The Strawberry Advisory System: A Web-Based Decision Support Tool for Timing Fungicide Applications in Strawberry

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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 systems enables growers to apply fungicides only when conditions are favorable for disease so that they can avoid unnecessary sprays and reduce production costs.

Equations to predict anthracnose and Botrytis fruit rots based on temperature and leaf wetness duration were evaluated in field trials during four strawberry seasons. Our results 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 Strawberry Advisory System, a web-based decision support system to make recommendations on timing of fungicide applications for control of anthracnose and Botrytis fruit rot epidemics on strawberries. SAS was developed as a tool under AgroClimate (http://agroclimate.org), and it can also be found on the FAWN website (http://fawn.ifas.ufl.edu). AgroClimate is a climate forecast and decision support system developed by the Southeast Climate Consortium (SECC) in partnership with the Cooperative State Extension Service to help agricultural producers reduce risks associated with climate variability in the southeastern United States.

Strawberry Diseases

Anthracnose fruit rot, caused by Colletotrichum acutatum, and Botrytis fruit rot, caused by Botrytis cinerea, are the most important diseases for production of annual strawberries in Central Florida and worldwide. C. acutatum affects the foliage, runners, crowns and fruit. Its development 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.

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 (>6h of LW) and temperatures between 60°F 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.
In Florida, the current recommended control for anthracnose and Botrytis fruit rots is based on preventive applications of fungicides throughout the season.

The Strawberry Advisory System

The information available in the AgroClimate Strawberry Advisory System includes the monitoring of weather data and forecast of disease incidence. The information is displayed in a GIS format using Google Maps. 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.

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 Advisory System, when loaded, displays to the user a page divided into five different sections (Figure 1). Section A (Figure 1A) shows information about the AgroClimate portal, the current climate El Niño Southern Oscillation (ENSO) phase\(^1\), 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 articles 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 section D in the map (Figure 1D). All functions developed for the system are presented in this area.

The components of the system are divided in the 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 Low risk) (Figure 2);
2. Spray recommendations for Botrytis and anthracnose based on a list of questions about previous fungicide applications and the stage of crop development (Figure 3);
3. Model outputs in graphic and table formats indicating risk levels (High risk, Moderate risk, or Low risk) based on weather data observed at the selected station and forecast for the next two days using data from the National Weather Service (NSW) pinpoint forecast (Figure 4); and
4. Display of weather data during the most recent 48-hour period (Figure 5).

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). Three different colors were used in this case: green (Low 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.

**Fungicide Spray Recommendations**

With the presence of either moderate- or high-risk disease 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: LIST)
3. Spray Contact Fungicide (Products recommended: LIST)

**Disease Simulation Outputs**

The disease 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 indexes for the last 30 days. The dashed line (right side of the plot) indicates the forecast infection index level for the following two days. As in the main map (station markers), the disease risk thresholds are divided into three colors: green (Low 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 (Low risk, Moderate risk or High risk). The disease simulation can be observed up to the current date and time.

**Weather Data**

The observed weather provided by the Florida Automated Weather Network (FAWN) is 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 48 hours, such as temperature, relative humidity, rain, leaf wetness duration, and the average temperature during the wet period (Figure 5).

**E-mail and Short Message Service**

E-mail and Short Message Service (SMS) technologies are 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.

**Conclusions**

The Strawberry Advisory System has been evaluated in research field trials for several strawberry seasons and has also been evaluated by commercial strawberry farms during the past three seasons. In most cases, the number of fungicide applications (sprays) was reduced 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.

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.**