A Web-Based Tool for Timing Copper Applications in Florida Citrus[1]

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Introduction

Web-based spray application tools are designed to help growers better manage application timing by providing a means to make accurate and timely decisions. Tools can assist growers in determining if an application is needed to maintain disease control levels before a planned application date or if an application can be delayed. Improved disease control and reduced application number will improve profitability for many operations.

An earlier version of the 'Citrus Copper Application Scheduler' was available as the 'DISC copper model', developed by Albrigo et al. (2005), which was a downloadable program that ran on the user's computer. Unfortunately, the 'DISC copper model' was incompatible with the Florida automated weather network (FAWN) system. Along with resolving compatibility issues, the 'Citrus Copper Application Scheduler' has an updated interface and is easier to use than the original program. An additional advantage of web-based applications is that software updates can be made in the server without user interaction, ensuring that the most updated version is available to all users. The web-based 'Citrus Copper Application Scheduler' was developed as a crop disease tool under *Agro*Climate (http://agroclimate.org) and can also be found on the FAWN website (http://fawn.ifas.ufl.edu/). *Agro*Climate is an information and decision support system to help producers manage agricultural risks associated with climate variability in the southeastern U.S. It provides climate forecasts and decision support tools (Fraisse et al. 2006) developed by the Southeast Climate Consortium (SECC) and the Cooperative State Extension Service (http://seclimate.org).

The equations at the heart of the model predict two factors: 1) fruit growth from petal fall to mid-June and 2) rate of copper residue decay based on the percent metallic copper applied, spray volume, application date, and daily rainfall accumulation. These models were developed by Albrigo et al. (1997, 2005).

Uses of Copper for Citrus Disease Control

Copper compounds are protectant fungicides/bactericides, meaning the copper must be present on the plant surface before fungal spores or bacteria come in contact. Once these compounds are on plant surfaces, they become immobile, thus cracks can be formed in the protective copper coating when young tissue expands. Copper compounds are also vulnerable to weathering, which reduces their effectiveness.

The mechanism by which copper inhibits fungal or bacterial growth is not well understood. It is thought that copper ions become soluble and cause cellular mechanisms to

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stop working, thereby killing the cells. When plant cells are rapidly growing, they can also be damaged by copper. That damage, called phytotoxicity, can cause direct tissue damage or further darken existing blemishes, such as insect damage, wind scar, or melanose, thus reducing the market value of fruit. Phytotoxicity often occurs when copper is mixed with acidic materials incorporated into complex pesticide and/or nutritional material tank mixes, or at high temperatures (> 94ºF/34ºC). In older groves where copper has been frequently used for many years, soil can contain up to 370 kg/ha metallic copper (Timmer and Zitko 1996). Such high levels of copper are toxic to citrus roots and inhibit the uptake of many nutrients, including iron, in acidic soils.

Historically, the recommended rates of metallic copper were higher than current IFAS recommendations because it was assumed that product efficacy for melanose control was solely dependent on metallic copper content and a single application. Studies have found that newer copper products with a lower percentage of metallic copper are just as effective for melanose and canker control as products containing more metallic copper (Graham et al. 2010; Timmer and Zitko 1996). It was also shown that using four applications without increasing the seasonal amount of metallic copper provided better melanose control than one application of the equivalent amount of copper (Timmer et al. 1998). This is because copper compounds do not redistribute as fruit grows, which is especially problematic in the early season when fruit expansion is the most rapid, and because there is some copper reduction from weathering by rain. On slower-growing midseason fruit, fruit growth and weathering may contribute equally to copper residue decay.

Based on IFAS research, to be most effective, copper should be applied approximately every 21 days. This is an average interval between sprays that does not account for periods of time when rainfall has been especially light or heavy. With high rainfall, the copper residue can weather more rapidly than expected and be insufficient for disease control before 21 days. Conversely, if there have been few rain events, the copper residue may be sufficient for disease control for longer than expected, and another application may not be necessary at 21 days. The 'Citrus Copper Application Scheduler' is designed to help growers determine if an application needs to occur early, on time, or can be delayed. It has been paired with the 'Citrus Pesticide Application Tool' on FAWN so rainfall forecasts and application conditions for the next 45 hours can be evaluated to assist decision making.

