INFLUENCE OF SUN EXPOSURE ON POWDERY MILDEW DEVELOPMENT

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Powdery mildew is often most severe in portions of the vineyard and/or individual canopies that are subject to shading. Although this phenomenon is widely recognized, it has received relatively little formal study.
Willocquet et al. (1996) showed that UV-B radiation negatively impacted both conidial germination and mycelial growth of Uncinula necator. They suggested that solar radiation is an important factor in the development of grape powdery mildew epidemics, and that training systems that increase exposure of the vines to sunlight could help to reduce disease development. Zahavi et al. (2001) monitored powdery mildew development in vineyard blocks with different row spacings and training systems, and associated increased disease development with decreased light intensity in the fruit zone. Keller et al. (2003) related the increased development of powdery mildew in low UV environments with various physiological characteristics of vines growing under such conditions, including low concentrations of constitutive phenolic compounds that might hinder fungal pathogenesis and reduced cuticular wax deposition.

Our field experience suggests that powdery mildew may be a particular problem not only in specific vineyard and canopy locations subjected to shading, but also regionally in seasons with reduced solar radiation resulting from prolonged periods of cloudy weather.
However, there are few data to which we can refer for guidance in quantifying these effects. Therefore, in 2005, we initiated a multi-year study whose objective is to better document and explain the relationship between sunlight exposure and powdery mildew development on fruit and foliage. Our results are as yet preliminary, but they are offered here for the purposes of further consideration and discussion.

In one set of experiments in a vineyard of the interspecific hybrid cv. Chancellor, vines were maintained (i) in full sunlight; (ii) beneath a single layer of shade cloth, which admitted a daily average of 45% of available solar radiation (as measured in the 400 to 1100 nm range using a LI-COR pyranometer); and (iii) two layers of shade cloth, which admitted 20% of available solar radiation. On three separate occasions, eight different replicate shoots per treatment were inoculated with U. necator conidia, and disease severity (% leaf area infected) was assessed on each leaf 2 weeks later. Across all runs of the experiment, mean disease severities were 21, 51, and 61%, respectively, in these three treatments.
Air temperature, relative humidity, and solar radiation in the range of 400-1100nm were measured every 15 min with a data logger. Additionally, ultraviolet radiation was measured with an Ultraviolet Multi-Filter Rotating Shadowband Radiometer (UV-MFRSR).
Shading had no effect on ambient air temperature or relative humidity. The proportion of UV radiation that was reduced by the shade cloths was similar to that within 400-1100 nm range measured with the pyranometer.

In another, factorial experiment in a vineyard of cv. Chardonnay (Umbrella-kniffen training system), we examined the effects of natural shading. One group of vines was located at the edge of the vineyard, immediately west of a line of tall trees that provided morning shade; the second was in the same row, but in a cleared area not shaded by the trees. Within these two groups, we inoculated U. necator conidia onto shoots that were either (a) on the outer edge of the canopy, fully

exposed to the sun, or (b) trained into the center of the canopy, which was dense and provided substantial shading at the time that the experiment was conducted in August. Disease severities were determined 2 weeks after inoculation.
The results are summarized in Figure 1. Note that both sources of shading increased disease development. Shade from the trees roughly doubled disease severity for both the outer and inner portions of the canopy.

Similarly, severity on leaves within the canopy was three to five times greater than on leaves comprising the outer edge, for both sets of vines. And these effects were cumulative, with fully 63% of the leaf area diseased on the inner shoots of vines shaded by the trees, versus only 9% on shoots that were provided full sunlight exposure.

Once again, there were no differences in ambient air temperature or relative humidity among these treatments. However, UV radiation measured within the center of the most heavily shaded canopy was reduced by 92 and 99% relative to a reference UV sensor in full sunlight, on two different occasions.

