Testing an Italian Model that Predicts Pear Scab Ascospore Release Based on Orchard Temperature and Wetness Conditions

INTERIM REPORT 2007

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Summary

Pear scab, caused by the fungus *Venturia pirina*, is an important disease in California that can reduce yield and quality. It is most damaging in the North Coast, but depending on the year and weather conditions, it can cause significant losses in the Delta. In the interest of saving money and protecting the environment, pear growers are looking for ways to improve their management of pear scab through increased efficacy of targeted fungicide use. Several weather-based models have been developed for describing the various stages in disease development and use in guiding fungicide applications. Some models such as Spotts & Cervantes 1991 predict infection events based on the interaction of plant surface wetness and temperature conditions and then curative fungicide applications are made based on this information. Other models (Spotts & Cervantes 1994) predict the maturity of the ascospores which can cause these primary infections on susceptible pear tissue. Knowing when these spores are mature and present in the orchard can be combined with information about weather conditions that enable the spores to infect pears to improve the efficiency of fungicide applications, more than if just infection conditions alone are known. However, trapping the ascospores and counting them directly is a tedious and specialized lab-based technique.

Objective 1. We tested a model developed in Italy (Rossi et al. 2000) to see if it could be used to predict ascospore capture based on weather variables measured in orchards. What seems to be key to understanding and controlling pear scab in California, and Italy, is not only wetness periods and when they occur and temperatures during those wetness periods, but also dry periods and how often and when they occur. These weather variables affect both ascospore release (and subsequent possible capture) and also whether those released spores can then infect susceptible pear tissue. The model developed by Rossi et al. 2000 attempts to use weather variables as inputs to calculate a wetness based degree day model (above 0 C, or 32 F) that might enable growers to know when inoculum is predicted to be present without having to trap spores. This information could then be combined with either the Mills Tables model or the Spotts & Cervantes 1991 infection risk model to determine when infection conditions are also present, and then control actions could be taken

if these two models indicate that the conditions coincide, and of course that susceptible host tissue is present. If the Rossi model predicts that most or all ascospores have been released then even if an infection event occurs, growers could ignore this information and not apply a fungicide. Conversely, if the Rossi model predicts early ascospore releases (and early exhaustion of spore load) before susceptible tissue is present, even if infection conditions also occur, no action for control needs to be taken.

Working with UC IPM programmers, we have developed a user-friendly tool, an MS excel spreadsheet version of the Rossi et al. 2000 model, to use in testing the validity of using the Rossi apple scab model in California pears.

We report here preliminary results from using that model with archival data collected in the 1998 and 1999 seasons at two locations in Mendocino County, Potter Valley and Talmage. This work was originally conducted by Doug Gubler and his lab and UCCE cooperators Chuck Ingels and Rachel Elkins with funding by the California Pear Board and Pear Pest Management fund, and with UC IPM funding. Their objective was to evaluate the Spott and Cervantes 1994 ascospore maturity model using spore trap data, spore maturity tests, and the collection of weather data. Preliminary results from our work show that the Rossi model predicted ascospore captures quite well in the 1999 season at both locations, but was less valuable in predicting ascospore captures in the 1998 season, where it was late in predicting the increase in spores released by several days to up to 4 weeks at the beginning and the ending of the ascospore release season. Further analysis of their data is planned and will provide more detailed information about the value of using this approach.

Objective 2. We set up a trial in the 2007 season in an organic pear orchard in Sacramento County, Eagle Point, with a continuous-run Burkhardt spore trap and 15 minute weather data collected and stored at the UC IPM web site to further test the Italian model under Sacramento conditions. We also evaluated the Spotts & Cervantes 1991 cumulative degree hours while wet model for infection conditions at this site, and the Spotts & Cervantes 1994 ascospore maturity model based on degree day accumulation. Some data collection is still ongoing (the spore trap counts from preserved microscope slides from Eagle Point 2007) and some additional data analysis is needed to determine the goodness of fit of the Rossi model for the three seasons (1998, 1999, 2007) weather data and spore catches. Therefore we can not yet report how well the Rossi model worked for Sacramento in 2007, but will in our final report later in 2008. We did run the two Spotts & Cervantes models with weather data from the Delta and report below on the results from this season. This season in the Sacramento Delta there was little to no scab observed in the Eagle Point orchard under study, nor in surrounding orchards.

The Spotts & Cervantes 1991 model predicts pear scab infection events based on temperature and wetness conditions that are very similar to the Mills Tables conditions for apple scab. During periods of leaf wetness, temperatures above 32 F contribute to the accumulation of degree-hours. The infection period ends when a continuous 12 hours of dryness is recorded. Then the degree hours are reset to zero and stay there until the next wetness period begins. The model predicts that a scab infection period has occurred when **320 degree hours** have accumulated. The model is being adapted and will be made available in the future at the Oregon State University IPPC website (http://ippc2.orst.edu/hr/). Working with the web site and model developers, we had them run weather data from a nearby weather station, Twitchell Island, through the model to assess predicted infection periods for the 2007 season for the area around the Eagle Point orchard. According to the model, there were very few weather related wetness and temperature events that could lead to infection and subsequent disease this 2007 season. Starting at March 5, 2007 with bud swell, a month and a half went by before conditions occurred that were capable of causing infection. Then the Spotts & Cervantes 1991 model predicted 2 infection events in mid to late April, and one in early May. Although I could not yet run our Eagle Point weather data through the Oregon state version of the Spotts & Cervantes 1991 model at this time, it looks like our weather station detected similar weather events which would have resulted in possible infection if inoculum were present and host tissue susceptible.

The Spotts and Cervantes 1994 model predicts maturity of ascospores of *V. pirina* to be closely related to accumulated degree-days with a base temperature of 32° F, starting with a biofix of bud swell. The Oregon researchers have determined that the primary spore season ends when 1620 degree days (DD) have accumulated, followed by at least 0.01 inch of rain or dew for spore discharge. If the orchard is free of scab up to this date, no additional fungicide applications are necessary for the season, regardless of subsequent infection periods. At the Oregon IPPC website (http://ippc2.orst.edu/hr/), we entered our Eagle Point weather data (daily max. and min. temperatures in F) and then calculated the cumulative degree days for the Eagle Point orchard. The biofix for this model is delayed dormant stage 1 (bud swell), estimated to have occurred on March 5, 2007 in this orchard. The model predicted that by April 4, 2007, 831 DD had accumulated which means the ascospore season was half over. By May 4, 2007, the model predicted 100% ascospore maturation and with 0.01 inches of rain the season would be over. However, no additional rain occurred.

Some data collection is still ongoing (spore trap counts from preserved microscope slides from Eagle Point 2007) and some additional data analysis is needed to determine the goodness of fit of the Rossi model for the archival and past season's weather and spore catches. Therefore we have requested an extension of the grant to complete the project. This is an interim report.

Objective 1. Develop tools to allow growers to understand when the few periods of peak ascospore discharge per year are upon them, without trapping spores. Test a Northern Italian apple scab model (Rossi et al. 2000) as a method for predicting California ascospore captures based on a cumulative degree day model (degree days accumulate only during wetness hours and T above 32 F (0 C)).

Develop MS Excel version of the Rossi apple scab model

We worked with UC IPM programmers to develop an MS excel version of the Rossi apple scab model (Figure 1), and see attached first generation version. The first generation spreadsheet version of the model is fairly user-friendly. The set up they have used can also accommodate other disease models and the handling of weather data inputs in the future. Weather data should be hourly averages and include temperature in degrees C, and minutes of leaf wetness per hour based on a resistance leaf wetness grid. It is also advisable to include hourly percent relative humidity and precipitation data in the weather data set for interpretation and interpolation if there is missing data. However, this data is not needed as inputs to the model as we are currently running it. The weather data is imported into the spreadsheet and then the model calculations are embedded in a prearranged and programmed worksheet with user friend tabs that enable the user to set up parameters (such as start date), and run the model to calculate daily degree days while wet, cumulative degree days while wet, and then predicted Percent Ascospores Trapped (PAT). A plot of PAT is also then set up to run in the spreadsheet at the click of a tab. We realize that leaf wetness sensors and data can be problematic, due to lack of proper maintenance and so it's possible with further testing, we will recommend use of relative humidity or other data as a proxy for leaf wetness.

