(a) PD's: Francis J. Ferrandino[1], Richard Kiyomoto[2], Daniel R. Cooley[3], Frank Caruso[4], James LaMondia[6], Hilary Sandler[4], and Philippe Rolshausen[2].
(b) Cooperating Investigators: William Coli[3], Sonia Schloemann[3], Nathaniel Mitkowski[5], and William Nail[1].

[1]The Connecticut Agricultural Experiment Station, New Haven, CT
[2]University of Connecticut, Integrated Pest Management, Storrs, CT
[3]University of Massachusetts, Amherst, MA
[4]University of Massachusetts Cranberry Station, Wareham, MA
[5]University of Rhode Island, Kingston, RI
[6]The Connecticut Agricultural Experiment Station, Valley Laboratory, Windsor, CT

Title: Combining a disease and weather monitoring network with measurements of inoculum potential for disease forecasting in vineyard IPM for southern New England

This is a Joint Research-Extension project focused on improving control of vineyard diseases while reducing pesticide inputs. This will be accomplished by providing growers via the internet with disease support information on the risk of infection of disease in real time. The system uses weather based disease-risk models. We will establish weather monitoring stations in research and commercial vineyards throughout southern New England. These stations will be connected through cellular modems to a central location. Initial inoculum levels will be directly assayed at test vineyards and the survival and maturation of the over-wintering stage pathogens will be evaluated. In addition, inoculum potential will be evaluated each week using potted trap plants and mechanical spore samplers to determine the concentration of airborne inoculum. Crop growth and disease severity will be assessed each week during the growing season. Trap plants will be sprayed with systemic fungicides to obtain information on the development of fungicide resistant strains in the endemic powdery mildew populations. All disease forecast and recommended management information obtained will be accessible to the growers via the internet. At the end of each season we will report our findings to the growers at an annual meeting. We are requesting $75,000 in Smith-Lever funds for extension and $99,000 in P.L. 89-106 funds for research.

Dr. Francis Ferrandino, PD

Project: Combining a disease and weather monitoring network with measurements of inoculum potential for disease forecasting in vineyard IPM for southern New England

Problem, Background and Justification

Problem:

Wine grapes and wineries are a relatively new industry in Southern New England. The first vineyard/winery in Connecticut opened for business in 1978 in Litchfield, CT. Since then statistics in Connecticut show that both the acreage and number of winery enterprises has increased, with a particularly large jump in new enterprises after 2000. This growth in commerce was accompanied by a steady increase in on-site winery visits and tours for sampling at the local wineries (Gary Crump, president, CT Wine Council). In addition, the vast majority of local wineries are able to sell most of their product through winery visitations at excellent prices and are not dependent upon the wholesale market.

In 2006, extension reports by Richard Kiyomoto (archived on the University of Connecticut IPM website) show that powdery mildew infected almost all fruit clusters at several Connecticut vineyards, especially those along the shoreline and in central Connecticut. R. Kiyomoto estimates as much as 1/3 of the Connecticut crop in 2006 was damaged in quality by powdery mildew. When fruit is infected, there may be a harvestable product, but growers do not produce high-quality wine from infected fruit. Thus, as much as 1/3 of the total Connecticut crop was down-graded because of powdery mildew. In contrast, downy mildew and black rot disease was a major problem in Litchfield County, CT in 2006. However, the downy mildew caused crop losses only at two vineyards (Richard Kiyomoto estimates 20% and 40% losses from berry infection), and black rot caused crop losses at one vineyard (70% fruit clusters infected). Losses from diseases were so severe in 2006 that Richard Kiyomoto (University of Connecticut) conducted 4 disease control sessions throughout Connecticut in January and February 2007. Fruit infection by powdery mildew occurred in 2006 even though growers were warned through email notices and weekly prediction models placed on the UCONN IPM website.

By 2007 growers were armed with the training on proper timing of disease controls and the alerts provided in email notices and information posted and archived on the UCONN IPM website. Although the Summer and Fall of 2007 was characterized by drought, the conditions for powdery mildew infection in the Spring were ideal (disease models archived on UCONN IPM website) and the result is that only one vineyard had approximately 60% of the clusters infected by powdery mildew on Chardonnay, but not on Cabernet Franc. Downy mildew caused no fruit losses in 2007, but low level infections persisted throughout Connecticut all season. Black rot infected 100% of the clusters on Chambourcin at one vineyard with only 10% infection at most in the remaining cultivars in the same vineyard in 2007.

The primary goal of this project is to combine research-based disease management strategies with on-site measurement of weather, inoculum, and vine development to deliver real-time disease-risk information to grape growers, tailored to their local climatic conditions in southern New England. The adoption of this locally informed disease management system will eliminate unneeded pesticide application while maintaining the economic value of the crop. Reduced chemical input will minimize deleterious effects on the environment and help protect the health of both the vineyard worker and the consumer.

The vineyard industry in Southern New England has doubled in the last 7 years. In 2008, there will be about 750 acres planted to wine grapes on 80-85 farms throughout Connecticut, Massachusetts, and Rhode Island. There are 63 commercial wineries with projected 2008 annual sales of $17-$20 million producing about three quarters of a million gallons of wine. Wine trails in southern New England (SNE) connecting the wineries increasing the cultural diversity infusing much-needed money into the local rural communities. In some cases vineyards provide an alternative, direct-sales opportunity on existing farms, while in others the vineyards represent new agricultural enterprises.

Wine grapes face a daunting array of fungal diseases, which, left unchecked, can significantly reduce the economic value of the crop. In the initial stages of this project, the research component will focus on the biology and management of grape powdery mildew which can infect all succulent grape tissue. This pathogen can also infect grape berries in the early stages of their development and cause a significant decrease in quality. The resultant loss in economic yield can be devastating and the need to control this disease results in many fungicide applications. As a result, the fungus that causes powdery mildew on grape (*Erysiphe necator* syn. *Uncinula necator* (Schw.)) has developed resistance to certain chemical pesticides. Fungicide resistance is widespread in New York State (Wilcox 2007). In Connecticut, most powdery mildew fungicides are still effective; however, there is an instance on at least one vineyard where we don't know if infections were due to fungicide resistance or poor timing of application.