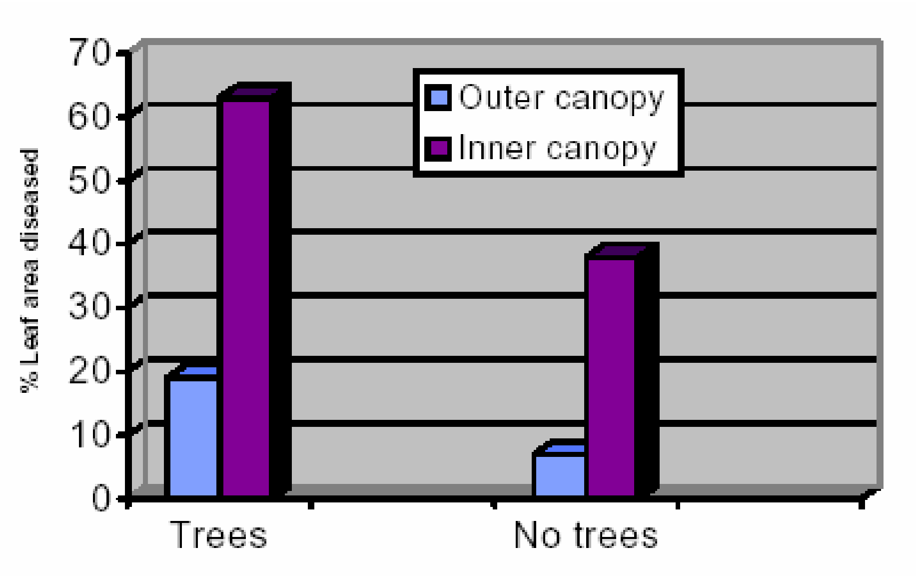

Fig. 1. Effect of two sources of shading on the development of powdery mildew. Evaluated leaves were from shoots on the outer (sun-exposed) or inner (shaded) portions of the vines, which were (a) adjacent to a group of tall trees (morning shade) or (b) away from the trees and exposed to available sunlight all day.

Although there was no effect of sunlight on ambient air temperatures in the different shading treatments, we hypothesized that leaf temperatures in full sunlight might be higher than those in the shade. Therefore, leaf temperatures were measured with a hand-held infra-red thermometer. On a calm sunny day in August, temperatures of leaves in direct sunlight were 8-14^{o}C higher than for leaves in the shade-cloth treatments.

Similarly, Chardonnay leaves in the direct sun were 6-11^{o}C warmer than the naturally-shaded leaves within those canopies; such leaves were near ambient temperature to a few degrees cooler. These vines were not irrigated. In separate sets of measurements of irrigated and water-stressed vines in different locations, the temperature elevation of sun-exposed leaves was greatest for vines that appeared to be drought stressed.

Nevertheless, these data suggest that under some conditions, the temperature of shaded leaves might be in the optimum range for disease development, whereas the temperature of those in full sun might be suboptimal or even lethal for the causal fungus. For example, in one set of

measurements in our experiment, leaves in the shade at midday measured 30°C, whereas those in full sunlight measured 38-43°C.
We examined the interactive effects of drought stress and leaf temperature in another set of experiments with potted Chardonnay vines maintained outdoors during the summer. One group of vines was watered regularly, whereas another was watered to induce a level of stress that would cause stomates to close. In two of the three repeats of the experiment, drought-stressed vines developed no signs of the disease, and in the third, only 8% of the leaf area was infected (i.e., <3% on average across all three runs of the experiment). In contrast, the well-watered plants averaged 25% leaf area infected across the three runs, with disease severity on some individual leaves as high as 85% in one experiment.

Leaf surface temperatures were 7-10°C higher on the drought-stressed versus well-watered vines, reaching values in the low 40's during midday. All vines were in full sunlight. Other vine responses to the imposed water deficit were not quantified.

Although this project is still young, our initial data confirm previous observations and experimental results indicating that full sun exposure can dramatically limit powdery mildew development relative to what might otherwise occur in its absence. In addition to the previously-suggested effects of UV radiation on disease development, our data also suggest that sun exposure might have a limiting effect by elevating the temperature of irradiated leaves, and that this effect might be further exacerbated under water-stressed conditions. Current data, and practical experience, suggest that solar radiation and perhaps some measure of plant water status might be useful environmental variables in models designed to forecast the development of grapevine powdery mildew.

Refereces

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Willocquet L., Colombet D., Rougier M., Fargues J. And Clerjeau M. 1996. Effects of radiation, especially ultraviolet B, on conidial germination and mycelial growth of grape powdery mildew. Eur. J. Plant Pathol. 102:441-449.
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