Use weather and spore trap data from the 1998 and 1999 seasons in Mendocino County to test Rossi apple scab model for use in California pear orchards.

We obtained archival data from our cooperator University of California extension plant pathologist Dr. Doug Gubler. This data set included two years of Burkhardt spore trap data for the 1998 and 1999 seasons for two locations labeled "Potter Valley" and "Talmage". We also obtained hourly temperature (°F), percent relative humidity, precipitation and leaf wetness data originally collected from the same orchards where the spore traps were placed. This data was kindly provided by Ag Unlimited with preliminary processing (turning 15 minute data into hourly averages, transforming data into metric format) by Adcon International to facilitate our use. We then transformed the Adcon style leaf wetness readings, which are reported on a scale of 1-10, with 3 and above being wet, into the format required by the UC IPM version, which is the number of minutes that are wet in an hour.

We then used these data, originally collected to test the Spott & Cervantes 1994 model for predicting ascospore maturity, to test the Rossi et al. 2000 cumulative degree-day wetness model (for degree days above 32 F) for predicting ascospore capture.

Gubler et al. Spore Trapping Methods

Continuous-run 7-day spore traps (1) were operated at Talmage and Potter Valley, during the 1998 and 1999 spring seasons. The vacuum was supplied by an internal turbine pump which maintained a flow of approximately 10 L/min for the duration of the trial. Spools were wrapped with acetate tape and coated with a thin layer of gelvetol. The traps were placed on top of a leaf pile 6-7 feet in diameter and several leaves deep. The bait leaves were collected from orchards with heavy disease pressure: in 1998 from an organic orchard in Philo, Mendocino Co., and in 1999 from an abandoned orchard in Scotts Valley which was also the source of the leaf samples for the study on model validation. Each weekly tape was brought back to the lab and processed for spore counting. The total length of tape exposed to the spore trap intake was measured, and compared to the total time the trap was deployed for that week in order to determine the accuracy of the clock. The tape was cut into 24 hr-size pieces, and taped from the edges onto a microscope slide. Spore counts were made under a compound microscope (Olympus CH-2) at 400x in 4 longitudinal passes of each tape, noting the slide holder micrometer reading of beginning and end of each tape. The location of each spore occurrence was also recorded with the micrometer. The time of each spore occurrence was determined by resolving the tape weekly replacement time with the micrometer readings, after adjusting for any clock inaccuracy.

The spore traps operated with a clock accuracy of 1 to 2 hours/week. The clock inaccuracy was adjusted for each week mathematically when converting spore location to time, to improve the time precision of the recorded spore catch. On one occasion, the trap for Potter Valley malfunctioned due to the spool slipping on the spindle (apparently due to a loose spool nut), resulting in 3 days of missing data. No other missing data occurred during the season. Spore readings were condensed to hourly totals for each day, in order to facilitate examination. The acetate tape which collected the spores is 19 mm in width, equal to 42 fields-of-view at 400x with our microscope. Four passes represents 4/42, or 9.5%, of the tape, and the spore counts represent approximately 9.5% of all spores on the tape.

Gubler et al. Spore Trap Results.

In the 1998 season, at Potter Valley spores were trapped from February 10, 1998 to April 12, 1998 for a total of 61 days and 4,628 spores were counted which leads to an estimate of 48,716 spores total caught in the trap. At the Talmage site in 1998, spores were first trapped at February 1, 1998 until April 13, 1998 for a total of 72 days and 12,422 spores total were counted which means approximately 130,575 spores may have been caught in the trap.

In the 1999 season, ascospores in Potter Valley were observed from February 5 to May 21 1999, a total of 106 days, and at Talmage from January 19 to May 21, 1999, a total of 123 days. The number of ascospores counted from the spore traps at Potter Valley and Talmage was 6,880 and 3,135, respectively. The total number of spores caught in the 2 traps was estimated to be 72,400 at Potter Valley and 33,000 at Talmage in 1999.

The number of spores trapped per day was then used to calculate the Percent of Ascospores trapped (PAT) per day for the season for each year and location.

Rossi et al. 2000 Model Evaluation.

We obtained the 1998 and 1999 weather data from the two sites from Ag Unlimited and Adcon International in November 2007. We have not yet had time to conduct a complete analysis of the goodness of fit of the Rossi model for the two years of weather data and spore trapping results. However, we did run the data through the UC IPM version of the Rossi model.

Preliminary results look promising. We graphed the actual and predicted results for Potter Valley 1998 (Figure 2) and Potter Valley 1999 (Figure 3), and Talmage 1998 (Figure

4) and Talmage 1999 (Figure 5). The predicted values were closer at both locations in the 1999 season, as compared to the 1998 season. In the 1998 season at both locations the model was slower to predict an increase in the percent ascospores trapped and lagged behind the actual observed spore trap data by a few days to up to 4 weeks at each location. We still need to conduct further analysis including "goodness of fit" analysis for the model and the data to state definitely how well the model worked or did not work.

However, one key issue for this model is the biofix point. As this model is a logistical model it is very important when it starts. For this archival data analysis we used the actual first day spores were trapped as the biofix point to start the model because we had that data. However, in the interest of not having to trap spores and have specialized equipment and knowledge, Rossi et al. 2000 proposed the use of an additional model that uses weather data variables as inputs to predict the biofix, or starting point, and then run the spore capture prediction model. The biofix model used by Rossi is a modification of the one developed by James and Sutton in 1982 to predict ascospore maturation and modified by the Italian researchers Mancini et al. in 1984. Initially in Italian trials, Rossi also used a calendar date of February 1 as a rough estimate for starting the model. We still have not run the Rossi et al. 2000 model using the biofix estimates based on the Mancini model and it's possible this might improve its performance, if perhaps some initial spores were missed during the original data collection in the 1998 season, although this is unlikely. We will test this possibility and report in our final report.

Objective 2. Collect new ascospore trap data along with orchard based weather data in a Sacramento organic orchard to "ground truth" the approach in objective 1 above and test the Rossi model under Sacramento conditions.

2007 Eagle Point Trial – Spore Traps and Weather Data

In an organic orchard which was abandoned this season (Eagle Point) in Sacramento County (38 deg 26 min N / 121 deg 32 min W, elevation: 12 ft) and had a history of pear scab, we placed a Burkhardt 7-day continuous-run spore trap on March 5, 2007 at 12:45 PM in the second row of the pear orchard on River Road. Leaves from the orchard were piled around the opening of the spore trap. Pear trees were estimated to be at bud swell at this point. Earlier in the season, on February 25, 2007, the trees in this orchard were estimated to be at delayed dormant. Spore trap tapes were run for a week at a time and then taken to Doug Gubler's lab for preservation and later analysis. By one week later, March 12, 2007, we changed the spore tape for the first time and the pear trees were then estimated to be between tight cluster and finger bud. On March 25, 2007 the orchard was estimated to be in first bloom, and by April 3, 2007 in full bloom. According to the PCA for this site, this orchard was about a week later than neighboring orchards due to it being abandoned and not having received a dormant oil treatment or been pruned.

