PROJECT SUMMARY

Project Director: Dr. Norman Lalancette
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Agricultural Research & Extension Center
Bridgeton, New Jersey

Project Title: Predicting Inoculum Availability for Peach Scab: Development and Validation of a Forecasting Model

Project Type: Research

This Research Project investigates the quantitative epidemiology of peach scab, caused by the plant pathogenic fungus *Fusicladosporium carpophilum*. Eastern states produce 62% of the total U.S. fresh production of peaches with an annual value of $179 million. Crop profiles for most peach growing states in this region, including NJ, PA, WV, and New England, list scab as a disease of major importance. Since resistant cultivars are not available and cultural controls alone are inadequate, scab is primarily managed by application of consecutive fungicide sprays on a calendar basis. This approach results in unnecessary fungicide applications when environmental conditions are unfavorable and loss of disease control when conditions are highly favorable. The New Jersey Pest Management Strategic Plan states “a better understanding of the epidemiology should allow more effective and efficient use of newer fungicides”. The major goal of the proposed project is to develop a forecasting model for predicting inoculum availability for infection. Specifically, sporulation of overwintering twig lesions, the major source of inoculum, will be quantitatively described as a function of temperature. A forecasting model algorithm will be created from this temperature relationship and previously published results. Predictions of this model will be field validated over two seasons. Implementation of the model will allow optimized fungicide application timing, thereby simultaneously reducing the potential for fungicide overuse and the likelihood of yield loss. Improvements in fungicide application efficiency will decrease amount of fungicide in the environment, enhance grower profitability, reduce applicator and field crew pesticide exposure, and decrease risk of pesticide residues on harvested fruit.

PROJECT NARRATIVE

Problem Statement

Importance. Peach scab, caused by the plant-pathogenic fungus *Fusicladosporium carpophilum* (syn. *Cladosporium carpophilum*) (16), occurs wherever peaches are grown in warm, humid climates (1,6). In the United States, scab is most prevalent and problematic in the eastern half of the country, which has approximately 71,250 bearing acres or 62% of the total U.S. fresh production, with a value of $179 million (7). Peaches are grown in every state in the Northeast Region, which has 17,539 bearing acres or 25% of the total eastern acreage (2). Crop profiles for northeastern (NJ, PA, WV, CT, MA, RI, VT, NH, ME), north central (MI, MO, IL), and southern (AK, GA, SC, LA, NC, TN, TX, VA) states list scab as major disease of peach.

Limited Management Options. There are no scab-resistant peach or nectarine cultivars available for use by commercial growers. Furthermore, since overwintering scab lesions on twigs do not visibly influence twig growth, detection of infected twigs necessitates close inspection and is therefore labor intensive. Thus, pruning out infected twigs, as recently demonstrated and practiced for constriction canker of peach (11,20), is not a practical means of scab control. Pruning can help improve scab management by promoting rapid drying after rains and spray penetration into the canopy, but this cultural practice alone is insufficient (6).

Fungicide Dependency. Given the lack of resistant cultivars and inability to easily remove the primary inoculum source, growers depend entirely on application of fungicides for management of peach scab. The most widely used materials are the protectants chlorothalonil, captan, and sulfur. Both chlorothalonil and captan have been under EPA scrutiny as potential carcinogens, and sulfur is the least effective of the three protectants. The benzimidazole thiophanate-methyl is occasionally used, but resistance development is a concern. The newer strobilurin fungicides have been shown to be effective, but are resistance-prone and more costly. Biological or biorational controls have not been found. Thus, as stated in the NJ PMSP, peach scab management has been heavily dependent on protectant fungicides.

Fungicide applications for scab control typically begin at shuck-split, when fruit tissue first becomes exposed, and continue at 7-14 day intervals until 40-days preharvest (5). Research has also shown that in some years an additional application at petal fall will improve control (19). Thus, the total number of fungicide applications for disease management usually ranges from 5 to 7 sprays per season, depending on time of harvest and spray interval. In NJ, late maturing cultivars are particularly popular because of their better quality and ability to fetch higher prices. Consequently, more fungicide is often applied for scab control on these cultivars than for any other fungal disease.

