PMI growers from their non-PMI counterparts? This paper uses survey data from California wine grape growers to explore these questions.

The Economics of the Powdery Mildew Index

After over a decade of testing and use of the PMI, important economic aspects of the index are still poorly understood. Growers face several potential costs and benefits when using the PMI. Beyond what growers may have to pay to access PMI information for their vineyard, these potential costs and benefits hinge on mediating factors such as how the PMI is used and the accuracy and relevance of a given PMI for a particular vineyard. Table 1 summarizes these potential costs and benefits and mediating factors.

During periods of low disease pressure, growers using the PMI may be able to stretch treatment intervals and save on treatment costs. Growers who regularly treat at minimum intervals are especially likely to benefit from these PMI-based fungicide savings. Note, however, that treating at minimum intervals also confers a benefit to such growers in the form of implicit production insurance. Thus, fungicide savings from using the PMI may come

Table 1. Potential Costs and Benefits of Using PMI and Mediating Factors

Potential Benefits	Potential Costs	Mediating Factors
Chemical Savings Stretched intervals when disease potential is low	**Information Costs** Onsite weather station or subscription to PMI service	**Disease Pressure** *How high and how variable day-to-day is disease pressure?*
Better Disease Control Better awareness of looming disease pressure used to improve timing of spraying at critical times	**Flexibility Costs** Equipment and operators must be "on call" to spray when PMI indicates	**Degree of Use** *How much does the PMI influence treatment-timing decisions?*
Slowed Resistance Spraying timed to match disease growth and unnecessary spraying eliminated	**Additional Risk Exposure** Stretched intervals between spraying based on PMI	**Model Accuracy** *How much do variables not in the PMI affect disease pressure?*
		Sensory Relevance *How well does the PMI available to a grower reflect actual field conditions?*
		Measurement Errors *How accurate are the data sensors and computations?*

only at the cost of some additional risk exposure. This trade-off may be tricky because—as PMI providers are wont to warn—powdery mildew can be at "economically damaging levels even when the PMI indicates a low likelihood of conditions favoring rapid development of the disease," (http://precisionagrilab.com/gpm) especially if previous treatment and monitoring were poorly executed or otherwise ineffective.

During periods of high disease pressure, growers who use the PMI may achieve better disease control by shortening their treatment intervals during high forecasted powdery mildew pressure. While the previous PMI benefits might be substantial, this benefit is potentially much more important because powdery mildew outbreaks can quickly spiral out of the growers' control. At critical disease thresholds, the damages sustained by stretching a treatment interval a day or two too long may far outweigh the associated fungicide savings. This suggests there is a clear risk asymmetry due to mistimed treatments: treating too early entails additional but known treatment costs, while treating too late might entail extreme production risks. As an important feature of its economic value, the PMI informs growers about the production risks associated with stretching treatment intervals and how these risks change over the course of a season.

By more accurately matching treatment timing and intervals to powdery mildew population dynamics, use of the PMI may also reduce the build up of fungicide-resistant strains in the pathogen population. Since growers bear the costs associated with fungicide resistance collectively, rather than individually, growers only internalize a portion of this PMI-based benefit. Still, many growers are familiar with the resistance problem and may value this benefit accordingly. As above, this resistance benefit accrues to growers collectively when, without the PMI, they tend to treat powdery mildew at minimum intervals. Once again, reaping this benefit may therefore entail additional exposure to production risk as intervals are stretched according to the PMI.

On the cost side, growers can access PMI information in several ways. The most accurate PMI information for a given grower would be based on data from onsite, high-quality weather stations with high-precision sensors properly placed to get relevant readings. Such a station can cost $3000 or more, and multiple stations may be needed to cover large vineyards. Of course, these stations also provide other useful information in addition to the PMI. Growers can also obtain PMI information based on offsite, external stations. Several private companies offer such PMI information online on a subscription basis. Others, including UC IPM, post the PMI online free-of-charge. Thus, depending on the size of the operation, these information costs range from essentially zero to thousands of dollars in the case of multiple onsite stations, and may include both fixed and variable cost components.

In contrast to upfront information costs, the other costs and benefits in Table 1 hinge on how the PMI shapes a grower's disease-management decisions. To use the PMI effectively a grower must be willing and able to adjust spray schedules within a few days of key changes in the index, requiring additional flexibility in equipment and operators that may be costly and inconvenient.

In sum, most of these PMI benefits and costs hinge on growers' treatment tendencies without the PMI. For growers who otherwise tend to treat at minimum intervals, using the PMI effectively substitutes better information for lesser insurance coverage and saves them treatment costs. For growers who tend to stretch intervals, using the PMI reduces their exposure to production risks, albeit potentially with additional treatment costs.

Who Uses the Powdery Mildew Index and How?