On March 15, 2007 at noon we placed a Campbell Scientific UC IPM CR10X weather station that collected temperature, relative humidity, precipitation and leaf wetness on a 15 minute basis. The station stored hourly and daily data including max and min. temperatures, hour of max or min., precipitation and chill hours. This weather data was obtained daily by UC IPM through automated polling of the station using a digital cell phone service. The data was checked for errors and posted on the UC IPM web site at http://www.ipm.ucdavis.edu/calludt.cgi/PCSTATIONDATA?MAP=&STN=Eagle_Point-01.P0015&SCALE=15. Earlier season weather data was supposed to be collected by an on site Spectrum weather station owned by the PCA for the location, however, it turns out the station was not functioning properly and so no data was available. However, we were able to use weather data from a nearby station, at Russell Road, from February 1, 2007 through March 15, 2007, and then used the on-site UC IPM weather station for the rest of the season.

Pear Scab Incidence

Unfortunately after all the early season work collecting weather data and spore trapping data, little disease was observed at this orchard this season. At the first two disease ratings on April 23, 2007 and April 30, 2007 we observed small bacterial-like lesions but no identifiable pear scab lesions. At the final disease rating on June 4, 2007 we found a few fruit lesions that were taken to UC Davis plant pathology department and were confirmed to contain pear scab conidia. We rated 50 fruit and 50 leaves from the 5 surrounding trees and found 2 to 6 % of fruit infected with 1-3 lesions. We did not find any leaf lesions. According to Broc Zoller, this low level of disease may have been due to the fact that it was an abandoned orchard and had been managed organically for several years prior to being abandoned (pers.comm.). Broc Zoller visited the orchard in May 23, 2007 and also found some scab lesions on fruit, but only on more vigorous trees further into the orchard. The trees in general in this orchard appeared to lack vigorous growth which may lead to less disease. This was despite earlier years when high levels of pear scab had been found in the orchard and by harvest mature fruit were severely impacted by the disease.

The collected weather data, disease incidence, and spore trap data were used to test model performance of the Rossi model in predicting potential ascospores trapped based on degree day accumulation of temperatures during wetness events. We also used these data to test the Spotts & Cervantes models to assess pear scab infection events and the ascospore maturity season.

Eagle Point 2007 Spore Trap Results

Tapes that held seven days of spore trap data were collected each week from the spore trap, taken to D. Gubler's lab and processed for later reading with a compound microscope. The tapes were carefully removed from the cylinders, aligned on a plastic marked plexiglass ruler and 24 hour pieces of the tape were removed, placed on to a microscope slide with 250 ul of spore preservative solution gelvetol. Tapes were placed face down onto this solution and the viscous liquid was gently pushed out to the edges to complete the seal and preservation of the tape and spores on it.

Microscope slides were later placed under the microscope at 400 x and four transects were run, noting ascospore numbers at each 2 mm interval, which would be per hour. Spore readings were condensed to hourly totals for each day and daily totals, in order to facilitate analysis. The acetate tape which collected the spores is 19 mm in width, equal to 42 fields-of-view at 400x with our microscope. Four passes represents 4/42, or 9.5%, of the tape, and the spore counts represent approximately 9.5% of all spores on the tape. Hourly, daily and seasonal totals of ascospores caught in a known volume of air sampled in this orchard are currently being determined. In addition we will be able to estimate the total number caught in the trap and the proportion of the total spore load captured on any one day. We will report when spores were first detected, and for how long they were detected.

Rossi et al. 2000 Model Evaluation

We chose to start the Rossi model on February 1, 2007 as an estimate of when ascospores might be sufficiently mature to be released. We were not trapping spores that early in the season at that location. However on March 5, we did collect old leaves from the ground and we found some pseudothecia present with mature ascospores, so we know that the biofix for this orchard should have been before then.

We have not yet finished the spore trap counts, we have at least another two months to assess and therefore can not compare model predictions with actual spores trapped. We hope to do this in the next month or so.

Spotts & Cervantes 1991 Pear Scab Infection Period Model – cumulative degree hours wet

This model (Spotts & Cervantes 1991) predicts pear scab infection events based on temperature and wetness conditions that are very similar to the Mills Tables conditions for apple scab. However, it was developed on pears for the pear scab pathogen in Oregon. During periods of leaf wetness, temperatures above 32 F contribute to the accumulation of degree-hours. Temperatures above 66 are kept at 66 because studies indicate the development rate of pear scab ascospores does not increase above this temperature. The infection period ends when a continuous 12 hours of dryness is recorded. Then the degree hours are reset to zero and stay there until the next wetness period begins. The model predicts that a scab infection period has occurred when **320 degree hours** have accumulated.

The model is being adapted and will be made available in the future at the Oregon State University IPPC website (http://ippc2.orst.edu/hr/). Working with the web site and model developers, we had them run weather data from a nearby weather station, Twitchell Island, through the model to assess predicted infection periods for the 2007 season for the Eagle Point orchard. This weather station however does not include a leaf wetness sensor nor do numerous stations in the Oregon network, therefore they are using an algorithm to predict leaf wetness based on relative humidity and temperature and dew point calculations. They are not yet set up for us to run our weather data through their web site but should be in the future (Figure 7).

This season in the Sacramento Delta there was little to no scab observed in the area, nor in the Eagle Point orchard under study. According to this model, there were very few weather related wetness and temperature events that could lead to infection and subsequent disease this 2007 season. Using the nearby weather data from Twitchell Island including calculated wetness data, the Spott & Cervantes 1991 model predicted 3 infection events. If we assume scab infection is possible from bud swell onward, estimated to have occurred on March 5, 2007, then a whole month and a half went by before an infection event occurred. The first one was estimated to have occurred on April 14, 2007 starting at 5 AM a rain related wetness event began to be measured which ran throughout the day and by 9 PM an infection scab cycle was predicted to have started. The wetness event continued until April 15, 2007 at 5 AM, by which time enough degree hours had accumulated to predict an ascospore infection event.

Again on April 21, 2007, at 7 PM a rain related wetness event began and by April 22, 2007 at 7 PM enough degree hours had accumulated to indicate an infection event had occurred.

Finally, on May 3 at 3 PM a wetness event began which ran until May 4 at 10 AM and accumulated enough degree hours to predict a possible infection event (figure 7).

Although I could not run our Eagle Point weather data through the Oregon state version of the Spotts & Cervantes model at this time, it looks like our weather station detected similar weather events which would have resulted in possible infection if inoculum were present.

Spotts & Cervantes 1994 Pear Scab Infection Season Ascospore Maturity Model – cumulative degree days over 32 F

Spotts and Cervantes 1994 model predicts maturity of ascospores of *V. pirina* to be closely related to accumulated degree-days with a base temperature of 32° F, starting with a biofix when bud scales separate (stage 1, delayed dormant). The Oregon researchers have determined that the primary spore season ends when 1620 degree days (DD) have accumulated, followed by at least 0.01 inch of rain or dew for spore discharge. If the orchard is free of scab up to this date, no additional fungicide applications are necessary for the season, regardless of subsequent infection periods.

At the Oregon IPPC website (http://ippc2.orst.edu/hr/), we entered our Eagle Point weather data (daily max. and min. temperatures in F) and then clicked on column 4 "pear scab season", entered information in the appropriate boxes, and then calculated the cumulative degree days for the Eagle Point orchard. The biofix chosen based on an estimate of bud swell was March 5, 2007. The model predicted that by April 4, 2007, 831 DD had accumulated which means the ascospore season was half over. By May 4, 2007, the model predicted 100% ascospore maturation at cumDD 1635 and with 0.01 inches of rain or a dew-based wetness event for ascospore release, and as there was no scab in the orchard, the season was predicted to be over. See the following for the print out of the results **http://ippc2.orst.edu/cgi-bin/ddmodel.pl?spp=asp and figure 8.**

Comparing the Models at Sacramento 2007

The Rossi et al. 2000 model predictions for the percent of ascospores trapped are similar to the Spotts & Cervantes 1994 predictions for ascospore maturation, although Spotts & Cervantes 1994 are predicting ascospore maturation based on temperature only, and Rossi et al. 2000 are predicting ascospore release based on temperature and wetness conditions. Looking at the Eagle Point 2007 run of the Rossi model, (Figure 6) by 4/4/07 the Rossi et al. 2000 model predicts almost 30% of the ascospores have been trapped as compared to 50% of the spores being mature according to Spotts & Cervantes 1994, and by 5/4/2007 almost 98% of the ascospores would be predicted to have been trapped according to Rossi et al. 2000, and according to Spotts & Cervantes 1994, 100% of ascospores would be mature and the "season over."