Influence of Environment. In any particular growing season, disease development and the resultant yield loss is very much dependent on favorableness of environmental conditions. For example, a survey of pests in commercial New Jersey peach orchards was conducted by the Rutgers Tree Fruit IPM Program in 1996 and 1997 (17). The 1996 season was quite wet, and scab ranked first in crop loss among the 11 disease and insect pests surveyed. Conversely, conditions were less favorable for scab in 1997, and it ranked only seventh in crop loss among the 10 pests surveyed in that year. Clearly, an optimized fungicide program for scab control would be quite different for each of these two years. Yet, without the necessary scientific knowledge, growers were forced to apply the same standard calendar-based program. Furthermore, the significant crop loss in 1996 indicates that growers were unable to adequately adjust the standard program to accommodate the higher disease pressure.

Lack of IPM Approach. Given all of the above, peach scab control has become dependent on calendar-based applications of fungicides. This approach results in unnecessary fungicide applications when environmental conditions are unfavorable and loss of disease control when conditions are highly favorable. Implementation of a forecasting model, based on the biological requirements for disease development, should allow optimized application timing, thereby simultaneously reducing the potential for fungicide overuse and the likihood of yield loss. The Eastern Peach Pest Management Strategic Plan, developed by representatives from GA, SC, NC, FL, NJ, PA, MI, and the EPA, lists development of a "*weather-based model to quantify and predict changes in scab potential throughout the season*" as an important research need for future disease control (7).

Background

Disease cycle. The pathogen overwinters as lesions on fruit-bearing 1-year-old twigs (8,6). Beginning at bloom in spring and extending into early summer, these lesions produce asexual spores (conidia) which act as the primary inoculum for the ensuing epidemic. These conidia are disseminated to newly formed fruit, current season vegetative shoots, and foliage during rainy periods (8). Recent research on inoculum dispersal mechanisms showed that fruit infection results primarily from rain-splash and twig runoff (12).

Infection of fruit results in the formation of circular, dark-olive colored lesions ranging in size from 2–4 mm in diameter (1,8). Lesions may be numerous and, under severe conditions, will coalesce to form large blotches over much of the fruit surface. Eventually, these scabbed areas become corky and suberized, resulting in epidermal cracking during final fruit swell prior to harvest. This cracking allows entry and establishment of rot pathogens such as *Monilinia fructicola*, causal agent of brown rot (1,6). These rotting fruit in turn produce copious amounts of *M. fructicola* spores capable of infecting additional healthy fruit. Thus, fruit scab infections not only result in direct yield loss, but can augment loss caused by *M. fructicola* and other rot-inducing pathogens.

Conidia released from the 1-year-old sporulating twig lesions also infect newly expanding vegetative shoots (6,8). New lesions appear on the young tender twigs at about the same time as first observed on fruit. However, these twig lesions generally do not completely develop and become infectious until the following year (8,13). In general, secondary inoculum from fruit infections also does not contribute significantly to epidemic development since the latent period is quite long, ranging from 42 to 77 days (6). Such secondary cycles would be most important on late cultivars that sustained early fruit infections. Thus, the majority of inoculum for the current season fruit infection originates from overwintering lesions on 1-year-old twigs.

Conidial production on 1-year-old twig lesions commences at bloom and continues for approximately 10 weeks, tapering off during early to mid-summer (4,13,15,18). Since these lesions are only superficial in nature, no permanent damage occurs to the twigs, which appear normal once bark forms. Similarly, leaf infections occur only under severe disease pressure, and even in this case rarely cause significant defoliation (6). Thus, twig and foliar infections are of little direct economic importance.

Availability of Inoculum. The availability of inoculum for fruit infection at any given time during the growing season is determined by two factors: (i) presence of overwintering lesions on 1-year-old twigs and (ii) a favorable environment for sporulation. Although in theory some orchards may have so few lesions that fungicide applications would be unnecessary, the risk of not spraying and suffering yield loss is too great. Furthermore, few if any disease control programs are 100% effective. Thus, it is generally assumed and accepted that overwintering inoculum exists in most orchards.

Research investigating the quantitative relationships between environmental factors and spore production by twig lesions has been conducted (13). Results showed that twig lesion sporulation was induced by periods of high relative humidity. Sporulation only occurred at 80-100% RH, and was most abundant at near saturation values of 98-100% RH. Thus, based on these findings, the production of inoculum would be limited by availability of atmospheric moisture, and would occur most commonly during evenings and rainfall periods.

