Maine Agricultural Center Integrated Research and Extension Grants: 2014–2015

MAC138:   Effects of Cook Method and Time on the Safety and Quality of Maine Fiddleheads

Principal investigator: Beth Calder, Dave Fuller, Katherine Davis-Dentici, Jason Bolton

Background

The ostrich fern *(Matteuccia struthiopteris)* or fiddlehead fern is a wild edible commonly consumed during the spring months of April to early June, not only in the northeastern United States, but also in Canada. Fiddleheads are also consumed in parts of Europe and Japan. While they are a favorite wild delicacy, fiddleheads have been associated with foodborne illness outbreaks in Canada and in the United States and these illnesses were attributed to the consumption of under-cooked fiddleheads. A toxin has been suspected as the possible cause of these illnesses. Whether this toxin is bacterial, fungal or plant-based in origin, it is not known. Even though the toxin may possibly be bacterial in nature, the current recommendations for properly cooking fiddleheads are based more on historical data rather than on actual, validated cook studies. Therefore, we propose several research objectives to provide more safety and quality information for fiddlehead retailers and consumers:

1. To determine the average microbial load and heavy metal concentrations of raw fiddleheads harvested from Maine watersheds compared to fiddleheads harvested from woodland sites.
2. To conduct fiddlehead cook studies to determine microbial reductions and also compare color and textural differences among treatment samples.

Research and/or extension education activities:

Two research studies will be conducted:

1. **Raw Fiddlehead Study:** This study will investigate what the average bacteria (including aerobic plate counts, coliforms/*E. coli, Staphylococcus aureus* and environmental *Listeria* presence), yeast, and mold counts are from 5 Maine watersheds: Wesserunsett Stream, Sandy, Penobscot, Androscoggin, and Kennebec Rivers compared to fiddleheads harvested from at least three woodland sites (Penobscot, Franklin and Somerset counties). Ten pounds of fiddleheads will be harvested from each site, placed into sterile sample bags and transported on ice to UMaine. Fiddleheads will be cleaned via the methods described in the UMaine Cooperative Extension Bulletin #4198 "Facts on Fiddleheads" and refrigerated (40 deg F or below) prior to analyses. Fiddleheads will be plated within 1-2 days after harvest. Samples will also be analyzed for heavy metal concentrations, such as cadmium, arsenic and lead. Samples will be sent to UMaine Sawyer Environmental Chemistry Research Laboratory for heavy metal analyses.
2. **Cooked Fiddlehead Study:** Raw fiddleheads from the above mentioned watersheds will be compiled into one collective sample and cook studies will be conducted to determine the overall bacteria, yeast and mold reductions of the cook method (boiling in water versus steam) over time (fiddleheads will be cooked for 2, 5, 10 and 15 minutes). The fiddleheads will then be immediately cooled in a 50:50 ice water slurry for 5 minutes. Samples will be plated for aerobic plate counts, yeast, molds, coliforms/*E. coli,* and *Staphylococcus aureus.* Cooked fiddlehead samples will be analyzed for color and subjected to texture tests to compare the color and texture changes as fiddleheads are cooked at longer periods of time and also compared between the two cook methods. We will use thermocouples to monitor temperatures during the cook process and monitor the internal temperature of fiddleheads.

Dr. Beth Calder is advising Felicia Dumont, a M.S. Food Science student from the School of Food & Agriculture. This grant will allow a M.S. student to conduct a more robust research project, which will also benefit UMaine Cooperative Extension outreach efforts.

Extension Education Activities:

Dave Fuller, Beth Calder and Jason Bolton will update the cooking instructions in Bulletin #4198 "Facts on Fiddleheads", which received 35,500 hits in 2013, which has more than doubled over the past three years. Other education activities are listed below in the outcomes section. This fact sheet will not only benefit Maine citizens, but also people in other states across the U.S. and Canada who also consume fiddleheads. Fiddlehead harvesting and processing is a significant cottage industry in Maine. Dave, Beth and Jason will also disseminate the findings to fiddlehead retailers who will benefit from validated cook method recommendations for their consumers. The heavy metal data will help determine which watersheds to avoid when harvesting fiddleheads.

Expected outcomes and method for sharing outcomes:

Not only will the fact sheet be updated, but investigators will also travel to the Institute of Food Technologists Annual Meeting in Chicago, IL in 2015 to present the research findings in the form of a research poster, and then draft a manuscript to be submitted to the *Journal of Food Science.* New findings will be delivered at the Forest Farmers Conference Fiddlehead segment convened by Dave Fuller on October 24-2 5, 2014 at the Arnot Teaching Forest in Ithaca, NY. Information will be presented at the Maine Fiddlehead Festival held in Farmington, Maine and will also be shared with colleagues in the Canadian Maritime Provinces.

Final Report

Nontechnical summary:

Two studies were conducted to investigate the microbial characteristics of raw fiddleheads to determine if microbial levels and heavy metal concentrations vary depending on location and to determine thermal processing effects on microbial load and quality of fiddleheads. Fiddleheads were harvested from 5 Maine riverbanks and 3 upland wooded sites. Two separate studies were conducted (raw and cooked) and all samples were analyzed for bacteria (*E. coli*/coliforms, aerobic plate counts (APCs), *Staphylococcus aureus*, yeast/molds). In the cooked study, fiddleheads were either steamed or boiled (100°C) for 0, 2, 5, 10 and 15 minutes. Texture, color and heavy metal analyses were conducted on fiddlehead samples. Raw study APCs ranged from 5.2-6.9 log cfu/g. No *E. coli* or yeast colonies were detected. Mold counts varied from 3.9-5.8 log cfu/g, coliforms from 0.3-5.6 log cfu/g and *Staphylococcus aureus* counts between 0.4-2.6 log cfu/g. The cook study showed substantial reductions of all microorganisms over cook time. Boiling appeared more consistent than steaming in lowering microbes. Shear force (N) significantly decreased as cook time increased, as fiddleheads softened over cook time. All samples became lighter in color than the control and more yellow, as cook time increased. Heavy metal concentrations in fiddleheads varied depending on location and would not be cause of concern since being consumed seasonally and in low quantities.