If we attempt to look at how the two Spotts & Cervantes models line up with each other in the 2007 season and how this relates to disease, we find that the infection events happened within the time frame that the ascospore maturity model predicts between 50-100% of the ascospores were mature. Therefore there were ascospores mature and a few infection conditions (3) present at the same time, and no fungicides were applied in this abandoned orchard. Very little disease was observed at this orchard in the 2007 season. This may be due to the abandoned nature of the orchard and the limited number of infection events later in the ascospore maturity season. It might also be due to the fact that the ascospore maturation model is based only on temperature degree day accumulation, whereas the Rossi et al. 2000 model is based on temperature degree day accumulation and wetness factors combined.

If we attempt to look at how the Spotts & Cervantes 1991 infection model predictions line up with the Rossi et al. 2000 model predictions of ascospore capture, we find that the 2007 season conditions that might lead to infection are closer to the end of the predicted ascospore trapping dates, with April 14/15 occurring at DDC 286, and 94% of all ascospores were predicted to have been trapped, April 21/22, occurred at DDC 294-298 and 97% of ascospores were predicted to have been trapped, and May 4 happening at DDC 311 and 98% of all ascospores were predicted to have been captured. Therefore, it appears possible that the release of ascospores was happening prior to weather events that could lead to actual pear tissue infection and most of the spore load was gone by the time the events that could lead to infection occurred. Once we finish the spore trap readings we can confirm this possibility. We can also more thoroughly compare how the Rossi et al. 2000 model predictions compare with the use of the Spotts & Cervantes 1994 approach for predicting the end of the ascospore season under California conditions.

Remaining data collection and analysis – January 2008 to September 30, 2008

There remains two months of slide spore trap data still to analyze from the 2007 season at Eagle Point orchard. The slides are preserved and will be read in January and final calculations of percent spores trapped calculated and then compared to the Rossi model predictions.

We intend to finish our statistical analysis of the goodness of fit of the Rossi model for the 3 seasons, Eagle Point 2007, Potter Valley 1998 and 1999, and Talmage 1998 and 1999. This will involve further plotting the results of the spore trap data collected in 1998 and 1999 against the range of model estimates based on the weather variable inputs and then counting the number of points which fall inside and outside this range, over the whole season of ascospore trapping.

We will also look at the seasons separately for the lag phase (that is when 20% of the season's ascospores are discharged, $PAT \leq 0.2$), the accelerated phase (when 70% of the season's ascospores are discharged, $0.2 < PAT \leq 0.9$), and the final phase (when the final 10% of the season's ascospores are discharged, $PAT > 0.9$) (MacHardy, 1996). Furthermore, we will analyze errors made by the model in estimating PAT, by calculating the differences 'observed minus estimated'. Ascospore trappings (dependent variable) will be regressed against model estimates (independent variable) and the properties of the linear model will be examined: the null hypothesis that a (intercept of regression line) is equal to zero, and b (slope of regression line) is equal to one will be tested using the Student t-test: $ta = (a-0)/SEa$; $tb = (b-1)/SEb$. If the t-test for a and b are not significant, then both null hypotheses can be accepted and the model can be considered a statistically accurate estimator of the observed data (Teng, 1981).

We plan to send a copy of the model to Rossi in Italy for him to evaluate how well we captured his model and inquire about work in the past year on a pear scab model.

References:

Gubler W.D. 1999. Report on "Potential of fall application of lime, lime-sulfur and urea in reducing pear scab inoculum in overwintered leaves and validation of a model predicting ascospore maturation." Pear pest management research fund.

James J.R., and Sutton T.B., 1982. A model for predicting ascospore maturation of Venturia inaequalis. Phtopathology 72: 1081-1085.

Jones, A.L., and H. S. Aldwinkle, 1991. Compendium of Apple and Pear Diseases, APS Press, St. Paul, MI. 100 pages.

Mancini G., A. Cotroneo, and A. Galliano 1984. Evaluation of two models for predicting ascospore maturation of Venturia inaequalis in Piedmont (NW Italy). Rivista di Patologia Vegetale 20:25-37.

Mills, W. D. 1944. Efficient use of sulfur dusts and sprays during rain to control apple scab. Cornell Ext. Bull. 630.

Spotts, R. A., and L. A. Cervantes. 1991. Effect of temperature and wetness on infection of pear by *Venturia pirina* and the relationship between preharvest inoculation and storage scab. Plant Dis. 75:1204-1207.

Spotts, R. A. and L.A. Cervantes 1994. Factors affecting maturation and release of ascospores of Venturia pirina in Oregon. Phytopathology 84:260-264.

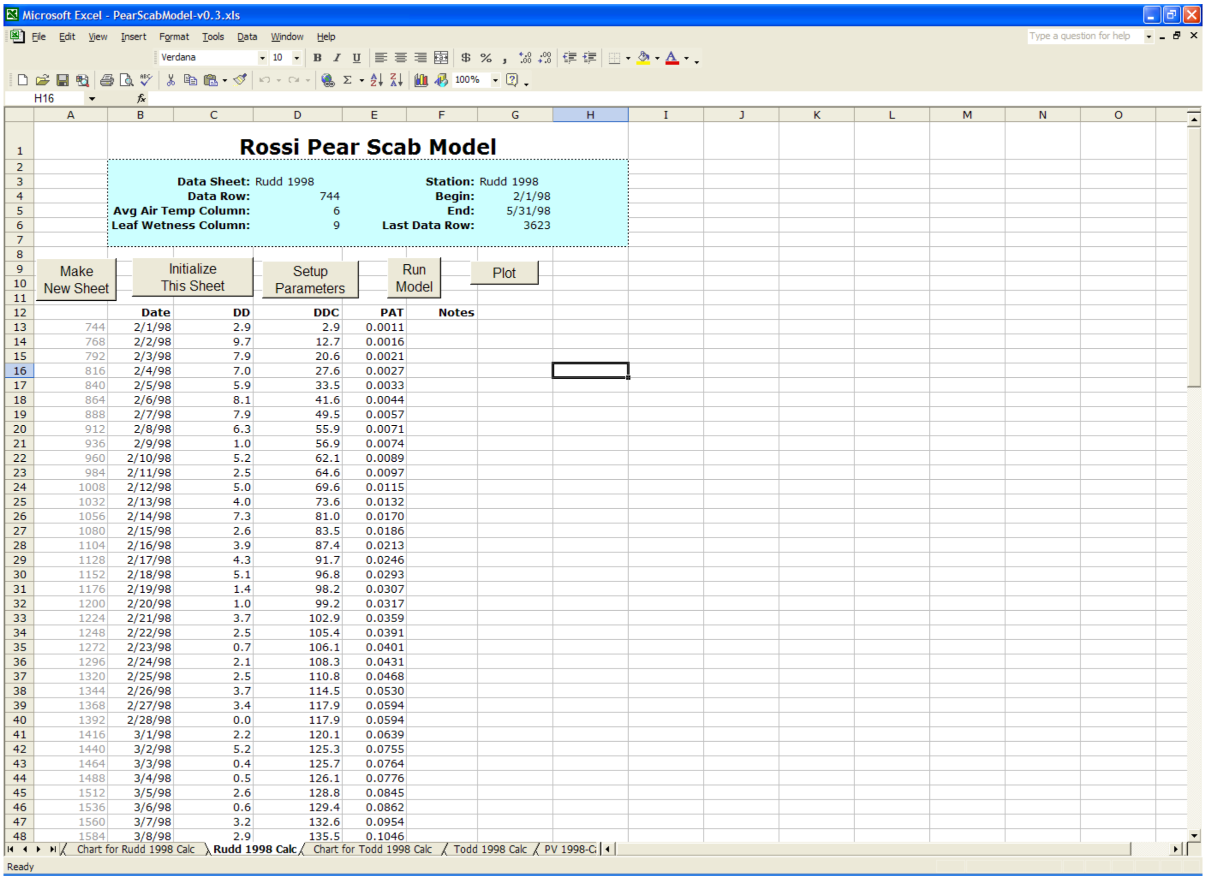
University of California, 1999. Integrated Pest Management for Apples and Pears, Second Edition, ANR publication # 3340, 231 pages.

