

# Final Report for Southern Region Small Fruit Consortium

## PROJECT TITLE:

### Development of a web-interface for grape and apple regional risk assessment system (2013-E04)

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#### A) OBJECTIVES

- 1) Development of web-interface for apple and grape risk assessment system

#### B) Project executive summary:

Our group has been working to develop a web-based grape and apple disease risk assessment system, which utilizes regional level weather information to evaluate risks of major diseases of grape and apple. We envision that in the future, it will be a component of risk assessment system where it will provide aids for IPM that will be tailored to the specific conditions for each grower. I.e., The system will provide a report of grape or apple disease risk snap-shot that includes history and forecast of disease risk at the site of interest, provide site-specific information based on user inputs, and maps will be generated to support areas that is not covered by existing weather stations.

The funding from SRSFC was requested as a part of a large project, where we proposed was to establish a framework for the disease risk assessment system (Table 1). Due to the leave of two key personnel in 2013-

2014, the project was delayed for a year; however, we were able to recruit Mr. Robert Bergholzer in 2014 and made significant progresses.

**Table 1. Proposed Objectives from the Original Proposal**

Phase	Timeline	Objective		Impact
<b>I</b> Development of the base system  A) Disease risk assessment system <u>(proposed here)</u>	2009-2013	1	Creating the infrastructure: a) Set up a data server; b) Create a web interface; c) Data management	Establish a weather data sharing structure between PSU and VT system
		2	Initial development of grape disease risk assessment tool 2009-2011: Selection of candidate models based on previous studies ( <i>on-going as of 2009 season</i> ) 2010-2012: Initial system run: testing and calibration of GIS modules, a hindcast of disease risks with existing datasets	
		3	Public deployment of the alpha system of disease maps (2013)	

## Materials and Methods

The work created this year had two main facets: 1) the “Fruit Disease Risk Forecasting System” (FDRFS) and the 2) “Geo-spatial Content Management System” (GeoCMS). The FDRFS is a web application which fulfilled the project goals of collecting remotely sensed weather data, running predictive fungal risk models based on that data, and providing a web portal for viewing and downloading weather data, summary reports, and disease risk model predictions. The FDRFS was built to collect data from Campbell Scientific weather station sensors (we currently have 9 weather stations in the state), and employed pathogen risk models written in Python (Table 2).

The GeoCMS was the backend framework upon which the FDRFS was built. As with any Content Management System (CMS), the GeoCMS provides a flexible web-based interface for aggregating content (in this case environmental data), providing for user login and access permissions management, flexible reporting capabilities, and page development tools. The GeoCMS extends the traditional CMS by supporting geospatial data types (point, line, polygon, etc), and also sophisticated geospatial analysis query capabilities. It also supports the creation of a monitoring and analysis framework such as this by supplying a robust data structure tailored to the needs of environmental monitoring for relating location information, monitoring stations properties, quantitative and qualitative parameter data, time series data and linkages amongst the various spatial and non-spatial components. Currently, we are working on mapping solution for the various grape disease risk models for GeoCMS. Scripts were written to obtain weather data and convert it into raster data for mapping, and data are stored to be exported out to GeoCMS.

The next step is to stream the raster data into the GeoCMS to have map display and create a set of scripts to do it automatically. We have established collaboration with Pennsylvania State University (Mr. Kyle Imhoff, the state climatologist for PA) in April 2015 to achieve this goal. We are expecting to see the data to be exported to our system in early 2016. In addition, we are planning to have import function for the FDRFS so that grower can upload their own weather data. This “crowd sourcing” of weather data will enhance our network of weather data.

