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Blueberry Advisory System: A Disease Alert System for Blueberry Anthracnose Fruit Rot[1]

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Introduction

Plant disease alert systems are developed to facilitate the management of crop diseases. These systems are especially useful for diseases that are not easy to predict, do not occur at the same level of severity every season, and can potentially cause yield losses under otherwise favorable growing conditions. Blueberry anthracnose fruit rot (AFR) is an important disease for blueberry growers in Florida that has those characteristics—the weather conditions favoring disease incidence and development can be difficult to predict, and it can significantly impact yield under conducive weather patterns. For that reason, we developed and validated a web-based disease alert system for blueberry AFR, the Blueberry Advisory System (BAS), to help blueberry growers in Florida identify weather conditions favorable for the disease and improve disease management. Our goal was to allow for a more sustainable AFR management program, restricting fungicide applications to only those times when necessary, reducing disease management costs, reducing selection pressure for fungicide resistance, and serving as an educational tool for growers to learn AFR dynamics in the field.

Blueberry Anthracnose Fruit Rot (AFR)

Blueberry AFR is primarily caused by *Colletotrichum gloeosporioides*in Florida (Phillips et al. 2018). The most typical symptoms of the disease occur during fruit ripening, including sunken lesions on the fruit and, in advanced stages, an orange gelatinous mass of spores erupting from the lesions (Figure 1). Anthracnose symptoms can also be seen as leaf spots and stem lesions, but their severity varies depending on cultivar susceptibility. Although most spores are produced during fruit infection, the pathogen can survive and produce spores on vegetative tissue when flowers are present, even when symptoms are not visible on those tissues (Waller et al. 2018). This is especially true in evergreen systems, where the prior year foliage carries over to the following season. Infection and spore production are dependent on inoculum levels and environmental favorability, and they can occur as early as bloom, with the infection not producing visible symptoms until fruit ripening and harvest.

Figure 1. Typical symptoms of blueberry anthracnose fruit rot (AFR) on fruit under wet conditions. Note the bright orange mass of spores.
Credit: Andre B. Gama

Favorable conditions for Blueberry AFR are temperatures between 59°F and 81°F when plants are wet for more than 12 h due to rain, dew, or overhead irrigation. The spread of conidia (fungal spores surrounded by orange-colored masses on the fruit) occurs by water splash during rainfall or overhead irrigation. Under ineffective management and favorable conditions, significant yield losses may occur pre- and postharvest.

Management practices to control AFR include cultural controls and fungicide applications. Cultural controls include avoiding the use of overhead irrigation when possible, postharvest pruning to open the plant canopy for better airflow, harvesting fruit soon after ripening, cooling

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the fruit as soon as possible after harvesting, and regular sanitizing of harvesting and packing equipment.

Fungicide applications should be initiated after postharvest hedging to control anthracnose on leaves and stems (particularly in evergreen systems), and may continue through bloom and the next harvest, especially under weather conditions favorable for AFR (Phillips et al. 2018). It is important to choose labeled fungicides that are effective against anthracnose and apply them at the right times to prevent yield losses. In the past, quinone-outside inhibitor (QoI) fungicides were generally effective in controlling AFR. QoIs are common systemic fungicides labeled for AFR, such as Cabrio and Abound. However, field studies conducted to validate the BAS found that more than 97% of *C. gloeosporioides*isolates collected on a blueberry farm in LaBelle in 2018 and 2019 were resistant to the QoI fungicides. Given the widespread resistance to fungicides in the QoI group, we suggest not using these fungicides alone for AFR management in areas where resistance is present. Instead, broad-spectrum fungicides such as Captan 80 WDG and the systemic fungicide Switch 62.5WG should be rotated.These fungicides are effective against AFR, and Captan tank-mixed with QoI fungicides are recommended to control this as well as other diseases.

The Blueberry Advisory System

Besides choosing effective fungicides in a program for AFR management, it is important to limit applications to only when needed. Due to the high value of the blueberry crop, growers are highly risk averse, and AFR management programs usually are based on a fungicide application calendar. However, favorable conditions for AFR may not occur throughout every season and may be difficult to predict. To predict disease occurrence, we used an equation that describes the incidence of strawberry AFR based on temperature and leaf wetness duration, assuming the pathogen is always present (Wilson et al. 1990). This equation is used in the widely adopted Strawberry Advisory System to predict risks for strawberry AFR, a disease alert system developed for Florida strawberry growers that is now utilized in several strawberry-producing areas in the United States. The equation used in the Strawberry Advisory System was used to develop the BAS given the similarities between the strawberry and blueberry anthracnose fruit rots. Both diseases are caused by species of the genus *Colletotrichum*, the pathogens have similar life cycles, and the conditions for important outbreaks are comparable. Both Strawberry and Blueberry Advisory Systems are part of the AgroClimate decision-support system, a comprehensive platform built for growers and stakeholders in the southeastern USA (Fraisse et al. 2006).

