

A Web-based Decision Support Tool for Timing Fungicide Applications in Strawberry¹

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Introduction

Plant disease decision support systems are management tools to help growers in assessing the risk of disease epidemics on their farms. The use of such a system enables growers to apply their fungicides only when the conditions are favorable for disease so that they can avoid unnecessary sprays and reduce production costs.

Equations to predict the severity of anthracnose and Botrytis fruit rots based on temperature and leaf wetness duration were evaluated in field trials during the past four strawberry seasons. Our field trials have shown that fungicide applications could be reduced by half in some years by following the recommendations of the system without affecting disease control and fruit quality. The best treatment for each disease was incorporated into the Web-based decision support system to make recommendations on timing of fungicide applications for control of anthracnose and Botrytis fruit rot epidemics on strawberries. The Web-based decision support system has been developed as a tool under *AgroClimate*. *AgroClimate* (<http://agroclimate.org>) is a climate

forecast and decision support system (Fraisse et al., 2006) developed by the Southeast Climate Consortium (SECC) in partnership with the Cooperative State Extension Service (<http://seclimate.org>). The main purpose of *AgroClimate* is to help agricultural producers reduce risks associated with climate variability in the southeastern USA.

Strawberry Diseases

Anthracnose fruit rot, caused by *Colletotrichum acutatum* (Smith, 1998), and Botrytis fruit rot, caused by *Botrytis cinerea* (Sutton, 1998), are the most important diseases for production of annual strawberries in Central Florida and worldwide. *C. acutatum* affects the foliage, runners, crowns and fruit. It is favored by temperatures greater than 65°F and wet weather (> 12h of Leaf Wetness – LW). Losses due to anthracnose can exceed 50% when conditions favor disease development, even in well-managed fields (Turechek et al., 2006). It is very difficult to control when conditions are favorable.

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Botrytis fruit rot is an important pre-harvest and post-harvest disease of strawberry affecting the floral parts, including stamens and petals. The spores are wind and splash-dispersed and the fungus requires free moisture (> 4h of LW) and temperatures between 60 and 72°F to infect and sporulate. The disease can be controlled by a combination of cultural practices and chemical methods. Strawberry cultivars vary in susceptibility, but no cultivar is completely resistant to the disease (Legard et al., 2005).

In Florida, the current recommended control for anthracnose and Botrytis fruit rots is based on weekly applications of fungicides during the season (Mertely and Peres, 2009; Mertely and Peres, 2006).

Web-based Disease Decision Support System

The information available in the *AgroClimate* Strawberry Disease Tool includes the monitoring of weather data and forecast of disease incidence. The information is displayed in a GIS format using Google Maps API, a free Web mapping technology, developed by Google, currently used in many systems around the world (Del Ponte et al., 2007).

Since the maps supplied by Google are based on satellite imagery and worldwide information, users of this tool can interact with the map, through page movements and zoom. Each point on the map is associated with specific information and can be viewed as text or as images. Beside points, polygons are drawn and overlap on the map providing information about the area in focus and allowing the user to delimitate county boundaries in Florida.

The system was developed to facilitate the inclusion of new diseases and locations (stations). It is completely dynamic with different levels of users who handle the information.

The Strawberry Disease Tool, when loaded, displays to the user a page divided in five different sections (Figure 1). Section A (Figure 1A) shows information about the *AgroClimate* portal, the current climate El Niño Southern Oscillation (ENSO) phase¹, language options and other tools. In section B (Figure 1B), the user can easily find the currently

available weather stations. When a specific weather station is selected, the map in section D (Figure 1D) is moved to the corresponding location showing information related to the selected station. The option "Draw/Clean the limits of the County" enables the user to turn on or off the boundaries of the county where the station is installed.

Current news and important messages prepared by the Extension specialists are presented in section C (Figure 1C). Important links, contact information, and the gate to the administration page are found in the section E (Figure 1E). The core of the system is found in the map (Figure 1D) in section D. All the functions developed for the system are presented in this area.