## GIS Risk Models

### Description of the model

- *The selection of candidate disease models:* the selection was made based on past usage (i.e., popularity among scientists and growers) and availability (Table 2)


**Table 2. List of candidate grape disease models**

Model	Parameters	Disease risk criteria
$T_{obs}$ = average temperature during wetness period (LW) $LW_{obs}$ = time (in hour) of wetness period		
<b>Botrytis model 1 (Nair and Allen 1993)</b>		
$I = I_{max} \cdot [1 - \exp[-(Q - t / K_{time})^2]]$ where $Q = \exp[-((T_{obs} - T_{opt}) / K_{temp})^2]$ and $t = LW_{obs}$	Tmin 5 Tmax 30 I <sub>max</sub> 100 T <sub>opt</sub> 20.8 K <sub>time</sub> 13.9 K <sub>temp</sub> 8.9	IF $0 \leq I < 20$ then Risk <sub>bot</sub> = low IF $20 \leq I < 50$ then Risk <sub>bot</sub> = Moderate IF $I \geq 50$ then Risk <sub>bot</sub> = high
<b>Powdery Mildew model 1 (Sall 1979)</b>		
PT = 0 if $T_{obs} \leq 0$ $PT = 0.000241 \cdot T_{obs}^{2.06737} \cdot (35 - T_{obs})^{0.72859}$ if $0 < T_{obs} < 35$ PT = 0 if $T_{obs} \geq 35$		IF $0 \leq PT < 0.2$ then Risk <sub>PM</sub> = low IF $0.2 \leq PT < 0.5$ then Risk <sub>PM</sub> = Moderate IF $PT \geq 0.5$ then Risk <sub>PM</sub> = high
<b>Black Rot model 1 (based on Spotts 1977)</b>		
If $T_{obs} < 10$ then Risk <sub>BR</sub> = low If $T_{obs} > 10$ then $Y = 6.6116027 - 0.0358765 \cdot T_{obs} + 0.0920909 \cdot (T_{obs} - 21.0556)^2 - 0.0039294 \cdot (T_{obs} - 21.0556)^3$ If $LW_{obs} > Y$ then Risk <sub>BR</sub> = high Else if Risk <sub>BR</sub> = low		
<b>Phomopsis model 1 (Erincik et al 2003)</b>		
$Y = \alpha \cdot t^{\beta} \cdot (1 - t)^{\gamma} \cdot W_{obs}^{\epsilon}$ Where $t = (T - T_{min}) / (T_{max} - T_{min})$	alpha 2.04 beta 3.47 gamma 4.86 epsilon 1.6  Tmin 5 Tmax 35	IF $0 \leq Y < 0.07$ then Risk <sub>phom</sub> = low IF $0.07 \leq Y < 0.15$ then Risk <sub>phom</sub> = Moderate IF $Y \geq 0.15$ then Risk <sub>phom</sub> = high

### Web-interface

In 2015, we published our web-interface to the selected users who agreed to evaluation systems performance. The current system requires a log in from the user, which enable us to provide tailored disease risk information for each growers (Fig. 1).

**Figure 1.** “GrapeIPM.org” for hosting weather data, as well as providing daily grape disease risk information: “Fruit Disease Risk Forecasting System” (FDRFS), Log in page