Original project objectives that were met and significant findings:

While fiddleheads are a favorite spring delicacy, these wild edibles have been associated with foodborne illness outbreaks in Canada and in the United States in the past. The illnesses were attributed to the consumption of under-cooked fiddleheads, although an unknown toxin has been suspected as the possible cause of these illnesses. Whether this toxin is bacterial, fungal or plant-based in origin, it is not known. Even though the toxin may possibly be bacterial in nature, the current recommendations for properly cooking fiddleheads are based more on historical data rather than on actual, validated cook studies. Therefore, we propose several research objectives to provide more safety and quality information for fiddlehead retailers and consumers.

The objectives of these two studies were to determine the average microbial load and heavy metal concentrations of raw fiddleheads harvested from Maine watersheds compared to fiddleheads harvested from upland wooded areas and to conduct fiddlehead cook studies to determine microbial reductions and also compare color and textural differences among treatment samples.

1. **Raw Fiddlehead Study:** This study investigated the total aerobic bacteria plate counts, as well as coliforms/*E. coli* and *Staphylococcus aureus* presence, yeast, and mold counts from 5 Maine watersheds: Wesserunsett Stream, Sandy, Penobscot, Androscoggin, and Kennebec Rivers. We also compared these bacterial counts to fiddleheads harvested from at least three upland wooded sites in Penobscot, Franklin and Somerset counties. Approximately, ten pounds of fiddleheads were harvested from each site and transported on ice to UMaine. Fiddleheads were cleaned utilizing the methods described in the UMaine Cooperative Extension Bulletin #4198 "Facts on Fiddleheads" and refrigerated (40 deg F or below) prior to the cook study analyses. Fiddleheads were plated within 1-2 days after harvest. Samples were analyzed for heavy metal concentrations, such as cadmium, arsenic and lead, at the UMaine Sawyer Environmental Chemistry Research Laboratory for heavy metal analyses using ICP-MS.

Significant Findings:

Based on the raw fiddlehead microbial results, fiddleheads had a fairly high microbial load, as aerobic bacterial plate counts (APCs) ranged from 5.2 to 6.9 log cfu/g. Although no *E. coli* or yeast colonies were detected, coliforms (0.3 to 5.6 log cfu/g) and molds were discovered (3.9-5.8 log cfu/g). *Staphylococcus aureus* was also detected, but at relatively low levels (0.4-2.6 log cfu/g). The coliform counts could be from the natural flora of the environment along these streams and woodlands, and/or it could be influenced from agricultural or industrial runoff along the Maine waterways where we sampled. Humans are known to be possible carriers of *Staphylococcus aureus* and could easily be transferred to fiddleheads during harvesting. We did detect *Staphylococcus aureus*, but at low levels. *Staph* is a poor competitor with other microorganisms and at these low levels, we would not expect *Staph* toxin to be an issue with these fiddlehead samples. Based on heavy metal results, fiddlehead samples had low lead, arsenic, and chromium concentrations. We did notice the fiddleheads harvested near the Kennebec river had significantly ($p<0.05$) higher cadmium and a higher copper level compared to the other samples. The fiddleheads harvested near Penobscot River also had significantly ($p<0.05$) higher nickel and chromium levels compared to the other samples. These fiddleheads were sampled downstream from agricultural and other manufacturing industries. However, the heavy metal results did not differ much from upland wooded area fiddlehead samples, which suggests the geology of these counties are rich in the heavy metals we analyzed. Because fiddleheads are so seasonal and consumed in limited quantities, these heavy metal results are not a concern for public health.

2. **Cooked Fiddlehead Study:** Raw fiddleheads from the above mentioned watersheds were compiled into one collective sample and cook studies were conducted to determine the overall bacteria, yeast and mold reductions of the cook method (boiling in water versus steam) over time (fiddleheads were cooked for 0 (control) 2, 5, 10 and 15 minutes). The fiddleheads were then immediately cooled in a 50:50 ice water slurry for 5 minutes to cool to below 40 deg F. Samples were plated for aerobic plate counts, yeast, molds, coliforms/*E. coli*, and *Staphylococcus aureus*. Cooked fiddlehead samples were analyzed for color and texture analyses to compare the color and texture changes over cook time and also between the two cook methods. We used thermocouples/datalogger to monitor and record the internal temperatures of the fiddleheads during the cook process and monitored the internal temperature of fiddleheads.

Significant Findings:

Based on the cook study microbial results, both cooking methods were adequate to reduce all microbial populations that were monitored. Blanching fiddleheads (2 minutes) in boiling water was adequate to destroy coliforms and *Staphylococcus aureus.* However, aerobic bacteria were more persistent and still low levels could be detected after a 10-minute boil. After boiling at 15 minutes, no microorganisms were detected. The steam results were less consistent, although a 2-minute steam blanch was adequate to destroy *Staphylococcus aureus.* It took at least a 5-10 minute steam to destroy the rest of the microorganisms. However, aerobic bacteria and coliforms were still detected at a 15

minute steam, which could have been due to sampling error or due to the fact we packed the fiddleheads in the colander to keep the thermocouple probe in place. The packed fiddleheads may represent a worse case scenario in the consumer kitchen and may not allow enough steam to penetrate the center of the fiddlehead sample and fiddleheads have curled fronds, which could protect bacteria if not thoroughly or adequately heated. Although we did not study adequate fiddlehead to cooking medium ratio, this type of research project should be conducted in the future.

