FINAL PROJECT REPORT

Project Title: Validation and implementation of the WA cherry powdery mildew model

PI: Gary G. Grove
Organization: WSU-IAREC
Telephone: 509-786-9283
Email: grove@wsu.edu
Address: 24106 N. Bunn Road
City: Prosser, WA
State/Zip: 99350

Cooperators: V.P. Jones

Other funding Sources:

Agency Name: Washington State Commission on Pesticide Registration

Amount requested/awarded: $16,030

Notes: 2008 only

BUDGET:

Organization: Washington State University	**Contract Administrator:** Stephanie Brock
Telephone:509 786 2226	**Email:** sabrock@wsu.edu

Item	**Year 1: 2007**	**Year 2: 2008**	**Year 3: N/A**
Salaries	28,309	29440	
Benefits	9,710	10,098	
Salaries (Hourly)		1,500	
Equipment			
Supplies	1700	1,700	
Travel	3,700	3,700	
Miscellaneous			
Total	43,419	46,438	

OBJECTIVES:

1) Continue model validation work on cv. ‘Bing’ and ‘Sweetheart’ and expand validation work to include other cultivars.

a. Determine the accuracy of the secondary infection risk index on Rainer cherries

b. Repeat studies designed to determine whether ascospore release and primary infection could result from the use of irrigation for frost protection.

2) Determine appropriate fungicides for use at critical points during mildew epidemics. In addition to repeating our 2007 work on overall program initiation, our 2008 work also focused on identification of the most efficacious fungicide class for use at the onset of secondary inoculum production (i.e. when the model indicates disease onset *after* primary infection).

3) Determine optimal spray intervals for various fungicide classes under ambient secondary mildew disease pressures as defined by the model’s risk index. Identify potential interval variation across cultivars.

4) Establish online training resources for model usage and related powdery mildew management. Develop similar training material for distribution via DVD (and by extension, other digital formats).

Significant Findings (by objective):

1a. Under the weather conditions that characterized the 2008 season, the secondary infection risk index was found to be a reasonably accurate and *conservative* predictor of the both the initial occurrence and intensification of mildew on unsprayed trees in the orchard (**Figure 1**). The risk index was more conservative on the foliage of cv. ‘Sweetheart’ than cvs. ‘Bing’ and ‘Rainier’. Results were similar in 2007 on ‘Sweetheart’ and ‘Bing’ (Rainier not tested in 2007).

1b. For the second year, evidence was collected that irrigation water used for frost protection contributes to ascospore release (**Table 1**). Propagules were detected using rotary impaction air samplers and PCR.

2. The powdery mildew model was used to initiate and schedule subsequent (objective 3) fungicide applications in 2008 (**Figures 2 and 3**). Because of their unique modes-of-action, quinoline (Quintec), QoI (strobilurin; Flint), DMI (Procure), and sulfur (Microthiol) fungicides were evaluated for their efficacy when used to *initiate* fungicide spray programs upon *primary infection* or *predicted disease onset*, both of which are critical [early] epidemiological events identified by the model. Specifically, the primary infection is predicted when 0.1” of precipitation is received at > 50 F. The second infection risk index is initiated at primary infection and looks for six consecutive hours between 59 and 81.3 F. These conditions need to be met for three consecutive days in order for the prediction of disease onset. In 2008, the secondary infection risk index was initiated at primary infection. Fungicide programs were initiated usually various fungicide chemistries at primary infection or disease onset. Subsequent applications were made at 14-day intervals through harvest. For example (**Figure 2**), a QoI program initiated at the first primary infection identified by the model resulted in disease incidence value of 25% and 0.4 disease severity index (DSI) while programs initiated according to crop phenology were 38.0% and 0.51 DSI respectively. As stated in above, the class of fungicide chosen to *initiate* spray programs was not significant when raw data was analyzed. *However, the application of a logit transformation (natural logarithm of incidencey/1-incidence) to the incidence data revealed that initiation of a fungicide program using Flint (QoI compound) or sulfur* **at disease onset** *resulted in control inferior to programs initiated using other modes-of-action at this critical epidemiological stage.*

3. Studies to ascertain the appropriate intervals between model-driven fungicide sprays continued in 2008 (**Figure 4**). In trials under extremely high disease pressure (i.e. high risk indices), QoI (Cabrio), QoI/pyridine (Pristine), DMI (Procure), oil (Stylet Oil), quinoline (Quintec), carbonate (Kaligreen), and sulfur (Microthiol Dispersee) fungicides appeared to require application intervals of 7 days (**Figure 4**) to provide adequate levels of control on both cvs. 'Bing' and 'Sweetheart'. Control was marginal at longer spray intervals. This finding stands in contrast to fungicide performance in 2007 when several compounds were effective at longer spray intervals. *Therefore, because of inconsistent performance 21-day spray intervals will not be recommended in conjunction with model usage*.

