PROJECT SUMMARY - USDA-CSREES-RIPM-001827

Title: Improving the Control of Mummy Berry Disease While Decreasing the Use of Fungicides in Blueberry Production of Northern New England

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This is a Joint Research (79% of funds)-Extension (21% of funds) project focused on improving control of mummy berry disease in blueberries while decreasing fungicide use in northern New England (NNE). This project will benefit lowbush and highbush blueberry growers, the public, and the environment near blueberry fields by decreasing the environmental impact and increasing the economic benefits of blueberry production. Mummy berry disease affects all species of blueberry and can decrease yield up to 50% in highbush and 100% in lowbush blueberries Currently the majority of growers in Maine, New Hampshire and Massachusetts are applying up to three fungicide applications using a calendar schedule which often results in incomplete control and unnecessary fungicide applications. The adoption of a mummy berry disease forecasting model (MBFM) will produce science-based pest management that safeguards human health and the environment and promotes economic benefits for growers. Our extension goals are: to increase the adoption of the MBFM by blueberry growers in NNE, and compare the MBFM with applications based on the calendar. There are few studies on the interactive effects of management inputs on disease in lowbush blueberry. Growers and consumers are also interested in reduced-risk fungicides and cultural techniques for managing disease. Our research goals are: to determine the interactive effects of weed pressure, fertility, and fungicide treatment on disease in lowbush blueberries, test low-animal toxicity fungicides and cultural amendments for their disease control efficacy and compare pollinators for their efficiency in spreading secondary fungal inoculum to blueberry flowers.

PROJECT NARRATIVE – Title: Improving the control of mummy berry disease while decreasing the use of fungicides in blueberry production of Northern New England

This is a Joint Research-Extension project focused on improving control of mummy berry disease in blueberries while decreasing fungicide use. This research and extension project will benefit lowbush and highbush blueberry growers, and the people and environment near blueberry fields by decreasing the environmental impact and increasing the economic benefits of blueberry production. Mummy berry disease, caused by the fungus *Monilinia vaccinii-corymbosi*, is a serious disease in all blueberry species grown in North America and can inflict losses of up to 50% in highbush blueberry from rejection of the berries due to mummy berry contamination, and 100% in lowbush blueberry by the damage inflicted during the flower and leaf bud blight stage. Most lowbush and highbush blueberry growers in ME, NH and MA use a calendar method to determine the timing of at least 2 to 3 applications of fungicide during and post- bud break in the spring to control mummy berry disease. Unfortunately, the calendar method does not take into account variations in weather conditions and development of the plants and fungus, so in most years there is incomplete control of this disease as well as ill-timed and unneeded applications of fungicides. This excessive and unnecessary fungicide use costs money, may have effects on non-target species such as bees, and results in unnecessary environmental contamination. The mummy berry forecasting model (MBFM) (Delbridge and Hildebrand, 1995; Yarborough, 1998) incorporates real-time weather events and the stages of phenological development of both the plant and fungus to determine the risk of infection occurring, and therefore whether or not fungicides need to be applied. There is a low level of adoption of the MBFM in northern New England (NNE) due to lack of awareness, knowledge of disease dynamics and training of growers, and lack of research validating the method under growing conditions in the Northeastern US. Extension objective **E1** (see Objectives p4) is to validate and increase the adoption of the MBFM which will decrease the use of fungicides, improve control of mummy berry disease and improve the economics of blueberry production in the NNE. The Extension program will provide training to over 200 growers in the NNE on how to implement the MBFM for their fields and also supply decision support by producing real-time disease-risk information available by telephone and on the internet. We will conduct training programs for cooperative extension personnel and workshops for growers on the MBFM. These workshops will be supplemented with web-based presentations, print materials and presentations at growers meetings to increase adoption of the MBFM. Growers attending workshops will be surveyed before training and one and two years afterwards to determine the extent of their knowledge and use of the MBFM and subsequent fungicide use.

Lowbush blueberry is a perennial, long-lived field crop with a two-year crop cycle where inputs in one year can have extensive impacts on its management and yield in following years. Fertility, pollination, and control of weeds, diseases and insect pests are some of the more expensive inputs associated with managing a lowbush blueberry field. While there has been research on individual aspects of lowbush blueberry management, there is a lack of research examining the interactions of these practices and particularly their effects on disease control. In a recently completed organic transition study, lowbush blueberry plants that were over-fertilized with N and had minimal weed control also had higher incidence of mummy berry disease than unfertilized plants with or without minimal weed control (Drummond et al., 2008; Smagula et al., 2008). Research objective **R1** addresses the interactions among weed control, fertility and disease control. These experiments will provide growers with information on which inputs are cost-effective and whether some inputs (alone or in combination with others) are not profitable due to the dynamics of the interactions between management tactics and disease.

Conventional northern highbush and lowbush blueberry growers currently use the chemical fungicides propiconazole and fenbuconazole to control mummy berry disease because there are no lower risk (in toxicity to animals) or organically-acceptable fungicides that have been demonstrated as effective in controlling the blight stage of the disease (McGovern, 2007; Yarborough, 2008). To control mummy berry disease, organic growers only have two management techniques to rely upon; burn pruning their plants or mulching entire fields both of which decrease inoculum levels. Research objective **R2** of this project is to test new, organically-approved (OMRI) materials for control of mummy berry disease. This will aid organic and conventional growers, as well as the public, by making available fungicides with lower toxicity to non-target organisms.

Pollination is critical for blueberry production. Both honey bees and bumble bees, at different densities per acre, are used to pollinate lowbush blueberries. Honeybees and bumble bees are both effective pollinators of lowbush blueberry flowers, but honey bees require more visits to a single flower to transfer similar amounts of pollen as transferred in a single visit by a bumble bee (Stubbs and Drummond, 2000; Stubbs and Drummond, 2001). Honey bees have been found to collect *M. vaccinii-corymbosi* spores from infected blueberry leaf and flower tissue and carry them on their body surface and in their corbiculae (P. Oudemans, personal communication) and bumble bees have been observed foraging on infected leaf tissue (Drummond, unpublished data). Research objective **R3** will determine if and how effectively bumble bees and honey bees vector *M. vaccinii-corymbosi* spores to blueberry flowers. This information may be one factor growers take into consideration when determining how to use their limited resources for managing their fields.