The likelihood of spread and infection by all grape pathogens within a vineyard and, in particular, powdery mildew is strongly dependent on local weather conditions. For this reason, the project will focus on the establishment of a network of vineyard-based weather stations that will sample the range of climate found in SNE. These weather stations will be remotely accessed from a central location (UCONN) via cellular phone modem technology. These weather data combined with powdery mildew prediction models can then be used to deliver timely disease-risk assessments to growers via the Internet. The most commonly used powdery mildew disease-risk model was developed in California (UC Davis model: Gubler *et al.* 1999), which has a much more arid climate than SNE. The early growing season in our region is characterized by cool, humid weather, and our first task is to test the applicability of the UC Davis model under these conditions.

The observed increase in disease levels in a vineyard, over a certain period of time, depends on more than just weather conditions. Basically, an observed large increase in the level of disease may be due to favorable weather conditions or simply a large amount of initial inoculum and high availability of susceptible tissue. For this reason, a disease-risk model based on weather alone cannot adequately forecast disease severity. To predict disease-risk models within a particular vineyard, we must coincidentally estimate the level of inoculum present, the resultant increase in the level of disease, and the stage of development and spatial density of susceptible host tissue within that field. Thus, over the course of this project we will create a new powdery mildew disease-risk model tailored for local weather conditions. This model must then be validated by independent disease and weather observations (data not used for its development) and used to deliver timely disease-risk information to the growers of SNE.

Background:

Quoting Wayne Wilcox (Wilcox 2003), "Powdery mildew (PM) afflicts vineyards worldwide. Eastern North America has the dubious distinction of being home to this disease, and we cannot grow grapes here without controlling it." For the past three years (2005 – 2007), in Connecticut, powdery mildew had the greatest impact on grape yield of all pathogens (crop reports by R. Kiyomoto; UCONN Grape IPM web site). The two highest priorities for grape IPM set by the state of New York in 2006 were:

- Powdery mildew biology and management
- Fungicide resistance management

This project will directly address both of these issues.

E. Necator is an obligate parasite, meaning it can only grow and reproduce on succulent grape tissue. Grape powdery mildew is a polycyclic disease and infects through primary (ascospore) and secondary (conidia) inoculum. The fungus overwinters in sexually produced resting structures called cleistothecia, which are washed by rain from infected foliage into folds and crevices in the bark of the trunk and canes before leaf fall. When mature cleistothecia are wetted, they produce ascospores, which are shot out into the air as primary inoculum. If susceptible grape tissue is available, a certain fraction of these airborne or rain-splashed ascospores will be deposited on grape leaves or petioles. This fraction will depend on wind, rainfall, and susceptible host area. Of these, only a certain weather-dependent fraction of the deposited ascospores will germinate. The resultant fungal mycelium grows externally over the leaf surface and after a temperature dependent time-period they will produces asexual airborne spores called conidia. These conidia are spread by wind to new host tissue over multiple generations. All succulent grape tissue is susceptible to infection. Most importantly, grape berries, are highly susceptible to infection up to 2-4 weeks from fruit set. Fruit infection during this relatively short window of time, causes most of the economic impact of powdery mildew on yield. However, as the fungus grows and spreads throughout the vineyard, the efficiency of photosynthesis is also reduced. This reduces the amount of sugar in fruit and the overall vigor of the grape vines. When mycelial densities reach a certain level, conidial production stops and the fungal mat starts to produce cleistothecia, mainly on infected leaves. Rain washes cleistothecia into folds and crevices in the bark of the trunk and canes. In order for these cleistothecia to act as primary inoculum the following spring, they must survive the winter, and not all do. Surviving cleistothecia that mature before bud break on the grape vines will harmlessly release their ascospores during rain events when no susceptible host tissue is available. Only those cleistothecia that survive the winter and reach maturity at the appropriate time will cause new infections to complete the disease cycle. Both survival and maturation rate of cleistothecia depend on local climate. In addition, structural changes of the bark in an aging vineyard will affect the number of cleistothecia available to produce primary inoculum of powdery mildew in the spring. The bark of grape vines changes considerably as vines mature. One and two year old canes have relatively smooth bark, while older canes have shaggy bark which starts to exfoliate after four or five seasons depending on cultivar. This may be especially important in SNE since, due to the rapid increase in vineyard acreage in the last seven years, between 25% – 30% of the vineyards in the region are less than 4 years old.

The UC Davis model (Gubler *et al.* 1999) uses two indices to measure the danger of disease spread reflecting the two types of spores produced by the powdery mildew fungus. The ascospore index, which measures the impact of a given amount of primary inoculum, is based on the average temperature during an extended leaf wetness event. The model utilizes the 'Conidial Mills Table' (Mills 1944) at 2/3 the value for hours of leaf wetness required at various temperatures (MacHardy and Gadoury, 1989; as amended by Stensvand, *et al*., 1997). This index does not account for the depletion of primary inoculum as the season progresses. In the UC Davis model, the spread of secondary inoculum is quantified as the conidial index, which is assumed to be proportional to the fraction of a day during which temperature is above 70 F. Epidemics are predicted when optimum temperatures of 70-85F occurred for at least 6 hours per day for at least 3 consecutive days. Weather data is processed through computer software, which downloads it to the model. Growers can access the readily usable information on their own computer via a modem and are warned when disease pressure is high. Conidial production below this temperature is ignored. However, conidia can be produced, disseminated, and cause new infections at temperatures lower than 70 F at high humidity (Carrol and Wilcox 2003). In SNE from mid-April to mid-June days with temperatures between 60-70 F and relative humidity between 60-80% are quite common and the UC Davis model does NOT predict these important early disease infection periods. In addition, under southern New England weather conditions, the requirement that temperature remains between 70 F and 85 F for a period of 6 hours per day for at least 3 consecutive days is often never met around the time grapes are in bloom. Thus, if SNE growers use the UC Davis disease-risk model predictions to determine whether or not to apply fungicide, the grape berries will often remain unprotected during their greatest period of susceptibility.

