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TITLE: Epidemiology and control of powdery mildew of peach and nectarine (Final Report)

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Objectives

I. Develop an epidemiological-based method of timing fungicide sprays for managing peach/nectarine powdery mildew.

* Investigated irrigation management as a potential means to delay the onset of peach mildew epidemics and/or reduce disease severity.

* Continued large plot (on-farm) testing of oil-based weather driven peach/nectarine powdery mildew management program.

*Investigated the influence of weather variables and current irrigation practices on aerial conidia populations of conidia of peach mildew fungus.

*Evaluated Rotorod, volumetric, and low (Burkhard) and high-efficiency (Innovatek) cyclonic air samplers for trapping propagules of *S. pannosa*. Evaluate the efficiency of ATV- mounted rotary impaction air samplers for detecting *S. pannosa*.

*Perfected techniques for extraction of DNA from *S. pannosa* mycelia; continue investigations of primer specificity. Determined that primers developed for *S. pannosa* on rose cannot be used in investigations of *S. pannosa* on soft fruit.

*Continued testing primers for cross-reaction with other powdery mildews.

*Determined the peach fruit infection window through bagging experiments and/or application of PCR techniques.

* Determined that nectarine fruit do not attain resistance at pit hardening

II. Practical Disease Management

*Continued field evaluations of various "soft" and organic fungicides for efficacy against stone fruit mildews and for effect on beneficial insects.

*Continued the development and implementation of practical fungicide resistance management programs.

Significant findings/developments:

* The large peach/nectarine orchard established at WSU Prosser used for experimentation in 2004. A large population of *S. pannosa* has been established in the orchard, which should alleviated research problems encountered in commercial orchards.

* Relationship of irrigation sets to orchard spore loads: both 2003 and 2004 spore trapping data showed no correlation with irrigation events.

* A primer designed to amplify DNA of *S. pannosa* did not amplify DNA of 46 other powdery mildews. Most importantly, it did not amplify DNA of the apple, cherry, grape, or hop powdery mildew fungi most likely to be in orchard air samples. The PCR assay was found to be extremely sensitive: it detected DNA extracted from 1-5 conidia of *S. pannosa* in reaction mixtures.

* The soft fruit degree day model provided a means to identify the onset of primary and secondary inoculum dispersal, but 2004 results indicated that the accumulation threshold should be lowered from 60 to 55 F.

* Organic fungicide programs equaled a conventional program in minimizing disease incidence.

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Methods:

Disease and fungicide resistance management programs. Fungicide sprays were applied to three-year-old nectarine trees for powdery mildew control at Prosser, WA. Sprays were applied at 100 gallons per acre with a Prop-Tec Sprayer (Blueline Manufacturing, Moxee, WA). Treatments consisted of four replications of single trees arranged in a randomized complete-block design. Treated trees were buffered by untreated adjacent trees in the same row. Treatments and rates are given in the table. Treatments began on 16 April and continued until 6 Jul on a 7 or 14-day interval. Foliar mildew severity was determined on 20 Jul. The percent leaf area colonized on each of ten leaves beginning at the first fully expanded leaf beneath the shoot apex was estimated. This evaluation was conducted on five inner-canopy shoots and 5 outer-canopy shoots on each treated tree. On 30 Jul 30 fruit on each treated tree were examined for the presence of mildew. The percent fruit area affected was estimated. Data were subjected to analysis of variance and means separated according to Tukey-Kramer HSD with $P = 0.05$.

Forecasting.

Detection of airborne S. pannosa. In 2004, powdery mildew DNA was successfully detected (using PCR) in air samples collected using rotary-impaction air samplers. Because of technical difficulties, our efforts 2004 efforts with the Innovatek sampler failed.

Irrigation studies. Investigations commenced in the new nectarine orchard at WSU-IAREC in 2004. The effect of irrigation type on orchard microclimate and airborne spore concentrations will be studied using CR-21X Dataloggers and volumetric spore traps. Volumetric and rotary impaction spore traps will be operated continuously. Once mildew is established, day or night irrigation sets of various lengths will be applied. Correlation, time series, and regression analyses will be applied to determine irrigation effects on airborne spore populations.

Oil-based disease management studies. Continued field-testing the oil-based mildew management program. A local commercial orchard was be used for this portion of the study. The experiment was terminated in mid-July due to lack of powdery mildew.