4. Personnel constraints precluded the completion of the model interface on the WSU Tree Fruit Decision Aid System (DAS; http://das.wsu.edu) in time for the 2008 growing season. However, the model on the AgWeatherNet (http://weather.wsu.edu) was improved in time for the 2008 growing season. Summary model outputs **(Figure 5)** were made available via text messaging **(Figure 6)** and a training video was completed using SnapZ Pro software. This software is utilized to make movies of the model configuration and output interpretation processes on the World Wide Web. Clients configure the text messaging function on the main AgWeatherNet web site. The distribution of summary outputs using text messaging and automated [PDF or text] email was tested several users during 2008 growing season. Upon completion of the DAS version of the model is complete, all model functionality will be transferred to the DAS site. A new (DAS-based) training module will be prepared prior to release by DAS. All training videos are (will be in the case of the DAS version) available on DVD upon request.

Results and Discussion

Model Rationale and Review

The cherry powdery mildew model is comprised of three components: 1) a growing degree day algorithm that tracks degradation of the overwintered inoculum supply following bud burst 2) a primary infection algorithm and 3) temperature-based Risk Assessment Index.

Component 1. The causal agent of grapevine powdery mildew, *Podosphaera clandestina* survives winter as cleistothecia in Eastern Washington. Cleistothecia persist until 250 growing degree days (base 50 F) have accumulated after bud burst.

Component 2. Studies in Eastern Washington have demonstrated that cleistothecia require 0.1" precipitation or greater at 50 F or greater in order to release ascospores. Component 2 of the cherry mildew model is a temperature/precipitation algorithm that looks for these conditions between bud burst and when 250 growing degree-days have accumulated. If the aforementioned temperature and moisture requirements are met within the specified time frame, primary infection occurs and the Risk Assessment Index (component 3) is initiated.

Components 1 and 2 are used to signal the beginning of the season's fungicide spray program. Although the post infective activity of the various fungicides needs to be determined for *P. clandestina* on cherries, work on other pathogenic fungi indicates that some synthetic fungicides (e.g. DMI) have higher post infective activity than contact fungicides and in some cases can be applied up to 96 hours after an infection event.

Component 3. Once powdery mildew is established, further fungicide treatments will be necessary because the fungus will continue to reproduce through the growing season. The rate of reproduction is temperature-dependent and best indicator of infection risk. The Risk Assessment Index ranges between 0-100 where indices of 0-30, 40-50, and 60-100 indicate low, moderate, or high disease pressure, respectively. The index measures how rapidly the fungus is reproducing and is used to provide general guidelines regarding the interval between fungicide applications. High risk indices result in shorter intervals between sprays whereas low indices allow "stretching" of application intervals. In general synthetic fungicides (Quinoline, DMI, QoI) compounds are more persistent that contact fungicides and protect fruit and foliage for longer periods of times.

After primary infection, an epidemic will begin when there are 3 consecutive days with 6 or more continuous hours of temperatures between 59 and 81.3° F. Starting with the index at 0 on the first day, 20 points are added for each day with 6 or more continuous hours of temperatures between 59° and 81.3°F. If fewer than 6 continuous hours of temperatures between 59° and 81.3°F occurs, 10 points are subtracted. If 6 or more continuous hours of temperatures between 59° and 81.3°F occurs, 20 points are added. If temperatures reached 90°F for more than 15 minutes, 10 points are subtracted. If there are 6 or more continuous hours with temperatures between 59° and 81.3°F and the temperature rises to or above 90°F for at least 15 minutes, 10 points are added.

Relationship to 2008 results.

Primary infection was predicted and occurred on 3 May 2008, which initiated the secondary infection component (risk index) of the model. Disease onset was predicted on May 11 and was actually observed (without the aid of a hand lens) on all three cultivars on 16 May (**Figure 1**). High levels of risk (short spray intervals) persisted from that point through harvest and then declined with the onset of summer heat. The rate of foliar disease increase on 'Bing' and 'Rainier' was slightly more rapid than the rate of increase on 'Sweetheart'. Fruit infections were not observed on any cultivars cultivar. The model was *conservative* under the growing conditions of 2008.