## Grape Pathology Information Center

### USER LOGIN

Username \*

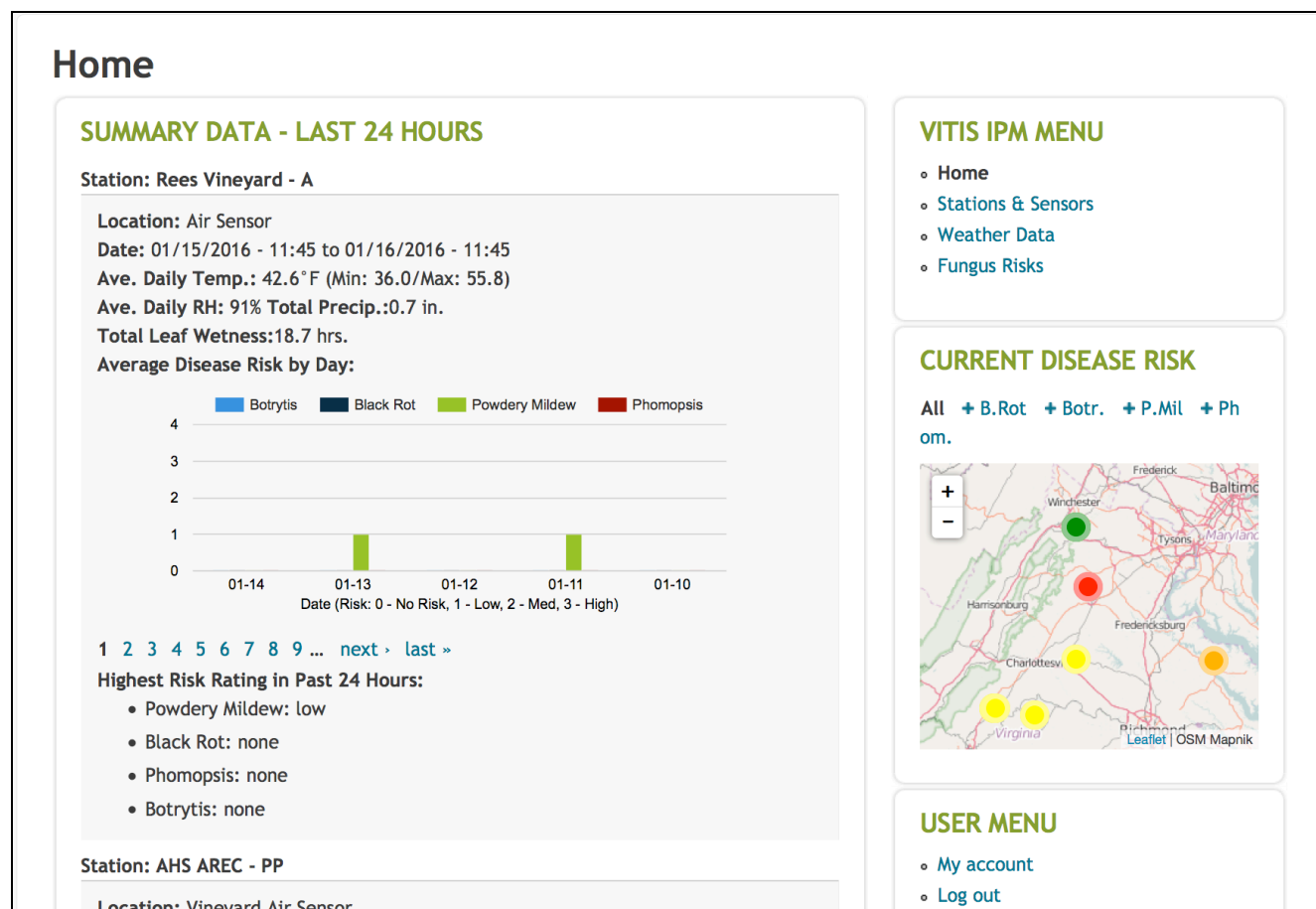
Password \*

[Create new account](#)  
[Request new password](#)

This grape/apple disease assessment tool is maintained by Nita Lab at Virginia Tech

When a user log in for the first time, he/she will choose a station (or stations) of interest, and then after that, the home screen will display weather information (average, max, and min temperature, average RH, total hours of leaf wetness, and total precipitation in the past 24 hours), and disease risk information from the past 5 days (Fig. 2). In addition, the users can see the risk of each disease in the past 24 hours as a map display. In addition, the user will have an access to past weather data (Fig. 3).

**Figure 2** User page for “Fruit Disease Risk Forecasting System” (FDRFS). Weather and recent disease risk information is shown on the left hand side “station information” window, and also, you can see the risk of each disease in the past 24 hours on the map display on the right hand side.



**Fig. 3** Interface for weather data for each station. Data can be downloaded as CSV file so that the user can import to Excel or other software.



## Conclusions, Discussions, and Impacts

We have successfully created a framework for future grape and apple disease risk assessment system by obtaining detailed weather data, and converting them into several grape disease risk assessment models utilizing database and geo-spatial technologies. In the mid-2015, we have published our new website (grapeIPM.org) to tier 1 and 2 groups for evaluation. Currently, we are adding more features to the website so that it will serve as a portal for grape and apple disease management.