The observed increase in disease levels in a vineyard, over a certain period of time, depends on more than just weather conditions. Inoculum density and the quantity of susceptible host also impact disease development. Thus, to evaluate disease-risk models, within a particular vineyard, the level of inoculum present, the resultant increase in the level of disease, and the stage of development of the crop within that field must all be measured. The total amount of potential primary inoculum can be directly measured by counting the number of cleistothecia extracted from weighed bark samples (Gadoury and Pearson 1988, Cortesi *et al*. 1995, Cortesi *et al*. 1997). However, the determination of the quantity of ascospores that become airborne in any one day requires another approach. In aerobiology, spore samplers and potted trap plants, together with wind speed measurements, are used to estimate *per diem* ascospore release rates and the inoculum potential (Aylor and Kiyomoto 1993). For the secondary stages of the epidemic, conidial density can be estimated in terms of the total area of observed powdery mildew colonies. However when disease measurements are taken within growers field, which of necessity will be sprayed, other methods to assess the potential spread of disease must be used. Spore samplers and potted trap plants will be used to estimate inoculum potential, independent of the disease progress within the vineyard. The exposure of sprayed and nonsprayed trap plants in a vineyard will enable testing for the presence of pesticide-tolerant strains of the pathogen.

The heart of the extension arm of this project is the creation of a grape IPM website which is updated daily, supported by annual grower meetings where results can be transmitted and growers can be taught how to access and act on the information provided on the website. The New England Wine Grape Growers' Resource Center (http://www.newenglandwinegrapes.org/) will be linked seamlessly to the disease-forecast site, managed in CT. This disease-forecast site will deliver weather and disease information for each of the weather stations in the network. The disease forecast, IPM fact sheets, and electronic newsletters will be accessible and downloadable from the site. As the season progresses growers will be reminded to look for signs of disease development at particular stages of crop development. To support diagnosis, pictures of various symptoms of disease and insect damage will be made available, and scouting for disease and insects will be encouraged. The site will also provide a channel for grower feedback via email and facilitate communication with Extension specialists. This addresses the NEREAP-IPM priority set in May 2006, *i.e.*: **Use of web-based technologies for IPM decision making**. The evaluation of the effect of the web site and support activities on fungicide application in southern New England vineyards will be done as described under "Evaluation plans" below. This addresses the NEIPM priority set in 2006, *i.e.*: **Assess the effectiveness of electronic-based communications to IPM users (growers, practitioners)**.

Justification:

This project ultimately addresses issues of agricultural viability and pesticide use in New England. Grape production is growing rapidly in the region, and provides an alternative source of income for existing farms, an opportunity for people who want to start a small farm, and a venue for wine tasting parlors that attract the general public to a farm. At the same time, grape production is pesticide intensive, particularly in the area of fungicide use, and growers new to grapes are not familiar with the most effective and efficient ways to manage the complex of grape diseases. Lacking effective disease management, vineyards are not viable, but excessive fungicide use will cost money, have unnecessary non-target impacts, and present a less than environmentally friendly picture to the general public.

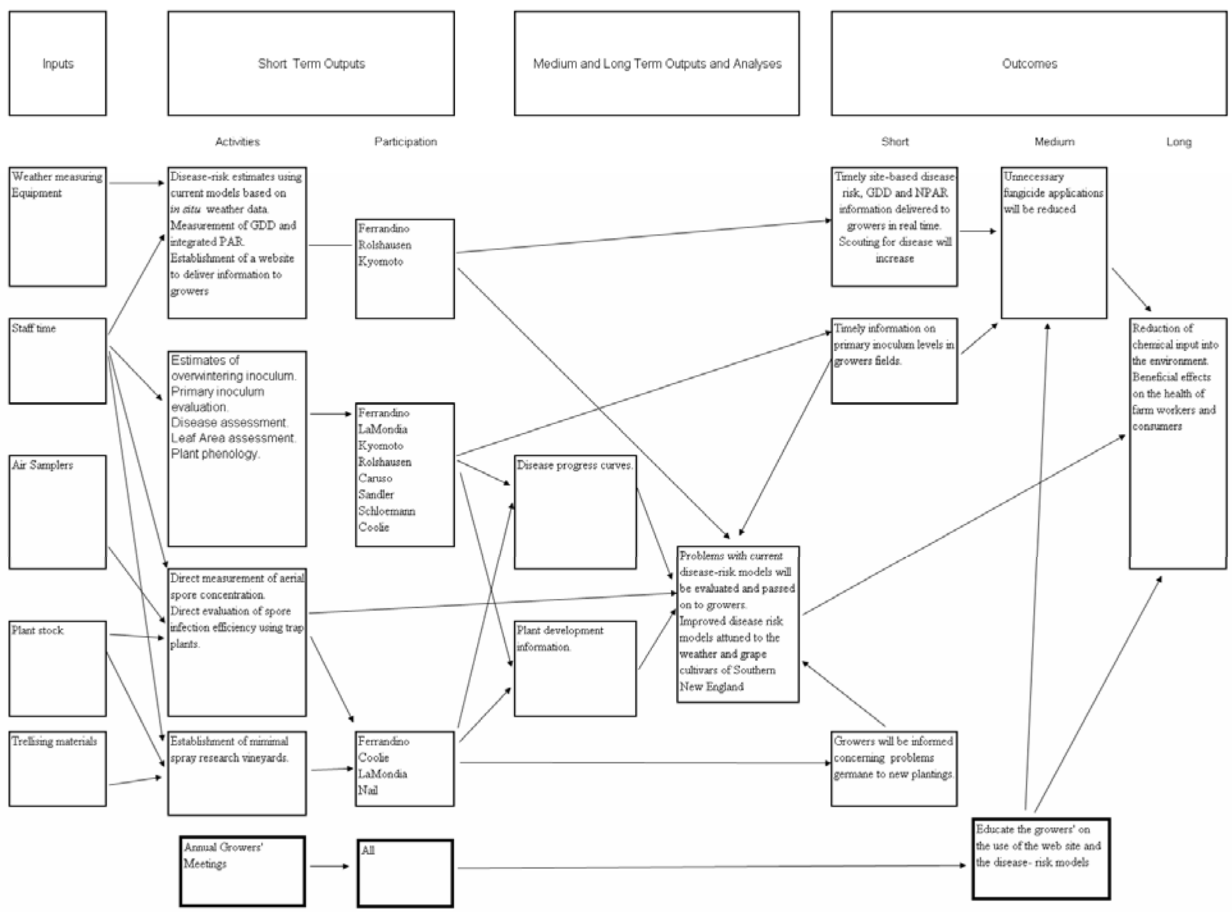
Fortunately, there is an extensive body of information on grape disease management, including disease-forecasting models, as exemplified by the powdery mildew model. This project will be combined effort to educate growers concerning the fundamentals of ecologically-sound disease management in vineyards and to provide growers with timely information that will support day-to-day management decisions. The project will provide real-time disease-risk information and an on-line resource of IPM information to more than 100 New England grape growers, vineyard managers, and farm workers via the Internet. Annual meetings will serve to provide feedback and information on growers' needs and concerns, and surveys conducted at the beginning of the project, at its completion, and at these annual meetings will provide information on the impact of this project on the extent of pesticide application in SNE. We also anticipate that powdery mildew resistance to DMI and strobilurine fungicides may be a problem in New England, leading growers to waste fungicide applications and still have inadequate disease control. To address this, vineyards experiencing difficulties with powdery mildew control will be visited and, if need be, the presence of fungicide resistance will be evaluated, on-site, using fungicide treated trap plants.