Timing of fruit infection. During April, May, and June, 2004 developing peaches were protected from mildew attack by enclosure in Nitex cloth bags. (Nitex cloth pores allow necessary gas exchange for normal photosynthetic processes but are too small for mildew conidia entry.) At nine sequential intervals protected fruit were exposed to potential mildew infection for one week. Each exposure treatment

consisted of one to four adjacent fruit at each of five locations on a tree. Each exposure treatment was replicated four times.

On 28 April sections of five flowering branches on each of thirty-two O'Henry cultivar peach trees were covered with Nitex cloth bags to protect the developing fruit from exposure to powdery mildew conidia. Beginning 5 May bags were removed for one week from all branches on each of four trees and then replaced one week later until 30 June; creating eight sequential exposure periods. A ninth exposure period was created by covering five previously un-protected sections on four trees on 5 May. All bags were removed and the fruit was inspected for presence of mildew on 15 July.

Comparative disease progression was evaluated on unsprayed nectarine and peach fruit (in the same orchard) beginning at shuck fall and continuing through harvest. Twenty-five fruit per plot were periodically assessed for the presence (incidence) and amount per fruit (severity).

Results and Discussion

Organic fungicide programs. Foliar disease severity on 20 Jul on all shoots was 46.6% on the non-treated control and ranged from 8.1% (Stylet Oil @ 1% on 7 day interval) to 38.8% (Sonata 4 qts/a on 7 day interval) on fungicide-treated trees. There were significant differences in foliar mildew severity among treatments and several treatments differed significantly from the non-treated control. Mildew severity on fruit **(Figure 1)** on 30 Jul was 11.3 on the non-treated control and ranged from 1.8% (Rally @ 5 oz/a alternated with Pristine @ 14.5 oz on a 14 day interval) to 6.7% (Water blank on 7 day interval). Incidence of mildew-affected fruit on 30 Jul was 52.5% on the non-treated control and ranged from 16.7% (Rally @ 5 oz/a alternated with Pristine @ 14.5 oz on a 14 day interval and Milk @10% on a 7 day interval) to 45.0% (Water blank on 7 day interval).

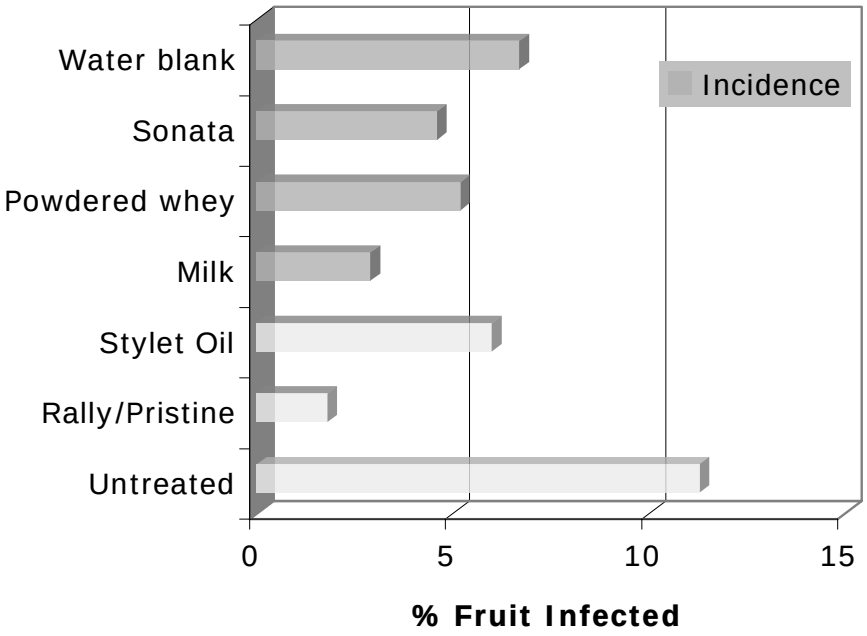

Figure 1. Control of powdery mildew using organic and conventional fungicide programs.

Both synthetic and organic management programs performed adequately for reducing disease incidence (% fruit infected) but only milk and the Rally/Pristine alternation appeared to reduce disease severity.