By processing weather information properly, this risk assessment system can provide summarized information of the risk of disease development with an easy to understand color-coded graph and map displays (Fig. 2). One of the purposes of the system is to provide an aid for fungicide and bactericide applications. Currently, we are working on the interface and new database structure where both weather and fungicide application record information can be displayed for growers, so that the user can make better decisions. However, it is not our intension to have a system that will replace traditional fungicide recommendation programs. Instead, it will help educate growers to take another look at weather information, which is a major driving force of plant disease development. By doing so, this risk assessment system will help growers make a better decision when they refer to the fungicide recommendation programs. Some growers have been implementing weather monitoring equipment in their orchards and vineyards. For them, this system will serve as additional information to confirm their decision making. Many others may not have funds to purchase weather monitoring equipment, or they may think they do not have time to examine weather data to assess disease risks. For those growers, this system serves as an aid for their decision making which they did not have an access before.

Benefits of this system are not limited to the money and time saved by growers at the time of pesticide application. Precisely applied fungicide application can increase an efficacy of disease prevention, which leads to increase in quality and quantity of the yield (Madden et al., 2007). In addition, the impact on the environment should not be discounted. Excessively applied fungicide will be a threat to growers' (and their neighbors') health, and it has an impact on the environment through chemical drifts and run-offs. Moreover, the reduced use of fungicide will act as a preventative measure for the pesticide resistance development of pathogen populations

(Bent 1978, Campbell and Madden 1990). Populations of both powdery and downy mildew pathogens of grape resistant to the QoI fungicide in Virginia have been documented (Baudoin et al, 2008), and apple powdery mildew and apple scab also has developed resistance to the QoI (Sallato 2006), and potentially DMI (Koller 2005). Use of this risk assessment system could reduce the use of the vulnerable fungicides, and it may prolong the product life of these fungicides. Considering the cost, time, and effort put into a fungicide development, also the potential concern on the public health, the impact of the risk assessment system is very high.

Having such a system will also benefit extension specialists and agent. State-wide information will help extension personnel to make recommendations to growers; especially if the field of the question is far from the office of the extension personnel, which is not uncommon in many of southern states. This system also provides a resource to other research and extension opportunities by collecting valuable weather information throughout Virginia and place into a dedicated server that can be accessible by specialists. The availability of weather information and the flexibility of the modular system will allow other projects to take an advantage of the system with ease. The data obtained in this project will be shared with others, and the database will be valuable for many disciplines. For example, this system can be adapted to predict the emergence of insects, such as grape berry moth (Tobin et al., 2001), which is based on a seasonal heat accumulation. Furthermore, it can be combined with existing mapping effort such as Virginia's vineyard suitability maps (Boyer 2000) to provide a more comprehensive picture of the viticulture in VA.

There are several challenges that have been addressed. One is the availability of the weather information at the local level. The RTMA technology is very sophisticated and suitable for creating maps. For example, the USDA's ipmPIPE system for soybean rust and other diseases uses the very similar technology; however, its grid is 5 km square. Some users may feel the resolution is not high enough. To provide more information, the proposed system incorporates data from weather stations across the state of Virginia; however, these stations are scattered around and some growers may not find the one close to their vineyard. In order to resolve this issue, we have contacted another pest-management weather database ([www.uspest.org](http://www.uspest.org)), and granted a permission to use their resources. We have a link for our weather station data to their website since 2014. We are also planning to submit some of models to them.

Another challenge is the continuous funding. Often, many disease risk assessment efforts only last while funds are available, presumably due to high running cost. We would like to have a system that can run cost efficiently, so that the risk of termination of the service is minimal at the end of the funding cycle. The proposed system will be designed to be as automated as possible once the system is built. Thus, it should require relatively low cost to build a system, and it will require very small maintenance in terms of both cost and time in a long run. The weather data acquisition has been automated, and the disease model module were built independent of the system so that modification in disease risk assessment models can be made without affecting the whole system. Thus, once the system is established, cost associated for the maintenance of the system will be minimal, what required yearly will be fees for weather station maintenance and costs for data storage.

