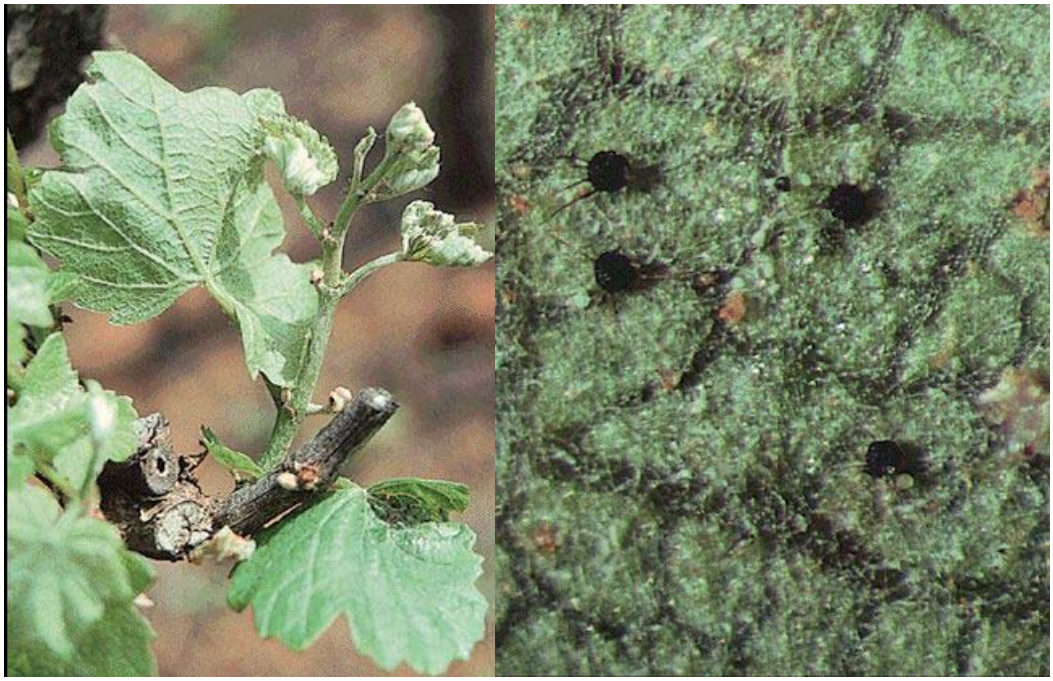
The Analysis of Powdery Mildew Epidemics



FINAL REPORT to GWRDC

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Principal Investigator: Mr Peter A. Magarey

Research Organisation: South Australian Research and Development Institute; DNRE, Agriculture Victoria
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EXECUTIVE SUMMARY

Although powdery mildew is a widespread, persistent disease of grapevines that causes major crop loss and decreases wine quality, little was known about the factors that controlled the rate and development of epidemics in Australian vineyards. In 1996, it was estimated that powdery mildew caused $17 m dollars in lost production in Australian viticulture (approximately 2% of the estimated crop) despite a further $10m being spent in control measures. Premium winegrape varieties such as Chardonnay are highly susceptible. Entire crops of susceptible varieties are lost when control measures are inadequate. Shipments of grapes with as little as 3-5% bunch disease can be rejected by wineries. Each season, 4-8 protectant fungicide sprays are applied for disease control, an inefficient and costly approach that is not always successful because of poor spray application timing and technique.

The present project forms part of a study on powdery mildew (see DAV 3, 7 and 94/1). Prior to this work, there were substantial gaps and flaws in the understanding of the spread of powdery mildew. Based on the Sall model (from California) and other data, it was thought that temperature plays the most important role in determining the rate of epidemic development. It was understood that the increase in powdery mildew incidence and severity follows an exponential (rapid multiplication) curve but the factors that control the rate of spread, were unknown. Experimental evidence indicated that temperatures between 20 and 28^{o} C favour growth of the powdery mildew fungus. Those seasons where temperatures predominated in this range, were thought to have severe epidemics. Although, cultivar resistance, aging of the foliage and fungicide application were known to reduce the severity of epidemics, little was known about how these related to disease progress and thus to improved management approaches to the control of the disease in Australian vineyards.

The objective of the project was to collaborate with overseas specialists in the analysis of disease epidemics to gain a better understanding of means of controlling powdery mildew. Drs Robert Seem and David Gadoury of Cornell University, New York, USA, joined the research team based at SARDI at Loxton, SA. The Hickinbotham Memorial Trust provided financial assistance to this project. Drs Seem and Gadoury have been leading players in improving the understanding of the epidemiology of powdery mildew, particularly the role of cleistothecia and ascosporic infection in initiating epidemics. The pair brought extensive data sets of powdery mildew disease progress in NY vineyards for analysis and comparison with Australian data. The first set contained data on disease progress on two cultivars over a three-year period in both unsprayed and sprayed vineyards. The second set comprised data for a range of cultivars in unsprayed vineyards over an eight-year period. Later, additional analyses of Australian and New Zealand data sets were undertaken as part of related projects on the spread of powdery mildew in vineyards (eg DAV 3, 7 and 94/1). These data sets mostly described the increase in disease incidence and severity in unsprayed vineyards.