Water-based frost protection was applied one of our IAREC research cherry orchards on 1,5, and 15 April (**Table 1**) while a second orchard was left protected. Rotorod air samplers were operated continuously through water-application periods and during drying periods the following morning. Using PCR, *Podosphaera clandestina* was detected in the air during consistently during watering. The causal organism was detected in the orchard left unprotected during frost periods. Powdery mildew was not detected in the orchard air prior to the application of irrigation water or (prior to primary infection) during cold evenings when water was not applied. Although additional work is needed in order to determine the effect of morning temperatures on primary infection (rather than just spore release), the results of this two-year study indicate the ascospore release can result from the application of irrigation water for frost protection.

Model studies were conducted in a Prosser orchard during 2008 (**Figure 1**). The model identified primary infection on 3 May. The powdery mildew risk index was initiated at this time. The model then predicted disease onset on 11 May following the first occurrence of 3 consecutive days of > 6 consecutive hours at the aforementioned critical temperatures (following primary infection). Weather- and detection-based fungicide programs were initiated on 4 May in response to the (3-May) rain event that promoted primary infection (0.31" of precipitation at 51.8 F) or at predicted disease onset on May 11. As in 2007, the effect of using various fungicide classes for program initiation in response to predicted *primary infection* was not significant. However, when control programs were initiated at disease onset (over 1 week after primary infection) with sulfur or QoI compounds disease levels were significantly more severe than in programs initiated with DMI or quinoline compounds (**Figures 2 and 3**). This finding could be particularly significant during years when abnormally warm or cool weather occurs immediately following primary infection. The incubation period between primary infection and disease onset is temperature dependent and is shortest when temperatures are in the 59-81.3 F range. Persistent temperatures outside of this range could extend the incubation period and perhaps eliminate a fungicide application provided that a DMI or quinoline fungicide was applied at disease onset.

Although all treatments were superior to the untreated controls, mildew levels were unacceptably high under 14- and 21-day application intervals (**Figure 4**, figure data expressed as % reduction from maximum disease severity value (4.2/5)).QoI, DMI, and sulfur fungicides provided the best levels of control on cv. ‘Bing’ and ‘Sweetheart’ when applied at 7-day intervals under the extremely high disease pressure. Disease severity in the untreated controls was 3.44 and 3.24 (maximum = 5.0) on cvs. ‘Bing’ and ‘Sweetheart’, respectively. At 7 day intervals severity ranged from 1.7 (Quintec) to 2.4 (Stylet Oil) on ‘Bing’ and 1.6 (Quintec) to 2.31 (Stylet Oil) on ‘Sweetheart’. At 14 day intervals severity ranged from 2.18 (Pristine) to 2.74 (Kaligreen) on ‘Bing’ and 2.06 (Quintec) to 2.71 (Cabrio) on ‘Sweetheart’. At 21 day intervals severity ranged from 2.46 (Quintec) to 3.14 (Stylet Oil) on ‘Bing’ and 2.37 (Quintec) to 2.97 (Stylet Oil) % (Kaligreen) on ‘Sweetheart’. It was apparent that at the extreme disease pressure of 2008 that fungicides applied at 21-day spray intervals do not provide adequate control regardless of class and that (with the exception of Pristine @ 14-day intervals on ‘Bing’) Quintec consistently performed best of any compound. The demonstration of marginal fungicide performance at 21 day spray intervals is significant: some QoI compounds are effective at these long intervals when used in conjunction with forecasting models developed for the powdery mildew of grapes and tomatoes.

Due to personnel constraints that precluded timely release of the full model on WSU-DAS in 2008, the model was improved on AgWeatherNet through the incorporation of new temperature algorithms, more detailed summary (**Figure 5**) and full model reports, and the addition of automatic email and text-message (**Figure 6**) functions. Coding used for all outputs were made available to the new WSU-DAS programmer for inclusion on the site for the 2009 season. All model outputs are hyperlinked to management information on disease biology, model rationale, and disease and fungicide management options. Training modules developed in 2007 Microsoft PowerPoint, Adobe Presenter, and SnapZ Pro are currently being updated using ScreenFlow software. Screen movies that actual depict real-time configuration of, and navigation through, the web-based modeling are made using ScreenFlow and SnapZPro. A ScreenFlow tutorial will be developed for DAS as the new interface is developed. The development of push technologies are particularly significant in the event of rapid change in the status of a pest or disease model: current information can be delivered directly to a client’s cellular phone as conditions change. In certain instances (e.g. apple scab, where spray timing is *everything*) receipt of this timely information could significantly improve disease management.