## References

- Agrios, G. N. (2005) Plant Pathology 5<sup>th</sup> Edition Academic Press, San Diego, CA.
- Baudoin, A., Olaya, G., Delmotte, F., Colcol, J. F., and Sierotzki, H. 2008. QoI resistance of *Plasmopara viticola* and *Erysiphe necator* in the mid-Atlantic United States. Online. Plant Health Progress doi:10.1094/PHP-2008-0211-02-RS.
- Bent, K. J. 1978 Chemical control of plant diseases: some relationships to pathogen ecology, in Plant Disease Epidemiology. Blackwell Scientific Publications, Oxford, UK.
- Boyer, J. and T.K. Wolf. 2000. GIS and GPS aid the exploration of viticultural potential in Virginia. Vineyard and Winery Management, Nov/Dec. 48-54.
- Broome, J. C., English, J. T., Marois, J. J., Latorre, B. A., and Aviles, J. C. 1995. Development of an infection model for Botrytis bunch rot of grapes based on wetness duration and temperature. *Phytopathology* 85:97-102.
- Bulit, J., and Lafon, R. 1970. Quelques aspects de la biologie du *Botrytis cinerea* Pers., agent de la pourriture grise des raisins. *Vigne Vin* 4:159-174.
- Campbell, C. L., and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. John Wiley & Sons, New York.
- Correiar, B. R. 1999. Use of automated weather stations and the Gubler-Thomaz model for control of powdery mildew (*Uncinula necator*) in California grapevines. *Summa Phytopathol.* 25:70-73.
- Dewdney, M. M., Biggs, A. R., and Turechek, W. W. 2007. A Statistical Comparison of the Blossom Blight Forecasts of MARYBLTY and Cougarblight with Receiver Operating Characteristic Curve Analysis. *Phytopathology* 97 (9):1164-1176.
- Ellis, M. A., 2005. Midwest Grape Production Guide. The Ohio State Extension Bulletin 919, Columbus, OH.
- Ellis, M. A., Madden, L. V., and Wilson, L. L. 1986. Electronic grape black rot predictor for scheduling fungicides with curative activity. *Plant Dis.* 70:938-940.
- Erincik, O., Madden, L. V., Ferree, D. C., and Ellis, M. A. 2003. Temperature and wetness-duration requirements for grape leaf and cane infection by *Phomopsis viticola*. *Plant Dis.* 87:832-840.
- Funt, R. C., Ellis, M. A., and Madden, L. V. 1990. Economic analysis of protectant and disease- forecast-based fungicide spray programs for control of apple scab and grape black rot in Ohio. *Plant Dis.* 74:638-642.
- Jones, A. L., and Aldwinckle H.S. (1990) Compendium of Apple and Pear Diseases. APS Press, St. Paul, MN.
- Jorgensen, S. E., and Bendoricchio, G 2001. Fundamentals of Ecological Modelling 3<sup>rd</sup> edition. Elsevier Oxford, UK.
- Gadoury, D. M., Pearson, R. C., Seem, R. C., and Park, E. W. 1997. Integrating the control programs for fungal diseases of grapevine in the northeastern United States. *Vitic. Enol. Sci.* 52:140-147.
- Karl, T. R., and Trenberth, K. E., 2003. Modern Global Climate Change. *Science* 302: 1719-1723
- Koller, W., Wilcox, W. F., and Parker, D. M. 2005. Sensitivity of *Venturia inaequalis* Populations to Anilinopyrimidine Fungicides and Their Contribution to Scab Management in New York. *Plant Disease* 89 (4):357-365.