The effect of temperature on sporulation of twig lesions was not examined in the former relative humidity experiment, which was conducted at a constant 25°C (13). Nevertheless, the effect of temperature on *in vitro* growth of *F. carpophilum* was examined. Results indicated that optimum growth occurred at 20-25C, with a sharp decline in growth below 20C and above 25C. Since conidiophore and conidia production on twig lesions is a growth phenomenon similar to mycelial growth, these results suggest that sporulation may be limited by temperature as well as relative humidity. Thus, a study examining the effects of temperature on *in vivo* sporulation is needed to complete the quantitative description of the sporulation process.

Environmental Limitations. Temperature limitation of sporulation would most likely occur during the early-season period from shuck-split through second cover. Several years of hourly weather data, collected by the RAREC weather station, were examined during the critical 6-week period following shuck-split. During this period, evening temperatures ranged from 1.1C to 18.3C with the vast majority of temperatures during the first 4 weeks of this period below 10.3C. Based on the above discussion, these temperatures are below the expected range for sporulation.

Similarly, relative humidity during the warmer daytime periods in this historical weather data was almost always below 80%, unless rainfall occurred. When precipitation did occur, typically as a result of a cold front, temperatures were often unfavorably cold. Thus, these environmental data indicate that sporulation in New Jersey during the early-season may be limited by temperature at night and relative humidity during the day. During the subsequent mid-season period, weather conditions generally become hotter and dryer, so both factors may be limiting. Similar circumstances may be true for other northeastern states and stone fruit regions in the eastern United States.

Justification

Absent IPM. There are no integrated approaches available for management of peach scab. Current programs in all eastern peach growing regions utilize a combined tree phenology and calendar-based approach for the timing of fungicide applications. These programs only indirectly incorporate knowledge on the biology of the scab pathosystem, and mostly ignore the important effects of environment on epidemic development. Examination of weather records in relation to current knowledge indicates that environment may be a limiting factor during the early-season period. Of particular interest is the combined effect of temperature and relative humidity on sporulation and therefore availability of inoculum for infection.

Improved Efficiency. Implementation of a sporulation-based forecasting model will allow growers to optimize fungicide applications according to the risk of infection. Applications will only be made prior to an infection event (e.g., rainfall) if the risk is high based on inoculum availability. This optimized approach will result in fewer applications when environmental conditions are less favorable to disease development and more appropriately timed applications when conditions are favorable. As a research priority, the Peach Pest Management Strategic Plan for New Jersey states that "*a better understanding of the epidemiology [of scab] should allow more effective and efficient use of newer fungicides*" (3). Since peach scab is listed as a disease of major importance in crop profiles throughout the eastern United States, growers throughout this region will benefit from this technology.

Benefits. Improvements in fungicide application efficiency from model usage will result in a number of economic and environmental benefits for the grower and the public in general. Fewer fungicide applications will: (i) improve grower profitability by reducing cost of control; (ii) decrease amount of pesticide [fungicide] in the environment; (iii) reduce exposure of applicator and field crews to the fungicide; and (iv) decrease the risk of pesticide residues on harvested fruit. Accurately timed fungicide applications will improve scab control and reduce yield loss, particularly during periods of erratic weather patterns. Furthermore, fungicide applied according to model predictions will be present at the highest concentration when it is needed the most, thereby providing growers with the greatest return for their investment.

Objectives and Anticipated Impacts

Stage 1 - Model Development. The proper creation, validation, and deployment of a commercial disease forecasting model requires successful completion of many steps conducted over several years. Since we are at the beginning of this process, the major goal of this project proposal is to create the knowledge base necessary for the initial development of a peach scab forecasting model.

Specifically, there are three sequential objectives for the proposed research project:

(1) Quantitatively describe the temperature-sporulation relationship

(2) Create model algorithm based on new and currently available information

(3) Field validate the biological criteria for the model, i.e., the sporulation predictions

Objective 1 involves modeling the quantitative effects of temperature on sporulation over time. This research examines spore production on twig lesions in controlled environment chambers. Objective 2 combines the newly developed temperature-sporulation relationship with already published information; e.g., effects of relative humidity. Finally, objective 3 field validates the inoculum availability predictions with separate sporulation data sets from different cultivars and test sites.

