Powdery Mildew Risk & Forecasting in Winegrapes: Do Growers Change Risk Management Strategies in Response to Disease Forecasts?

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The treatment of powdery mildew, the greatest disease risk to winegrape growers, is among growers' most important management practices. Growers' only real hope in the powdery mildew battle is proper prevention. This 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 single poorly timed treatment for powdery mildew. In response, growers apply heavy and frequent doses of sulfur products and other fungicides to vineyards.

Powdery mildew growth models such as the Powdery Mildew Index (PMI) aim to forecast outbreaks and improve the timing of preventative treatments. The PMI, a daily risk index ranging from 0 to 100, uses hourly temperature to forecast the disease. In field trials, use of the PMI reduced fungicides by 2-3 applications over the season with equal or better disease control. The social and environmental benefits of reduced fungicide use due to better treatment timing could be substantial: by one estimate one million pounds of sulfur would not have been applied in California if 25% of raisin growers had used the PMI in 2003. Grape growing countries worldwide stand to reap similar benefits from these disease forecasts.

Despite these favorable trials and potential benefits, important economic aspects of the PMI are still poorly understood. PMI adopters are still in the minority among California grape growers, raising questions about adoption decisions and constraints. Furthermore, the purported value of the PMI to growers has been extrapolated from controlled field trials in which powdery mildew treatments are strictly determined by the PMI. Does the PMI change growers' management of powdery mildew risks in practice? If so, do these

changes lead to a reduction in pesticide application? In addressing these questions, this paper is the most rigorous assessment to date of the value to agricultural producers of disease forecasting as a risk management tool.

We estimate models of growers' disease management strategies using high resolution temporal and spatial data collected at the grower- and plot-level. We have collected and compiled this data from three sources: (i) a detailed survey of California grape growers that among other things elicited their perceptions and use of the PMI, (ii) Pesticide Use Reports (available from the California Department of Pesticide Regulation) that include detailed pesticide use histories for all California grape growers since 1990, and (iii) detailed intra-day weather data for hundreds of weather stations throughout the grape growing regions of California since 1996. The temporal and spatial resolution of this data allows us to estimate the value of disease forecasts at an unprecedented level of detail. We leverage the panel structure of our data to identify the actual impact of PMI use on pesticide applications.

Our results suggest that contrary to the intent of the PMI model, most growers do not adjust treatment intervals in response to this forecast information. Instead, the growers who use the PMI most heavily use it to decide *what* to spray rather than *when* to spray. This response, however, is mediated importantly by the value and susceptibility of the grapes produced. We use the panel nature of the data to explore the dynamics of this response over time. Finally, in order to estimate the impact of the PMI on total pesticide usage, we use established toxicity measures to evaluate the net environmental impact of growers' response to the PMI.

The research question and results of this paper are broadly relevant, especially given current attempts to improve risk and production decision making via high-resolution weather and forecast information. The unprecedented data resolution and empirical approach offer an intriguing and rigorous perspective on grower responses to this kind of information and the environmental implications of these responses.