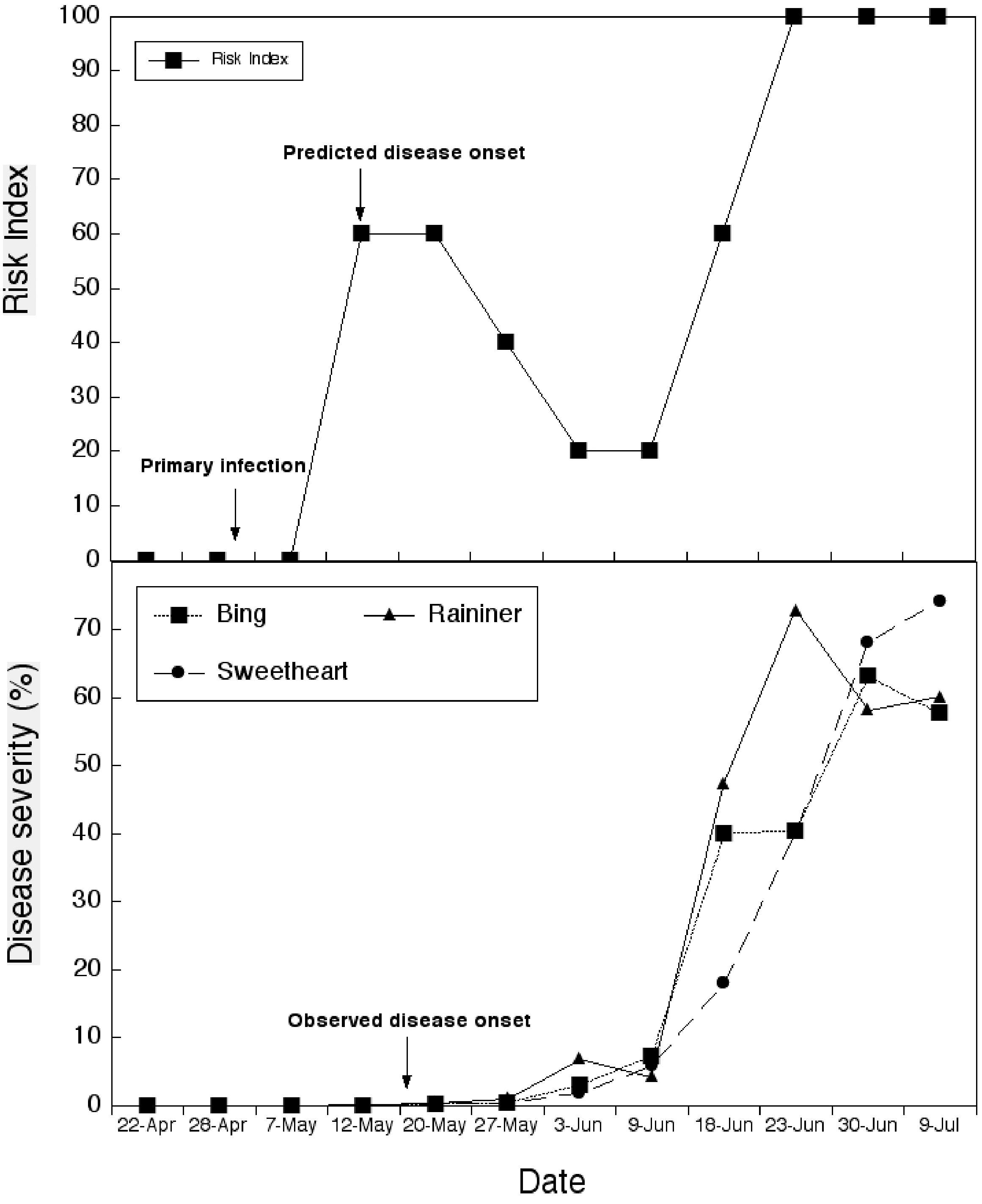


Figure 1. Progression of powdery mildew on cultivars 'Bing', 'Rainier', and 'Sweetheart' at Prosser. Presented in the upper graph are dates of predicted primary infection, disease onset, and the secondary risk index to harvest. Lower graph indicates disease severity on the various cultivars.