This research and extension project will address top priorities identified by the Wild Blueberry Advisory Committee (WBAC), the National Berry Crop Initiative (NBCI), Maine Organic Farmers and Gardeners Association (MOFGA), the Northeast IPM Center and the Pest Management Alternatives Program (PMAP). General IPM Priorities for the Northeast (2006) that this grant supports are “research on biological control of diseases, arthropods, and weeds; extension of this research into production systems of horticultural crops” and “Test the efficacy of pest management materials allowable in organic production systems”. PMAP consists of multiple groups interested in decreasing pesticide use in the USA. This project also is applicable to two of their 2007 specific priorities: “3. Conduct research and outreach on alternative cultural and biological pest control in organic and/or conventional horticultural production systems” and “4. Assess, develop, and distribute new or improved methods for pest monitoring systems”. The WBAC is comprised of a diversity of growers and processors of lowbush blueberry. They meet annually with blueberry researchers to set research and extension priorities. In the last two years they have ranked the implementation of a mummy berry forecasting model (MBFM) as a high priority. The NBCI consists of groups in industry, academia and government that promote the growth and sustainability of berry crops in the USA. This grant fulfills their objectives: “2.2 To promote long-term sustainable production by increasing long-term sustainability of water, energy, nutrients and soil through practices such as water and soil conservation, efficient nutrient utilization and IPM" and "2.3 To improve berry production efficiency and profitability which includes efforts involving labor efficiency, harvest mechanization, improved pest control (new reduced-risk pesticides, cultural practices, increased understanding of pest biology, improved utilization of existing pest control methods, plant nutrition, irrigation technology, cultural methods and practices, and breeding and germplasm improvement)". This research will also fulfill specific needs of lowbush blueberry growers in NNE by determining the interactions among tactics for controlling weeds, diseases and fertility and how they may alter the effectiveness of control for disease.

Regional Importance and Economic Significance. The lowbush blueberry crop has tripled over the past 20 years and is now harvested on over 60,000 ha in North America, averaging more than 82 million kg per year. Lowbush blueberries contribute approximately $75 to $150 million to Maine's economy and are mostly grown in the economically challenged areas of ME, such as Washington Co., a county with a depressed economy where 60% of the blueberry production takes place (Yarborough, 2008). About one third of the lowbush blueberry crop is produced by approximately 770 growers in ME, but only a few growers manage the majority of the acreage, so any change in their management can affect a large number of acres in ME. MA and NH have about 50 growers with small acreages (total NH: 170 acres and MA: 400 acres) of lowbush blueberries and the remaining acreage occurs in the northeastern Canadian provinces (Strik and Yarborough, 2005; Yarborough 1998; Yarborough, 2008). There are about 109 growers of highbush blueberry in NH (170 acres) and about 235 growers with smaller farms (5 acres) across MA. The small number of acres belies the economic significance of the blueberry crop since the highbush crop is worth approx $1.5 million per year in NH alone. Lowbush blueberry production in MA and NH have declined as have resources to support them, so the research and Extension efforts from Maine provide an important source of information. There has been an increase in demand for lowbush blueberries and an increase in prices received by growers. Unfortunately costs of management inputs have also increased in the last year, so efficiency and profitability are becoming increasingly critical factors in sustaining a viable industry in NNE.

Environmental Risk Reduction in Lowbush Blueberry Production. Reducing risk associated with pesticides and fertilizers is an important outcome of any cropping system (Matthias, 2000). This may be especially true for blueberries in NH, ME and MA since many of the production areas are proximal to rivers and streams and are surrounded by forests. We believe that there is potential to change the way in which mummy berry disease is managed by establishing the interactive effects of over-fertilization, level of weed control and fungicide application as well as implementing the MBFM to decrease the number of applications of fungicides for control of mummy berry disease. Most commercial fungicides are highly toxic to fish and this causes concern in areas that are listed for the Atlantic salmon; reducing the number and frequency of fungicide applications would help protect the salmon habitat that is in close proximity to lowbush blueberry fields in Washington County.

Objectives and Anticipated Impacts

This is a Joint Research-Extension project focused on improving control of mummy berry disease in blueberries while decreasing fungicide use. We have designed our research so that each objective provides information on improving control of mummy berry disease, and can be accomplished independently of the other objectives.

Extension

E1. Increase the use of the MBFM for timing fungicide applications to control mummy berry blight in Maine, New Hampshire and Massachusetts, and validate the forecast model by comparing it to the application of fungicides via a calendar schedule.

Research

R1. Determine the interactive effects of weed pressure, fertility, and fungicide treatment on severity of mummy berry blight on lowbush blueberries.

R2. Test low-risk fungicides and cultural amendments for their effectiveness in controlling mummy berry blight.

R3. Compare pollinators, honey bees and bumble bees, for their efficiency in spreading inoculum of *Monilinia vaccinii-corymbosi* to flowers.

Anticipated Impacts:

Safeguarding human health and the environment	- There will be reduced risk to human health and the environment with reduced use of fungicides to control mummy berry disease. There will be an increase in the acreage of lowbush blueberries that will be treated with only one or no application of fungicide when more growers adopt the MBFM to determine if and when they need to apply fungicides. - Data obtained by testing the efficacy of reduced-risk fungicides (decreased toxicity to animals), organically acceptable materials or cultural methods to control mummy berry disease will be used to develop recommendations for growers who wish to decrease their use of chemical pesticides or to use organic production methods. Some of these methods will be applicable disease management in other species of cultivated blueberry. - Research on the interactive effects of inputs to manage fertility, weed control and mummy berry disease control may lead to decreased over-fertilization of fields and fewer pesticide applications in lowbush blueberry fields.
Economic benefits	- Growers would save at least $50/acre (estimated 2008 costs) in fungicide material and applications costs each year for each application of fungicide they do not use. Information obtained from the experiment on the interactions of management techniques may lead to new recommendations to decrease inputs and save growers money. This will be significant for both growers with few acres which have a low profit margin, and large growers who manage thousands of acres and are often one of the major industries in economically depressed regions. - Some of the organically approved materials and cultural control methods use locally produced materials, which if adopted may boost local industries.
Implementation of IPM	- We will use workshops, scouting meetings and presentations to introduce and train growers on how to implement the mummy berry forecast model in their fields. Growers using the forecasting model will be supported by information on disease risk both on the web and on a toll-free telephone line during the spring. Participating growers will be

	surveyed before and after the workshop and at annual meetings over two years to determine their use of pesticides and adoption of the forecasting model. We would expect 200 growers/personnel representing 70% of the lowbush production in ME, NH and MA to be trained. We expect 100 or more growers would adopt IPM practices directly as a result of this project. Presentation materials, a guide to the development stages of the fungus and plants, updates to existing lowbush blueberry fact sheets 217 and 219, and new factsheets will be developed. These will be available on the internet and in print. We expect heavy use of the phone line and website during the spring infection period, since the Wild Blueberry website www.wildblueberries.maine.edu generates more than 20,000 hits/month and so is an excellent method of getting information out to growers and the public. New recommendations will be developed from data obtained from field testing new materials, methods of controlling the disease, and the effects of interaction among management methods on disease. Collaboration among growers will be enhanced by organizing regional areas where growers will have access to the information. We will send surveys to over 770 growers and stakeholders on the lowbush Blueberry Newsletter mailing list, and will get input directly from the Lowbush Blueberry Advisory Committee and growers in NH and MA.

