Final Project Report – SRSFC Research Grant 2011-01
Southern Region Small Fruit Consortium

Proposal Category: ____X_____RESEARCH

PROJECT TITLE: Predictive model verification and review of utility for initiation of downy mildew fungicide programs for Georgia and North Carolina wine grape vineyards

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Objective: To determine whether a downy mildew model will accurately determine the initial infection of grapevines, allowing for targeted application of fungicides during this timeframe.

Justification: Winegrapes have been planted for some time in the Southeast, but the industry is expanding into new areas. North Carolina is home to over 90 wineries with an estimated annual economic impact of $813 million (http://www.visitncwine.com/about/about-north-carolina-wine). Georgia's industry is smaller and newer (>20 wineries with sales of >50,000 cases per year), but a recent study by the Carl Vinson Institute (Univ. of Georgia) predicted over $585 million in business revenues from the winery industry over the next 20 years.

With the current value of the southeastern winegrape industry firmly established, it has become clear that diseases can have a substantially negative economic impact. Among these, downy mildew, caused by *Plasmopara viticola*, is one of the more difficult diseases to manage in the Southeast, as the regional growing conditions (warm and wet) generally favor the disease. The *Vitis vinifera* grapes are particularly susceptible to downy mildew, and damage can result in 100% losses without effective management through use of chemical fungicides. Young berries are highly susceptible to the fungus, and infections which occur through the stomata result in a direct fruit rot. As berries mature they do not have stomata so they become more resistant to infection, though the rachis can be infected, resulting in additional fruit loss. Leaf infections are particularly difficult to address, as season-long infections can occur on leaves, and the loss of photosynthetic tissues can affect fruit development and quality, as well as promote winter kill and reduced fruit set in the following year.

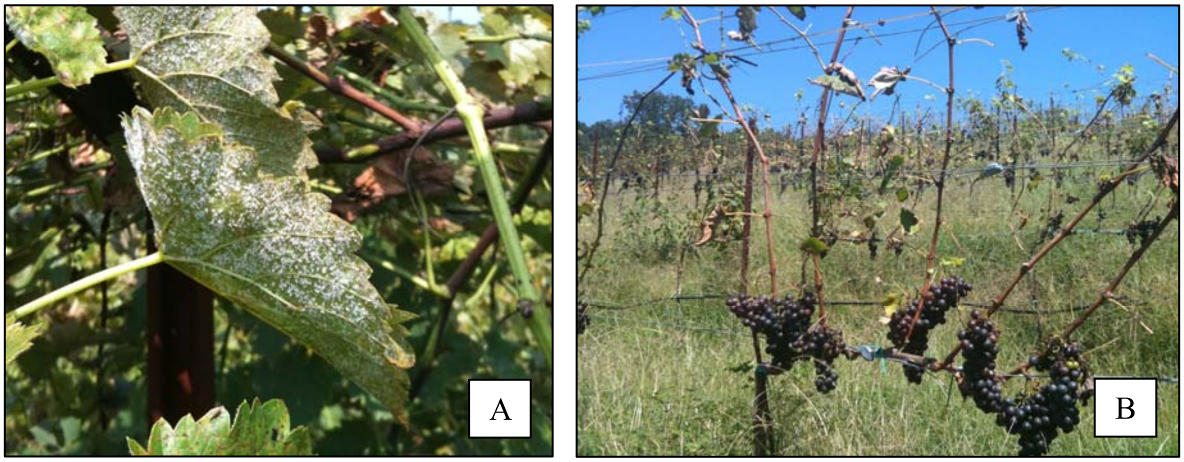

Figure 1. Downy mildew of grape. Direct damage from downy mildew can include fruit rots (not shown), especially if early-season spray programs are not efficacious. However, damage to foliage is often observed (A), and under severe pressure, complete defoliation can occur before harvest (B) or after harvest. In addition to current-season yield and quality issues, premature defoliation can weaken the plant, resulting in winter kill and/or decreased plant health and berry production in the following year.