To address this question, we conducted an online survey of California wine grape growers in January and February 2008. The survey included questions on disease management generally, and powdery mildew specifically, on vineyard and vineyard manager characteristics, and on their use of the PMI. Members of the California Association of Winegrape Growers and several other state and local grape growers' associations were

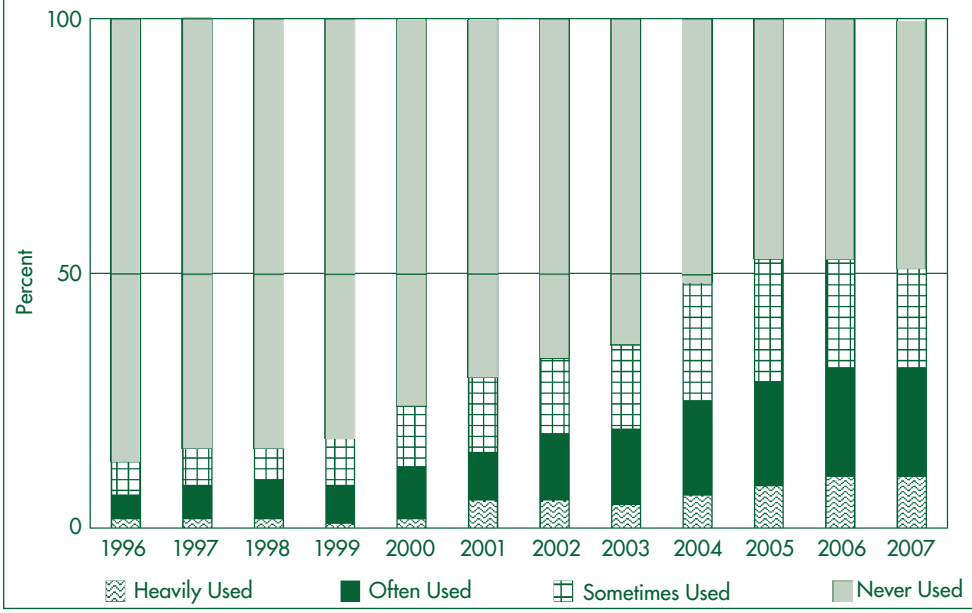
invited to participate in the survey. Ultimately, 108 wine grape growers participated in the survey. Nearly two-thirds of our surveyed growers have used or currently use the PMI to some degree. This seems consistent with Californian wine grape growers generally, who tend to rely on the PMI more than table and raisin grape growers.

Figure 1 shows how use of the PMI has diffused among our surveyed growers since the index was launched in 1996. Most of the growers were familiar with the PMI. Many of those not using the PMI cite their preference for a set calendar spray schedule as the primary reason for not using it. Other cited reasons for not using it include: relevant PMI not available (18 percent), lack of trust (16 percent), and equipment or operator constraints that make flexible spray schedules difficult (13 percent). Related to these flexibility costs, 65 percent of all our surveyed growers are never constrained by availability of equipment, operators or chemicals; only 10 percent are sometimes or often constrained.

Of the growers who have used the PMI, 15 percent have stopped using the index. Many of these disadopters prefer a calendar spray schedule or believe that the PMI model is not well-suited for their growing conditions and, hence, contributes little that monitoring and experience do not already confer.

Table 2 displays the means of selected variables for growers who use or have used the PMI and those who have not. We constructed a factor analytic index of PMI-use intensity using several variables that capture growers' current degree of PMI use and their confidence in the PMI. Table 2 displays correlation coefficients between these selected variables and this PMI-use intensity index. Based on the variables that, on average, seem to be quite different for these two groups, PMI users appear to be more experienced, to be significantly less likely

Figure 1. Intensity of PMI Uses over Time for Surveyed Growers



to own the vineyards they manage, and to manage more acres. PMI users have larger primary vineyards with higher yields and substantially more valuable production per acre.

Although slightly weaker statistically, PMI users also seem to have more education and to rely less on minimum-interval spray schedules. Although more sprayers per land unit should enable a grower to be more flexible and responsive to spontaneous spraying demands, the correlation with PMI-use intensity actually runs in the opposite direction. Given that 90 percent of our surveyed growers never or rarely feel constrained by equipment availability, the lack of a positive correlation is perhaps not surprising.