Approach and Procedures

<u>Extension Objective</u>

E1. Increase the use of the mummy berry forecast model for timing fungicide applications to control mummy berry blight in Maine, New Hampshire and Massachusetts, and validate the forecast model by comparing it to the application of fungicides via a calendar schedule.
The initial stage of infection of mummy berry disease, caused by the fungus *Monilinia vaccinii-corymbosi* (Reade) Honey, is a blight of leaf and flower buds in the crop year, and this stage also has the greatest potential impact on yield of lowbush blueberries (Penman and Annis, 2005). Leaves and flowers of blueberries are susceptible once their bud scales open, and they continue to be susceptible throughout their development (Hildebrand and Braun, 1991; Ehlenfeldt and Stretch, 2002). Leaf and flower blight is caused by wind-borne ascospores produced on germinating mummy berries that have overwintered in the soil. On the infected leaves and flowers, the fungus produces spores that are carried by pollinators to healthy flowers (Batra and Batra, 1985) where the spores infect the flower ovaries and colonize the developing fruit to produce a mummy berry (a fungal sclerotium) which overwinters (Shinners and Olson, 1996).

The calendar method consists of timing the application of fungicides when the majority of the stems appear to have broken bud and then spraying every 7 to 10 days until the majority of the leaves are unfurled. The mummy berry forecast model (MBFM) developed by Paul Hildebrand (Delbridge and Hildebrand, 1995) tracks the development of the plant, fungus and weather conditions to determine the probability that ascospores have infected the plant. Fungicides are then applied within 72 hours of the start of the infection period providing protection against the infection and subsequent infections for 7 days. This method has been widely adopted by growers in Nova Scotia and has decreased the number of fungicide applications in most fields to one per season and often none if the weather conditions are not conducive to infection. The MBFM has been introduced to lowbush blueberry growers in the Northeastern US but has not been widely adopted due to lack of knowledge about the disease and the model, validation of the method in local environmental conditions, and time, money and personnel to train scouts and growers to obtain the necessary monitoring equipment and training to use this method. The MBFM has many advantages to the calendar method (see below).

Factor	**MBFM**	**Calendar Method**
Plant development	Threshold of susceptibility of plants occurs when > 40 % of flower buds at stage F2 from a random sample of stems	Visual estimation of leaf bud development (often results in an overestimation of plant development progress)
Fungal development	Examination of a mummy berry plot to determine when ascospores start and stop being produced (ranges from 1 to 3 weeks depending upon field and weather)	Not accounted for
Weather	Infection periods are determined by the duration and temperature during rain and fog events longer than 6 hours	Not accounted for
Timing of fungicide applications	<u>1st application:</u> if plants are susceptible and ascospores are present, within 72 hours of an infection period <u>Subsequent applications:</u> if second infection period occurs more than 7 days after first application <u>Stop of applications:</u> when no further ascospores are produced	<u>1st Application:</u> when majority of leaf buds appear to have opened (ascospores may not be present) <u>Subsequent applications:</u> every 7 to 10 days <u>Stop of applications:</u> when it appears the majority of leaves have unfurled (if ascospores are present, plants are still susceptible at this stage)

The MBFM requires data on the development of mummy berries of the fungus and flower buds of the lowbush blueberry plants and information of the length of time and temperature during rain or fog events. Development of mummy berries can be observed by planting a mummy berry plot in the fall in a field that will be in crop the following year. The plot contains approximately 50 mummy berries gathered during harvest or the fall from a nearby crop field. The mummy berry plot is then observed twice a week for development of the mummy berries from before the buds of the plants open until all of the apothecia of the mummy berries have dried up, which can be from 1 to 3 weeks. When mature apothecia are present in the mummy berry plot then ascospores are present on the plants. Flower and leaf buds become susceptible when green tissue is exposed after the bud scales separate (Stage V2 for vegetative buds and F2 for flower buds; Hildebrand and Braun, 1991). The threshold of when there are enough susceptible buds occurs when greater than 40% of the flower buds are at stage F2 from a random sample of 20 stems collected across the field. An infection period occurs when a rain or fog event last long enough at a particular temperature to allow the germination and penetration of the plants by ascospores (Delbridge and Hildebrand, 1995). If propiconazole or fenbuconazole are applied within 72 hours of the start of an infection period than the infecting fungus is killed and the fungicide will protect the plants from subsequent infection periods for at least 7 days (10 days if little rain occurs) (Delbridge and Hildebrand, 1995; Yarborough, 1998).

In 2007 and 2008, the MBFM was used to determine timing of fungicide applications at the University of Maine Blueberry Hill Farm in Jonesboro, ME and resulted in excellent control of mummy berry blight (< 5% stems with disease). The production of ascospores appears to vary according to conditions in the field, particularly soil drainage, local weather, and adaptation to the timing of bud development of the plant in a field. Mummy berries from highbush blueberry cultivars are adapted to develop when their particular cultivar's buds will be susceptible (Lehman and Oudemans, 1997, 2000). Mummy berries from a field in Deblois, ME were overwintered in a field approximately 50 miles south near Union, ME, but did not develop until approximately a week later than mummy berries from the Union field (Annis, unpublished data). In 2007, germinating mummy berries were searched for and located in blueberry fields near Union, Belfast, and Deblois, ME and were found to vary in the timing of the start and stop of the production of ascospores by approximately 7 days, while the length of time for ascospore production varied from 2 to 3 weeks. In 2008, timing of when ascospore production started and stopped varied by approximately 3 days and most fields only had ascospore production for approximately 7 to 10 days (Annis, unpublished data).