Based on the heavy metal analyses of the cooked fiddlehead samples, cooking method did not appear to affect or dilute out heavy metals in the samples we analyzed at a 10-minute boil or steam. For texture results, overall trends showed that as cook time increased, the shear force to penetrate through fiddlehead samples significantly ($p<0.05$) decreased over cook time, which indicates the fiddleheads did get softer as the cook time increased. There were no significant texture differences between the steam and boil cook treatments. Texture shear force values (N) were quite similar among the 10-minutes boil, 10-minute steam, and 15-minute boiled samples, which indicated no real texture differences among these treatments. For the color results, all samples became significantly ($p<0.05$) lighter in color than the control, and all fiddlehead samples were more green than red in color, and as cooking time increased to 10 minutes, the fiddleheads became more yellow in color.

Based on the overall research results, we recommend that fiddleheads be boiled for at least 15 minutes and steamed for over 10 minutes to ensure all microorganisms are inhibited. We also recommend not to densely pack fiddleheads during cooking to allow for adequate heat penetration from boiling water or steam. We would not recommend sautéing or microwave cook methods based on the varied bacterial results we noted, and the curled nature of the fiddleheads, as these methods probably would not provide a thorough cook process to adequately destroy potential foodborne illness causing microorganisms.

Original project objectives that were not met:

We originally proposed monitoring *Listeria* bacteria in fiddlehead samples, but we decided not to plate for *Listeria* because of the environmental nature of this bacteria. We would expect its presence on raw fiddleheads. *Listeria* is not a true indicator organism for pollution or contamination so we decided the data would not be helpful for this project.

Methods used to evaluate outcomes:

Audiences/participants will be evaluated via written surveys, personal communications and verbal cues.

Integration of research and extension activities:

Dave Fuller, Beth Calder and Jason Bolton will update the cooking instructions in Bulletin #4198 "Facts on Fiddleheads". Dave will also disseminate the findings to fiddlehead retailers who will benefit from validated cook method recommendations for their consumers.

External funding both sought and received:

External funds were not pursued since this grant was adequate to meet our research needs to complete this project.

Educational material, publications, and programs:

At the present time, no new educational materials or programs have been created. However, existing educational materials, such as the Extension Bulletin #4198 "Facts on Fiddleheads", which received 35,500 hits in 2013, will be revised to include new recommendations based on this research project. David Fuller and Beth Calder will also share the results with Ag Canada. David Fuller can incorporate parts of the research results into newspaper articles during fiddlehead season next spring and into non-timber forest products educational programs. David will also spend time with fiddlehead processors that contact him during the fiddlehead season as an ongoing educational opportunity. Additionally, the outcomes from this project will be shared with Native American populations who consume significant amounts of fiddleheads.

Research publications, abstracts, and presentations:

Beth Calder presented a research poster titled "The Effects of Thermal Processing on the Microbial Levels, Heavy Metal Concentrations and Physical Qualities of Fresh, Maine Fiddleheads" at the Institute of Food Technologists Annual Meeting in Chicago, IL on July 14, 2015. This research poster abstract was peer-reviewed. A manuscript will be submitted to the Journal of Food Protection in 2016. David Fuller will be presenting the research project and results at the Fiddlehead Festival (Farmington, ME) in May 2016.

Beth Calder did advise Felicia Dumont, to obtain her M.S. degree in Food Science & Human Nutrition, from the School of Food & Agriculture. Felicia completed a M.S. thesis on this research project, which is available through the UMaine Fogler Library.

MAC139:   Survival of Streptococcus equi in Equine Compost

Principal investigator(s):   Robert Causey, Alexandria Garcia, Mark Hutchinson

Background

Strangles is a highly contagious respiratory infection of equines caused by *Streptococcus equi* subspecies *equi* (*S. equi*). An outbreak of *S. equi* on a farm may last up to 4 to 6 months (Taylor et al., 2006), and outbreaks in Maine usually occur every year. Infected horses may continue to shed the organism for over a year after clinical signs resolve, the longest documented shedding being 39 months (Taylor et al., 2006). In 2012, two farms within 20 miles of Orono had out breaks of strangles. These outbreaks cause serious economic hardship, such as loss of riding activities, veterinary expenses, and cost of horse disposal. Concern exists regarding infectivity of both manure and animals that have died from the illness. In addition, *Streptococcus equi* subspecies *zooepidemicus* (*S. zooepidemicus*) is an equine commensal closely related to *S. equi* and has been reported to cause rare but serious infections in humans exposed to horses or horse manure (Andie and Dyer, 2004; Pelkonen et al., 2013).

Effective management of equine waste and mortalities is needed to prevent spread of strangles. The number of people that come in contact with horses and horse byproducts is high. Infected manure is handled daily and is spread by shovels, wheel barrows, pitch forks, clothing, and shoes. Most farmers spread fresh manure on their fields. According to the American College of Veterinary Internal Medicine, manure from strangles cases "should be composted in an isolated location" (Sweeney et al., 2005). However, there is no research to support whether abatement of equine *Streptococci* occurs in compost.

In New England, there has been an increase in organic farming and the use of compost as a soil amendment. Most composting in Maine utilizes horse bedding as a major feedstock. However, a case was reported in which a 79 year old man contracted a fatal infection of *S. zooepidemicus* from the fresh, un-composted manure he spread onto his garden (Andie and Dyer., 2004). Other fatal cases have been reported where people contracted *S. zooepidemicus* infection following horse contact (Pelkonen et al., 2013). Thus there are some public health concerns regarding human exposure to horse manure containing *S. zooepidemicus.*

Because strangles has a 4-8% mortality rate, equine disposal is an important consideration in strangles outbreaks (Taylor et al., 2006). Burial is a common disposal option for many horse owners, however burying a horse in the state of Maine is challenging because of high water tables and shallow bedrock. Composting is increasingly recognized as an environmentally sound and economical way to dispose of dead horses. With their access to horse manure, composting may be an economically viable and bio-secure option for disposing of strangles cases on horse farms. However, as mentioned above, data on the survival of *S. equi* in compost is lacking.