The BAS helps growers identify critical periods for blueberry AFR management by gathering weather data from automated weather stations in the FAWN network (https://fawn.ifas.ufl.edu/) located in important blueberry-producing regions in Florida and calculating AFR risk using the disease model described previously. Each weather station is georeferenced using the Leaflet Maps interface (https://leafletjs.com) so growers can easily locate the nearest station to their fields. It is important to choose the closest weather station to increase the accuracy of the risk prediction as environmental conditions may change within a few miles in Florida.

The graphical interface of the BAS is like that of the Strawberry Advisory System. First-time users are prompted to participate in a walkthrough tutorial (http://agroclimate.org/tools/bas/) (Figure 2) that explains how to navigate the system. If the user chooses to navigate through the tutorial, they may click on the Begin Tutorial Button (Figure 2A). The walkthrough will begin by highlighting the map with the weather stations linked to the system (Figure 2B). There are currently 15 weather stations available to the user. The next step of the tutorial shows the information on the selected weather station (Figure 2C), including its location (given by geographical coordinates, city, state, and county), the last time its data were updated, and the current risk for AFR. The current risk considers the maximum daily AFR risk for the past 24 hours. The color of the circle with an A (referring to anthracnose) is related to the current risk—green for low risk, yellow for moderate risk, and red for high risk. The walkthrough continues by highlighting the Disease Risk tab, where a graphical summary of the maximum daily risks for anthracnose is presented (Figure 2D). Next to the Disease Risk tab is the Weather tab, where more detailed weather data are shown, including temperature, relative humidity, rain, leaf wetness duration, the average temperature during leaf wetness, and anthracnose risk (Figure 2E). The detailed weather data are obtained and included in the system at 15-minute intervals. Lastly, the walkthrough shows the user how to change the period of the data, which can be interesting when users want to recall anthracnose risks or weather data from earlier in the season or in past years (Figure 2F). The main information growers usually get from the system is shown on the disease chart (Figure 3) and the weather data chart (Figure 4). The data to the right of the dotted line on the disease chart represents the three-day forecast provided by the National Weather Service (https://www.weather.gov/). If the dotted line is above the risk thresholds for moderate and high risk, we advise the user to be cautious and plan for a fungicide spray in the next few days. The forecast is especially desirable on large properties where an area-wide fungicide application may take more than one day. In those cases, preventive sprays may be appropriate. Fields with blueberry cultivars that are highly susceptible to AFR should be prioritized over more resistant cultivars. The fungicides that should be used for the application are briefly described in the previous section of this document, but a more thorough explanation can be found in https://edis.ifas.ufl.edu/publication/PP337. Users should be aware that fungicide applications have residual effects on disease development, and if an application was made in the past seven days, the plants are protected against the disease in most cases unless extremely favorable weather occurs (continuous wetness periods of more than 24 h). Users must also be attentive to preharvest intervals and maximum fungicide use per season, and they must avoid using QoI fungicides successively even when resistance is not a problem in their fields, prioritizing active ingredient rotations, compatible tank mixes, or fungicides with two distinct modes of action from different FRAC groups.

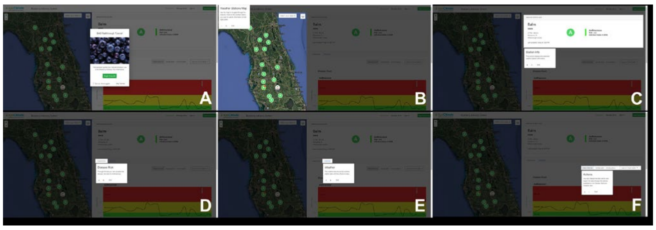

Figure 2. Walkthrough for new users. Prompted message to begin tutorial (A), weather station map (B), weather station info (C), disease risk tab (D), weather tab (E), action tab (F).

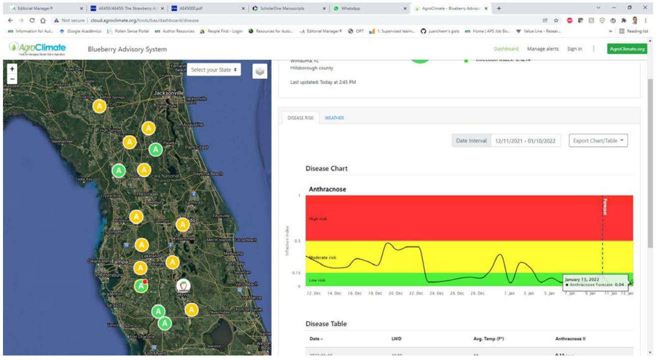

Figure 3. Model output for daily maximum anthracnose fruit rot risk for the past month and predicted risk for the next three days, based on the weather forecast from the National Weather Service.