Stage 2 - Model Deployment. To continue the model development process, the following three objectives would follow in a subsequent research/extension project. This information is being presented here for completeness.

(4) Field test model in experimental plots for optimum timing / reduced applications

(5) Field test model in large-scale commercial orchards with grower cooperators

(6) Technology transfer to private industry /or/ university sanctioned (PC-based)

Objective 4 would involve field testing in a research site(s) capable of examining multiple, replicated treatments. Essentially, model forecasted fungicide treatments would be compared to standard programs. Successful model approaches would then be validated and demonstrated at the commercial level in objective 5. These studies could be done in multiple states or regions. The grower validation is particularly important since it generates commercial data and user testimony. Objective 6 entertains various approaches to model deployment, such as with companies that manufacture model-based weather stations (e.g., Spectrum technologies) or provide virtual weather and model forecasts (e.g., SkyBit). Or alternatively, a PC-based model could be deployed through the university/extension system (e.g., Maryblyt, Univ. of Maryland).

Anticipated Impacts. The obvious, measurable responses that will determine successful model implementation and, ultimately, impact on stakeholders will be:

(1) Reduction in number of fungicide applications (relative to the standard)
AND / OR
(2) Improved disease control (lower disease incidence or severity)

Any "spray savings" would be a function of both the accuracy of the model and favorableness of the environment. The greatest reduction in applications would, of course, occur in less favorable seasons. We would also expect more consistent scab control since growers will now have more knowledge on the sporulation activity of the pathogen. That is, loss of control and the resultant yield loss will be less likely in high pressure seasons.

Determination of the exact extent of the impacts – the number of sprays saved or reduction in yield loss – is difficult at this time. However, based on past experiences with many disease forecasting models on a variety of other crops (Neogen Corp.), typical spray savings range from 2 per season for an apple scab model (MI) to 4 per season for a peanut late leaf spot model (GA). Fungicide applications were reduced by 1 to 6 sprays per season when implementing a grape downy mildew model, depending on favorableness of the weather (14).

One final comment concerning disease forecasting model development and impacts. Software-based forecasting models are not static but dynamic entities. They can be improved over time with increase in accuracy of the current algorithm or addition of new components, such as other phases of the disease cycle or aspects related to plant growth and development. Thus, the resultant impacts also are dynamic and can be augmented by future updates to the model.

Approach and Procedures

Objective 1. Modeling Sporulation as a Function of Temperature

Design and treatments. During the peak sporulation period from petal fall through approximately second cover, 1-year-old twigs harboring overwintering scab lesions will be collected from non-sprayed experimental peach or nectarine orchards. Samples of these twigs, 20 cm in length, will be washed, dried, and incubated in moist chambers at >95% RH. The moist chambers will be placed in incubators maintained at constant temperatures ranging from 5C through 35C. This range encompasses those temperatures for which fungal growth was observed *in vitro* (13). Twigs at each temperature level will be removed at regular intervals for assessment. Thus, the experimental design will be a temperature × time factorial.

Assessment. After removal from incubation, the twigs will be shaken in water plus surfactant to harvest the conidia. If necessary, aliquots of the suspension will then be centrifuged to concentrate the conidia. Spore counts will be performed using a hemacytometer under a compound microscope. With the aid of a stereoscope at low power, the number of lesions on each twig will be counted and the diameters of a sub-sample of lesions will be measured. Lesion numbers and average size will be used to estimate total lesion area. Given the data collected, two dependent variables will be calculated: # condia/mm^2 lesion and # conidia/cm of twig length. These procedures have been successfully used in prior experimentation with peach scab (15).

Statistical analysis. The dependent variables will define response surfaces with temperature and time as the independent variables. A regression model, most likely non-linear, will be fit to the data. The modeling procedure will be similar to that used previously for developing sporulation models for constriction canker of peach (9) and grape downy mildew (10). The experiment will be performed in year 1 and repeated in year 2. Full and reduced models will be compared to determine if the data sets from each year can be pooled.

Objective 2. Creation of Model Algorithm

An alpha version of the model will be created from the regression functions delineated in the first objective. A relative humidity component will be added based on results from prior research (13). Environmental data functions will be included to allow transparent input of hourly weather data from different sources, such as commercial or scientific data loggers or the internet. Scaling parameters may be added to allow tweaking of model behavior.