Increasing adoption of the MBFM: Extension specialists Grube and Schloemann from New Hampshire and Massachusetts, respectively, will come to Maine for the first year for training in the MBFM, and then Yarborough and Annis will conduct field sessions in NH and MA in the second year of the project. We will use previously scheduled grower meetings in March, scouting schools in April, newly organized workshops in the winter and presentations to growers groups to introduce and train growers on how to implement the mummy berry forecast model in their fields. We will establish weather monitoring stations and fungus monitoring plots in blueberry growing areas within NNE (5 in lowbush fields in ME, 1 in lowbush and 1 in highbush in NH, and 1 in lowbush in MA) to provide disease risk forecasts and demonstrations of the MBFM. Growers using the MBFM will be supported by information on disease risk estimated for regions of lowbush blueberry production, both on the web and on a toll-free telephone line during the spring. Growers will be able to use these disease risk forecasts to estimate the timing for fungicide applications even if they are not able to fully implement the method in their fields until 2010. For maximum effectiveness, growers will need to measure plant development and weather conditions in their fields and most importantly, plant a plot of mummy berries from their own plants that will overwinter and develop under their field conditions. The MBFM is well established and tested in lowbush blueberry in Nova Scotia but is applicable to lowbush blueberry in ME, and is likely to apply to lowbush blueberry in NH and MA due to higher altitude and therefore similar climate that lowbush blueberries are grown at in those states. The MBFM has not been evaluated in highbush blueberry in northern New England. In NH and MA during the first year, we will determine the duration and temperatures occurring during periods of leaf wetness, when the plant are susceptible, when the mummy berries are producing ascospores and infection severity to determine if the lowbush infection model can be conservatively applied to highbush blueberry in MA and NH. It is likely the MBFM will be conservatively applicable to highbush blueberry in these northern states since the MBFM has been designed to predict the growth of and penetration into plants by the fungus at a wide range of temperatures (from 36° F to 65° F) similar to those experienced during highbush blueberry bud break in northern New England. Lowbush and highbush blueberry plants in general are susceptible to infection by *M. vaccinii-corymbosi* ascospores, and although some tolerant clones and varieties exist in both types of plants, none are resistant. While the severity of the infection may be affected by frost damage, susceptibility of the plants is not dependent upon temperature (Hildebrand and Braun, 1991).

We will use workshops, scouting meetings and presentations to introduce and train growers on how to implement the mummy berry forecast model in their fields. Participating growers will be surveyed before and one and two years after workshops. The survey will also be conducted at annual blueberry grower meetings over two years to determine use of fungicides and adoption of the MBFM. Presentation materials, a guide to the development stages of the fungus and plants, updates to existing wild blueberry fact sheets 217 and 219, and new factsheets will be developed to explain the model and how to use it effectively. These will be available on the internet and in print. Growers using the MBFM will be supported by information on disease risk both on the web and on a toll-free telephone line during the spring. We expect heavy use of the phone line and website during the spring infection period. In addition, many localized field visits will be made to explain the disease cycle and the MBFM. Several demonstration field sites will be established in Maine, illustrating equipment use and method, and one or more sites will be established in New Hampshire and Massachusetts. We will send surveys to over 770 growers and stakeholders on the Wild Blueberry Newsletter mailing list and get input directly from the Wild Blueberry Advisory Committee and growers in NH and MA.

Validation of the MBFM in lowbush blueberry in Maine

Material and Methods: In two crop fields in 2009 and another two crop fields in 2010, experimental plots will be set up to validate the effectiveness of the MBFM over calendar based applications for determining timing of fungicide application and to serve as farm sites for demonstrating the method to growers. Plots will be set up in a replicated split-plot design with 8 blocks; the main effect will be timing of fungicide application and the split plot or nested effect will be fungicide or control method used. Plots 2 m wide and 20 m long will set up for each fungicide tested along with a check plot (no treatment), and each plot will be split into 2 subplots, 2 m wide and 10m long. Each subplot will be treated with one of the two chemical fungicides currently used, propiconazole (Orbit) and fenbuconazole (Indar with 1% crop oil concentrate), but the timing of application will be determined by either the calendar method or the MBFM (Delbridge and Hildebrand, 1995). In the calendar method, the first application is made when leaf buds have started to elongate and subsequently applications are made every 7 to 10 days until the majority of the leaf buds have unfurled. The MBFM uses the development of the fungal apothecia and plant buds, and estimates of risk of infection due to weather events, to determine when fungicide should be applied.

The effects of the treatments on the incidence and severity of mummy berry disease will be measured two times in the crop year. In early June, the percentage of stems with symptoms of mummy berry blight and the number of infected leaves per stem will be determined for 80 stems along a transect through the middle of each plot. In August before harvest, the percentage of stems with mummy berries (sclerotia of the fungus) and the number of mummy berries per stem will be determined for 80 stems along a transect through the middle of each plot. Yield will be estimated by machine-harvesting a two-foot wide strip down the center of each treatment plot. Disease incidence and severity is proportional and so will be normalized by applying a square-root of the arc-sine transformation of the data. Analysis of variance will be performed on the main effects of fungicide timing and split plot effect of fungicide.

Research Objectives

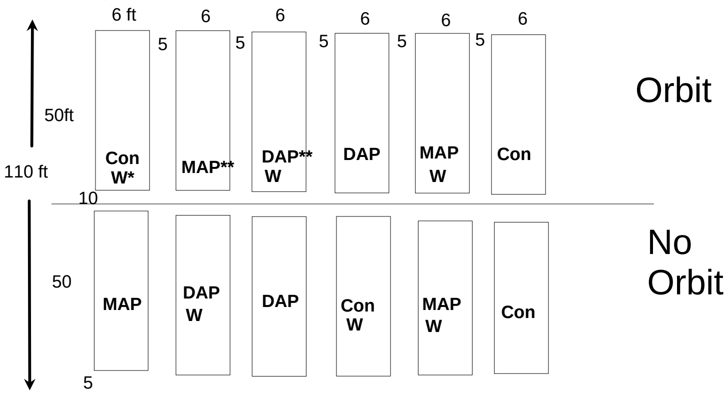
Objective R1. Determine the interactive effects of weed pressure, fertility and fungicide treatment on severity of mummy berry blight on lowbush blueberries.

Lowbush blueberry fields consist of a patchwork of plants that form a dense carpet of stems (129 to 1260 stems/m^2) growing up from a network of rhizomes living in the top 20cm of soil. The 2-year crop cycle consists of a year of vegetative growth culminating in the production of flower and vegetative buds and a second year of fruit production followed by pruning of the plants to the ground to produce new vegetative growth again. Lowbush blueberries are adapted to low nutrient, acidic well-drained soils that many other plants, including many weed species, have limited growth (Yarborough, 1998). Most lowbush blueberry fields are not deficient in N but may be deficient in P, and must be fertilized accordingly since addition of excess N increases weed production (Yarborough and Smagula, 1993). Some growers also do not aggressively control weeds to provide cover for blueberry seedlings to get established in bare areas in fields (Annis, personal observation). Weeds not only absorb water and nutrients from lowbush blueberry plants but also may affect the microclimate around the plants because many of the weeds are as tall as or taller than the lowbush blueberry stems. Weeds may also affect the microclimate at the soil surface by shading and holding humidity near the soil, and thereby may increase germination of mummy berries which is mainly affected by moisture after a critical length of cold period has been attained (Batra, 1983). Excess fertilizer may also produce faster development of the lowbush blueberry plants or more susceptible tissue during the time of infection. Recommendations for growers with N sufficiency and P deficiency are to apply monoammonium phosphate (MAP) which has equal inputs of N and P and therefore will not add excess N to the soil. Unfortunately, MAP is more expensive than diammonium phosphate (DAP, with twice as much N but the same amount of P as MAP) so many growers apply DAP to their fields and over-fertilize with N (Smagula, personal observation).