U. Mass Amherst 2004. New England Apple Pest Management Guide, 2003-2004. Scab management strategies, Available on-line at http://www.umass.edu/fruitadvisor/NEAPMG/12-17.pdf.

Rossi, V., I. Ponti, M. Marinelli, S. Giosue and R. Bugiani. 1999. Field evaluation of some models estimating the seasonal pattern of airborne ascospores of *Venturia inaequalis.* Journal of Phytopathology 147:567-575.

Rossi, V., I. Ponti, M. Marinelli, S. Giosuè and R. Bugiani 2000. A New Model Estimating The Seasonal Pattern Of Air-Borne Ascospores Of Venturia Inaequalis (Cooke) Wint. In Relation To Weather Conditions. Journal of Plant Pathology (2000), 82 (2), 111-118.

Rossi, V., S.Giosue and R. Bugiani. 2003. Influence of air temperature on the release of ascospores of *Venturia inaequalis*. Journal of Phytopathology 151:50-58.



Microsoft Excel - PearScabModel-v0.3.xls

Rossi Pear Scab Model

Data Sheet:	Rudd 1998	**Station:**	Rudd 1998
Data Row:	744	**Begin:**	2/1/98
Avg Air Temp Column:	6	**End:**	5/31/98
Leaf Wetness Column:	9	**Last Data Row:**	3623

Make New Sheet | Initialize This Sheet | Setup Parameters | Run Model | Plot

	Date	DD	DDC	PAT	Notes
744	2/1/98	2.9	2.9	0.0011	
768	2/2/98	9.7	12.7	0.0016	
792	2/3/98	7.9	20.6	0.0021	
816	2/4/98	7.0	27.6	0.0027	
840	2/5/98	5.9	33.5	0.0033	
864	2/6/98	8.1	41.6	0.0044	
888	2/7/98	7.9	49.5	0.0057	
912	2/8/98	6.3	55.9	0.0071	
936	2/9/98	1.0	56.9	0.0074	
960	2/10/98	5.2	62.1	0.0089	
984	2/11/98	2.5	64.6	0.0097	
1008	2/12/98	5.0	69.6	0.0115	
1032	2/13/98	4.0	73.6	0.0132	
1056	2/14/98	7.3	81.0	0.0170	
1080	2/15/98	2.6	83.5	0.0186	
1104	2/16/98	3.9	87.4	0.0213	
1128	2/17/98	4.3	91.7	0.0246	
1152	2/18/98	5.1	96.8	0.0293	
1176	2/19/98	1.4	98.2	0.0307	
1200	2/20/98	1.0	99.2	0.0317	
1224	2/21/98	3.7	102.9	0.0359	
1248	2/22/98	2.5	105.4	0.0391	
1272	2/23/98	0.7	106.1	0.0401	
1296	2/24/98	2.1	108.3	0.0431	
1320	2/25/98	2.5	110.8	0.0468	
1344	2/26/98	3.7	114.5	0.0530	
1368	2/27/98	3.4	117.9	0.0594	
1392	2/28/98	0.0	117.9	0.0594	
1416	3/1/98	2.2	120.1	0.0639	
1440	3/2/98	5.2	125.3	0.0755	
1464	3/3/98	0.4	125.7	0.0764	
1488	3/4/98	0.5	126.1	0.0776	
1512	3/5/98	2.6	128.8	0.0845	
1536	3/6/98	0.6	129.4	0.0862	
1560	3/7/98	3.2	132.6	0.0954	
1584	3/8/98	2.9	135.5	0.1046	

Chart for Rudd 1998 Calc | Rudd 1998 Calc | Chart for Todd 1998 Calc | Todd 1998 Calc | PV 1998-C

Ready

Figure 1. Output of the MS excel version 1.0 of the Rossi apple scab model for evaluation on California pears.

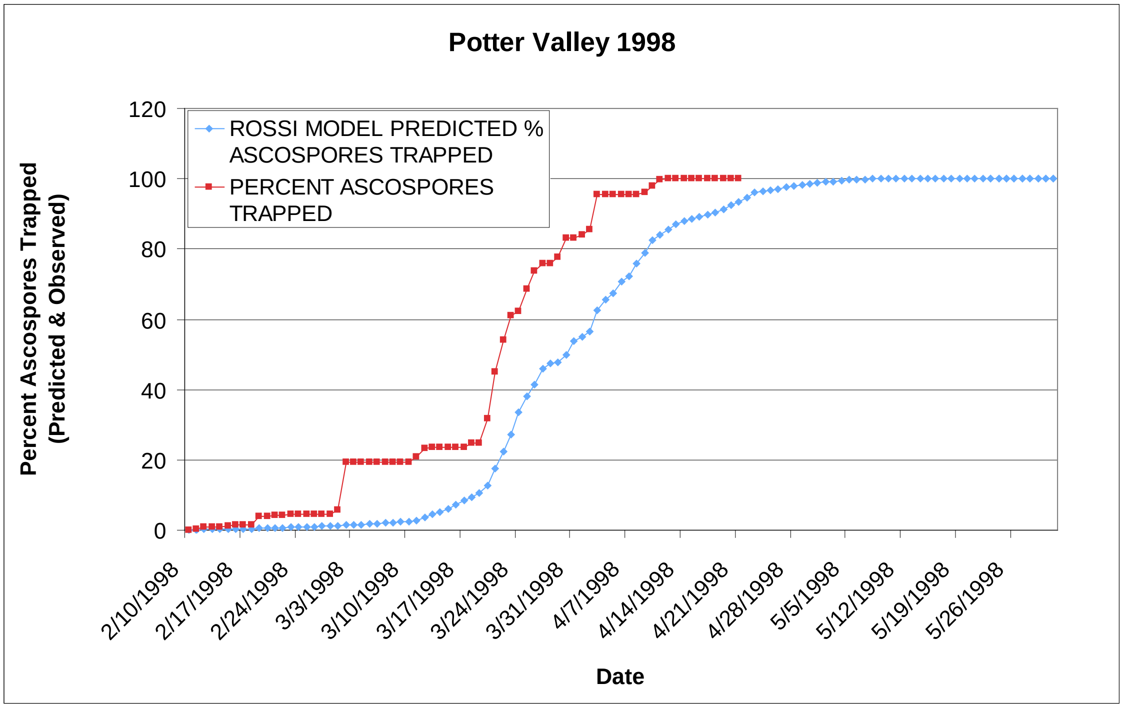


Figure 2. Potter Valley percent of ascopores trapped in the 1998 season and predicted percent ascospores trapped according to the Rossi model.