While we anticipate that this combination of grower education and decision support will reduce fungicide use in New England vineyards, we recognize a need to improve the disease forecasting models. Current disease-risk models for grape powdery mildew are probably not appropriate for the highly variable climate conditions found in different regions within SNE. The addition of estimates of inoculum levels into the disease risk model will reduce the number of recommended sprays without sacrificing disease controls. Once the sampling and cleistothecial extraction techniques are perfected, we will teach these methods to growers and IPM consultants.

SITUATION: The climate of southern New England differs from the climate where current grape disease-risk models were developed.

PRIORITIES: Deliver information to growers and improve disease forecasting models.

PROGRAM ACTION- LOGIC MODEL



Objectives and Anticipated Impacts

The primary goal of this project is to combine research-based disease management strategies with on-site measurement of weather, inoculum, and vine development to deliver real-time disease-risk information tailored to the local climatic conditions of wine grape growing found throughout southern New England grape growers, backed by an educational program to optimize IPM use in the region. In order to attain this goal a number of research and Extension objectives must be reached:

Research Objectives**:**

1) Improve disease forecasts for grape powdery mildew by including measurements of inoculum density and availability of susceptible host tissue. This will be accomplished by simultaneously measuring the magnitude of powdery mildew inoculum sources, the resulting concentration of airborne inoculum, spore deposition on host tissue, the spore infection efficiency, the expanse and composition of susceptible host tissue, and the resultant increase in disease incidence.
2) Quantify the overwintering survival and maturation of cleistothecia of *E. Necator* under a range of climatic conditions as part of the inoculum density component of the model.
3) To perform the above evaluations on established research and commercial vineyards, as well as newly planted research vineyards. These test vineyards will span the range of climatic conditions and cultivar selections that mirror the variation found in Southern New England.
4) Use the above results to create a new powdery mildew disease-risk model suitable for the climate of southern New England. This model will provide for the input of field-based measures of inoculum potential (cleistothecial counts, and disease severity estimates) and use differential susceptibility of planted grape cultivars to adjust risk levels.

Extension Objectives**:**

1) Provide the grape growers of SNE a web-based information network that provides daily updates of disease-risk information, growing degree days (GDD), and cumulative photosynthetically active radiation (PAR) that is measured within their climatic region.
2) Link the disease-forecast web site to existing web-based IPM resources, and develop new management resources for the site.
3) Help SNE grape growers assess and pest management consultants learn to assess the primary inoculum levels of powdery mildew in their vineyards. This will include late season assays of foliar disease severity and early spring determination of cleisothecial counts on pruned canes and exfoliated bark.
4) Educate growers on the problem of fungicide resistance and visit vineyards having problems controlling powdery mildew to determine whether or not fungicide resistant strains of *E. Necator* are present in our region.
5) To hold annual meetings to educate growers in use of the grape IPM web site, forecast models, and IPM options for grape disease management, as well as to discuss progress made and report scientific findings that impact disease management

strategies. These meetings will also provide a venue for grower feedback and project evaluation.

Impact

Improved disease-risk assessment will reduce the number of pesticide sprays. The cost of a single pesticide spray, including labor and equipment costs, ranges between $50 and $70 per acre, depending on the chemicals used (White 2004). However, an unneeded pesticide application causes deleterious impacts on the environment and adversely affects the health of both vineyard workers and consumers. An extra spray also increases the likelihood of the development of fungicide resistance in the pathogen population. If fungicide resistance arises while fruit is susceptible, very significant reduction in the economic yield of the vineyard will result.

Approach and Procedures

Our approach to the solution of the above problem first requires the establishment of a number of measurement and communication tools, before the research or extension objectives can be addressed:

1. The development of a network of vineyard-based weather stations that can be remotely accessed from a central location in real-time, spanning the range in climate found in southern New England.
2. Training of vineyard scouts using common assessment protocols to estimate disease levels and vine growth in each vineyard hosting a weather station.
3. The creation of a southern New England grape disease management web site that will be updated daily and will provide weather, disease management, and cultural information to grape growers.
4. The establishment of three new research vineyards that, over the course of this project, will allow for the determination of the role of vineyard age on the epidemiology of grape pathogens. These research vineyards will allow for experiments using controlled inoculation and destructive sampling, which would not be possible in commercial vineyards.