Table 2. Selected Variable Statistics for Growers Who Use and Do Not Use the PMI

	Mean		Correlation with PMI Use
	Do Not Use PMI (N=34)	Use PMI (N=65)	
Grape experience (years)	11.2	15.8	0.25*
Vineyard ownership {0,1}	0.853	0.600	-0.33*
Acres managed in 2007	310	1,015	0.28*
Higher education (years)	4.6	5.3	0.12
Influence of minimum intervals on treatment timing (% of decision)	16.2	12.7	0.05
Primary vineyard size (acres)	327	717	0.19*
Avg. primary vineyard production (tons)	2,266	4,324	0.12
Yield in 2007 (tons/acre)	4.0	5.1	0.22*
Price ($/ton)	$1,108	$1,429	0.16
Production value per acre	$3,680	$6,443	0.32*
Production value total	$365,655	$3,304,377	0.34*
Sprayers per acre	0.20	0.12	-0.14
Number of weather stations	0.76	1.5	0.24*
Yield insurance {0,1}	0.41	0.43	0.08

** Indicates significance at 10% level*

In addition to the variables in Table 2, we asked growers how important considerations such as yield, costs, environmental impacts, and the flavor, appearance, and price of grapes were to the management of their vineyards. Interestingly, users and non-users differed significantly in their responses to only one of these considerations: PMI users were more concerned about disease resistance build up (p-value 0.06).

Initially, most PMI users received the index from onsite weather stations. As use of the index spread, newer users were more likely to get PMI information second-hand from private companies. By 2003, more users received the index from private companies than from their own weather stations. In 2007, roughly 50 percent received it from private companies, while 30 percent used their own stations.

Because the relevance of the PMI model and susceptibility to powdery mildew varies across grape varieties, we consider correlations between PMI-use intensity and varieties grown (Table 3). Among the wine grape varieties commonly grown by our surveyed growers, Cabernet Franc and Petit Verdot are most strongly correlated with PMI-use intensity. Growers of Chardonnay, Cabernet Sauvignon, Pinot Noir and Gris, and Malbec varieties also seem more likely to proactively use the PMI. These varieties—especially the red wine grape varieties—fetch relatively high prices, which may explain their growers' reliance on the PMI. With these valuable varieties, the value-at-risk throughout the growing season is high and so too is the payoff to better powdery mildew control.

Conclusion

The descriptive results reported in this paper shed some light on how wine grape growers think about the costs and benefits outlined in Table 1. Among potential benefits, better disease control stands out as the driving adoption benefit. PMI users tend to produce high-value grapes and thus enjoy higher returns to better disease control. While PMI users cite chemical savings as a motivation for PMI use, they attach the same importance to saving chemical costs as their non-PMI use counterparts. PMI users do, however, attach more importance to controlling disease-resistance build up than non-users.

On the cost front, many PMI users freely access the index from external sources, but those with onsite weather stations seem more satisfied with the performance of the index. Although most of our growers are not constrained by equipment or operator availability, those deciding not to use or to stop using the PMI often think that the benefits of PMI use do not offset the hassles of deviating from a set spray schedule. Similarly, assessing the importance of the additional risk exposure implied by PMI use (relative to minimum-interval sprays) is difficult. Compared to their peers, PMI users are neither more nor less likely to purchase yield insurance, but they are less likely to own the vineyards they manage and, hence, to bear a personal share of any additional risk exposure.

Table 3. PMI Use Intensity by Selected Wine Grape Varieties

	Share of Growers	Correlation, PMI Intensity	Avg. $/ton 2007 †
WHITE			**$482**
Chardonnay	65%	0.18*	$718
Pinot Gris	34%	0.20*	$588
Sauvignon Blanc	49%	0.14	$687
Viognier	49%	0.03	$761
RED			**$626**
Cabernet Franc	29%	0.26*	$1,359
Cabernet Sauvignon	67%	0.21*	$989
Malbec	29%	0.19*	$1,117
Merlot	55%	0.08	$592
Petit Verdot	29%	0.27*	$1,214
Petite Sirah	39%	-0.02	$881
Pinot Noir	36%	0.18*	$2,094
Syrah	49%	-0.09	$660
Zinfandel	59%	-0.03	$467

† 2007 Grape Crush Report, California Dept. of Food and Agriculture
** Indicates significance at 10% level*

For Additional Information, the Authors Recommend:

Gubler, W.D., M.R. Rademacher, S.J. Vasquez, and C.S. Thomas. 1999. Control of Powdery Mildew Using the UC Davis Powdery Mildew Risk Index. http://www.apsnet.org/online/feature/pmildew/Top.html.

Thomas, C.S., W.D. Gubler, and G. Leavitt. 1994. Field Testing of a Powdery Mildew Disease Forecast Model on Grapes in California. *Phytopathology* 84: 1070.

UC ANR. 2005. UC Cooperative Extension helps farmers reduce fungicide use in the San Joaquin Valley. http://ucanr.org/spotlight/powdery.shtml.

Weber, E., W.D. Gubler, and A. Derr. 1996. Powdery Mildew Controlled with Fewer Fungicide Applications. *Practical Winery & Vineyard,* January/February.

Travis J. Lybbert is an assistant professor in the Department of Agricultural and Resource Economics at UC Davis. He can be contacted by e-mail at tlybbert@ucdavis.edu. W. Douglas Gubler is a Cooperative Extension plant pathologist at UC Davis who can be reached at wdgubler@ucdavis.edu.