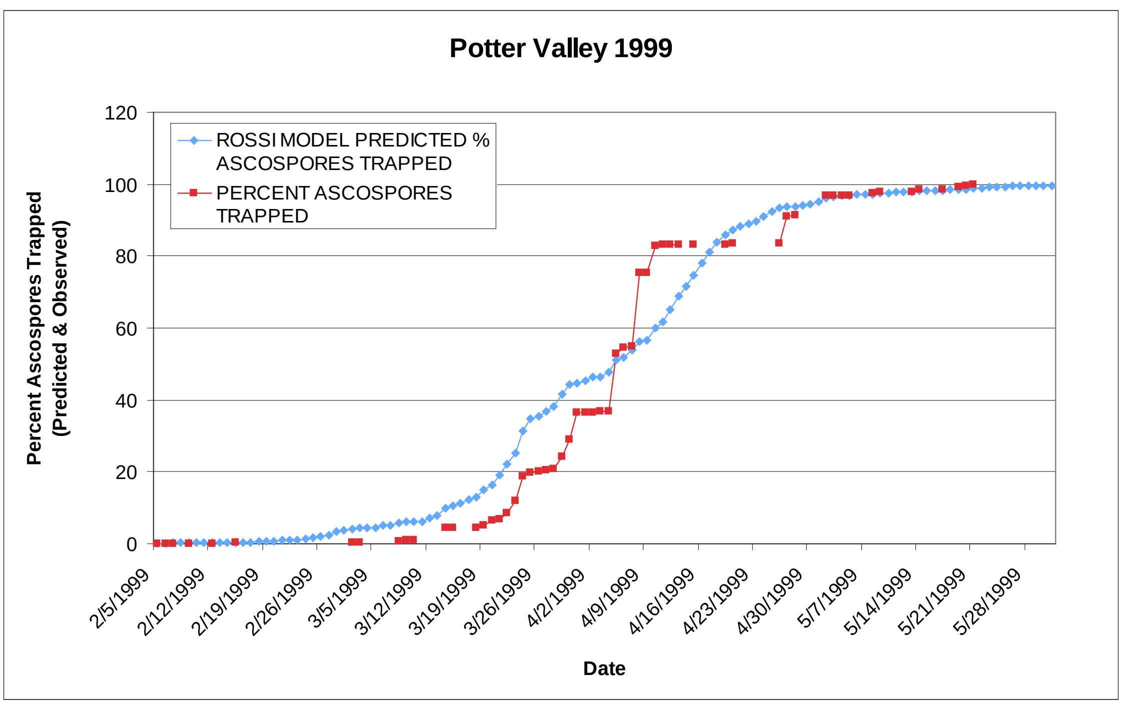


Figure 3. Potter Valley percent of ascospores trapped in the 1999 season and predicted percent ascospores trapped according to the Rossi model.

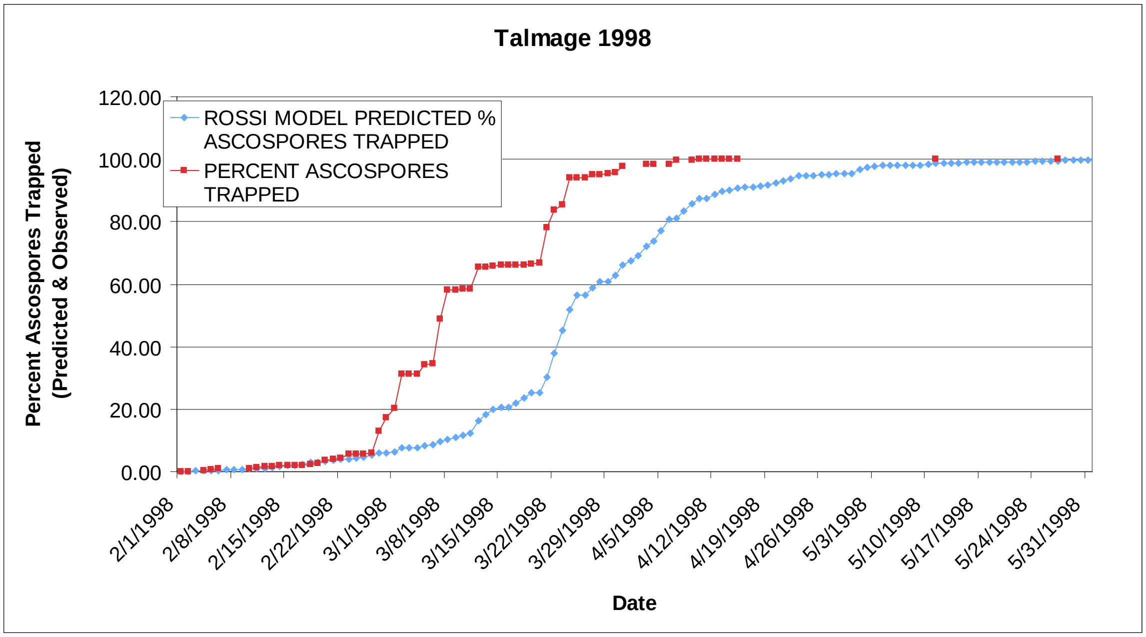


Figure 4. Talmage percent of ascopores trapped in the 1998 season and predicted percent ascospores trapped according to the Rossi model.

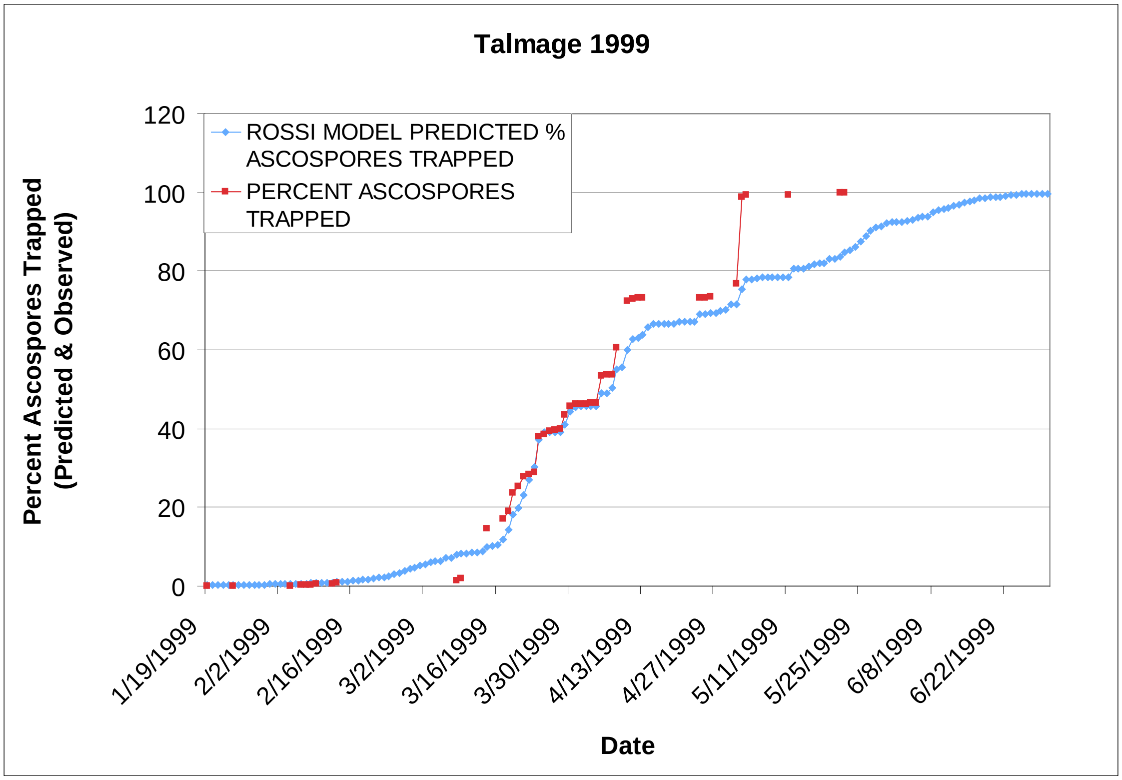


Figure 5. Talmage percent of ascopores trapped in the 1999 season and predicted percent ascospores trapped according to the Rossi model.