Research:

1) Epidemiological Experiments. Test vineyards will be monitored throughout the growing season using trap plants to evaluate when, and in what quantity, PM inoculum is present. This eliminates confusion as to the timing of spore release due to the temperature dependent latent period between infection and visible symptoms of disease. However, in order to objectively evaluate weather-based disease-risk, inoculum levels must also be estimated.

   a) Quantification of PM inoculum sources.

      i) Primary inoculum (ascospores). To harvest cleistothecia, bark samples will be immersed in an Erlenmeyer flask with a known quantity of water and placed in a shaker arm for three minutes. The supernatant liquid is passed through a stack of micromesh sieves. This rinsing is repeated (three times is recommended) and the material trapped in the appropriate size sieve is examined under a microscope and cleistothecia are counted (Pearson and Gadoury 1987, Gadoury and Pearson 1988, Cortesi *et al.*1995, Cortesi *et al.* 1997, Grove 2004). Although this procedure gives a measure of the total potential amount of primary inoculum, it neither indicates if the cleistothecia are viable nor how many ascospores will be released during a given leaf wetness event. In the first year of the study, we will investigate the use of staining (Cortesi *et al.*1997) to determine ascospore survival and maturity, in analogy to the squash mounts used for apple scab (Gadoury and MacHardy 1982). Alternatively spore towers can be used to directly evaluate the release of ascospores per unit area of bark (Aylor and Qui 1996). Alternatively, airborne inoculum can be directly measures in the field using the tools of aerobiology, as outlined below.

ii) Secondary inoculum (Disease severity assessment). As a first approximation, secondary (conidial) inoculum pressure will be assumed to be proportional to the total area of powdery mildew colonies per unit length of row in the vineyard. This will be evaluated by a two-step process. First the percent of the leaves covered by PM colonies will be estimated (PC), then the total leaf area per unit length of row (LAD) will be estimated. An estimate of the conidial inoculum pressure is then given as the product PC x LAD. Alternatively, airborne inoculum can be directly measures in the field using the tools of aerobiology, as outlined below.

b) Aerial concentration of inoculum.

i) Rotating impaction samplers. The concentration of airborne ascospores and conidia of *E. Necator* will be evaluated using Rotorods © (Surveillance Data Inc.; Plymouth Meeting, PA). Airborne spores are impacted on rapidly spinning pairs of greased plastic rectangular rods. The rods are then removed and spores are counted under a microscope. Rotorods sample about 40 liters of air per minute (Aylor and Ferrandino 1988, Aylor and Kiyomoto 1993).

ii) High volume air samplers. For low inoculum levels we will use high volume air samplers (Hi-Q Environmental Products Co.; San Diego, CA). These samplers, designed for pollen counts, can be run using one deep cycle marine battery (12 V) for approximately three hours at a sampling rate of 200 liters of air per minute. Two batteries in parallel (24 V) raises the sampling rate to 380 liters of air per minute.

c) Spore deposition and inoculum efficiency.

i) Trap plants. Potted grape vines will be placed out in test vineyards for from one to seven days. These plants will then be incubated under controlled conditions and the resultant number of PM colonies per unit leaf area will be evaluated.

ii) Glass slides. Greased microscope slides will be exposed to inoculum with the trap plants. Ascospores and/or conidia deposited on the slides will be counted and expressed as number of infectious units per unit area. A comparison of the PM colony density found on trap plant leaves and the microscope slide dose will yield the infection efficiency of deposited spores.

   d) Host measurements.
      i) Leaf area. A correlation between the product of the measured length and width of detached leaves and leaf area, measured with a leaf area meter will be established for each grape cultivar of interest. The total leaf area of selected grape vines will be estimated each week using a combination of cane and leaf counts and leaf length and width measurements made in the field.
      ii) Leaf age. Each time leaf area is estimated on the above selected grapevines, the growing tip will be marked with a plastic tag indicating the date. In this way, disease severity can be evaluated by weekly leaf age categories.
2) Overwintering.
   a) Leaf Sandwiches. Leaves infected with PM will be collected late in the season to obtain a test population of cleistothecia. Groups of 20 leaves from the same vineyard and grape cultivar will be sealed in a nylon mesh bag and exposed to the elements in each of the test vineyards. These leaves will be sampled weekly starting early April and tested for survival and maturity of their resident cleistothecia.
   b) Bark samples. In like manner exfoliated bark samples will be taken from the same heavily infected vineyard and grape cultivar. Groups of 20 pieces of bark will be sealed in nylon mesh bags and exposed to the elements in each of the test vineyards. These bark samples will be sampled weekly starting early April and tested for survival and maturity of their resident cleistothecia.
3) Test vineyards. Two established research vineyards will be used as test vineyards: one in Belchertown, MA (planted 2004) and the second at the Valley Laboratory in Windsor, CT (planted 1999). Three new research vineyards will also be established: one at Lockwood Farm in Hamden, CT, one at the Valley Laboratory in Windsor, CT, and the third the State of Connecticut DEP Nursery located in Voluntown, CT. In addition three Connecticut commercial vineyards will be used as test vineyards: one coastal and two inland.
4) Disease-Risk models. The UC Davis model will be tested using a simple juxtaposition of observed trap plant infection, inoculum potential estimates, and the weather record at each test site.

Extension:

1) Information Network. We will dedicate the first year of the project to the establishment of the weather network and the creation and fine tuning of a web-based grape information network. This will include an interactive website which updates data as frequently as possible and allows for grower input.
2) Primary Inoculum. Once the proper protocol for evaluating primary inoculum levels from bark samples is determined, we will educate growers and IPM consultants on the use of this technique. As data accumulates, correlations between primary inoculum in the spring and disease assessments in the fall for the various climate regions will be posted on the web site.
3) Fungicide Resistance. The importance of fungicide resistance will be communicated over the website and sprayed trap plant assessments will be used at potentially problematic vineyards, as needed.

4) Annual Meetings. Annual meetings of growers, vineyard managers, grape IPM extension specialists, and research scientists involved with this project will be held during the winter months, sequentially in each of the participating states. Project participants will report their findings and a round table discussion will serve as a venue for stakeholder feedback. At these meetings we will survey growers in order to evaluate whether or not this project has affected their use of pesticides.

Management

Since both the research and the Extension parts of this project are based on data collection, the first order of business is the establishment of common protocols for weather station installment, disease assessment, leaf area estimation, and cane sampling (cleistothecia counting). This will be accomplished at a meeting held early in the project with a representative from each institution present (CAES, UCONN, and UMASS). This meeting will result in printed protocols for each of the data collecting activities to be distributed to the people in the field. Also at this meeting we will decide the target vineyards on which to concentrate our efforts. This decision will depend on manpower limitations and on a preliminary evaluation of previous disease levels in these vineyards.

Each institution will be responsible for setting up the weather stations within its own state. The coordination of remote data collection and web site development will be performed by a third party web site master located at UCONN. This work will be overseen by PD's Rolshausen, Kiyomoto and Ferrandino. The content of the website will be determined by the consensus of all PD's and collaborators and will be adjusted throughout the project to fill growers' needs.