Due to the warm and moist conditions in the Southeast, integrated pest management (IPM) models and expert systems for downy mildew prediction may have limited utility, as the conditions are generally more favorable for downy mildew and other diseases than the northern or Mediterranean climates where they are traditionally utilized. Even if conditions were not favorable for downy mildew in our southeastern climates, many of the same fungicides used for downy mildew control would be applied for the multitude of other diseases, and fungicide applications would not necessarily be saved. However, timing of the initial infection would be of great importance for a critical reason; if one understands that the initial infection has occurred, one could focus on the urgent need for application of a downy mildew active fungicide – specifically Ridomil Gold MZ (mefenoxam + mancozeb) or Ridomil Gold Copper. Ridomil Gold products are generally applied one time per season, due to long preharvest intervals (66 and 42 days, respectively), and they have to be applied in a timely manner to control downy mildew and help avoid resistance development. Ridomil Gold is particularly active against downy mildew, it has good "kickback" activity, and it has been described as by far the most efficacious fungicide available for control of downy mildew. *P. viticola* predominantly overwinters as oospores in leaf litter, and disease initiation occurs when oospores germinate to produce sporangia and zoospores which are rain-splashed to susceptible tissue. Timing of the application of Ridomil Gold products in conjunction with downy mildew initiation would substantially impact epidemic development, if in fact this could be timed accurately with existing models.

Materials and Methods: There are multiple models available for timing downy mildew applications. Some, such as the 3-10 and EPI models, are empirically-driven and may be too simple for generalized application without local validatation (Caffi et al, 2007). We intended to test two more detailed mechanistic models which take into account stages in the disease process and therefore have a greater chance for success in a new region. The first, DMCast (Park et al, 1997), has been used to successfully predict disease initiation and development in upstate New York and Pennsylvania. The original tool utilized hourly inputs of temperature, relative humidity, precipitation, and leaf wetness, coupled with grape phenological stage, to forecast onset of primary infection and later severity, but updates (Kennelly et al, 2001) use only temperature and precipitation data. Unfortunately, this model could not be utilized for the trial, and it may not be readily available for use in the future. The second model was developed at the Catholic University Sacro Cuore in Italy, where it has reliably predicted disease onset in studies using historical data (Rossi et al, 2008, T. Caffi, *personal communication*). Dr. Tito Caffi, instrumental in developing this "UCSC" model, has conducted preliminary work as a visiting scientist at the University of Georgia to apply it to northern Georgia vineyards, and he advised us on this project.

For the 2011 grape season, test of the UCSC model for downy mildew initiation was only conducted in Georgia at the Georgia Mountain Branch Experiment Station (Blairsville, GA). This research station has a full University of Georgia weather station on site (Georgia Automated Environmental Monitoring Network; www.georgiaweather.net), so detailed weather data was available throughout the season. Data on temperature, relative humidity, and precipitation from the weather station was recorded every 15 minutes and downloaded daily. Coupled with observations from vineyard personnel of grape phenological stage, we were able to use the UCSC algorithm to estimate whether primary oospore germination and/or infection had been initiated each day. Data was e-mailed to Italy for assessment through the Italian model, as the model is proprietary at this time.

Field assessment of the model was tested through use of various fungicide regimens (Table 1), two of which included application of Ridomil Gold MZ as triggered by the model. The fungicide regimens were tested in a 6-yr-old vineyard of 'Merlot' and 'Chardonnay' vines, also located at the Georgia Mountain Research and Education Center (Blairsville, GA). In addition to a fungicidal standard program (regimen 2), a program was developed which allowed only downy mildew (regimen 1), while preventing other grape diseases – the equivalent of an untreated control relative downy mildew. A experimental compound with excellent efficacy was included for comparison with standards (Zampro; ametoctradin + dimethomorph; regimen 3). Zampro was applied with a UAP 80/20 non-ionic surfactant (3.2 oz/50 gallons); other products were not applied with surfactant. Additional regimens incorporated Ridomil Gold MZ either at oospore germination (regimen 4) or shortly after oospore germination and potential zoospore infection (regimen 5). Within the non-treated plot, the station superintendant scouted for downy mildew initiation (greasy spot) weekly during the course of the season. The time from infection to first symptom appearance is ~ 4 days, but this varies somewhat due to environmental conditions and plant genetics. All fungicides were applied with an airblast sprayer (35 gal/A spray volume) at each application date. The experimental design was a randomized complete block, with each plot consisting of six vines. Unsprayed rows were left between each spray row. Treatments were replicated three and four times for 'Merlot' and 'Chardonnay,' respectively. All cultural practices were in keeping with grape production methods commonly observed throughout the Southeast. A single naturally-infected plant was observed in the plot on 21 Jul, so plots were inoculated with downy mildew from a commercial vineyard in order to increase disease pressure. Plots were rated for downy mildew through a visual field assessment of severity (% foliage covered by downy mildew), and incidence and severity data were also collected from 25 leaves per plot on 1 Sep. Downy mildew did not develop on clusters.