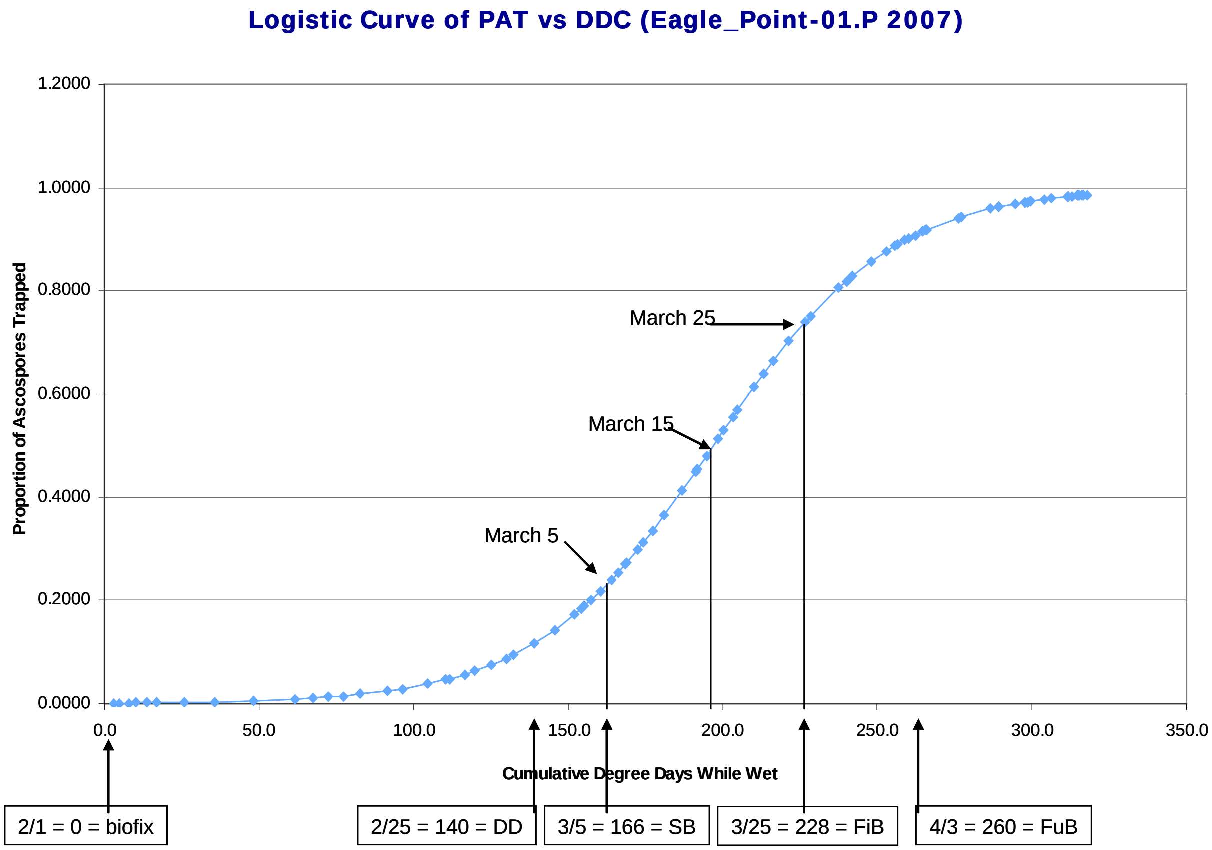


Figure 6. Eagle Point weather data used to predict Proportion of Ascospores Trapped (PAT) in a Sacramento Delta pear orchard, 2007 season. **Does not yet include actual ascospores trapped at this location for comparison.** Model estimates are indicated for predicted 25% of spores trapped on March 5, 50% on March 15, and 75% on March 25, 2007. Pear phenological stages and dates are shown at the base on the graph, where 2/1 was the biofix date, 2/25 is DD = delayed dormant, 3/5 is SB = swollen bud, 3/25 is FiB = first bloom, and 4/2 is FuB = full bloom.

Figure 7. Spotts ascospore infection model output, using Twitchell Island weather data, for 2007 season, Sacramento Delta. Available online at http://pnwpest.org/cgi-bin/risk_model/risk_models?start_month=02&start_day=1&span=150&station=CI140&models=pear_scab&weather_params=temp&weather_params=leafwet