- Lalancette, N., Ellis, M. A., and Madden, L. V. 1988. Development of an infection efficiency model for *Plasmopara viticola* on American grape based on temperature and duration of leaf wetness. *Phytopathology* 78:794-800.
- Madden, L. V., Ellis, M. A., Lalancette, N., Hughes, G., and Wilson, L. L. 2000. Evaluation of a disease warning system for downy mildew of grapes. *Plant Dis.* 84:549-554.
- Madden, L. V., Hughes, G., and van den Bosch, F. 2007. The study of plant disease epidemics, APS press, St. Paul, MN.
- Nair, N. G., and Allen, R. N. 1993. Infection of grape flowers and berries by *Botrytis cinerea* as a function of time and temperature. *Mycol. Res.* 97:1012-1014.
- Nita, M., Ellis, M. A., Wilson, L. L., and Madden, L. V. 2006. Evaluation of a disease warning system for *Phomopsis* cane and leaf spot of grape: A field study. *Plant Dis.* 90:1239-1246.
- Nita, M., De Wolf, E., Madden, L., Paul, P., Shaner, G., Adhikari, T., Ali, S., Stein, J., Osborne, L., and Wegulo, S. (2008) "Use of Mechanistic simulation models to predict disease intensity of *Fusarium* head blight and deoxynivalenol" *Phytopathology* 98: S113.
- Redak, R. A., Purcell, A. H., Lopes, J. R. S., Blua, M. J., Mizell, R. F., III, Andersen, P. C 2004. The biology of xylem fluid-feeding insect vectors of *Xylella fastidiosa* and their relation to disease epidemiology. *Annual review of entomology* 49:243-270.
- Sallato, B. V., Latorre, B. A., and Aylwin, G. 2006. First Report of Practical Resistance to QoI Fungicides in *Venturia inaequalis* (Apple Scab) in Chile. *Plant Disease* 90 (3):375-375.
- Shtienberg, D., and Elad, Y. 1997. Incorporation of weather forecasting in integrated, biological-chemical management of *Botrytis cinerea*. *Phytopathology* 87:332-340.
- Strzyk, S. 1983. Modele d'etar potential infection application au *Botrytis cinerea*. Assoc. de Coordination Technique Agricole. Paris.
- Sutton, J. C., Gillespie, T. J., and Hildebrand, P. D. 1984. Monitoring weather factors in relation to plant disease. *Plant Dis.* 68:78-84.
- Tobin P. C., Nagarkatti, S., and Saunders, M. C. 2001 Modeling development in grape berry moth (Lepidoptera: Tortricidae). *Environ. Entomol.* 30:692-699.
- Tarr, S. A. J. 1972. Principal of plant pathology. Winchester, New York.
- Thomas, C. S., Skinner, P. W., Fox, C. A., Greer, C. A., and Gubler, W. D. 2002. Utilization of GIS/GPS-based information technology in commercial crop decision making in California, Washington, Oregon, Idaho, and Arizona. *J. Nematol.* 34:200-206.
- Virginia Orchard Survey (2005) [http://www.nass.usda.gov/Statistics\\_by\\_State/Virginia/Publications/2005fruitpub.pdf](http://www.nass.usda.gov/Statistics_by_State/Virginia/Publications/2005fruitpub.pdf)
- Virginia, West Virginia, and Maryland Cooperative Extension 2010 Spray Bulletin for Commercial Tree Fruit Growers, Publication 456-419 (<http://www.pubs.ext.vt.edu/456/456-419/456-419.pdf>)
- Wolf, A. 2008. Leafroll virus issues. *Viticulture Notes* (Nov/Dec 2008). (<http://www.ext.vt.edu/news/periodicals/viticulture/08novemberdecember/08novemberdecember.html#3>)
- Zadoks, J. C. 1984. A quarter century of disease warning, 1958-1983. *Plant Dis.* 68:352-355