Initial model output or forecasts will consist of quantitative sporulation predictions to allow direct comparison to validation data (see below). A subsequent beta version of the model, created after successful field validation of the biological criteria, will output current relative inoculum availability, risk of infection, spray recommendations, and other pertinent user-friendly information. The model will be programmed in a computer language (standard or object-oriented) for the PC Windows platform.

Objective 3. Field Validation of Model Sporulation Predictions

Design. During the peak sporulation period in years 1 and 2 of the project, infected 1-year-old twigs in non-sprayed experimental orchards will be tagged. Lesions on these twigs will be washed with water to remove any trace of conidia, and allowed to incubate under natural environmental conditions. Temperature and relative humidity data will be collected every minute and summarized hourly using an electronic weather data logger.

Assessment. After incubation in the field, twig samples will be brought into the lab for evaluation of sporulation. Spore numbers will be quantified using the same procedure as outlined for model development. Temperature and relative humidity data for the duration of the twig incubation period will be input into the model to generate predictions. Independent twig samples will be harvested and examined throughout the sporulation period following bloom to provide test data encompassing a wide range of environmental conditions.

Statistical analysis. Observed sporulation data obtained from the orchard in both years will be compared to model predictions (expected values). The agreement between these values will be compared statistically using the chi-square goodness-of-fit statistic (χ^2). In addition, observed data can be examined for fit within the 95% confidence interval about the predicted values for the temperature-based component of the model (when RH $\geq$ 95%).

Project Timetable

Below is a complete timetable for the **Stage 1 – Model Development Phase** (this proposal) and **Stage 2 – Model Deployment Phase** (future proposal). The entire process is shown for completeness.

Peach Scab Model Development and Deployment Timeline

		2007				**2008**				**09**	**10**	**11**
Phase	**Objective/Activity**	**S**	**S**	**F**	**W**	**S**	**S**	**F**	**W**			
1	Temperature Sporulation Study	x	x			x	x					
	Statistical Analysis – Model Devel.			x				x				
	Create Algorithm – alpha version				x*				x			
	Biological Field Validation Study	x	x			x	x					
	Statistical Analysis - Validation				x*				x			
2	Spray Forecast Validation – beta ver.											
	> Experimental Sites									x	x	
	> Grower Cooperator Sites										x	x
	> Stats: Forecasted vs. Conventional									x	x	x
	Commercial Deployment											
	> Technology transfer										x	x
	> Release v1.0											x

* An initial alpha model version could be constructed & validated from just year 1 data. However, this work will most likely be performed after two years of experimental data are obtained.

Evaluation Plans

Experimental. Evaluation of the model's ability to predict accurately is an integral part of the project as outlined above (objective 3 - validation). Below is some additional information on the methods used for subsequent evaluation of the model prior to commercial release.

Commercial. Field testing of the beta version in years 4 and 5 with growers will (i) validate the model on a larger, commercial scale and (ii) generate the necessary data for marketing the model. Also, testimonials / experiences from cooperating growers will be important for teaching other growers about the new system. At experimental and grower cooperator sites, results from scab management programs following the model and standard calendar-based schedules will be compared. Disease levels, application timing, and number of fungicide applications can be compared to show the benefits of following model predictions over conventional approaches. These data can be transformed into expected economic savings from fungicide costs and/or reduced yield loss. Environmental and health benefits can be derived as well, e.g., total pounds reduction in fungicide use across all peach acreage in a given state or region.

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KEY PERSONNEL

<u>Stage 1 – Model Development</u>

- **Ms. Kathleen A. McFarland**, Tree Fruit Pathology Technician, Rutgers University, Agricultural Research and Extension Center, Bridgeton, NJ.