Aerobiological measurements will all be overseen by PD Ferrandino to establish consistency. In the first year, these weekly measurements will be performed at two research vineyards (Belchertown, MA and Windsor, CT) and at one commercial vineyard as yet to be determined.

Timetable

Objectives	Year 1	Year 2	Year 3	Completion
UC Davis Model Evaluation	X	X		
Primary Inoculum Protocol	X	X		
Primary Inoculum Outreach		X	X	X
Epidemiological Data Collection	X	X	X	
Disease and Host Evaluation Protocol	X			
New Disease-Risk Model Development			X	X
Annual Meetings		X	X	X
Website Development	X			
Weather Network Establishment	X			
Website and Weather Network Maintenance and fine tuning		X	X	X

Evaluation Plans

Because evaluation of outcomes presumes an accurate understanding of pre-program practices and grower condition, the first step in the project will be development and execution of a Dillman Method survey (Dillman, 1978) to all SNE grape growers to determine baseline disease management practices, with emphasis on the type and extent of disease forecast model use and annual fungicide use. Data from a previous SARE project in SNE grapes (Coli *et al.*, 2003) will also provide baseline information. The survey will be repeated at the end of the project, to determine the extent of change in model use and impacts on fungicide use in vineyards.

Key Personnel

Francis J. Ferrandino, Ph. D. Physics. Over 25 years experience in epidemiological modeling, field sampling of airborne spores and spray droplets, and statistical sampling of spatially aggregated variables.

Richard Kyomoto, Ph. D. Plant Pathology. Over 32 years experience as a plant breeder, performing photosynthesis and fruit crop research, wine grape IPM specialist.

Daniel Cooley, Ph.D. Plant Pathology. Over 20 years experience with research and Extension. Field and lab staff supervisor, participant in on-farm research and education, newsletter contributor.

James A. LaMondia, Ph. D. Plant Pathology. Over 23 years of experience with research and Extension. Head of the Valley Laboratory in Windsor, CT.

Philippe Rolshausen, Ph. D. Plant Pathology. 8 years of experience in grape pathology, trunk diseases and the effects of various fungicides on disease control.

William R. Nail, Ph. D. Horticulture. Viticulture Specialist at The Connecticut Agricultural Experiment Station.

Frank Caruso, Ph.D. Plant Pathology. Over 23 years research and extension experience. Field and lab staff supervisor/coordinator, participant in on-farm research and education, newsletter contributor.

Hilary Sandler, Ph.D. Plant Pathology, Weed Science. Over 23 years extension and research experience. Field staff supervisor/coordinator, participant in on-farm research and education, newsletter contributor.

Sonia Schloemann, M.S. Small fruit IPM Specialist. Over 20 years extension and research experience. Newsletter author/editor, field staff supervisor, participant in on-farm research and organizer of educational meetings.

Nathanial A. Mitkowski, Ph. D. Plant Pathology.

William Coli, Ph.D. Entomology and Plant Science. Over 25 years extension and applied research experience.

Dr. Francis Ferrandino

CAES, 203-974-8459

Project: Combining a disease and weather monitoring network with measurements of inoculum potential for disease forecasting in vineyard IPM for southern New England

Reference and Bibliography

Aylor, D. E., and Ferrandino, F. J. 1988. Dispersion of spores released from an elevated line source within a wheat canopy. Boundary Layer Meteorology 46:251-273.

Aylor, D. E., and Kiyomoto, R. K. 1993. Relation between aerial concentration of Venturia inaequalis ascospores and development of apple scab. Agric. For. Meteorol. 63:133-147.

Aylor D.E., and Qui, J. 1996. Micrometeorological determination of release rate of Venturia inaequalis ascospores from a ground-level source during rain. Agric. For. Met. 81:157-178.

Bélanger, R. R., Bushnell, W. R.; Dik, A. J., Carver, T. L.W. 2002. The powdery mildews: A comprehensive treatise. American Phytopathological Society. St. Paul, MN, USA. 292 pp.

Braun, U., and Takamatsu, S. 2000. Phylogeny of Erysiphe, Microsphaera, Uncinula (Erysipheae) and Cystotheca, Podosphaera, Sphaerotheca (Cystotheceae) inferred from rDNA ITS sequences-some taxonomic consequences. Schlechtendalia 4:1-33.

Carroll, J. E., and Wilcox, W. F. 2003. Effects of humidity on the development of grapevine powdery mildew. Phytopathology 93:1137-1144.

Coli, W. H. Sandler, Schloemann, S., Caruso, F., Vanden Heuvel J., and Cooley, D. 2003. Integrated and sustainable wine grape production in southern New England. Project for Northeast Sustainable Agriculture Research and Education Program.

Cortesi, P., Gadoury, D. M., Seem, R. C., Pearson, R. C. 1995. Distribution and retention of *Uncinula necator* on the bark of grapevines. Plant Dis. 79:15-19.

Cortesi, P., Bisiach, M., Ricciolini, M., and Gadoury, D. M. 1997. Cleistothecia of *Uncinula necator*—An additional source of inoculum in Italian vineyards. Plant. Dis. 81:922-926.

Diehl, HJ; Heintz, C. 1987. Studies on the generative reproduction of grapevine powdery mildew (*Uncinula necator* Berk.). Vitis. Vol. 26, no. 2, pp. 114-122.

Dillman, D.A. 1978. Mail and telephone surveys: The Total Design Method. Wiley, New York.

Doster, M. A., and Schnathorst, W. C. 1985. Phytopathology. Vol. 75, no. 3, pp. 318-321. 1985.

Ficke, A., Gadoury, D. M., and Seem, R. C. 2002. Ontogenic resistance and plant disease management: A case study of grape powdery mildew. Phytopathology 92:671-675.

Flaherty, D. L., L. P. Christiansen, W. T. Lanini, J. J. Marois, P. A. Phillips, and L. T. Wilson. Eds. 1992. Grape Pest Management. Univ. of Calif. DANR Publication. 400 pp.

Fuzi, I. 2003. The role of environmental conditions in the dynamics of epidemics of *Uncinula Necator* (Schw.) Burr. Doctoral Thesis. Veszprém University; Georgikon Faculty of Agriculture; Crop Production and Horticultural Sciences, Veszprém, Hungary.