Equestrian centers and compost users are therefore interested in determining if either of these equine *streptococci* (*S. equi or S. zooepidemicus*) can survive the composting process in equine manure and bedding, and, if so, what are the optimal conditions for streptococcal abatement. To address these concerns, a joint research – extension project is proposed between UMaine's School of Food and Agriculture, Cooperative Extension, Animal and Veterinary Sciences and Plant, Soil and Environmental Sciences.

Hypothesis

It is hypothesized that viable *S. equi* and *S. zooepidemicus,* inoculated into a compost static pile, will not be detectable in the pile 35 days after the inoculation.

Objectives

1. Assess the viability of *S. equi* and *S. zooepidemicus* at various depths in compost windrows.
2. Determine the effect of different compost C:N ratios on the elimination of streptococci.
3. Formulate best management practices to eliminate streptococci from equine compost.

Research and/or extension education activities:

Methods

Composting will occur at the Compost Research and Education Center located at the Maine Agricultural and Forest Experiment Station (Highmoor Farm) in Monmouth, Maine, on the isolated compost pad. Three static compost windrow piles, each with different C:N ratio, will be built using horse bedding and waste feed. For each bacteria, inocula in Dacron bags will be placed at 2 different depths (1 and 3 feet) and withdrawn at 7 time points (2, 4, 7, 14, 21, 28, and 35 days.) Six replicates at each time and depth combination will be made in each pile. The total number of observations will therefore be 504 (n = 3(piles) x 2(bacteria) x 2(depths) x 7(timepoints) x 6(replicates) = 504). Piles will be 4 feet in height, width of 6 feet, and length of 20 feet. Temperatures will be recorded daily at each testing site, using HOBO data loggers (Onset Computer Corporation, Bourne, MA).

Prior to addition of *streptococci*, representative samples of each media will be inoculated on blood agar to assess background flora. Compost media in Dacron bags will then be inoculated with 10^9 Colony Forming Units (CFU) of each streptococcal organism. The bags will be randomly assigned to each combination of pile, depth, time and will be removed from the pile on the appropriate date. Samples from each bag will be streaked on blood agar to assess presence or absence of viable *streptococci.* Beginning and ending samples will be sent to IDEXX for independent confirmation by PCR of streptococcal clearance. The Dacron bag technique is an accepted method to manage samples during microbial digestion (Hopson et al., 1963). The viability of streptococci at different times, depths and C:N ratio will be determined.

As a control to distinguish the role of temperature versus microbial activity in abating *streptococci*, 7 Dacron bags of both *S. equi* and *S. zooepidemicus* inoculated compost samples will be incubated in the laboratory at the mean weekly temperature of the compost piles, and viability of *streptococci* assessed each time bags are removed from the compost pile.

Education / Outreach

Research findings and outcomes will be presented at a University of Maine, Orono, School of Food and Agriculture seminar, and at an equine health conference. A fact sheet of best management practices will be created and made available to producers. The current UMaine Strangles fact sheet will be updated. Research will be submitted for publication in a peer reviewed journal. Project updates and information will be made available on social media sites. A request for presentation at a veterinary continuing education conference will be submitted. A field day at Highmoor farm will be created where research information will be presented to the equine, veterinary and organic farming communities.

References

- Andie, S. L., and J. R. Dyer. 2004. Severe *Streptococcus zooepidemicus* infection in a gardener. The Medical Journal of Australia. 180: 366
- Hopson, J. D., R. R. Johnson and B. A. Dehority. 1963. Evaluation of the Dacron Bag Technique as a Method for Measuring Cellulose Digestibility and Rate of Forage Digestion. Journal of Animal Science. 22:448-453.
- Pelkonen, S., S. B.Suomala, P. Karhukorpi, J. Vuorinen, S. Koivula, I. Väisänen, T. Pentikäinen, J. Autio, T. Tuuminen, and Tamara. 2013. Transmission of *Streptococcus equi* subspecies *zooepidemicus* Infection from Horses to Humans. Emerging Infectious Diseases. 19.7: 1041-1048
- Sweeney, C. R., J. F Timoney, J. R. Newton, and M. T. Hines. 2005. *Streptococcus equi* Infections in Horses: Guidelines for Treatment, Control, and Prevention of Strangles. Journal of Veterinary Internal Medicine, 19:123–134.
- Taylor, S. D., and D. W. Wilson. 2006. *Streptococcus equi* subsp. *equi* (strangles) Infection. Clinical Techniques in Equine Practice. 5.3: 211-17.

Expected outcomes and method for sharing outcomes:

If *S. equi* and *S. zooepidemicus* cannot be recovered from a compost pile of specific C:N ratio, after a certain length of time, at a specific depth, this will allow best management practices for the elimination of streptococci from equine compost to be developed for the equine industry. This will also allow horse owners and veterinarians to have a safe method for disposal of manure. Farmers and growers who use compost will have greater confidence that the compost they use will be safe for field workers, food handlers, and consumers.