Preliminary evidence suggests there are interactions among weed control, fertilization and mummy berry disease. In 2005, there were significantly higher levels of mummy berry blight in lowbush blueberry plots with minimal weed control and high levels of fertilizer than plots that were treated with half the rate of fertilizer or not-fertilized (Drummond et al., 2008). The higher rates of fertilizer also had higher percent coverage of grasses and broadleaf weeds (Smagula et al., 2008). Field experiments will performed to determine the interactions among the above management practices and their consequences on disease and yield.

Materials and Methods: In 2009, two fields in prune year with past histories of mummy berry disease and records of leaf N sufficiency and leaf P deficiency will be selected for this study. To determine if fertilizing with high rates of N when not required will enhance mummy berry disease infection, 6 ft by 110 ft plots will receive 80 lbs P/acre to correct P deficiency using monoammonium phosphate (0-9-46) (MAP) or diammonium phosphate (0-18-46) (DAP). DAP contributes almost equal amounts of N and P, while MAP provides half the amount of N. Applied to a field that has adequate leaf N but low leaf P concentrations, these treatments will create a situation of increasing leaf N concentrations through the MAP and DAP treatments, while correcting the leaf P deficiency, and test the effect of over-fertilization with N on incidence and severity of mummy berry disease. To separate the effect of increased weed populations from the direct effect of N fertilization on plant susceptibility to mummy berry infection, half of the MAP and DAP treated plots will also get weed control using 1lb Velpar/acre plus 6oz Callisto/acre applied pre-emergence. The fungicide propiconazole (Orbit, 6oz/acre) will be applied as recommended by using the MBFM to half the plots as the main effect in a split-plot design, with eight blocks (see Figure 1 for plot plan for one block).

Figure 1 Weed/Fertility/Mummy berry Disease Interaction Study



*Weed Control
(1.0 lb Velpar/a + 6 oz Calisto/a)

**MAP and DAP both provide 80 lbs P/acre

The soil will be sampled using a standard soil sample tube removing a 2 cm diameter core to a depth of 7.62 cm. Ten cores per treatment plot will be combined and analyzed for soil pH (water), organic matter, and nutrient analysis. Organic matter will be measured by loss on ignition (LOI) at 375° C. Available nutrients will be extracted in pH 4.8 ammonium acetate (Modified Morgan method) and measured by plasma emission. Composite leaf tissue samples from 50 stems will be sampled from treatment plots to determine leaf nutrient concentrations (Trevett et al., 1968). Leaf samples will be prepared according to the methods of Kalra and Maynard (1991) and submitted to the University of Maine Soil and Plant Tissue Testing Laboratory for analysis of nutrients. To measure effects of management systems on growth characteristics, stem samples from four randomly placed 0.03 m^2 quadrats per plot will be collected in the fall of each prune cycle for measurement of stem density, stem height, branching and flower bud formation. Yield will be estimated by machine-harvesting a two-foot wide strip down the center of each treatment plot (Smagula, 2008).

Treatment effects on broadleaf, fern and grass weed cover and lowbush blueberry phytotoxicity will be assessed at one and three months (non-bearing year) and one year after treatment. All measures will be expressed in percent cover and assessed in four 1 m^2 subplots within each treatment by using a Daubenmire Cover Class Scale (Mueller-Dombois and Ellenburg, 1974). A list of the weed species controlled and not controlled will be made for each site. A carryover weed control assessment and representative yield samples will be taken in the bearing year (Smagula, 2008). The effects of the management systems on the incidence and severity of mummy berry disease will be measured in two times in the crop year. In early June, the percentage of stems with symptoms of mummy berry blight and the number of infected leaves per stem will be determined for 40 stems along a transect through the middle of each plot. In August before harvest, the percentage of stems with mummy berries (sclerotia of the fungus) and the number of mummy berries per stem will be determined for 40 stems along a transect through the middle of each plot.

Batra and Batra (1985) have shown that pollinating insects can pickup and carry mummy berry conidia and thus bees specifically have been implicated as vectors of mummy berry during the secondary infection cycle (infected leaf to flower). Assuming that this dynamics might operate in lowbush blueberry fields during infection we plan to measure the pollinator force in the plots during bloom. The species richness and relative abundance of bees will be quantified using water bowl traps (Drummond and Stubbs, 1997) placed in each plot. These measures of the bee community will be used as covariates in an analysis of covariance in order to assess whether bees play a significant role in the level of mummy berries produced in the research plots, and also to correct for differential bee visitation among plots and thus assist in elucidating the main effects in the above described experimental design.

Analysis: Disease incidence and severity is proportional and so will be normalized by applying a square-root of the arc-sine transformation of the data. Analysis of covariance (split-plot design) will be performed on the main effects of fungicide and the nested crossed effects of fertilizer and weed control. Contrasts among selected treatment combination will be determined by the presence of the interaction of effects and tested.

Objective R2. Test reduced-risk fungicides and cultural amendments for their effectiveness in controlling mummy berry blight.

Many of the cultural management methods used in highbush and rabbiteye blueberries to control mummy berry disease, such as burying the mummy berries by cultivation or killing them by applying caustic materials (Scherm and Krewer, 2008), will not work in lowbush blueberry fields due to the damage that will occur to the plants. Cultural techniques that have been tried in lowbush blueberry are pruning the stems by burning them down to the surface of the soil which also kills mummy berries in the leaf litter or on the top of the soil (Lambert, 1990). However, burn pruning has become less common because of increases in oil prices, the danger and nuisance of burning large areas, and the problem of not pruning effectively or burning too hot and killing off the plants. Applying a 3cm deep layer of peat mulch to a field to bury mummy berries before they germinated did decrease disease in one field (McGovern, 2007), but this method may only work for one cropping cycle since the mulch layer provides a moister, more conducive environment for germination of mummy berries from the next cropping cycle. Various organically acceptable materials, such as applications of compost teas, garlic extract, neem oil, and a bacterial biocontrol agent containing *Bacillus pumilus* were not effective in controlling mummy berry disease (McGovern, 2007). Currently burn pruning and mulching are the only cultural options for organic growers or growers interested in lower toxicity materials for controlling mummy berry disease. The biocontrol material Serenade (Agraquest, Davis, CA) contains *Bacillus subtilis* and showed potential as a control for the blight stage of mummy berry disease (McGovern, 2007; Yarborough, 2008). Finding a fungicide that is lower in toxicity, organically registered, and effective at controlling mummy berry disease will be a boon to the lowbush blueberry industry and the general public.