Gadoury, D. M., and MacHardy, W. E. 1982. Preparation and Interpretation of Squash Mounts of Pseudothecia of Venturia inaequalis. Phytopathology 72:92-95.

Gadoury, D. M., and Pearson, R. C. 1988. Initiation, development, dispersal, and survival of cleistothecia of *Uncinula necator* in New York vineyards. Phytopathology 78:1413-1421.

Gadoury, D. M., and Pearson, R. C. 1990. Germination of ascospores and infection of *Vitis* by *Uncinula necator*. Phytopathology 80:1198-1203.

Gadoury, D. M., Seem, R. C., Pearson, R. C., Wilcox, W. F., and Dunst, R. M. 2001. Effects of powdery mildew on vine growth, yield, and quality of Concord grapes. Plant Dis. 85:137-140.

Gadoury, D. M., Seem, R. C., Ficke, A., and Wilcox, W. F. 2001. The epidemiology of powdery mildew on Concord grapes. Phytopathology 91:948-955.

Gadoury, D. M., Seem, R. C., Ficke, A., and Wilcox, W. F. 2003. Ontogenic resistance to powdery mildew in grape berries. Phytopathology 93:547-555.

Grove, G. G., Davis, G. H., and Boal, R. J.1999. Powdery mildew of grape: Perennation of *Uncinula necator* in Eastern Washington. (Abstr.) Phytopathology 89:S30.

Grove, G. G., and Watson, J. 1996. Washington researchers attack powdery mildew. Good Fruit Grow. 48(5):27-32.

Grove, G. G., and Watson, J. 2000. Powdery mildew: Local insights into eastern Washington's primary grape disease. Good Fruit Grow. 52(12):65-70.

Grove, G. G. 2004. Perennation of *Uncinula necator* in vineyards of Eastern Washington. Plant Dis. 88:242-247.

Gubler, W. D., Rademacher, M. R., Vasquez, S. J., and Thomas, C. S. 1999. Control of powdery mildew using the UC Davis powdery mildew risk index. APSnet Feature, January 6 thru January 31, 1999. (http://www.apsnet.org/online/feature/pmildew/)

Jailloux, F., Willocquet, L., Chapuis, L., and Froidefond, G. 1999. Effect of weather factors on the release of ascospores of *Uncinula necator*, the cause of grape powdery mildew, in the Bordeaux region. Can. J. Bot. **77**: 1044–1051 (1999)

Johnson, D. A., and Ahmedulla, M. 1983. Powdery mildew of grapes in Washington.Wash. State Univ. Coop. Ext. Bull. EB1202.

MacHardy, W. E. and Gadoury, D. M. 1989. A revision of Mills's criteria for predicting apple scab infection periods. Phytopathology 79:33, 304-310.

Magarey, P. A., Gadoury, D. M., Emmett, R.W., Biggins, L. T., Clarke, K., Wicks, T. J., and Seem, R. C. 1997. Cleistothecia of *Uncinula necator* in Australia. Vitic. Enol. Sci. 50:210-218.

Mills, W. D. 1944. Efficient use of sulfur dusts and sprays during rain to control apple scab. Cornell Ext. Bull. 630.

Pearson, R.C. and Gadoury, D.M. 1987. Cleistothecia, the source of primary inoculum for grape powdery mildew in New York. Phytopathology. 77:1509-1514.

Pearson, R. C., and Goheen, A. C. 1988. Compendium of Grape Diseases. American Phytopathological Society Press, St. Paul, MN.

Sall, M. A. and Wyrinski, J. 1982. Perennation of powdery mildew in buds of grapevines. Plant Dis. 66:678-679.

Stapleton, J. J., Gubler, W. D., Fogle, D.,Chellemi, D., Bettiga, L., Leavitt, G., Verdegaal, P., Smith R., and Kelley, K. 1988. Relationships among climate, primary inoculum source, dormant and post emergence control sprays, and grape powdery mildew in California. (Abstr.) Phytopathology 78:1531.

Steinkellner, S. 1998. Overwintering of *Uncinula necator* in Austrailian vineyards. Vitis 37:193-194.

Stensvand, A., Gadoury, D. M., Amundsen, T., Semb, L., and Seem, R. C. 1997. Ascospore release and infection of apple leaves by conidia and ascospores of *Venturia inaequalis* at low temperatures. Phytopathology 87:1046-1053.

White, G. B. 2004. Cost of establishment and production of vinifera grapes in the Finger Lakes region of New York. Cornell University Extension Bulletin 2005-06.

Wilcox, W. F. 2003. Strategies to control powdery mildew. Practical Winery and Vineyard April-May 2003.

Willocquet, L., Colombet, D., Rougier, M., Fargues, J., and Clerjeau, M. 1996. Effects of radiation, especially ultraviolet B, on conidial germination and mycelial growth of grape powdery mildew. European Journal of Plant Pathology 102: 441-449.

Willocquet, L., Clerjeau, M 1998. An analysis of the effects of environmental factors on conidial dispersal of *Uncinula necator* (grape powdery mildew) in vineyards. Plant Pathol. 47:227-233.

Willocquet, L., Berud, F., Raoux, L., Clerjeau, M. 1998. Effects of wind, relative humidity, leaf movement and colony age on dispersal of conidia of *Uncinula necator*, causal agent of grape powdery mildew. Plant Pathol. 47: 234-242.

Ypema, H. L. and Gubler, W. D. 1997. Long term effect of temperature and triadimefon on proliferation of *Uncinula necator*: Implications for fungicide resistance and disease risk assessment. Plant Dis. 81:1187-1192.