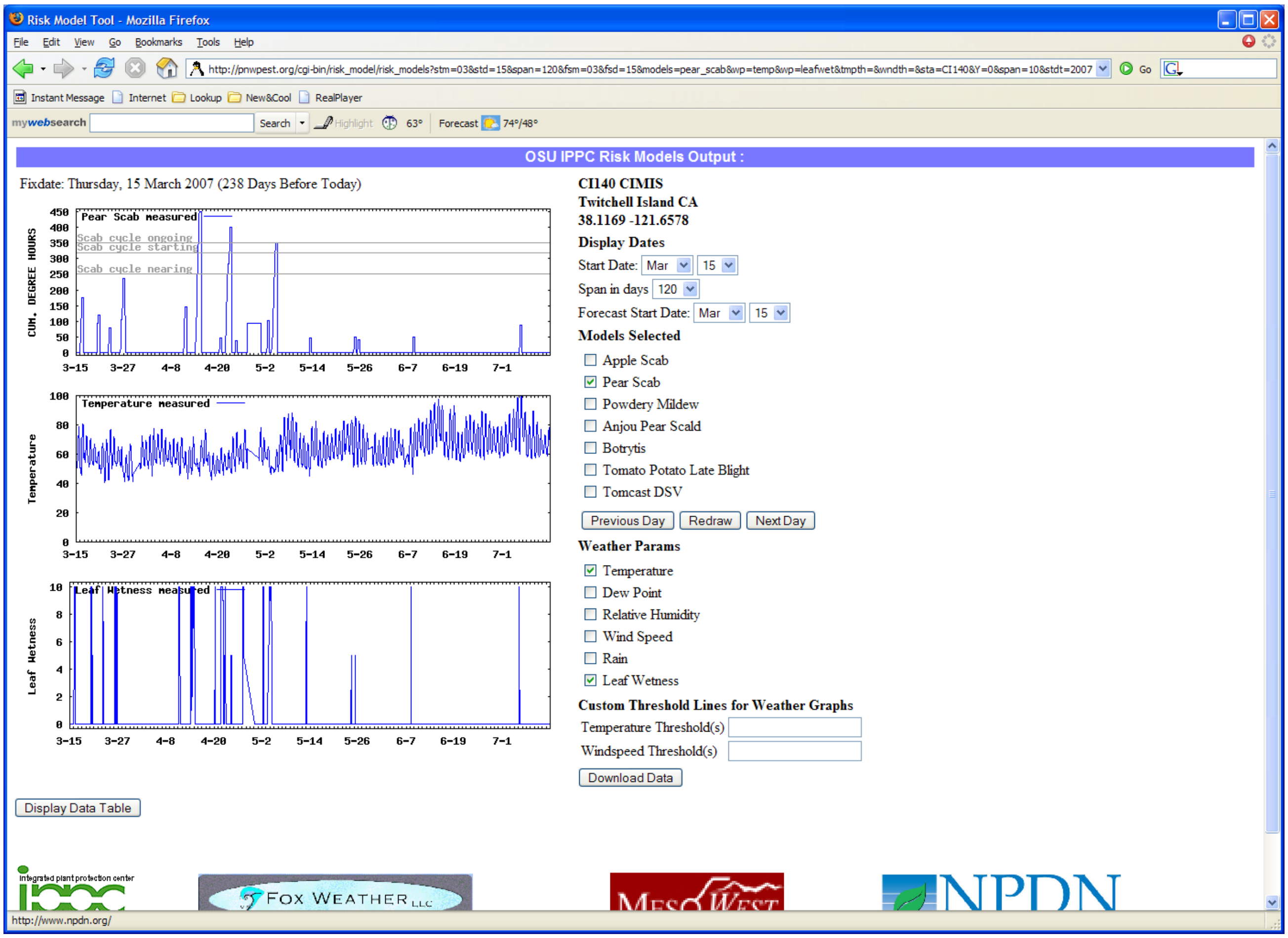
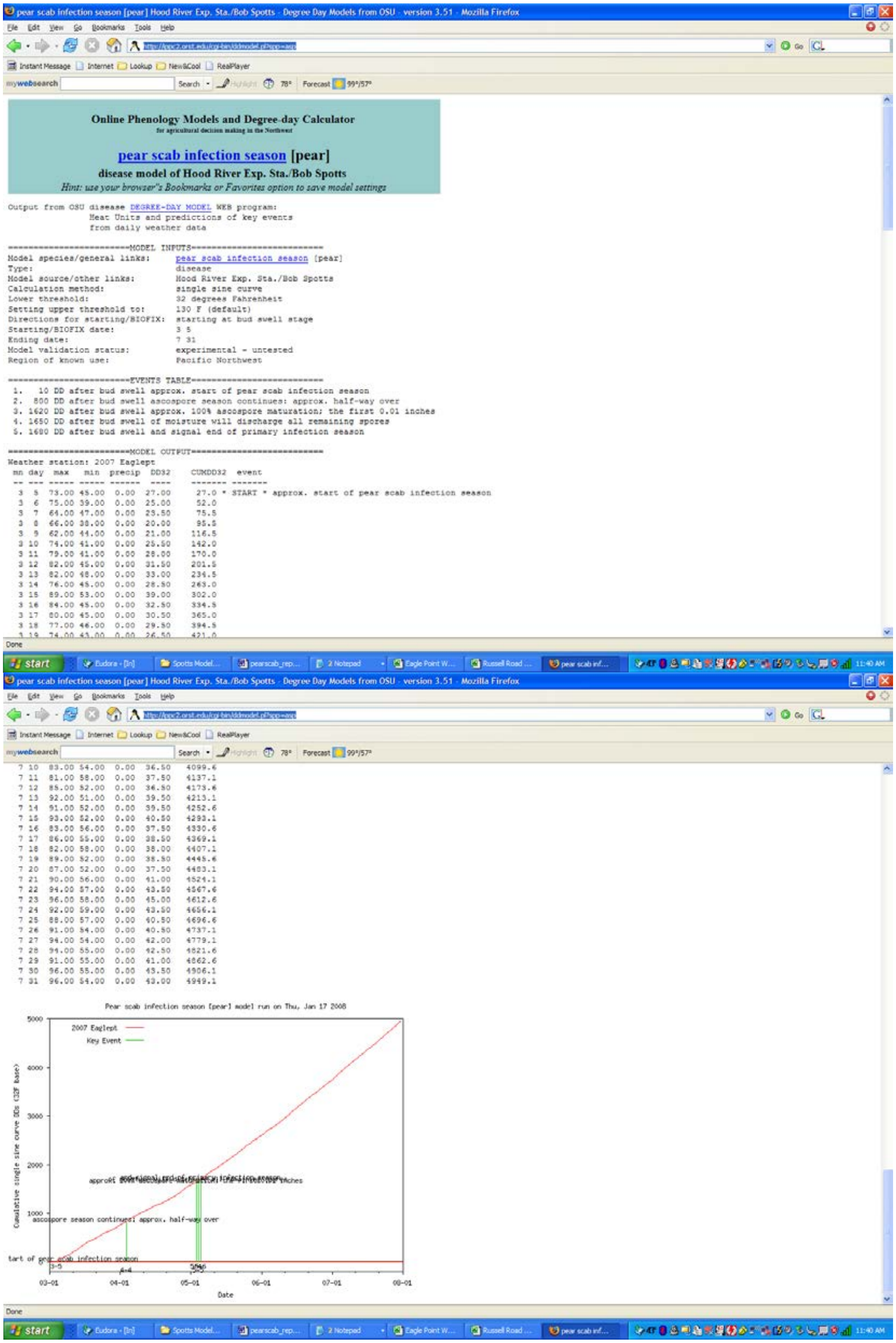


Figure 8. Spott's pear scab infection season output for predicting ascospore maturity based on daily max. and min. temperatures in F. Available online at http://ippc2.orst.edu/hr/



Online Phenology Models and Degree-day Calculator
for agricultural decision making in the Northwest

pear scab infection season [pear]
disease model of Hood River Exp. Sta./Bob Spotts
Hint: use your browser"s Bookmarks or Favorites option to save model settings

```
Output from OSU disease DEGREE-DAY MODEL WEB program:
                Heat Units and predictions of key events
                from daily weather data

=======================MODEL INPUTS========================
Model species/general links:      pear scab infection season [pear]
Type:                             disease
Model source/other links:         Hood River Exp. Sta./Bob Spotts
Calculation method:               single sine curve
Lower threshold:                  32 degrees Fahrenheit
Setting upper threshold to:       130 F (default)
Directions for starting/BIOFIX:   starting at bud swell stage
Starting/BIOFIX date:             3 5
Ending date:                      7 31
Model validation status:          experimental - untested
Region of known use:              Pacific Northwest

=======================EVENTS TABLE========================
 1.   10 DD after bud swell approx. start of pear scab infection season
 2.  800 DD after bud swell ascospore season continues: approx. half-way over
 3. 1620 DD after bud swell approx. 100% ascospore maturation; the first 0.01 inches
 4. 1650 DD after bud swell of moisture will discharge all remaining spores
 5. 1680 DD after bud swell and signal end of primary infection season

=======================MODEL OUTPUT========================
Weather station: 2007 Eaglept
```

mn	day	max	min	precip	DD32	CUMDD32	event
3	5	73.00	45.00	0.00	27.00	27.0	* START * approx. start of pear scab infection season
3	6	75.00	39.00	0.00	25.00	52.0	
3	7	64.00	47.00	0.00	23.50	75.5	
3	8	66.00	38.00	0.00	20.00	95.5	
3	9	62.00	44.00	0.00	21.00	116.5	
3	10	74.00	41.00	0.00	25.50	142.0	
3	11	79.00	41.00	0.00	28.00	170.0	
3	12	82.00	45.00	0.00	31.50	201.5	
3	13	82.00	48.00	0.00	33.00	234.5	
3	14	76.00	45.00	0.00	28.50	263.0	
3	15	89.00	53.00	0.00	39.00	302.0	
3	16	84.00	45.00	0.00	32.50	334.5	
3	17	80.00	45.00	0.00	30.50	365.0	
3	18	77.00	46.00	0.00	29.50	394.5	
3	19	74.00	45.00	0.00	26.50	421.0	
7	10	83.00	54.00	0.00	36.50	4099.6	
7	11	81.00	58.00	0.00	37.50	4137.1	
7	12	85.00	52.00	0.00	36.50	4173.6	
7	13	92.00	51.00	0.00	39.50	4213.1	
7	14	91.00	52.00	0.00	39.50	4252.6	
7	15	93.00	52.00	0.00	40.50	4293.1	
7	16	83.00	56.00	0.00	37.50	4330.6	
7	17	86.00	55.00	0.00	38.50	4369.1	
7	18	82.00	58.00	0.00	38.00	4407.1	
7	19	89.00	52.00	0.00	38.50	4445.6	
7	20	87.00	52.00	0.00	37.50	4483.1	
7	21	90.00	56.00	0.00	41.00	4524.1	
7	22	94.00	57.00	0.00	43.50	4567.6	
7	23	96.00	58.00	0.00	45.00	4612.6	
7	24	92.00	59.00	0.00	43.50	4656.1	
7	25	88.00	57.00	0.00	40.50	4696.6	
7	26	91.00	54.00	0.00	40.50	4737.1	
7	27	94.00	54.00	0.00	42.00	4779.1	
7	28	94.00	55.00	0.00	42.50	4821.6	
7	29	91.00	55.00	0.00	41.00	4862.6	
7	30	96.00	55.00	0.00	43.50	4906.1	
7	31	96.00	54.00	0.00	43.00	4949.1	