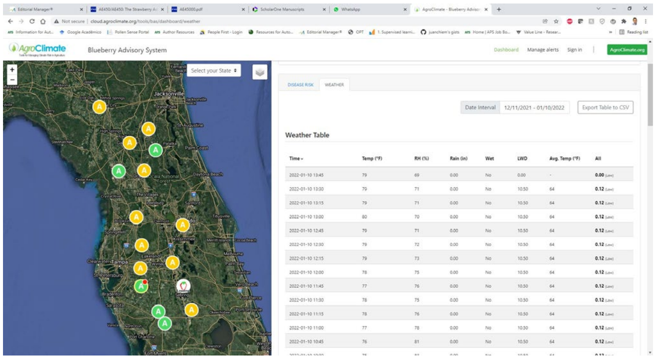

Figure 4. Weather data from a selected weather station showing 15 min readings for temperature, relative humidity, rain, and leaf wetness readings used to calculate LWD (leaf wetness duration) and average temperature for input into the anthracnose model (AII).

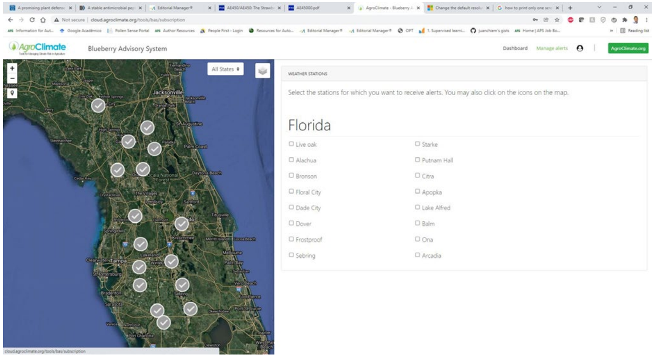

Figure 5. Interface showing map and list of weather stations that users could select and subscribe to receive automated alerts.

Users can create a personal account by clicking on the sign-in button on the upper right side of the web page. By creating an account, growers can select a weather station of interest and receive email and/or text alerts when risks are moderate or high for blueberry AFR by clicking on the "Manage Alerts" tab. Users can easily subscribe to a weather station by selecting it on the map and then deselecting it to unsubscribe.

Implications of Adopting the Blueberry Advisory System

Like other diseases caused by the genus *Colletotrichum*, appropriate fungicide application timing is essential to effective management of blueberry AFR. We conducted several field trials during two seasons (2017/2018 and 2018/2019) in Florida to test whether following the BAS recommendations would improve AFR management compared to more traditional calendar-based fungicide application programs traditionally used by the growers. In these trials, the difference in the number of fungicide applications based on the BAS and the grower's traditional system varied. At times, growers sprayed their plants more often than the system recommended, but other growers performed the same number of fungicide applications or even performed slightly fewer sprays than our model indicated. However, we observed improved yield and reduced disease levels when the BAS and our fungicide management program were used, especially under high frequency of QoI-resistant isolates (Gama et al. 2021).

Whether the system will reduce the number of fungicide applications depends on the user's aversion to risk, current management strategies, and weather favorability for the disease during critical periods for disease management. Under weather unfavorable for AFR, it is more likely that adopting the BAS will lead to a reduced number of fungicide applications per season. However, the system might indicate an increased number of applications than traditional calendar-based programs or the number of applications originally planned by growers if weather conditions are highly favorable for the disease. When growers are experienced with the disease, the number of fungicide applications recommended by the disease alert system may be equal to the grower's program, as we observed in our validation experiments (Gama et al. 2021). The BAS can be especially useful for growers with little experience with the disease to help them identify periods of high AFR favorability and assist them in understanding this disease's dynamics. In addition, the alerts from the system can help growers in making fungicide product selections, possibly choosing lower-cost products such as Captan when there is a moderate risk of disease development and saving higher-cost products that may be more effective for when there is a high level of risk.

Conclusions

The Blueberry Advisory System is an online tool to help Florida blueberry growers manage anthracnose fruit rot. The system may reduce the number of fungicide applications, especially when adopted by growers with a high aversion to risk. The system can also be an educational tool to help growers familiarize themselves with anthracnose dynamics and avoid unnecessary fungicide applications. However, the Blueberry Advisory System may recommend more fungicide applications in years of high favorability for AFR.

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