Results: Based on a conservative interpretation of the model oospore germination data (Figure 2), we triggered Ridomil Gold MZ applications very early in the season (22 or 28 Apr). We also anticipated early and extensive downy mildew pressure in our commercial vineyards. However, the first observed downy mildew did not occur till early July in commercial vineyards, and it was not observed till 22 Jul at the research station (Figure 3). The question arises as to whether the program failed to predict an accurate outcome, and the answer is that in fact the program did not fail, but utilizing the generated information can allow for an early application when one is not needed. Though we would need to test the program in multiple years and locations to be comfortable with it, it is not likely that it would allow an infection without our knowledge, but we could continue to spray earlier than needed, as we did in 2011.

If we review the logic behind our decisions, the reasoning becomes clearer. By 21 Apr, the model indicated that 50% of the first oospore cohort had germinated (Figure 2), and initial germination would have started on roughly 12 Apr. On 27 Apr, we had predictions of storms, many of which ultimately resulted in tornado development, rain, and high winds. This prediction triggered an application of Ridomil Gold MZ in the 4th regimen, not based on the model alone, but based on the fact that zoospore activity could have resulted in infection with the high winds and rain splash potential. A second Ridomil Gold MZ spray was activated in regimen five to further address this initial anticipated infection event. In reality, the infection event did not occur in Georgia, and the model actually did not show that an infection event occurred (Figure 2). Dry conditions prevailed in early May, and these continued for much of the summer in Georgia. In contrast, North Carolina vineyards often developed very early downy mildew infections, as the subsequent rainfall and temperatures were conducive to downy mildew development. The Ridomil Gold applications in Georgia were ill timed and of no value to downy mildew management, as they were based on the potential for future infection, as opposed to real infection.

At the research station, rainfall was not prevalent throughout the test period, so downy mildew did not develop early, as indicated by the lack of diseased clusters and late symptom development. However, the foliage was moderately infected by the end of the season (Table 1). Other diseases were not readily observed in the test, as the test was successfully designed to allow downy mildew only. Zampro was particularly efficacious in this trial, as expected. The fungicidal standard program did not provide acceptable management, and this may indicate that the inoculum utilized for disease establishment may have been resistant to strobilurin fungicides; this will need to be confirmed in 2012, as this would be the first report of resistance in Georgia if so. The addition of Ridomil Gold MZ either at oospore germination (treatment regimen 4) or shortly after oospore germination (treatment regimen 5) did not result in increased control of the disease; oospore germination did not coincide with infection in Georgia, since rainfall was limited after oospore germination.

Conclusions: The earliest that downy mildew occurred in commercial vineyards in Georgia was early July. Through testing the disease initiation component of this downy mildew prediction model, we were able to at least in part determine whether it accurately predicted downy mildew initiation under southeastern environmental conditions. If it accurately predicted disease initiation, this would allow for a targeted application of an efficacious fungicide with curative and protective properties. Though individual vineyard prediction would be best, we could also foresee the development of regionalized predictive models as well, which would allow for general warnings of downy mildew initiation. This has indeed been done using the DMCast model to generate risk maps for upstate New York. Utilizing a regional climate model such as the mesoscale atmospheric simulation system (MASS) to provide temperature and precipitation inputs where weather station data does not exist, we could use the DMCast and UCSC models to estimate disease onset and severity and create similar risk maps for northern Georgia and western North Carolina. Therefore this research would have regional importance. Symptom development would further allow us to predict disease initiation dates. The success or failure of such models will depend on how accurately disease initiation is predicted. Currently, there is no prediction of downy mildew initiation in the Southeast, so even a day or two variance from the actual initiation would be of great value. The 2011 test of the UCSC system was encouraging, in that we learned at least one or two of the idiosyncrasies associated with this model, and we would better understand the limits of the model. Additional testing would be required if we are to expand use of such models in the future. Testing needs to be conducted with the concept of allowing the model to predict the first infection (allowing initial infection before applying Ridomil Gold MZ); this will be the target of future studies.