Citrus Diseases for Which Copper Is Used

Copper compounds can be used for control of most foliar citrus diseases. These include Asian citrus canker, melanose, alternaria brown spot, greasy spot, citrus scab, and citrus black spot. Copper applications are not effective for controlling systemic diseases, such as huanglongbing (HLB [citrus greening]). Copper products can be economical choices and an important part of fungicide resistance management programs. For citrus canker, copper compounds are the only registered chemical control options that have demonstrated efficacy over many years of trials. For registered copper products and complete disease management recommendations, including disease-specific application timings, please consult the current edition of the *Florida Citrus Pest Management Guide* (http://www.crec.ifas.ufl.edu/extension/pest/), the *Citrus Black Spot Management Timing Schedule* (http://edis.ifas.ufl.edu/pp277), or the *Quick Reference Guide to Foliar Fungicides* (http://edis.ifas.ufl.edu/pp275). It is important to remember that the pesticide label is the law. When using any pesticide, one should always follow the label instructions.

About the 'Citrus Copper Application Scheduler'

The 'Citrus Copper Application Scheduler' monitors rainfall and predicts the level of copper residue available for disease control. The information is displayed graphically as well as in a table that lists the details and can be downloaded to a user's computer. The system can be used with weather data from a FAWN station or rainfall data from the user, which allows it to be used for most citrus production locations within Florida.

The system displays a page that is divided into six sections (Fig. 1). Section A (Fig. 1A) shows its affiliation with the *Agro*Climate portal, the current phase of the El Niño Southern Oscillation (ENSO) phase,[1] and other tools. Section B (Fig. 1B) explains the purpose of the tool and has more detailed information about the model, plus a help screencast. In section C (Fig. 1C), the user can select from the available FAWN stations or upload rain data using a comma-separated values (CSV) file. A link is provided with instructions on how to format and upload rain data if the user clicks on the blue "Help" link. In section D (Fig. 1D), the user can select the cultivar and enter the bloom date. The bloom and application dates are entered via pop-up calendars. The application attributes (application dates, the amount of copper applied, and the application volume) are entered in section E (Fig. 1E). The default quantity of metallic copper and spray volume can be changed by clicking on the corresponding data fields. To calculate the metallic copper used, multiply the percent metallic copper in a product (found on the label) by lbs/acre used. Application dates can be added or removed with the green (plus) and red (minus) buttons. To start the simulation and to review model results, click the "Simulate Copper Residue" button. Results can be viewed in chart or table formats in section F (Fig. 1F). A link to the 'Application Conditions Forecast' is provided underneath the graph if the user decides to check the application conditions forecast for the next 45 hours.

How to Interpret the Model Output

Figure 2 shows an example of the graphical model output. This is for grapefruit near the Lake Alfred FAWN station with a bloom date of March 15, 2011. Three copper applications were made using 0.75 lb/acre of metallic copper in 125 gal/acre spray volume. The left axis (Y_1) gives the residual copper predicted to be remaining on the fruit and the right axis (Y_2) is the measured daily rainfall in inches. The bottom axis is the date, and the top axis shows the number of days since the last spray. The dotted line is the predicted copper residue. If there is little to no precipitation after an application, the curve will gently decline toward zero, as between April 6 and 24 (Fig. 2). If a rain event occurs (vertical blue bars along the bottom), the curve will drop more sharply, like between May 12 and 18 (Fig. 2). When an application is made, the curve increases in a straight line, indicating a sharp increase in copper residue. After the first application, additional applications add copper to the remaining residue, which is why the later applications result in more residual copper than earlier ones for the same amount applied. The dashed line past the "Today" line (vertical black line) predicts the amount of residue remaining based on fruit growth for the following week. In this example, by July 5th the copper residue approaches 0.25 μg/cm^2, provided no rain events occur. The yellow-shaded area from 0.5 to 0.25 μg/cm^2 is the warning threshold where disease control is still adequate, provided there are no rain events, but an application should be considered. The red-shaded area below 0.25 μg/cm^2 indicates that there is no longer adequate residue and an application is needed as soon as possible. In this example, the 21-day application interval was appropriate for the second and third applications based on fruit growth and rain events. However, June was relatively dry in 2011, and 21 days after the third application the residue was approximately 1 μg/cm^2—well above the warning threshold. It was not until 31 days that the residue levels reached the warning threshold level, and an application may not be needed for another 37 days.