## Appendix I

**Table 1.** A timeline of the proposed disease information systems and its impact (*original*)

Phase	Timeline	Objective		Impact
<b>I</b> Development of the base system  A) Disease risk assessment system <b>(proposed here)</b>	2009-2013	1	Creating the infrastructure: a) Set up a data server; b) Create a web interface; c) Data management	Establish a weather data sharing structure between PSU and VT system
		2	Initial development of grape disease risk assessment tool <i>2009-2011</i> : Selection of candidate models based on previous studies ( <i>on-going as of 2009 season</i> ) <i>2010-2012</i> : Initial system run: testing and calibration of GIS modules, a hindcast of disease risks with existing datasets	
		3	Public deployment of the alpha system of disease maps	
<b>II</b> Initial runs  A) Disease risk assessment system B) Grape and Apple disease information center	2009-2014	1	Validation of models by comparing model outputs with actual observations in the fields	
		2	Validation of weather station input by comparing with national weather service data and RTMA model results ( <i>on-going as of 2009 season</i> )	
		3	Establishment of the web-interface for grape and apple disease information center	
		4	<i>2011-2014</i> : Initiation of experiments where participating plots will be using results of risk models to schedule fungicide application	– Student education – Public awareness development – Extension education
		5	Public deployment of the beta system that includes grape and apple disease information such as factsheets and pesticide spray recommendations (existing information will be fully utilized)	
<b>III</b> Public deployment  A) Disease risk assessment system B) Grape and Apple disease information center	2013-2016	1	System deployment and feedback: a) System maintenance and evaluation, b) Conduct survey to obtain user comments and suggestions; c) Continuation of validation of models and weather stations	
		2	Use of disease risk assessment system as an extension education tool	
<b>IV</b> Value addition A) Disease risk assessment system B) Grape and Apple disease information center	2011-2016	1	Toward more comprehensive information system for grape management; 1) Implementation of other disease risk maps (Pierce's disease forecast, grape leafroll virus distribution map, etc); 2) Establish links to existing disease databases (e.g., ipmPIPE products) and other information sources 3) Establish apple disease module which is another important fruit crop in VA	– More extended collaboration among faculties and institutions – Extension education beyond mid-Atlantic grape and apple production
		2	Expansion of the system beyond VA and plant pathology: 1) Continuation of the validation of the system; 2) Expansion of the system to other states; 3) Consult viticulturists and entomologists for application of the system; 4) Expansion of the system beyond grape plant pathology.	



## Appendix II

A copy of poster presented at 2012 GEOINT Symposium in Orlando, FL (October 8 – 11, 2012).

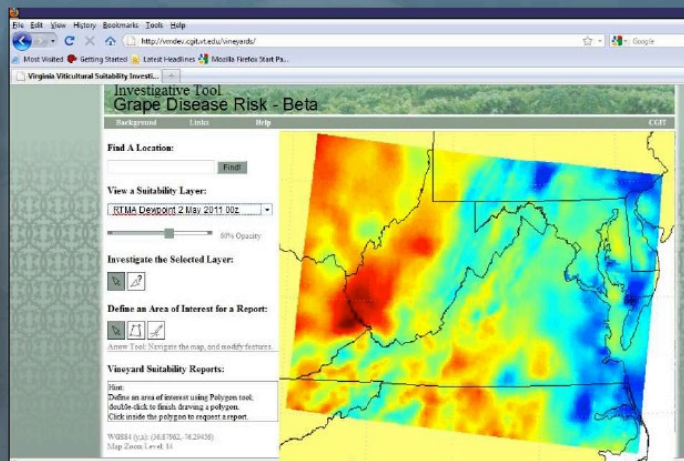
### Selected Project: Grape Disease Forecasting

CGIT is creating a predictive model to assess blight risks in grapes. The model considers blossom, canker, shoot, and trauma blight conditions to show infection risks (low to high) to determine risks two days in advance using forecasted weather information.

The model will generate hourly risk prediction rasters to determine when the symptoms of blights would occur. This can help growers to make decisions on the need for blight-preventive measures.



*Botrytis cinerea* on grapes  
Source: davitydave, Wikimedia Commons



Read RTMA climate data. Accept user inputs for phenology, wetness, and spray conditions.

Calculate Degree Day and Epiphytic Insect Potential.

Do symptoms indicate blight conditions: trauma, shoot, canker and blossom?

**NO:**  
Repeat previous steps.

**YES:**  
1. Calculate probability of blight occurrence and the area of grapes being affected.  
2. Assign risk scores  
3. Calculate weighted index.