  Ms. McFarland, formerly K. Foster, holds a B.S. in Biology from Rowan University. She began working as a technician with Dr. Lalancette in 1999. Over the last seven years, she has gained research and technical experience in numerous field, greenhouse, and laboratory experiments on the epidemiology and control of tree fruit pathogens. In many of these studies, Ms. McFarland cooperated and provided technical support to both Rutgers graduate and undergraduate students. However, she has also worked independently on research projects. Of particular relevance to this proposal, Ms. McFarland was the key individual who generated the necessary data for creation of quantitative models describing the effects of temperature and moisture on sporulation of *Phomopsis amygdali*, causal agent of constriction canker of peach. More recently, she has worked with Dr. Lalancette on studies investigating peach scab infection and sporulation processes (See PD Vitae for publications involved Ms. McFarland / Foster). In the proposed project, she will be responsible for the execution of the temperature-sporulation experiment outlined in objective 1 and the gathering of field validation data for objective 3. Ms. McFarland will also be responsible for setup and deployment of weather equipment and all computer data entry for the entire project.

Below are possible additional key personnel for the subsequent research / extension project.

<u>Stage 2 – Model Deployment</u>

- **Mr. Douglas Zee, Jr.,** JerZee Orchards, 708 Mullica Hill Rd, P.O. Box 40, Richwood, NJ
- **Mr. Carl Heilig,** Heilig Orchards, 211 Heilig Rd, Sewell, NJ
- **Mr. Rolf DeCou,** Springdale Orchards, 78 Auburn Rd, Woodstown, NJ

  Although Stage 2 is a few years away, these peach growers have expressed interest in cooperating on a peach scab management project. Each grower has provided excellent cooperation with Dr. Lalancette in past commercial orchard experiments on constriction canker, Phytophthora root and crown rot, and most recently, rusty spot.

- **Mr. Dean Polk,** Fruit IPM Agent, Dept. of Agriculture and Resource Management Agents, Rutgers Cooperative Extension, Fruit Research and Extension Center, Cream Ridge, NJ

  Mr. Dave Schmidt, Program Associate, Tree Fruit IPM, Rutgers Cooperative Extension of Gloucester County, Clayton, NJ.

  In New Jersey, the Rutgers Tree Fruit IPM Program plays a pivotal role in grower adoption of new pest management strategies. Both Mr. Polk and Mr. Schmidt have cooperated in past demonstration projects. Their expertise would be sought and invaluable for Stage 2.

RELEVANCE STATEMENT

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Problem. Peach scab, caused by the plant-pathogenic fungus *Fusicladosporium carpophilum* occurs wherever peaches are grown in warm, humid climates. In the United States, scab is most prevalent and problematic in the eastern half of the country, which has approximately 71,250 bearing acres or 62% of the total U.S. fresh production, with a value of $179 million. Peaches are grown in every state in the Northeast Region, which has 17,539 bearing acres or 25% of the total eastern acreage. Crop profiles for NJ, PA, WV, and New England, as well as most other eastern states, list peach scab as a disease of major importance.

There are no scab-resistant peach or nectarine cultivars available for use by commercial growers. Pruning to promote rapid drying aids scab management, but this practice alone is insufficient. Thus, as stated in the NJ PMSP, growers depend entirely on application of fungicides for management of peach scab. The total number of applications necessary for control usually ranges from 5 to 7 sprays per season, depending on time of harvest and spray interval. On popular high quality late maturing cultivars, more fungicide is typically applied for scab than for any other fungal disease. Biological or biorational controls have not been found.

Peach scab control has become dependent on calendar-based applications of fungicides. This approach results in unnecessary fungicide applications when environmental conditions are unfavorable and loss of disease control when conditions are highly favorable. In NJ, favorable environmental conditions combined with higher than normal inoculum levels has caused commercial outbreaks of scab. Consequently, most growers have experienced significant fruit infection in one year or another, and are therefore hesitant to reduce fungicide usage.

Background. The pathogen overwinters as lesions on fruit-bearing 1-year-old twigs. Beginning at bloom in spring and extending into early summer, these lesions produce spores which act as the primary inoculum for the ensuing epidemic. These spores are disseminated to newly formed fruit, current season vegetative shoots, and foliage during rainy periods.

Past research has shown that twig lesion sporulation was induced by periods of high relative humidity. The effect of temperature on sporulation of twig lesions has not been examined. Nevertheless, studies on *in vitro* growth of *F. carpophilum* mycelium have indicated an optimum of 20-25C, with a sharp decline in growth below 20C and above 25C. These results suggest that sporulation may be limited by temperature as well as relative humidity. Thus, a study examining the effects of temperature on *in vivo* sporulation is needed to complete the quantitative description of the sporulation process.