Data are also available in table format (Fig. 3) under the simulation details tab above the chart (Fig. 2). The information given includes date, days since bloom, residue levels, rainfall, the spray volume used, and the concentration of metallic copper used. This table can be downloaded as a CSV file to the user's computer as a permanent record. A CSV file can be opened by most spreadsheet programs, like Microsoft® Excel.

Since the original model was designed to predict copper residues from bloom to mid-June, no residue data were collected past those dates by Albrigo et al. (1997; 2005). As the growing season approaches midsummer, fruit surface area no longer increases as rapidly. It is suspected that the copper residue over the summer is more affected by weathering than fruit growth. If there are no heavy (> 0.75 inch) or frequent rain events, the copper residue is thought to be reduced more slowly than what will be predicted by the 'Citrus Copper Application Scheduler'. The application scheduler can still be a guide for copper applications, but the user should keep in mind that predictions will not be as accurate as in the early season. IFAS researchers are currently collecting fruit growth and copper residue data to be able to improve the mid- to late-season accuracy of the model.

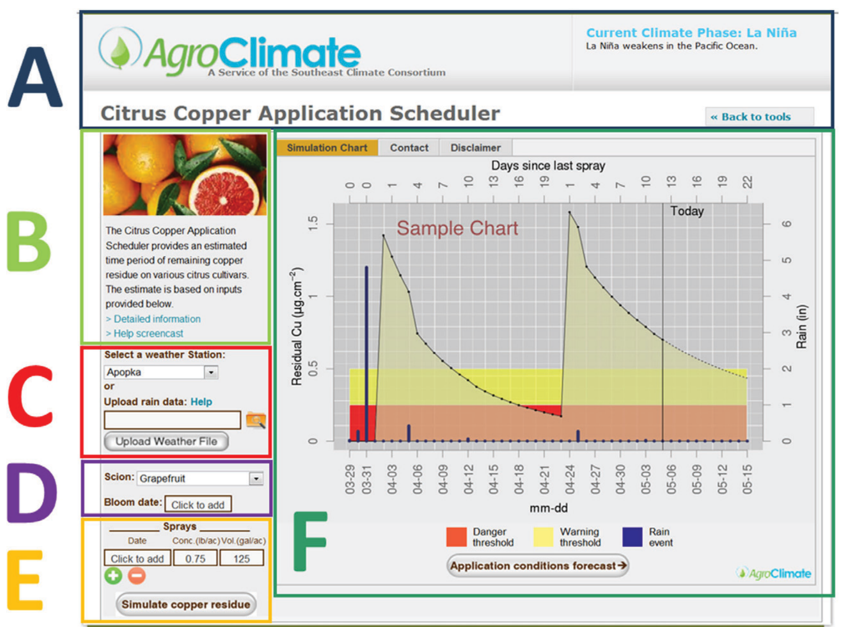

Figure 1. The main web page of the 'Citrus Copper Application Scheduler' and its sections.