Materials and Methods: Two fields in crop in 2009 and 2010 will be used to set up experimental plots to test the effectiveness of lower risk fungicides, organically acceptable materials and cultural methods for the control of mummy berry disease will be tested. To compare the effectiveness of lower risk fungicides, organically acceptable materials and cultural methods to currently used fungicides for control of mummy berry blight, treatments will include application of propiconazole at the recommended rate. Each treatment will be applied in plots 2 m wide by 10 m long in a replicated complete randomized-block design with eight blocks. Treatments will include a check (no treatment), application of 3 cm of mulch (bark or peat) before bud break and mummy berry germination, and applications of Orbit (propiconazole, Syngenta, Greensboro, NC) following the timing of the MBFM. Other treatments will be Serenade (containing the bacteria, *Bacillus subtilis,* AgraQuest, Davis, CA), Citrex (water-soluble organic acids, Citrex Inc, Miami, FL), Sulforix (calcium polysulfides, Best Sulfur Products, Fresno, CA), Organic Gem (fish oil product, Advanced Marine Technologies, New Bedford, MA), Neptune's Harvest (fish oil product, Neptune's Harvest Fertilizer, Gloucester, MA) applied at their recommended rate. These materials act as protective substances and cannot move systemically in the plant, so to ensure coverage of new bud growth, applications will start before there are germinating mummy berries in the field and will continue every 3 to 4 days until mummy berry development ceases.

The effects of the treatments on the incidence and severity of mummy berry disease will be measured two times in the crop year. In early June, the percentage of stems with symptoms of mummy berry blight and the number of infected leaves per stem will be determined for 80 stems along a transect through the middle of each plot. In August before harvest, the percentage of stems with mummy berries (sclerotia of the fungus) and the number of mummy berries per stem will be determined for 80 stems along a transect through the middle of each plot. Yield will be estimated by machine-harvesting a two-foot wide strip down the center of each treatment plot.

The second part of this objective involves assessing the likelihood of propiconazole (Orbit) residues on flowers during bloom when applied prior to bloom for mummy berry disease control. This is a particularly important sub-objective if propiconazole continues to be the standard fungicide used by blueberry growers for mummy berry disease control and if the currently registered insecticide, acetamiprid (Assail), is adopted for control of spring insects such as blueberry flea beetle or blueberry spanworm just prior to or during bloom. Assail is not considered highly toxic to honey bees at dosages used to control pests (El Hassani et al., 2008), however recent research (Iwasa et al., 2004) has demonstrated that while acetamiprid has a relatively low toxicity to honey bees, acetamiprid and propiconazole together result in a synergistic effect of enhanced mortality to honey bees even though propiconazole is considered relatively non-toxic by itself to honey bees and smaller native bees (Ladurner et al., 2008). We propose assessing residues of propiconazole on floral tissue after field applications for disease control. In 2009 and 2010, three treated propiconazole blueberry plots (2m x 10m) and three non-treated controls will be set out (completely randomized design) at the University of Maine Blueberry Hill Research Farm. The treated plots will have propiconazole applied with a boom sprayer at recommended rates and liquid volume after the first infection period determined by the MBFM. Thirty flowers will be collected at 10% bloom (time recommended that honey bees are placed in blueberry fields, (Drummond 2002)) and peak bloom in each of the six plots. The 30 flower samples will be sent to the University of Maine Pesticide/Food Safety Laboratory and using standard procedures the concentrations of propiconazole will be determined by reverse-phase high-performance chromatography (Merkulova et al., 2005).

Analysis: Disease incidence and severity is proportional and so will be normalized by applying a square-root of the arc-sine transformation of the data. Analysis of variance will be used to determine the effectiveness of the treatments on mummy berry disease control and yield. Analysis of variance will be used to determine if concentrations of propiconazole are significantly higher in treated plots than in non-treated controls at the time of 10% bloom. In addition, estimates of the median concentration will be determined if they are significantly greater than 10 µg/g flower petal tissue (the level that is known to synergize acetamiprid in honey bees (Iwasa et al., 2004)).

Objective R3. Compare pollinators, honey bees and bumble bees, for their efficiency in spreading inoculum of *Monilinia vaccinii-corymbosi* to flowers.
In highbush blueberries it has been suggested that honey bees are significant vectors of mummy berry conidia (Woronin, 1888; Batra and Batra, 1985; Cox and Scherm, 2001), however, no evidence exists for lowbush blueberry that pollinators vector mummy berry although we hypothesize that this is the case.

Materials and Methods: Two experiments will be conducted. The first experiment will assess transmission potential of mummy berry conidia on lowbush blueberry plants by honey bees and commercial bumble bees. In 2009 and 2010, nine insect flight cages (2 x 2 x 4m) will be set up (randomized complete block design) in a non-blooming vegetative blueberry field at the University of Maine Blueberry Hill Research Farm. Flats of lowbush blueberry plants (30 x 90 cm) in bloom that have no signs of infection from *M. vaccinii-corymbosi* will be introduced into each of the cages. Three cages will house a nucleus colony of honey bees (*Apis mellifera* L.), three cages will house a quad of commercial bumble bees (*Bombus impatiens* Cresson, Koppert Biological Systems, Romulus, MI), and three cages will contain no pollinators. Following the introduction of the flowering blueberry flats, a mummy berry infected blueberry stem with infective conidia will be placed adjacent to the flat in each cage. Visitation to the infective stem and to the flat in bloom will be recorded for 30 minutes. After the 30 minute bioassay the infective stem will be removed from the cages and the flats will be left in the cage for three days to insure adequate pollination. The flats will then be removed from the cages and placed in a protective cage in a greenhouse that will protect them from additional visits from pollinators. New flats with new infected stems will be placed in the cages and this procedure will be repeated 4-5 times during the typical month long period of bloom in lowbush blueberry. The incidence of mummy berry infection due to secondary infection by bees will be assessed in late July when mummified fruit are easily distinguished from healthy berries.

The second experiment will also be conducted in 2009 and 2010. In the greenhouse a flight cage (2 x 2x 3m) will be erected. The day previous to a bioassay a flat of flowering blueberries will be placed in the cage and either a honey bee nucleus colony or a commercial bumble bee colony will be put in the cage to allow bee foraging on the blueberries. On the day of the assay, the flowering plants will be removed from the cage and pairs of cut stems in test tubes, 15 cm apart in a test tube holder, will be offered to the bees. The paired stems will consist of a stem with both flowers, 1-3 days after pollen anthesis, and mummy berry infected foliage producing conidia and a non-infected stem also with flowers 1-3 days after pollen anthesis (this flower age is when stigmatal receptivity is maximal, Drummond, unpublished data). The preference of honey bees and bumble bees for visiting infected or non-infected stems will be recorded. In addition, if infected foliage is visited, bees will either: 1) be collected and anesthetized with CO_2 so that the head and mouthparts can be inspected under a microscope for *M. vaccinii-corymbosi* conidia (location and number of conidia on each bee will be recorded, Batra and Batra, 1985), or 2) allowed to forage on flowers. Flowers that are visited after infected foliage has been visited will be collected and the stigmatal surface will be inspected under a light microscope for conidia. After a single visit, new pairs of stems will be offered to the foraging bees in the flight cage. Our aim will be to collect fifty bees of each species visiting infected foliage and 50 visited flowers by each of the two bee species over the experiment.