Temperatures limiting sporulation would most likely occur earlier in the season from shuck-split through second cover. Several years of hourly NJ weather data collected during this period were examined. Evening temperatures ranged from 1.1C to 18.3C with the vast majority of temperatures during the first 4 weeks of this period below 10.3C. These temperatures are below the expected range for sporulation. Similarly, relative humidity during the warmer daytime periods was almost always below 80%. When rainfall occurred, typically as a result of a cold front, RH was high but temperatures were unfavorably cold. Thus, these environmental data indicate that sporulation in New Jersey may be limited by temperature at night and relative humidity during the day. Similar circumstances may be true for other northeastern states and stone fruit regions in the eastern United States.

Justification. There are no integrated approaches available for management of peach scab. Current programs in all eastern peach growing regions utilize a calendar-based approach for the timing of fungicide applications. These programs do not incorporate knowledge of the scab pathosystem, and ignore the important effects of environment on epidemic development. Examination of weather records indicates that environment may be a limiting factor.

Implementation of a forecasting model will allow growers to optimize fungicide usage. This approach will result in fewer applications when environmental conditions are less favorable to disease development and more appropriately timed applications when conditions are favorable. The Eastern Peach Pest Management Strategic Plan, developed by representatives from GA, SC, NC, FL, NJ, PA, MI, and the EPA, lists development of a "*weather-based model to quantify and predict changes in scab potential throughout the season*" as an important research need for future disease control. Since scab is listed as a disease of major importance in crop profiles for most eastern peach-growing states, growers throughout this region would benefit from this technology.

Improvements in fungicide application efficiency from model usage will: (1) improve grower profitability by reducing cost of control; (2) decrease amount of fungicide in the environment; (3) reduce exposure of applicator and field crews to fungicide; and (4) decrease the risk of pesticide residues on harvested fruit. Accurately timed fungicide applications will improve scab control and reduce likelihood of yield loss. Furthermore, fungicide applied according to model predictions will be present at the highest concentration when it is needed the most, thereby providing growers with the greatest return for their investment.

Objectives and Anticipated Outcomes

Stage 1 – Model Development. There are three sequential objectives for the *proposed* project:

(1) Quantitatively describe the temperature-sporulation relationship
(2) Create model algorithm (alpha version) based on new and currently available information
(3) Field validate the biological criteria for the model, i.e., the sporulation predictions

Objective 1 involves characterization of the quantitative effects of temperature on sporulation over time. In objective 2, a software program is created which combines the temperature-sporulation relationship with already published results. Finally, objective 3 field validates model predictions with separate sporulation data sets from different cultivars and test sites.

Stage 2 - Model Deployment. To complete the model development process, the following three objectives would follow in a *subsequent* research/extension project.

(4) Field test model in experimental plots for optimum timing / reduced applications
(5) Field test model in large-scale commercial orchards with grower cooperators
(6) Technology transfer to private industry /or/ university sanctioned (PC-based)

In objectives 4 and 5, model forecasted fungicide treatments from the successful beta version would be compared to standard control programs. These studies could be done in multiple states or regions. Objective 6 entertains various approaches to model deployment, such as with companies that sell model-based weather stations or provide virtual weather and model forecasts. Alternatively, a PC-based model could be deployed through the university/extension system.

Anticipated Impacts. The obvious, measurable responses that will determine successful model implementation and, ultimately, impact on stakeholders will be (1) reduction in number of fungicide applications and/or (2) improved disease control. Any spray savings would be a function of both the accuracy of the model and favorableness of the environment. The greatest reduction in applications would, of course, occur in less favorable seasons and yield loss will be less likely in high pressure seasons. Furthermore, since models are dynamic entities, these impacts could be improved over time with software upgrades. For example, other phases of the disease cycle or aspects related to plant growth and development could be added.

Determination of the extent of the impacts is difficult at this time. However, based on past experiences with disease forecasting models on various crops (Neogen Corp.), typical spray savings range from two per season for an apple scab model (MI) to four per season for a peanut late leaf spot model (GA), the latter case resulting in a 50% reduction in usage. Fungicide applications were reduced by 1 to 6 sprays per season when implementing a grape downy mildew model (OH). Saving two sprays for peach scab would translate into a 30-40% reduction in fungicide usage, potentially over 100% of acreage since all cultivars are susceptible.