In the NY data, disease progress was measured as incidence and severity. The incidence was the number of diseased leaves per shoot. The severity was the percentage of the leaf surface area diseased. Incidence relates to the spread of the disease throughout the vineyard, while severity relates directly to crop loss. For statistical analyses, the rate of epidemic development was linearised with a log transformation. The analyses included the influence of fungicides, cultivar, temperature and rainfall.

Many of the results of the analyses of New York data were surprising. They cast particular light upon the use of fungicides. First, fungicide application slows the rate of increase in severity but does not change the rate of increase of disease incidence. This means that fungicides in effect, delay but do not completely prevent the onset of the rise in disease incidence. The extent of the delay is related to the extent and effectiveness of spray coverage equivalent to the removal of a proportion of the primary inoculum. These results highlight the importance of an effective and efficient early season spray program. Sprays applied early in the season delay both incidence and

severity, while late season sprays only slow (but do not prevent) the rate of increase in severity. Cultivar resistance also slows the rate of disease increase.

The analysis also showed surprising results about the influence of the weather on disease. Once disease was initiated, the rate of epidemic development was independent of weather conditions. When temperature was used as a variable to predict disease progress, the accuracy of predictions decreased as compared to using only time as a factor. Under controlled conditions, powdery mildew spread is greatest when temperatures are between 25-27^{o} C. However, these analyses showed that in the field, the rate of spread of an epidemic is not influenced by temperature. These results were later confirmed by studies using Australian data.

In addition, it was shown that rainfall prior to flowering increased the severity of disease. This probably occurred because wet conditions promote primary infection from ascospores. Later in the season, rain appeared to have no affect on the rate of epidemic increase. In Australia, disease progress is also influenced by the incidence of flagshoot infection. Where large numbers of flagshoots (shoots that arise from diseased buds) are present, the disease proceeds rapidly. Results from studies in Australia and overseas have shown that sprays applied before flowering reduce the numbers of flagshoots in the following season. Good early season control of disease is essential to reduce the incidence of primary infection in subsequent seasons.

The above results were used to interpret the output from Sall's model. It showed that by using good control methods to delay primary infection by 30 days, the level of powdery mildew severity could be decreased from more than 50% to a 5% level. Sall also used the model to evaluate the effects of various weather patterns on the development of epidemics. Generalised cool or hot springs and summers were created from climatic records. Scattered rain or no rain was included as an additional factor. The results of the model are profound. No weather scenario made more than +/- 12% difference in severity from the average climatic scenario. In summary, it is apparent that primary infection is the controlling biological factor in epidemic development and not the extent or rate of secondary spread. Other factors such as effective fungicide application, canopy management and cultivar resistance are also critical factors.

In another aspect of the present project, early season disease progress was mapped in Riverland and Sunraysia vineyards. Data from this were used to study the spatial patterns of disease spread. Results showed that when disease is initiated from flag shoots, the pattern of spread of powdery mildew is focal (infections are concentrated on individual vines), but when disease is initiated from ascospores or wind blown spores (conidia), the pattern is random (infections appear as spots scattered in the vineyard). An obvious outcome of this work relates to the methods used to monitor vineyards for this disease. For monitoring to be effective in vineyards with a focal patterns, more vines will need to be surveyed than when the disease is scattered.

The above analyses also highlighted that early season control is critical. Once primary infection has occurred, powdery mildew multiplies rapidly. In as little as five to seven weeks (40 days) from budburst in an under-sprayed vineyard, the disease may spread from initial, small foci of infection around flag shoot infection sites to be seen as isolated colonies on leaves and bunches throughout the vineyard. Subsequently, disease severity also increases rapidly. Leaves, shoots and berry stems remain susceptible while green but show an age-related resistance that may slow the epidemic late in the season. However, this is too late to prevent crop loss. Canopy management may also influence the development of age-related resistance. Our studies also showed that berries are susceptible only until 4 - 6 weeks after flowering, ie until pea size and bunch closure. The application of early season fungicides or the absence of early season primary infection, prevents the epidemic reaching damaging levels during the period when berries and the canopy are most susceptible. These results have been fundamental to the development of the *2-4-6 strategy*. This strategy emphasises the need for three sprays before flowering. If sprays are applied effectively at these times, good control of disease in both short and long-term can be achieved efficiently.

As also indicated in the companion studies referred to above, the present work indicated the need for better prediction of powdery mildew epidemics. Existing overseas predictors, like the UC Davis Risk Assessment Model (eg. as used by Adcon™), are unlikely to adequately address disease development in Australian conditions because of the importance of flag shoot inoculum. A model is needed that also accounts for this infection source. Disease data are available to improve prediction of powdery mildew epidemics for Australian grape growers and a model framework is proposed in the report of the companion investigations. The inputs required for this model include: temperature and rainfall data, a vine canopy and growth model, monitoring data for disease incidence and vine growth and spray records.

As a result of this and other studies on the rate of progress of powdery mildew epidemics, procedures for monitoring powdery mildew have been revised. Data from the present investigation indicated that correct application of these monitoring procedures, can detect disease early in the season. When this is coupled with use of effective spray machinery in commercial vineyards, efficient control strategies of powdery mildew should be achieved.