Final Report

Nontechnical summary:

Streptococcus equi subspecies *equi* (S. *equi*), causes potentially fatal respiratory disease in horses, and *Streptococcus equi* subspecies *zooepidemicus* (S. *zooepidemicus*) causes potentially fatal infections in humans. A study was undertaken to determine the survival of these organisms in equine compost. Compost piles of equine bedding and feed waste were inoculated with *S. zooepidemicus* and samples taken at 48, 96, 168 and 336 hours relative to placing samples 0 hours. No *streptococci* were isolated at or after 48 hours. Next, *S. equi* was similarly inoculated into equine compost, and sampled at 2, 4, 8, 12, 24, 48, 168 and 336 hours. No s*treptococci* were isolated. To rule out killing of *streptococci* by microflora in equine waste, samples of soiled bedding, both autoclaved and un-autoclaved (with moisture added) were inoculated with *S. zooepidemicus* and s*ampled at 0, 6, 12, 24, 48, 72, 120, 168 and 264 hours. In autoclaved bedding, *S. zooepidemicus* was isolated from 0 – 120hours, but replaced by other flora at 264 hours. In un-autoclaved samples, *streptococci* were not present after 48 hours. A repeated trial with *S. equi* yielded similar results. This data suggest that microbial activity of equine waste bedding may eliminate *streptococci* within 24 - 48 hours.

Original project objectives that were met and significant findings:

1. Assess the viability of *S. equi* and *S. zooepidemicus* at various depths in compost windrows.
2. Determine the effect of different compost C:N ratios on the elimination of streptococci.
3. Formulate best management practices to eliminate *streptococci* from equine compost.

Original project objectives that were not met:

Determine the effect of different compost C:N ratios on the elimination of streptococci.

No effect of C:N ratio was observed due to all *streptococci* being eliminated by 24 hours. However, moisture appeared to be a key factor in allowing microflora to eliminate *streptococci*. When the compost material dried out *streptococci* were able to survive. Insufficient moisture in compost may create conditions suitable for streptococcal growth.

Methods used to evaluate outcomes:

Participants of the extension field day will be asked to participate in a survey at the end of the event. This survey will assess whether the information they learned was relevant and useful to their everyday work.

Integration of research and extension activities:

An extension field day at Highmoor Farm, "On-Farm Composting to Manage Animal Diseases and Mortalities" is scheduled for October 7, 2015. This program is intended for horse owners, small farm owners, and anyone interested in learning about compost as a sustainable method for animal disposal. Participants will also learn about current research at the University of Maine relevant to composting and disease control on small farms.

External funding both sought and received:

- Remediation of antibiotics and antibiotic resistant bacteria in compost used on small farms. Proposal #2015-07853, Funds requested 149,619.07 – not funded

Educational material, publications, and programs:

Updates are planed that will incorporate the information learned from this research to University of Maine published factsheets on S. *equi.*

Research publications, abstracts, and presentations:

- Poulin A, Mitchell SD, Myer A, Harvey K, Hutchinson MS, Causey R. (2015). A sustainable approach to the control of pathogens: The fate for *streptococci* in equine compost. European Scientific Journal*, 2015; *11*(10) 390-400.

MAC140:   Incidence of Endophyte Infected Forage in Maine Livestock Forage Sources

Principal investigator(s):   Donna R. Coffin, Rick Kersbergen, Anne Lichtenwalner, Don Hoenig

Background

In other parts of the United States feeding endophyte infected forages to pregnant beef cattle has been documented to cause lameness, poor gains and abortion.[1] Monitoring the level of infection in pastures allows livestock owners to avoid the fields with the highest infection level. Managing fields with known endophyte levels by mowing prior to seedhead development may reduce toxicity. Conserved forage has also been identified as a problem for susceptible animals.

In Maine, ergot toxicity has been documented in horses, and ergot has been reported in wild rice. However, distribution of endophytes in pastures and harvested Maine forages is unknown. The economic impact on beef producers may be high, since pregnancy rates of beef cows on endophyte infected pastures can be reduced by 34%.[2] In addition, beef cattle consuming endophyte-infected forages in the last third of their pregnancy are more susceptible to prolonged gestation, calving difficulty, thickened placentae, decrease of milk production and rebreeding difficulties. Calves may be born weak or dead.

Mowing prior to seed head development, or reseeding with endophyte free tall fescue varieties may help alleviate endophyte problems, however few livestock farms have the opportunity to reseed their pastures or hayfields. Knowing the prevalence of endophyte infected pastures in Maine may help farmers make more informed decisions.

Objective:

In Maine, we do not know if endophyte fungus has infected the tall fescue or perennial ryegrass to a level that pregnant cows, heifers and other livestock are at risk. Also, some farms are considering importing hay from South and Midwest states where widespread plantings of the endophyte infected tall fescue were planted.[2] Is this practice cause for concern for among livestock farms? Are native conserved forages fed to beef and other livestock infected with endophyte fungus? How much endophyte infected forage that is fed to livestock in Maine?

This project will try to assess the level of endophyte infected forages present in pasture and hays fed to beef cows, heifers and other livestock in Maine. It will also inform producers about detection of endophytes, avoiding contaminated feeds, and management for reduction of impact.

Research and/or extension education activities:

This project will work with ten livestock farms to test their forage (hay &/or pasture) for the presence and level of endophyte infected tall fescue &/or ryegrass. Staff (Student labor and Faculty) will travel to selected farms to take samples of hay &/or pasture and samples will be sent to a university lab for endophyte testing. Currently, Rick Kersbergen manages a perennial ryegrass cultivar trial at the Rogers Farm as part of a different research project. This trial contains numberous varieties and commercial mixes of perennial ryegrass.

Herd health histories from participating farms, with special attention to productivity of females, vaccination protocols, mineral feeding, feeding practices, loss of offspring, birthing difficulties within the past two years will be recorded.

A survey of Maine veterinarians to detect frequency of endophyte-associated cases will be disseminated. All findings will be reported at Extension and regional agricultural meetings.

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[1] Freeman, D.; P. Pratt; R. Woods Jr.; Fescue Toxicity and Horses, Oklahoma Cooperative Extension Service Currant Report, CR – 3917; July 2002.