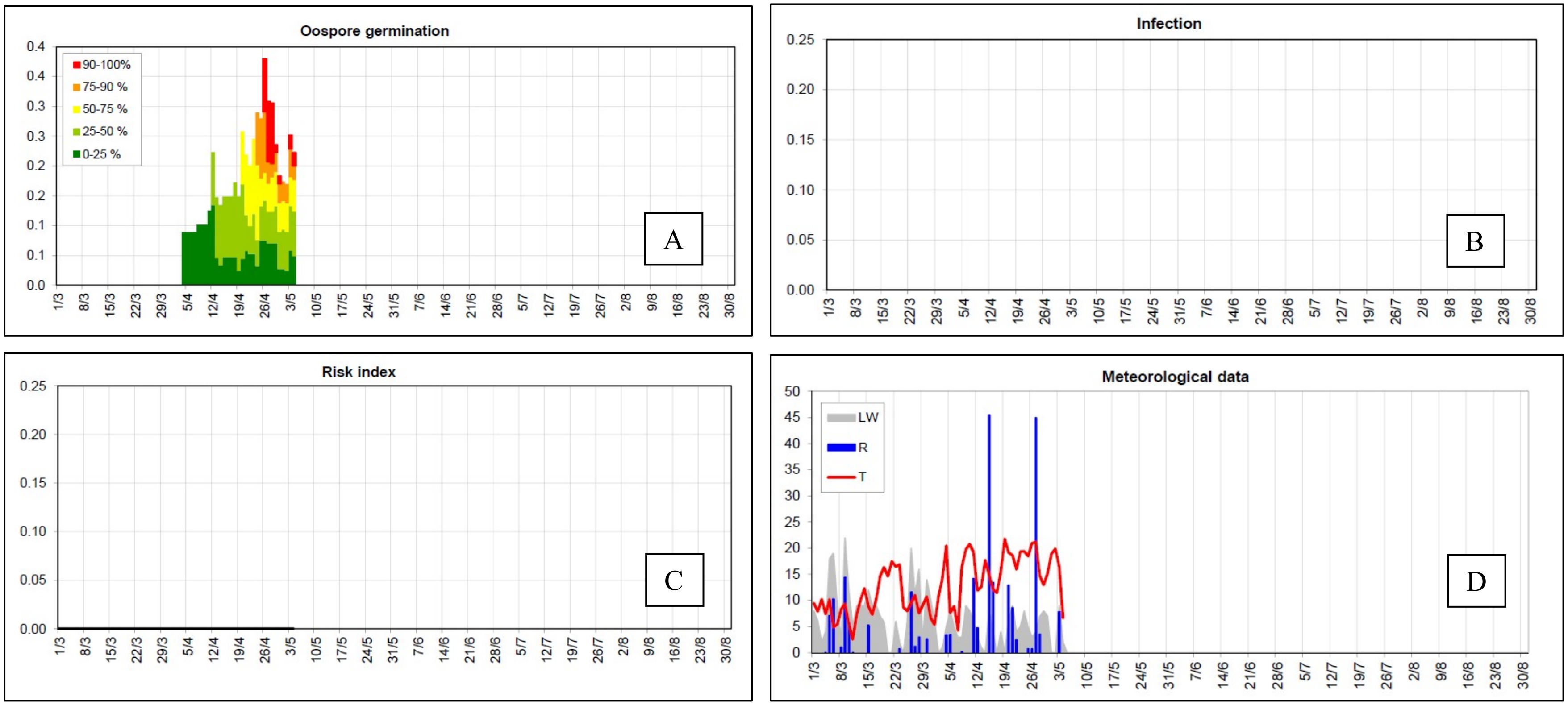

Figure 2. Downy mildew early season model development. Based on the oospore development (A), previous rainfall and temperatures (D) and potential for rainfall and wind, a Ridomil Gold MZ application was administered on 22 Apr, whereas the initial symptoms of disease were not observed till 22 Jul. Neither the infection information (B) nor the risk index (C) indicated that infection occurred, but the psychological danger of infection, based on oospore germination data, resulted in a wasted application of Ridomil Gold MZ. If this model is to be accurately timed for use of this specific fungicide, infection would have to be shown by the model before application of Ridomil Gold MZ. Additional testing would be required to confirm that this is the best utility of this model for the Southeast.

Figure 3. Early-season downy mildew detection in commercial vineyards. The first observed downy mildew did not occur till early July in commercial vineyards in Georgia, and it was not observed till 22 July at the research station. Hot, dry conditions in Georgia were ultimately not conducive to downy mildew development. In North Carolina, many vineyards experienced very early disease development, as conditions were much more conducive to downy mildew development.