Table 1. Effect of early season irrigation (used for frost protection) on ascospore release by *P. clandestina*.

Date	Orchard	Water Applied	PCR Signal Strength	Minimum Temperature (F)
4/1	D39[1]	Yes	Bright	25
4/1	D51[2]	No	None	25
4/5	D39[1]	Yes	Bright	28.7
4/5	D51[2]	No	None	28.7
4/15	D39[1]	Yes	Bright	28.2
4/15	D51[2]	No	None	28.2

[1] water used for frost protection within orchard;[2] water not used

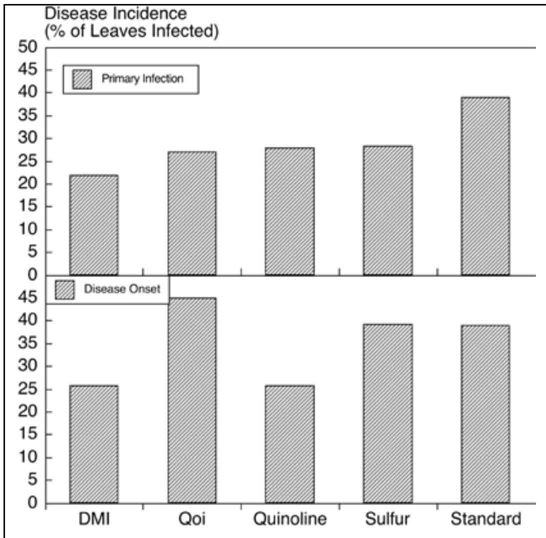


Figure 2. Incidence of powdery mildew on 'Bing' cherries when fungicide programs were initiated at predicted primary infection (upper graph) or disease onset (lower graph) using different fungicide chemistries.

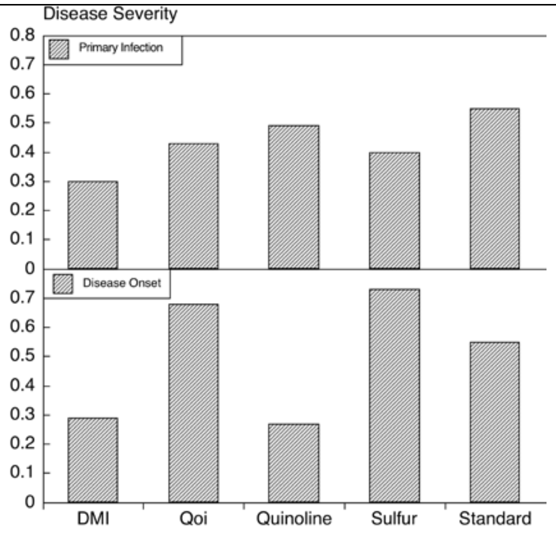


Figure 3. Severity of powdery mildew on 'Bing' cherries when fungicide programs were initiated at predicted primary infection (upper graph) or disease onset (lower graph) using different fungicide chemistries.