[2] Ball, D.; G. Lacefield; & C. Hoveland; The Fescue Endophyte Story, http://www.caf.wvu.edu~forage/fescue_endophyte/story.htm; accessed 10/24/06

Expected outcomes and method for sharing outcomes:

The project's farmers will learn about endophyte content of their own forages and can make informed decisions about management. The project team will prepare evidence-based recommendations for Maine livestock owners who grow or purchase feeds from Maine. This information will be shared through Extension educational meetings, newsletters and newspaper columns in livestock related publications. An update will be submitted to the Maine Veterinary Medical newsletter, and results will be reported at a Maine Large Animal Veterinary group meeting. Also, information will be posted on the University of Maine Cooperative Extension Livestock Web site.

Final Report

Nontechnical summary:

Endophyte-infected forages consumed by beef cattle and other livestock can cause lameness, poor gains, reduced milk production and abortion. The economic impact on Maine's $142 Million livestock industry could be high. Cattle fed endophyte-infected forages could experience 34% reduction in pregnancy rates, 50% reduction in average daily gains or 50% reduction in milk production.

Sheep being moved to new paddock with mixed grasses including fescue. Photo: Coffin

In Maine the level of endophyte-infected tall fescue or perennial ryegrass is unknown. This project will assess the level of endophyte-infected forages present in pasture and hay fed to livestock in Maine.

Staff will take samples of forage (hay and/or pasture) from ten livestock farms that will be sent to a university lab for testing for the presence and level of endophyte-infection. Herd health histories will also be recorded. A perennial ryegrass cultivar trial at the UMaine Rogers Farm will also have samples submitted for testing. A survey of Maine veterinarians to detect the frequency of endophyte-associated cases will be disseminated.

As a result of this project, the project team will prepare evidence-based recommendations for Maine livestock owners to reduce impacts from endophyte-infected forage. This information will be shared through Extension educational meetings, print and electronic media.

Original project objectives that were met and significant findings:

1. Survey of Maine Veterinarians to detect frequency of endophyte-associated cases
   a. An electronic survey was sent to 83 licensed veterinarians through the state veterinarian. No reports of adverse effects from endophyte were received from the two veterinarians who responded. Follow-up discussions revealed little evidence from long-established Maine livestock vets of suspect cases.
   b. Beef, sheep and goat producers were invited to participate in the project if they had adverse effects from fescue or perennial ryegrass forages. Only two producers (cattle and sheep) requested that their pasture grasses be tested. Herd/flock health histories were noted. Both follow veterinarian recommended vaccination and treatment of any disease symptoms. Both farms kept animals on good nutrient levels that resulted in good body condition.
2. Assess the level of Endophyte-infected forages present in pastures and hays.
   a. Findings-
      i. 14 samples of pasture fescue or perennial ryegrass were tested and 13 found to have no detectable concentration of alkaloids (toxins in endophyte-infected forages that cause adverse effects.) One had

levels of 75 to 430 ppb (parts per billion) of the alkaloids and a total alkaloid level of 1,160 ppb but no detectable level of ergovaline, the primary alkaloid of interest. Livestock performance is considered to be affected when concentrations of ergovaline exceed 100 to 200 ppb.

ii. Of the 14 samples submitted for testing, 6 samples from livestock pastures were gathered from fields of mixed grasses from two farms. Only fescue samples were submitted for testing. In general, livestock are not grazed on 100% fescue pastures so the risk of adverse effects are less.

Original project objectives that were not met:

1. Findings will be reported at Extension and regional agricultural meetings.

   a. Since observed adverse effects from endophyte-infected forages were not observed by Maine veterinarians, the levels of ergovaline measured in fescue and perennial ryegrass samples were well below the threshold where symptoms could be observed, and Maine pastures and hayfields are not typically composed of 100% fescue or perennial ryegrass, the risk to Maine livestock from endophyte-infected forages is low. Due to this assessment of low risk, no reports have yet been given at livestock meetings, but will be given during winter 2015-6.

   b. Staff changes in the PI's office and the absence of urgency as a livestock production risk resulted in this objective not being met during the funding period.

Methods used to evaluate outcomes:

Lack of observed reports of adverse effects of endophyte-infected forages from Maine veterinarians, low concentrations of the toxin that causes adverse effects in forage samples and typical forage mix of grasses all suggest that risk from endophyte-infected forages to Maine livestock is low. However, the small sample size of farms tested limits conclusions from the study.

Integration of research and extension activities:

Extension clientele initially expressed concern about the risk of endophyte-infected forages affecting the productivity of their animals when 6% of bred heifers were found to be nonpregnant after being on pasture that contained fescue. This observational research project was developed to document the incidence of endophyte-infected forages in Maine by testing grass samples and surveying veterinarians about cases they have encountered. Producers were also made aware of the project through newsletters and emails and were given an option to test their forage for endophyte toxins.

External funding both sought and received:

To date, the only external support consisted of "in-kind" support from farmers allowing us to come onto their farm to take samples or collecting and sending samples to us for analysis.

Educational material, publications, and programs:

None to date, but a report will be given at the upcoming Maine Agricultural Expo during January, 2016.

Research publications, abstracts, and presentations:

None to date.