The components of the system were divided in four sections listed below:

1. Map of strawberry-producing regions showing weather stations with a color flag for the current disease risk level (High risk, Moderate risk, or No risk);
2. Spray recommendations for Botrytis and anthracnose based on a list of questions about previous fungicide applications and the stage of crop development;
3. Model outputs in graphic and table formats indicating risk levels (High risk, Moderate risk, or No risk) based on weather data observed at the selected station and forecast for the next 3 days using data from the National Weather Service (NSW) pinpoint forecast; and
4. Display of weather data observed during the most recent 24-hour period and the forecast for the next 24-hours.

Simple tools that can provide the information in a clear and objective way are usually sought by decision-makers. Based on this idea, the system starts by showing the available weather stations, using different colors to quickly show whether conditions are favorable for diseases or not (Figure 1D). We used three different colors in this case: green (No risk), yellow (Moderate risk) and red (High risk). By passing the mouse over the stations, the user can

check the name of that weather station and which specific diseases are affecting that area.

If more information is needed, users can select the weather station with a simple click and get more specific information in a balloon (Figure 2). If the information available is sufficient, the system can be closed. If still more information is needed to make a decision, the user can click on the link to check recommendations or on the button "+" available on the top of balloon, which is expanded and presents a list of questions to guide the recommendation.

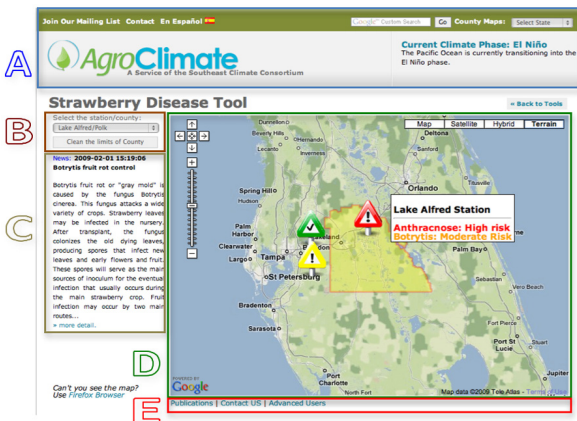


Figure 1. The Main Web Page for the Strawberry Diseases Tool.

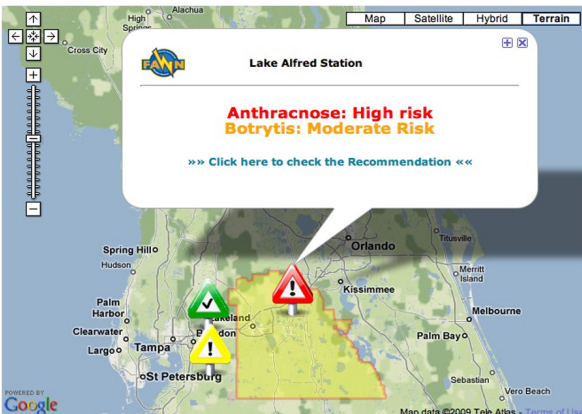


Figure 2. Current Risk Level Flag.

Fungicide Spray Recommendations

With the presence of either moderate or high-risk levels, a list of questions is displayed and the user must enter the required information before a recommendation is provided by the system (Figure 3). In this case, the recommendation is based on a set of rules that take into account previous fungicide applications and the current stage of development of

the crop. Once the responses are entered, the system applies the rules and displays the recommendation for each of the diseases in the form of one of the following messages:

1. No spray!
2. Spray Systemic Fungicide (Products recommended: LIST²)
3. Spray Contact Fungicide (Products recommended: LIST²)

Registered producers have also the option of storing the date, location and type of product used (systemic or contact) when applications were made in their computers. This kind of information can be used for the next infection events, replacing the list of questions.



Figure 3. Spray recommendation.

Disease Simulation Outputs

The disease simulation models are automatically processed every hour and their results are presented through the "Disease Simulation" tab on the Web tool. Figure 4 demonstrates how the results are presented, showing a plot of infection index values for each of the diseases, Botrytis and Anthracnose, depending on the tab selected. The plots show simulated infection indices for the last 45 days. The dashed line (right side of the plot) indicates the forecast infection index level for the next three days. As in the main map (station markers), the thresholds are divided into three colors: green (No risk), yellow (Moderate risk) and red (High risk). A disease alert is considered when the line crosses the moderate level

threshold. When the user clicks on the graph, an expanded window is opened, allowing the visualization of details.