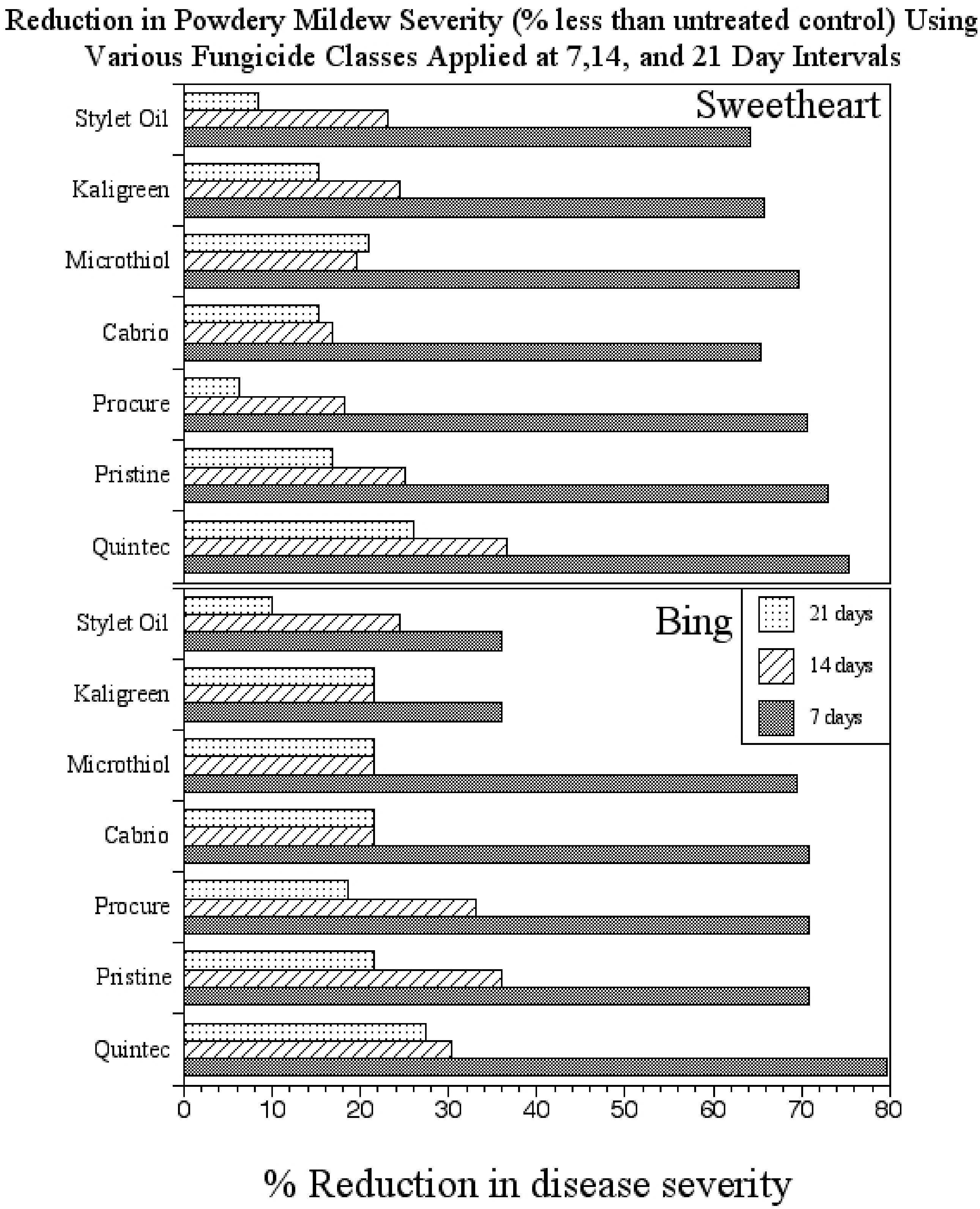
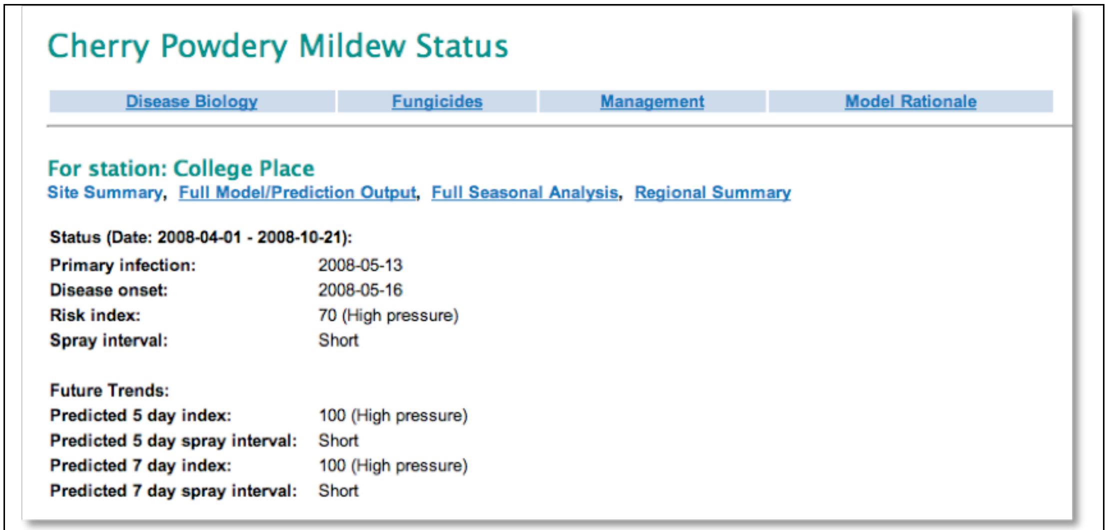


Figure 4. Effect of application interval on reduction of powdery mildew on 'Bing' and 'Sweetheart' cherries under extreme disease pressure. X axis expresses the % reduction in disease severity attained in untreated controls.