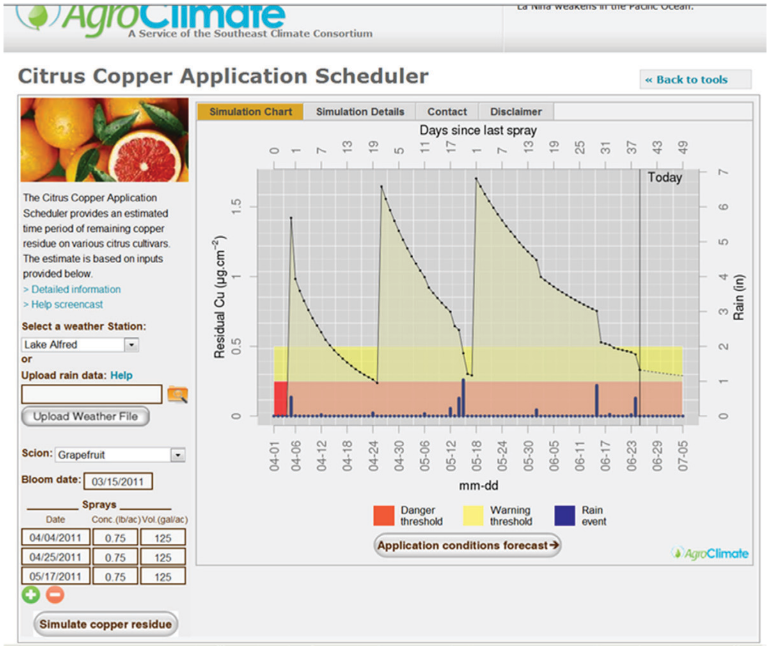

Figure 2. The graphical representation of a copper application program in Lake Alfred on grapefruit with three applications. The yellow-shaded area is the warning zone, and the red-shaded area is the minimum threshold level.

date	bloom (days)	residue (ug/cm*cm)	rain (inches)	spray vol (gal/ac)	spray conc (lb/ac)
04-01	1	0	0	0	0
04-02	2	0	0	0	0
04-03	3	0	0	0	0
04-04	4	0	0	125	0.75
04-05	5	1.42	0.54	0	0
04-06	6	0.98	0.01	0	0
04-07	7	0.9	0	0	0
04-08	8	0.83	0	0	0
04-09	9	0.76	0	0	0
04-10	10	0.7	0	0	0
04-11	11	0.65	0	0	0
04-12	12	0.6	0.04	0	0
04-13	13	0.55	0	0	0
04-14	14	0.51	0	0	0
04-15	15	0.47	0	0	0
04-16	16	0.44	0	0	0
04-17	17	0.41	0	0	0
04-18	18	0.38	0	0	0
04-19	19	0.36	0.01	0	0

Figure 3. The tabular output of the results of a copper application program in Lake Alfred on grapefruit with three applications of 0.75 lb/acre of metallic copper in 125 gal/acre spray volume.

Conclusions

The 'Citrus Copper Application Scheduler' provides citrus growers with an easy-to-use tool to guide copper application decisions. It is an updated version of a previous copper residue model called the 'DISC Copper Model' that was originally designed to predict copper residues until mid-June. The current model can be used to estimate summer copper residues but will not be as accurate as early season estimates. Summer copper residue predictions will be improved with the data generated by ongoing experiments in the next few years.

References

Albrigo, L.G., Beck, H.W., Timmer, L.W., and Stover, E. 2005. Development and testing of recommendation system to schedule copper sprays for citrus disease control. *Journal of ASTM International* 2:1-12.

Albrigo, L.G., Timmer, L.W., Townsend, K., and Beck, H.W. 1997. Copper fungicides - residues for disease control and potential for spray burn. *Proceedings of the Florida State Horticultural Society* 110:67-70.

Fraisse, C.W., Breuer, N.E., Zierden, D., Bellow, J.G., Paz, J., Cabrera, V.E., Garcia y Garcia, A., Ingram, K.T., Hatch, U., Hoogenboom, G., Jones, J.W., and O'Brien, J.J. 2006. AgClimate: A climate forecast information system for agricultural risk management in the southeastern USA. *Computers and Electronics in Agriculture* 53 (1):13-27.

Graham, J.H., Dewdney, M.M., and Myers, M.E. 2010. Streptomycin and copper formulations for control of citrus canker on grapefruit. *Proceedings of the Florida State Horticultural Society* 123:92-99.

Timmer, L.W., and Zitko, S.E. 1996. Evaluation of copper fungicides and rates of metallic copper for control of melanose on grapefruit in Florida. *Plant Disease* 80 (2):166-169.Timmer, L.W., Zitko, S.E., and Albrigo, L.G. 1998. Split applications of copper fungicides improve control of melanose on grapefruit in Florida. *Plant Disease* 82 (9):983-986.

[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.*