PD's: Francis J. Ferrandino[1], Richard Kiyomoto[2], Daniel R. Cooley[3], Frank Caruso[4], James LaMondia[6], Hilary Sandler[4], and Philippe Rolshausen[2].
Cooperating Investigators: William Coli[3], Sonia Schloemann[3], Nathaniel Mitkowski[5], and William Nail[1].
[1]The Connecticut Agricultural Experiment Station, New Haven, CT
[2]University of Connecticut, Integrated Pest Management, Storrs, CT
[3]University of Massachusetts, Amherst, MA
[4]University of Massachusetts Cranberry Station, Wareham, MA
[5]University of Rhode Island, Kingston, RI
[6]The Connecticut Agricultural Experiment Station, Valley Laboratory, Windsor, CT

(b) Project title: Combining a disease and weather monitoring network with measurements of inoculum potential for disease forecasting in vineyard IPM for southern New England

(c) Project type: Joint Research-Extension

(d) Project summary: This is a Joint Research-Extension project focused on improving control of vineyard diseases while reducing the input of pesticides into the environment. This will be accomplished by informing growers via the internet of the risk of infection of disease in real time. This involves the use of weather based disease-risk models, which will be improved over the course of the project. We will establish weather monitoring stations in unsprayed research vineyards and commercial vineyards throughout southern New England to sample the range in climate in the region. These stations will be connected through cellular modems to a central location. Initial inoculum levels will be directly assayed at test vineyards and the survival and maturation of the over-wintering stage pathogens will be evaluated. In addition, inoculum potential will be evaluated each week using potted trap plants and mechanical spore samplers to determine the concentration of airborne inoculum. Crop growth and disease severity will also be assessed each week during the growing season. By spraying some of the trap plants with various systemic fungicides, we will also obtain information on the development of fungicide resistant strains in the endemic pathogen populations. All disease information obtained will be passed on to the growers through the internet. At the end of each season we will report our findings to the growers at an annual meeting. We are requesting $75,000 in Smith-Lever funds for extension and $99,000 in P.L. 89-106 funds for research.

(e) Problem, Background and Justification

Problem:

The primary goal of this project is to combine research-based disease management strategies with on-site measurement of weather, inoculum, and vine development to deliver real-time disease-risk information to grape growers, tailored to their local climatic conditions in Southern New England. The adoption of this locally informed disease management system will eliminate unneeded pesticide application while maintaining the economic value of the crop. Reduced chemical input will minimize deleterious effects on the environment and help protect the health of both the vineyard worker and the consumer.

The vineyard industry in Southern New England has doubled in the last 7 years. In 2008, there will be about 750 acres planted to wine grapes on 80-85 farms throughout Connecticut, Massachusetts, and Rhode Island. There are 63 commercial wineries with projected 2008 annual sales of 17-20 million dollars producing about three quarters of a million gallons of wine. The numerous wine trails in Southern New England (SNE) connecting the wineries increase the cultural diversity of the region. This attracts agro-tourism, which infuses much needed money into the local communities.

Wine grapes are subject to many fungal pathogens, which, left unchecked, can significantly reduce the economic value of the crop. In the initial stages of this project, the research component will focus on the biology and management of grape powdery mildew. This foliar pathogen can also infect grape berries in the early stages of their development and cause a significant decrease in quality. The resultant loss in economic yield can be devastating and the need to control this disease results in many fungicide applications. As a result, the fungus that causes powdery mildew on grape (*Uncinula necator*) has developed resistance to certain chemical pesticides in other states (New York ref).

The most commonly used powdery mildew disease-risk model was developed in California (UC Davis model: ref), which has a much more arid climate than SNE. The early growing season in our region is characterized by cool, humid weather, and our first task is to test the applicability of the UC Davis model under these conditions. To assess the accuracy of disease-risk models within a particular vineyard, we must coincidentally estimate the level of inoculum present, the resultant increase in the level of disease, and the stage of development and spatial density of susceptible host tissue within that field. This is the exact data needed to create a disease-risk model in the first place. Thus, over the course of this project we will create a new powdery mildew disease-risk model tailored for local weather conditions. This model must then be validated by independent disease and weather observations (data not used for its development) and used to deliver timely disease-risk information to the growers of SNE.

Background:

Quoting Wayne Wilcox (Wilcox 2003), "Powdery mildew (PM) afflicts vineyards worldwide. Eastern North America has the dubious distinction of being home to this disease, and we cannot grow grapes here without controlling it." The two highest priorities for grape IPM set by the state of New York in 2006 were:

- Powdery mildew biology and management
- Fungicide resistance management

This project will directly address both of these issues.

The UC Davis model (ref) uses two indices to measure the danger of disease spread reflecting the two types of spores produced by the powdery mildew fungus. The ascospore index, which measures the impact of a given amount of primary inoculum, is based on the average temperature during an extended leaf wetness event. The model utilizes the 'Conidial Mills Table' (Mills 1944) at 2/3 value for hours of leaf wetness required at various temperatures (MacHardy and Gadoury, 1989; as amended by Stensvand, *et al*., 1997). In the UC Davis model, the spread of secondary inoculum is quantified as the conidial index, which is assumed to be proportional to the fraction of a day during which temperature is above 70 F. However, conidia can be produced, disseminated, and cause new infections at temperatures lower than 70 F at high humidity

(Carrol and Wilcox 2003). In SNE from mid April to mid June days with temperatures between 60-70 F and relative humidity between 60-80% are quite common and these important early disease infection periods that this represents are NOT predicted by the UC Davis model.

The heart of the extension arm of this project is the creation of a grape IPM website which is updated daily. This site will deliver weather and disease information for each of the weather stations in the network. The site will also provide a channel for grower feedback via Email and, if the situation warrants it, on-site visits will made by our extension people. This is in keeping with the NEREAP-IPM priority list set in May 2006, *i.e.*: **Use of web-based technologies for IPM decision making**. The evaluation of the effect of this web site on fungicide application in southern New England will be done at yearly meetings through questionnaires and discussion groups in keeping with the NEIPM Priority 2006, *i.e.*: **Assess the effectiveness of electronic-based communications to IPM users (growers, practitioners)**.

Justification:

Current disease-risk models for grape powdery mildew are probably not appropriate for the climate conditions found in SNE. This project will provide improved disease-risk information, in a timely fashion, to in excess of 100 grape growers, vineyard managers, and farm workers via the internet. The addition of estimates of inoculum levels into the disease risk model will reduce the number of recommended sprays without sacrificing disease controls. Annual meetings will serve to provide feedback and information on growers' needs and concerns, and surveys conducted via the internet and at these annual meetings will provide information on the impact of this project on the extent of pesticide application in SNE. Reduced pesticide applications will help reduce both deleterious effects on the environment and detrimental effects on the health of farm workers and consumers.