Molecular detection/air sampling studies. The technique developed in late 2002 to remove powdery mildew from plant surfaces and to extract and amplify DNA was further refined in 2004. The former involves the use of a small handheld cyclonic air sampler that deposits mycelia and conidia of S. *pannosa* into a small vials. The PCR primers found to be highly specific for the peach powdery mildew fungus. The primers did not react with DNA collected from powdery mildews collected from 46 disparate hosts from 26 plant families. The PCR assay was found to be extremely sensitive: it detected DNA extracted from 1-5 conidia *S. pannosa* in reaction mixtures. We conclude that the primers are specific enough to be used in epidemiological studies. The primers were used successfully in conjunction with air sampling studies. Proof of concept was demonstrated using stationary and

ATV-mounted Rotorod air samplers. This finding is significant because at $500 the sampler is affordable.

Temporal studies of fruit infection. Studies on the temporal susceptibility of fruit were conducted in Prosser. Developing peaches exposed to mildew infection between 5 May and 26 May were the only ones on which mildew developed (Table 1), although the level of infection was not statistically significant. The fact that the three "windows" which allowed infection are chronologically contiguous suggests that this is the period when peach fruit infection is most likely to occur.

Disease progress was measured on peaches and nectarines contained in the same orchard. Peach fruit appeared to attain some level of resistance with age while those of nectarine *did not*. Fruit infection of peaches (Figure 3) did not change appreciably throughout the inspection period (17 June through 26 August) suggesting that fruit infection occurred prior to 17 June. Nectarine fruit infection was at least double the level of peach fruit infection from 17 June through 16 July. Subsequently the incidence of infection began to increase during the following month.

INITIAL DATE BAGS ON	DATES WINDOW WAS OPEN	% INFECTED FRUIT[z]
5-May	PRE 5/5	0a
28-Apr	5/5 TO 5/12	5.65a
28-Apr	5/12 TO 5/19	3.58a
28-Apr	5/19 TO 5/26	5.9a
28-Apr	5/26 TO 6/02	0a
28-Apr	6/02 TO 6/09	0a
28-Apr	6/09 TO 6/16	0a
28-Apr	6/16 TO 6/23	0a
28-Apr	6/23 TO 6/30	0a

Table 1. Powdery mildew of peach fruit when exposed to infection at various periods. ([z] Means within a column followed by the same letter are not significantly different according to Tukey-Kramer HSD $P = 0.05$).

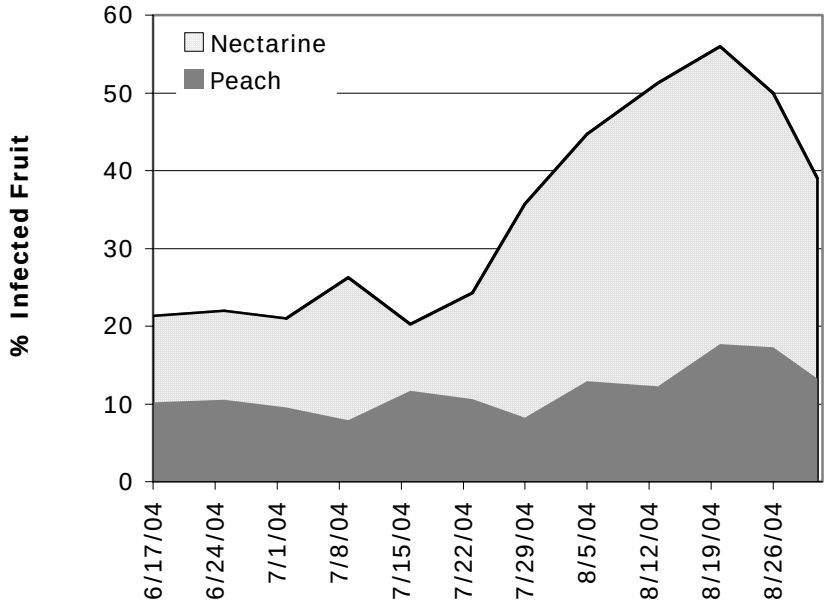

Figure 2. Powdery mildew incidence on peach and nectarine fruit at Prosser, 2004. Pit hardening occurred in late July.