MAC141:   Evaluation of Garlic Clove/Bulb Distribution Relationship

Principal investigator(s): David Fuller, Steven B. Johnson

Background

Garlic has been cultivated for thousands of years and is widely used in many cultures. Hardneck garlic varieties (*Allium sativum* var. *ophioscorodon*), the predominant variety of garlic grown in Maine, produces a sterile flower stalk, technically a scape. Hardneck garlic is propagated from cloves, since garlic rarely produces true seed. There are over 70 commercial garlic growers in Maine representing all 16 counties (http://www.mofga.org/). Most garlic producers in Maine are market gardeners producing many crops. However, the contribution to farm income from garlic is disproportionally large when compared to the area planted. Garlic is an important portion of their farm income. There are several garlic growers in Maine that have over 80 percent of their farm income from garlic. Preliminary research done by the investigators has suggested that planting large garlic cloves will yield correspondingly large bulbs and greater yields and small cloves yield small bulbs and smaller harvests. It is common practice for farmers to sell their larger stock due to buyer preference, but this practice leaves the famer with small stock to plant and probable reduced yields and profits. However, the relationship between the size of a garlic clove to the size of the bulb harvested has not been firmly established in Maine.

Research and/or extension education activities:

Experiments will be conducted at five sites: the Maine Agricultural Experiment Station in Presque Isle (Aroostook Farm), and on garlic farms in Chesterville, Jackson, St. Albans and Deer Isle. All of the sites will be growing the same four varieties of hardneck garlic: Chesnok Red, German Extra Hardy, Music and Romanian Red. Each of the four garlic varieties will have two sets of 50-clove populations that have been individually weighed. The two sets are composed of visually similar small and large cloves. Plots were established in October of 2013. The harvested bulbs will be dried and then individually weighed in the late summer of 2014. The two populations from each plot will then be analyzed to establish a distribution curve to determine a relationship between the size of clove planted to the size of the bulb harvested. Plots will be grown under appropriate conditions for the crop. The plot arrangement will be randomized such that a T-test can be performed on resultant data. Data from the trial will be statistically analyzed and summarized for publication.

Expected outcomes and method for sharing outcomes:

This information will help garlic growers make sound decisions when deciding what size garlic stock to plant, helping in turn to make garlic a more profitable crop. Possible outcomes from this project include: • Yield data from the planting of large and small garlic cloves to make recommendations for garlic growers. • Suggestion for a possible pricing structure, based on the size of garlic bulbs. There is no pricing scheme currently for garlic and large and small bulbs are usually sold for the same price. • Change in garlic farmer practices. If larger cloves yield larger bulbs, then farmers will be more likely to save some of the larger stock to perpetuate larger bulbs and higher yields • Higher farm profits from higher garlic yields • Results of this study will be presented to growers through presentations at meetings, which may include: the Maine Vegetable and Small Fruit Growers Annual Meeting; the New England Vegetable & Berry Growers Winter Meeting; MOFGA annual meeting; Master Gardener meetings, as well as local producer meetings and colleagues within Cooperative Extension. The results will also be available to Master Gardeners and the 268 members of the Maine Garlic Project. There may be opportunities to have the data in other media forms such as print and YouTube educational video.

Final Report

Original project objectives that were met and significant findings:

- The relationship between the size of a planted garlic clove and the resulting harvested bulb was established under Maine conditions.
- A change in farmer practices has begun with initial establishment of planting stock recommendations.

- Efforts on a pricing structure for garlic seed based on bulb size has begun which should lead to increased farm profits.

Original project objectives that were not met:

N/A

Methods used to evaluate outcomes:

Experiments were conducted at two locations to determine the relationship between the size of a planted garlic clove and the resulting harvested bulb. Trial locations were the UMaine Agricultural Experiment Station in Presque Isle (Aroostook Farm) and on a private garlic farms in Chesterville, Jackson, St. Albans and Deer Isle All sites grew the same four varieties of hardneck garlic: Chesnok Red, German Extra Hardy, Music and Romanian Red. Plots were established in October of 2013 and were grown under conditions appropriate for the crop.

Figure 1 has data from two sites presented. Data from all varieties are included owing to unforeseen complications at the grower level. The high R^2 indicates a strong relationship between planted clove weight and resultant harvested bulb weight. Said differently, planting bigger cloves results in bigger harvested bulbs. The slopes of the lines are not the same from the different sites as would be expected as the growing practices differed from site to site. The strong relationship is encouraging and is information garlic growers have been seeking. This information will help lead to improved recommendations to garlic growers and will assist them in making sound decisions when deciding what size garlic stock to plant. This in turn, helps to make garlic a more profitable crop.

Figure 1. Planted clove to harvested bulb relationship.
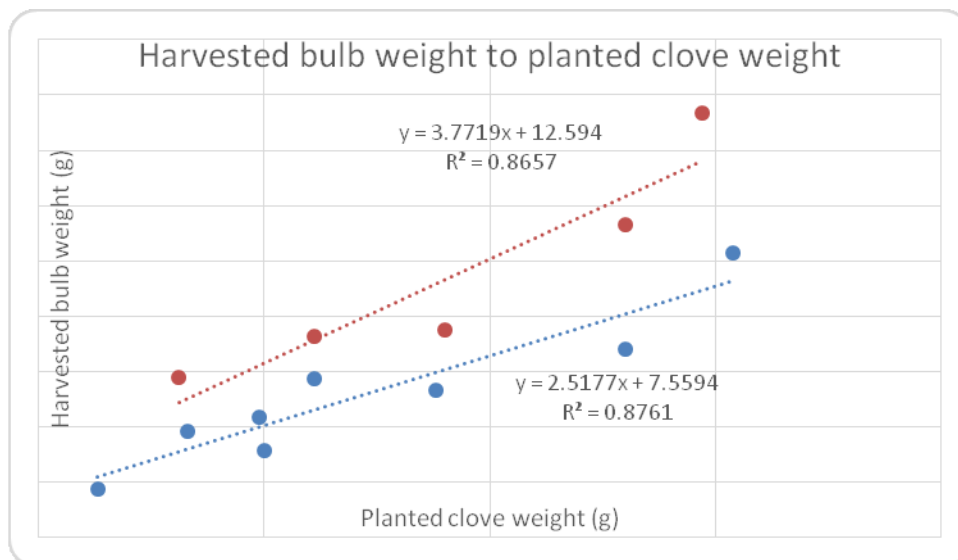
Integration of research and extension activities:

Results of this study were presented to growers and colleagues through presentations. Future outreach plans include presentation of the information at upcoming meetings such as: the Maine Vegetable and Small Fruit Growers Annual Meeting; the New England Vegetable & Berry Growers Winter Meeting. The information will also be distributed to Master Gardeners and directly delivered to garlic growers in Maine. The information is also expected to be available on-line and possibly in video media format.