Analysis. Experiment 1. Analysis of covariance (number of visits as a regressor) will be used to assess if there is a difference in transmission rates between cages with bees and the control cages and between the two species of bees corrected for visitation intensity. Experiment 2. A paired t-test will be used to compare the propensity of each species to pickup spores, the location on the head that spores are carried, and the number of spores moved to the stigma by each bee species.

TIMETABLE

Time Period	**Objective E1**	**Objective R1**	**Objective R2**	**Objective R3**
April – June 2009	Monitor for MBFM. Timing of fungicide application study	Set up and apply fertilizer and herbicide to interaction study. Rate for weeds.	Alternative for mummy berry control study. Propiconazole residue study	Field transmission study Greenhouse preference and vector study
July – Aug. 2009	Harvest experimental plots.	Rate for weeds	Harvest experimental plots.	Collect data on spore distribution
Sept. – Dec. 2009	Process plant samples. Analyze data.	Process soil and plant samples for nutrients and fertility	Process plant samples. Analyze data.	Data entry and analysis
Jan.- March, 2010	Develop education materials, hold workshops and grower meetings.	Analyze results.		Assess change in design or methods for year 2
April – June 2010	Monitor for MBFM. Timing of fungicide application study	Rate for weeds. Fungicide applications, rate for disease.	Alternative for mummy berry control study. Propiconazole residue study.	Field transmission study Greenhouse preference and vector study
July to Aug. 2010	Harvest experimental plots.	Harvest experimental	Harvest experimental	Data entry and analysis

		plots.	plots.	
Sept. 2010 to April, 2011	Analyze data. Develop education materials, hold workshops and grower meetings.	Process plant samples. Analyze data. Prepare manuscripts and fact sheets.	Analyze data Revise fact sheets as needed. Prepare manuscripts.	Revise fact sheets as needed. Prepare manuscripts.

Evaluation plans

The major products from this project will be the increase in the adoption of the mummy berry forecast model by growers in the NNE, new information on the efficacy of reduced risk and organically acceptable methods of controlling mummy berry disease and new information on the interactive effects of management techniques for fertility and weed and disease control. We have designed our research so that each objective provides information on improving control of mummy berry disease and decreasing the use of pesticides. Growers will be surveyed both before, and one year after training in the forecast method to evaluate their use of fungicides, costs of materials and application, use of the website and telephone disease forecasts, and satisfaction with mummy berry disease control. Costs of the producing and mailing the surveys are included in the publication and postage budgets. We expect 200 growers covering 70% of the lowbush blueberry production will be trained and over 100 growers will adopt the MBFM with concurrent less use of fungicides to produce a cost savings to these growers. The number of visits to the webpage with the disease risk estimates will be tracked. We will be producing educational materials in the forms of web-based presentations and information and newsletters and printed factsheets. Webpages will be designed to record the number of times that they are accessed and distribution of factsheets will be tracked. We will be producing recommendations for growers and scientific publications from the experiments on interaction among management practices and for testing of efficacy of alternative controls of mummy berry disease.

Key Personnel List and their roles

Annis (Associate Professor of Mycology: UMaine) and Yarborough (Blueberry Specialist and Professor of Horticulture: UMaine) will be training Grube (UNH Sustainable Horticultural Crop Specialist) and Schloemann (UMass Extension Small Fruit Specialist) in the first year on the MBFM and implementation of the method in New Hampshire and Massachusetts, respectively. Grube and Schloemann will be setting up mummy berry patches and weather stations and consulting with Annis on disease forecasts. They will also be conducting grower training at planned growers meetings in their respective states. Annis and Yarborough will be conducting training workshops for growers, designing web-based materials and revising fact sheets. Annis will be conducting farm visits and will set up and monitor with the research assistant all mummy berry plots and weather tracking sites in Maine. Annis will be providing real-time disease forecasts for growers in Maine and supervise the research assistant who will be applying fungicides and other treatments, evaluating disease severity and incidence and measuring yield for all experimental plots. The research assistant will also be helping analyze data and develop educational materials with Annis and Yarborough. Yarborough will also conduct all herbicide and weed evaluations in the experiments. Smagula (Professor of Horticulture: UMaine) will be responsible for fertility and plant productivity applications and measures in objective R1. Drummond (Professor of Insect Ecology and Cooperative Extension Professor: UMaine) will be responsible for all pollination studies in objective R2 and R3.

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Improving the control of mummy berry disease while decreasing the use of fungicides in blueberry production of Northern New England

Project Summary: This is a Joint Research-Extension project focused on improving control of mummy berry disease in blueberries while decreasing fungicide use in northern New England (NNE). This project will benefit lowbush and highbush blueberry growers, the public, and the environment near blueberry fields by decreasing the environmental impact and increasing the economic benefits of blueberry production. Mummy berry disease affects all species of blueberry and can decrease yield up to 50% in highbush and 100% in lowbush blueberries Currently the majority of growers in Maine, New Hampshire and Massachusetts are applying up to 3 fungicide applications using a calendar schedule which often results in incomplete control and unnecessary fungicide applications. The adoption of a mummy berry disease forecasting model (MBFM) will produce science-based pest management that safeguards human health and the environment and promotes economic benefits for growers. Our extension goals (21% of funds) are: to increase the adoption of the MBFM by blueberry growers in NNE, and compare the MBFM with applications based on the calendar. There are few studies on the interactive effects of management inputs on disease in lowbush blueberry. Growers and consumers are also interested in reduced-risk fungicides and cultural techniques for managing disease. Our research goals (79% of funds) are: to determine the interactive effects of weed pressure, fertility, and fungicide treatment on disease in lowbush blueberries, test low-animal toxicity fungicides and cultural amendments for their disease control efficacy and compare pollinators for their efficiency in spreading secondary fungal inoculum to blueberry flowers.