Forecasting Model. Spore and weather data permitted the development of a degree-day model that can be used to identify the onset of primary and secondary inoculum production. The most appropriate threshold for the historical spore data appears to be cumulative degree-days >55 F past bud break (Figure 4). CDD values of 0 (bud burst (biofix)), 20 (epidemic onset), and 90 (window of peach susceptibility) identify critical events in host development and disease epidemiology and may be the most appropriate times for fungicide applications. **The latter threshold appears to identify the concurrence of inoculum availability and the window of peach susceptibility described in bagging studies.**

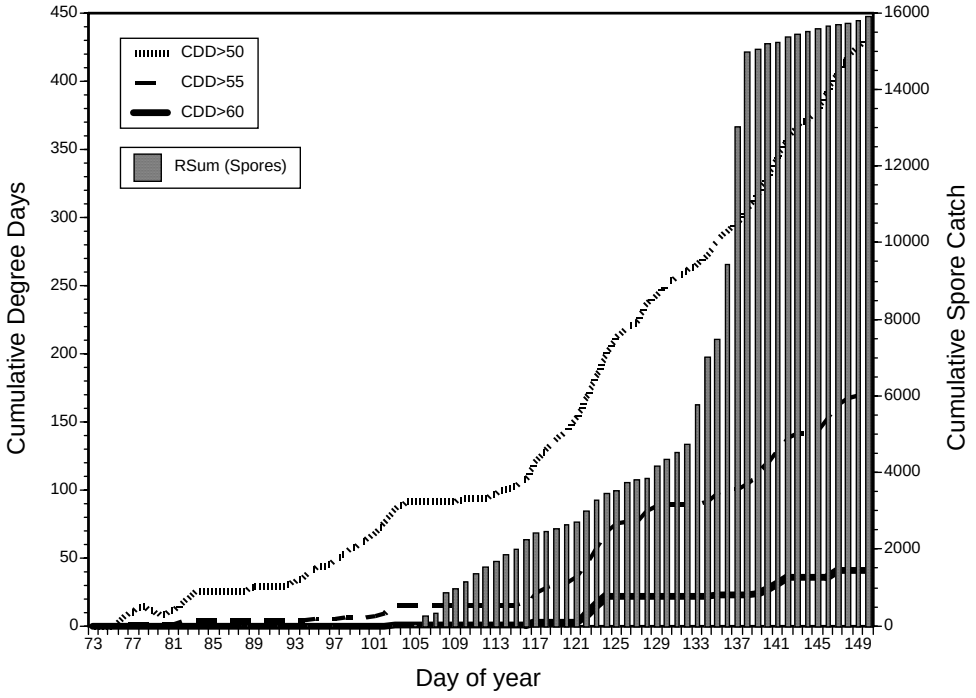

Figure 3. Cumulative early-season spore catch (shaded vertical bars, right "Y" axis) plotted versus three degree day (lines, left "Y" axis) thresholds. Note that significant epidemiological events occur at about 30 and 90 cumulative degree-days > 55 F. The latter threshold appears to identify the concurrence of inoculum availability and the window of peach susceptibility described in bagging studies.

Use of roses as indicator plants. The infection of roses during the early stages of fruit susceptibility may offer an alternative (albeit risky) means of signaling the beginning of the spray program *provided that highly susceptible rose varieties are used as indicators and that a high powered hand lense is used to scrutinize foliage for early symptoms*. *Because of the labor involved, this method does not appear to be cost-effective.* On moderately resistant or resistant cultivars powdery mildew appears too late to be of practical significance. However, this observation needs to be verified using expanded fruit bagging experiments and the aforementioned PCR techniques.

Publications

Falacy, J.S., Grove, G.G., Larsen, R.C., Vandermark, G.J., Glawe, D.A., and Galloway, H. 2004. Detection powdery mildews with Polymerase Chain Reaction and Species-Specific Primers. Phytopathology 94: 000-000 (in journal review).

Grove, G.G., Xiao, C.L., and Nelson, M.E. 2004. Fungicide stewardship in perennial crops. http://fruit.wsu.edu/Diseases/stewardship.pdf
Smith, T.J., Beers, E.H., Brunner, J.F., Dunley, G.G. , Jones, V., Grove, G.G., Xiao, C.L., Peryea, F.J., Parker, R., Mayer, D.F., Witmer, G., Schreiber, A., Daniels, C., and Roberts, S. 2004. *Crop Protection Guide for Tree Fruits in Washington*. EB0419, Washington State University Cooperative Extension. 90 pp.

Budget:

Item	**Year 1 (01-02)**	**Year 2 (02-03)**	**Year 3 (03-04)**	**Total**
00 Salaries				
Graduate Research Assistant	7,557			32,771
Associate in Research		12,360	12,854	
01 Wages	5,000	0	0	5,000
03 Goods and services	1,000	0	0	0
07 Benefits				
Graduate Research Assistant Beneftis	1,480			
Associate in Research		3,832	3,985	9,297
Total:	16,037	16,192	16,839	49,068