Impact Statement: Currently, there is no prediction of downy mildew initiation in the Southeast, so even a day or two variance from the actual initiation would be of great value. The 2011 test of the UCSC system was encouraging, in that we learned at least one or two of the idiosyncrasies associated with this model, and we would better understand the limits of the model for future testing. Additional testing would be required if we are to expand use of such models in the Southeast. Testing needs to be conducted with the concept of allowing the model to predict the first infection (allowing initial infection before applying Ridomil Gold MZ); this will be the target of future studies.

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Table 1. Downy mildew management results from varying spray regimens.

Treatment and rate/A	Treatment date[z]	Merlot: Field severity (% foliage area w/ symptoms)	Merlot: Leaf incidence (%)	Merlot: Leaf severity (% area infected)	Chardonnay: Field severity (% foliage area w/ symptoms)	Chardonnay: Leaf Incidence (%)	Chardonnay: Leaf severity (% area infected)
(1) Lime sulfur 13 gal	1						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb	2						
Microthiol Disperse 5 lb + Topsin M 70WDG 1.5 lb + Rally 40W 5 oz	3,5,7-8,10,13						
Microthiol Disperse 5 lb + Elevate 50WDG 1 lb + Rally 40W 5 oz	6,9,11						
Microthiol Disperse 5 lb + Topsin M 70WDG 1.5 lb + Rally 40W 5 oz + Elevate 50WDG 1 lb…………………	12	10.0 [y]	18.7	1.5	20.0 a[y]	44.0 a	2.8 a
(2) Lime sulfur 13 gal	1						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb	2						
Manzate Pro-Stick 3 lb + Microthiol Disperse 5 lb	3,5,7-8						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb + Vangard 10 oz	6						
Pristine 23 oz	9						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz	10,13						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz + Elevate 50WDG 1 lb	11						
Pristine 23 oz……………………………………………..…	12	6.7	18.7	1.5	5.5 b	38.0 a	2.2 a
(3) Lime sulfur 13 gal	1						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb	2						
Microthiol Disperse 5 lb + Topsin M 70WDG 1.5 lb + Rally 40W 5 oz + Zampro 14 oz	3,5,7-8,10,13						
Microthiol Disperse 5 lb + Elevate 50WDG 1 lb + Rally 40W 5 oz + Zampro 14 oz[x]	6,9,11						
Microthiol Disperse 5 lb + Topsin M 70WDG 1.5 lb + Rally 40W 5 oz + Elevate 50WDG 1 lb + Zampro 14 oz	12	0.0	4.0	0.1	0.0 c	0.0 b	0.0 b
(4) Lime sulfur 13 gal	1						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb	2						
Ridomil Gold MZ 2.5 lb + Microthiol Disperse 5 lb	3						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb + Vangard 10 oz	6						
Manzate Pro-Stick 3 lb + Microthiol Disperse 5 lb	5,7,8						
Pristine 23 oz	9,12						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz	10,13						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz + Elevate 50WDG 1 lb……………………………..….	11	3.3	17.3	0.9	6.3 b	30.0 a	1.8 ab
(5) Lime sulfur 13 gal	1						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb	2						
Ridomil Gold MZ 2.5 lb + Microthiol Disperse 5 lb	4						
Manzate Pro-Stick 3 lb + Microthiol Disperse 10 lb + Vangard 10 oz	6						
Manzate Pro-Stick 3 lb + Microthiol Disperse 5 lb	3,5,7,8						
Pristine 23 oz	9,12						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz	10,13						
Captan 80WP 2.5 lb + ProPhyt 3 pt + Rally 40W 5 oz + Elevate 50WDG 1 lb………………………………….	11	6.0	5.3	1.0	4.5 b	30.0 a	1.3 ab
LSD (P = 0.05)		NS	NS	NS	4.2	14.7	2.0

[z]Treatment dates: 1 = 21 Mar (late dormant); 2 = 8 Apr (budbreak); 3 = 22 Apr (2-inch shoot growth or Ridomil Gold MZ trigger for pre-infection); 4 = 28 Apr (theoretical post-infection Ridomil Gold MZ application); 5 = 2 May (prebloom); 6 = 10 May (bloom); 7 = 25 May (postbloom); 8 = 10 Jun (first cover); 9 = 24 Jun (bunch closure); 10 = 12 Jul (second cover); 11 = 27 Jul (veraison); 12 = 10 Aug (preharvest); 13 = 23 Aug (postharvest)

[y]Means within columns followed by the same letters are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).