Below the graph, the disease simulation outputs are presented in a tabular format. Each line in the table contains the date, number of uninterrupted hours of leaf wetness, temperature in degrees Fahrenheit and Celsius, disease infection index (0-1), and a respective description of disease level (No risk, Moderate risk or High risk). The disease simulation can be observed up to the current date and time, as well as for the next three days based on the weather forecast.

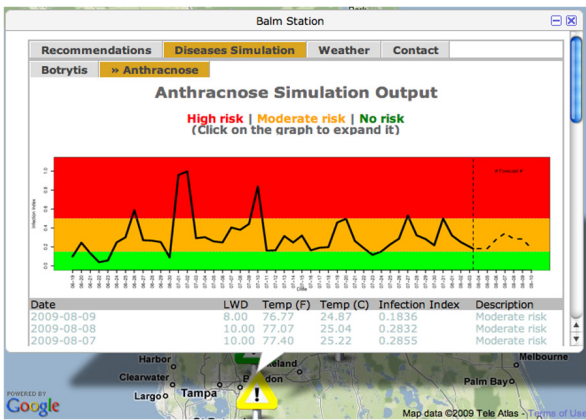


Figure 4. Model outputs in graphic and table formats.

Weather Data

The observed weather and short-term forecast provided by the Florida Automated Weather Network (FAWN) and National Weather Service – National Digital Forecast Database (NWS-NDFD), respectively, are presented through the "Weather" tab. Such information is useful for decision-making, assisting the users in understanding the weather phenomena associated with diseases. This component presents weather variables for the last 24 hours, such as temperature, relative humidity, rain, leaf wetness duration, and the mean temperature during the wet period. The same structure is used to show the prediction for the next 24 hours ("Forecast" sub-tab) (Figure 5).

E-mail and Short Message Service

E-mail and Short Message Service technologies (SMS) will be available during the strawberry season to provide information to producers and Extension

agents rapidly. The system automatically sends SMS messages (Figure 6) and e-mails to registered users whenever the infection index calculated crosses an established threshold.

The communication via SMS is reasonably inexpensive and gives the system the ability to communicate with users at any time. SMS is a successful technology already in use in other systems (Pavan et al., 2006).

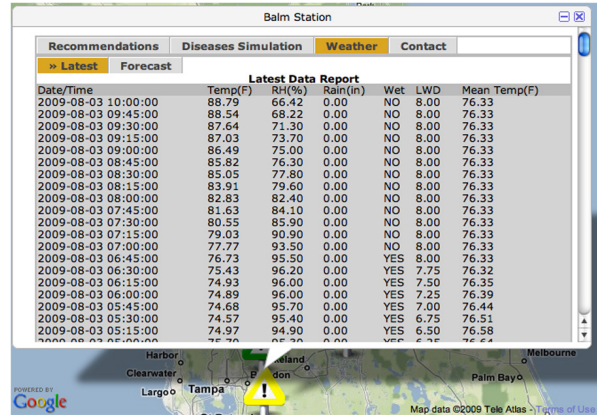


Figure 5. Weather Data (observed and forecast).



Figure 6. Short Message Service (SMS) with disease alert.

Conclusions

The strawberry disease decision support system was evaluated in replicated field trials during the last 2 to 4 strawberry seasons and was also evaluated by a producer in a commercial strawberry farm during the 2008/2009 season. In most cases, the number of fungicide applications (sprays) was reduced to about

half without any significant loss of yield or quality. The use of the system can help growers to reduce the number of sprays and the cost of production especially in years when the conditions for disease are not favorable.

This internet-based decision support system will enable strawberry growers to easily access the information necessary for making decisions concerning fungicide applications. The benefits of such a tool is that growers will be able to apply fungicides only when conditions are favorable for disease development, thus reducing the number of applications and production costs without compromising disease control.

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¹*ENSO phases are related to sea surface temperatures (SST) in the eastern equatorial Pacific Ocean. When the SST is higher than normal, the phenomenon is referred to as El Niño. When the SST is lower than normal, the phenomenon is referred to as La Niña. When the temperature is normal, the event is referred to as Neutral.*

²*List of fungicides recommended for each disease based on results from our trials.*