Mummy berry disease, caused by the fungus *Monilinia vaccinii-corymbosi*, is a serious disease in all blueberry species grown in North America and can inflict serious losses to growers of all types of blueberries. Reducing risk associated with pesticides and fertilizers is an important outcome of any cropping system. This may be especially true for blueberries in NH, ME and MA since many of the production areas are proximal to rivers and streams and are surrounded by forests, and most commercial fungicides are highly toxic to fish. Conventional northern highbush and lowbush blueberry growers currently use the chemical fungicides propiconazole and fenbuconazole to control mummy berry disease since there are no lower risk (in toxicity to animals) or organically-acceptable fungicides that have been demonstrated as effective to control the blight stage of the disease. To control mummy berry disease, organic growers only have two management techniques to rely upon; burn pruning their plants or mulching entire fields both of which decrease inoculum levels.

Lowbush blueberry is a perennial, long-lived field crop with a two-year crop cycle where inputs in one year can have extensive impacts on its management and yield in following years. Fertility, pollination, and control of weeds, diseases and insect pests are some of the more expensive inputs associated with managing a lowbush blueberry field. While there has been research on individual aspects of lowbush blueberry management, there is a lack of research examining the interactions of these practices and particularly their effects on disease control. In a recent organic transition study, lowbush blueberry plants that were over-fertilized with N and had minimal weed control also had higher incidence of mummy berry disease than unfertilized plants with or without weed control. Pollination is also critical for blueberry production. Both honey bees and bumble bees can be used to pollinate lowbush blueberries and both are effective pollinators, but honey bees require more visits to a single flower to transfer similar amounts of pollen as transferred in a single visit by a bumble bee. Honey bees will collect *M. vaccinii-corymbosi* spores from infected blueberry leaf and flower tissue and carry them on their body surface, and bumble bees will visit infected leaf tissue.

This research and extension project will address top priorities identified by the Wild Blueberry Advisory Committee (WBAC), the National Berry Crop Initiative (NBCI), Maine Organic Farmers and Gardeners Association (MOFGA), the Northeast IPM center and the Pest Management Alternatives Program (PMAP). General IPM Priorities for the Northeast (2006) that this grant supports are “research on biological control of diseases, arthropods, and weeds; extension of this research into production systems of horticultural crops” and “Test the efficacy of pest management materials allowable in organic production systems”. PMAP consists of multiple groups interested in decreasing pesticide use in the USA. This project also is applicable to two of their 2007 specific priorities “3. Conduct research and outreach on alternative cultural and biological pest control in organic and/or conventional horticultural production systems” and “4. Assess, develop, and distribute new or improved methods for pest monitoring systems”. The WBAC is comprised of growers and processors of lowbush blueberry who annually meet with blueberry researchers to set research and extension priorities. In 2008 and 2009, they have ranked the implementation of a MBFM as a high priority. The NBCI consists of groups in industry, academia and government that promote the growth and sustainability of berry crops in the USA. This grant fulfills their objectives: “2.2. To promote long-term sustainable production by increasing long-term sustainability of water, energy, nutrients and soil through practices such as water and soil conservation, efficient nutrient utilization and IPM” and “2.3 To improve berry production efficiency and profitability which includes efforts involving labor efficiency, harvest mechanization, improved pest control (new reduced-risk pesticides, cultural practices, increased understanding of pest biology, improved utilization of existing pest control methods, plant nutrition, irrigation technology, cultural methods and practices, and breeding and germplasm improvement)”.

The lowbush blueberry crop is harvested on over 60,000 ha in North America, averaging more than 82 million kg per year. Lowbush blueberries contribute approximately $75 to $150 million to Maine’s economy and are mostly grown in economically challenged areas, such as Washington Co., a county with a depressed economy where 60% of the blueberry production takes place. About one third of the lowbush blueberry crop is produced by approximately 770 growers in ME, but only a few growers manage the majority of the acreage, so any change in their management methods can affect a large number of acres. MA and NH have about 50 growers with small acreages (total NH: 170 acres and MA: 400 acres) of lowbush blueberries and the remaining acreage occurs in the northeastern Canadian provinces. There are about 109 growers of highbush blueberry in NH (170 acres) and about 235 growers with smaller farms (5 acres each) across MA. The small number of acres belies the economic significance of the blueberry crop since the highbush crop is worth approx. $1.5 million per year in NH alone.

There has been an increase in demand for lowbush blueberries and an increase in prices received by growers. Unfortunately costs of management inputs have also increased in the last year, so efficiency and profitability are becoming increasingly critical factors in sustaining a viable industry in NNE. We believe that there is potential to change the way in which mummy berry disease is managed by establishing the interactive effects of over-fertilization, level of weed control and fungicide application as well as implementing the MBFM to decrease the number of applications of fungicides for control of mummy berry disease.

Objectives and Anticipated Impacts

Extension **E1.** Increase the use of the MBFM for timing fungicide applications to control mummy berry blight in Maine, New Hampshire and Massachusetts and validate the forecast model by comparing it to the application of fungicides via a calendar schedule.

Research **R1**. Determine the interactive effects of weed pressure, fertility, and fungicide treatment on severity of mummy berry blight on lowbush blueberries.

R2. Test low-risk fungicides and cultural amendments for their effectiveness in controlling mummy berry blight.

R3. Compare pollinators, honey bees and bumble bees, for their efficiency in spreading inoculum of *Monilinia vaccinii-corymbosi* to flowers.

There will be reduced risk to human health and the environment with reduced use of fungicides to control mummy berry disease. There will be an increase in the acreage of lowbush blueberries that will be treated with only one or no application of fungicide when more growers adopt the MBFM to determine if and when they need to apply fungicides. Data obtained by testing the efficacy of reduced-risk fungicides (decreased toxicity to animals), organically acceptable materials or cultural methods to control mummy berry disease will be used to develop recommendations for growers who wish to decrease their use of chemical pesticides or to use organic production methods. Some of these alternative methods for controlling disease will also be applicable to other species of cultivated blueberry. Research on the interactive effects of inputs to manage fertility, weed control and mummy berry disease control may lead to decreased over-fertilization of fields and fewer pesticide applications in lowbush blueberry fields.

Growers would save at least $50/acre (estimated 2008 costs) in fungicide material and applications costs each year for each application of fungicide they do not use. Information obtained from the experiment on the interactions of management techniques may lead to new recommendations to decrease inputs and save growers money. This will be significant for both growers with few acres which have a low profit margin and large growers who manage thousands of acres and are often one of the major industries in economically depressed regions. Some of the organically approved materials and cultural control methods use locally produced materials, which if adopted may boost local industries.

We will use workshops, scouting meetings and presentations to introduce and train growers on how to implement the MBFM in their fields. Growers using the MBFM will be supported by guides to the development of the fungus, plants, and disease cycle, factsheets, and information on disease risk both on the web and on a toll-free telephone line during the spring. Participating growers will be surveyed before and after workshops and at annual meetings over two years to determine their use of pesticides and adoption of the MBFM. We expect 200 growers representing 70% of the lowbush production in ME, NH and MA to be trained. We expect 100 or more growers will adopt IPM practices directly as a result of this project.