Cherry Powdery Mildew Status

For station: College Place

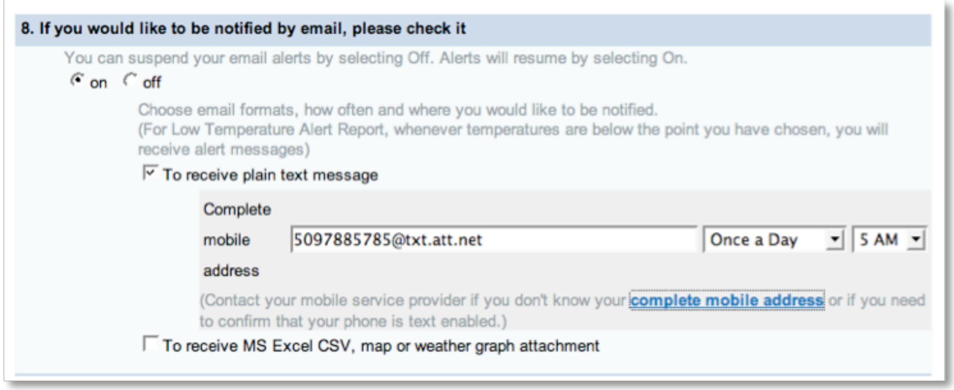
Status (Date: 2008-04-01 - 2008-10-21):

Primary infection:	2008-05-13
Disease onset:	2008-05-16
Risk index:	70 (High pressure)
Spray interval:	Short

Future Trends:

Predicted 5 day index:	100 (High pressure)
Predicted 5 day spray interval:	Short
Predicted 7 day index:	100 (High pressure)
Predicted 7 day spray interval:	Short

Figure 5. Summary model output from WSU-AWN College Place weather station. Note that dates of primary infection, disease onset, and current and predicted disease indices and spray intervals are presented. Summary outputs are also available using “push” technologies.



8. If you would like to be notified by email, please check it

You can suspend your email alerts by selecting Off. Alerts will resume by selecting On.

● on ○ off

Choose email formats, how often and where you would like to be notified.
(For Low Temperature Alert Report, whenever temperatures are below the point you have chosen, you will receive alert messages)

☑ To receive plain text message

Complete mobile address: 5097885785@txt.att.net | Once a Day | 5 AM

(Contact your mobile service provider if you don't know your complete mobile address or if you need to confirm that your phone is text enabled.)

☐ To receive MS Excel CSV, map or weather graph attachment

Figure 6. Configuration page for “push” model outputs available from WSU AgWeatherNet.

Executive Summary

Validation and Implementation of the WA cherry powdery mildew model

Gary G. Grove

The Northwest Powdery Mildew Model was developed over a period of years using controlled-environment and field studies. The current model is comprised of three components. Components 1 and 2 are used to predict primary infection while component 3 is used to predict the onset of disease in the orchard and to adjust the intervals between sprays. Components 1 and 2 were validated in the orchard using air sampling and PCR studies, while component 3 was validated were validated using disease progression studies across three cultivars. Efforts during this two- year study were focused in improving the model, developing management recommendations, and distributing model outputs to growers. Significant improvements were made in the temperature algorithms used to generate the second infection risk index and the identification of water-based frost protection as a mechanism to promote ascospore release. The model was also used to conduct disease control studies focused on the unique characteristic of each fungicide class. It was demonstrated that any of the synthetic fungicide classes and sulfur could be used to initiate fungicide programs if commenced at *primary infection*. Conversely, the initiation of programs *at disease onset* requires the use of a DMI or quinoline fungicide. Concurrent studies indicated that irrespective of fungicide mode-of-action application intervals should not exceed 14 days. Fungicide performance at 21-day intervals was inconsistent and is therefore not recommended. The model and associated recommendations were made available on the AgWeatherNet web site in 2007. The model was updated in 2008 with improved temperature algorithms, improved interface, and the inclusion of text message and email functions that "push" model outputs to client cell phones, PDA's, or computers. A new and inclusive interface is being developed for WSU-DAS. All model functionality will be transferred to DAS once the new interface is complete.