External funding both sought and received:

Initial discussions have been initiated but no external funding requests have been submitted to date.

Educational material, publications, and programs:

Extension publications are in the early stage of development

Research publications, abstracts, and presentations:

- Johnson, S. B. 2015. Garlic and Root Crops Storage: What Works and What Doesn't. Presented at the Empire State Producers Expo on January 20, 2015 in Syracuse, NY
- Fuller, D. 2014. Growing Healthy Garlic. Presented in Livermore Falls, ME on October 2, 2014.)

MAC142:   Exploratory Study to Identify Business Interest in Local Foods in the Somerset County Region

Principal investigator(s):   Kathryn Hopkins, Debra Kantor

Background

Local food is not only in demand at farmers' markets, through community supported agriculture (CSA), and other direct-to-consumer channels; it is also in demand in schools, hospitals, restaurants—any place where food is purchased.

Consumers increasingly value and seek out local foods for a variety of reasons with upwards of 85% citing the presence of local food as an important factor in their purchasing decision.[3] These trends are mirrored in the foodservice industry. Chefs surveyed by the National Restaurant Association have identified locally grown foods as one of the top 20 food trends each year since 2009.[4]

To meet this demand, local food supply systems need to identify the food preferences of these markets, and a way to meet these demands in an effective and cost efficient manner. By identifying local businesses interested in expanding their local food sales, growers would be able to expand and diversify their crops, and have more stability, provide additional local jobs, and enhance economic growth.

Maine Food Strategy Project Research Summary Report[5] made several recommendations that inform Maine's Food Strategy development process including: identifying key products/markets for production expansion, encouraging consumers to shop at locally owned businesses and restaurants, and encouraging food hub development where businesses are complimentary to one another for example: outputs of one business are inputs of another, strong co-marketing/co-distribution potential. This report cited a Washington study that estimated spending $100 at a local restaurant results in $79 in additional income to local businesses, while spending the same $100 at a chain restaurant results in just $31 being re-spent locally. While the many strengths of Maine's agriculture were noted in the report, it currently produces only 20% of the food needs of its citizens.

In 2010, Lambke and Scholz began a Skowhegan Food Hub Development Project[6] by purchasing the historic Somerset County Jail, located in downtown Skowhegan and established Maine Grains, the anchor tenant at the Somerset Grist Mill, a hub of food and farm businesses for the region. The sixteen-year-old Skowhegan Farmer's Market relocated to the Mill's parking lot. The Pickup, a multi-farm CSA that purchases food from twenty farms for weekly deliveries of "shares" to individuals and institutions occupies the first floor space at the mill. A commercial kitchen, is used by both the Pickup Café, and the Pickup CSA to make value-added products. It is used by the Maine Grain Alliance for educational purposes, and also provides meals via the Pickup Café that feature local foods.

In meeting organized by the Somerset Economic Development Corporation in October 2013, the need to increase the penetration of local foods and to increase sales to high disposable income customers were specifically identified as key needs of the developing food hub.

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[3] Central Minnesota Food Hub Feasibility Study: 2012. http://ngfn.org/resources/ngfn-database/knowledge/Central_Minnesota_Food_Hub_Feasibility_Study.pdf. accessed Feb. 12, 2014.
[4] National Restaurant Association Food Trends 2014. http://www.restaurant.org/News-Research/Research/What-s-Hot . accessed Feb. 12, 2014.
[5] Maine Food Strategy Project Research Summary Report. http://mainefoodplan.files.wordpress.com/2013/02/mfs-phs-1-research-report-with-dedication.pdf . Accessed Feb. 10, 2014.
[6] Lambke, Amber. "The Renaissance of a Food-Based Economy in Skowhegan." Maine Policy Review 20.1 (2011): 238-238. http://digitalcommons.library.umaine.edu/mpr/vol20/issI/39.

Research and/or extension education activities:

In this exploratory study, the co-principal investigators will conduct buyer outreach research in the Somerset County region that will:

1. Develop an interview instrument that will explore local food consumption and expenditures and factors that influence local food purchase decisions including:
   o desired use of local foods, types of produce buyers demand, in what quantities, at what time of year, other requirements including: quality of product, food safety certification requirements, price, client preference, and consistency. Specific questions about value-added and processed foods will also be included.
2. Identify potential buyers (restaurants, hospitals, schools, tourist destinations) for purchasing local foods.
3. Select representative sample of local businesses to insure reflect the Somerset County region.
4. Conduct 10 to12 in-person audiotaped interviews.
5. Transcribe and code interviews.
6. Share data with University of Maine Extension business and economic specialist and food specialists for input in developing summary and recommendations.
7. Final written report and resource directory developed.

Expected outcomes and method for sharing outcomes:

A written report of our methodology and findings will be provided to the growers and businesses connected to the Skowhegan Food Hub and the Somerset County Economic Development organization. It will also be shared with Cooperative Extension personnel interested in pursuing local food development strategies. The report will include:

- A summary of interview responses that includes general observations.
- A directory of those interviewed and their potential as local buyers. The directory will include information about individual businesses, key contacts, and their interest in local food/products.
- A business viability summary that includes a financial model for expanding local food markets.

Final Report

Nontechnical summary:

Local food is not only in demand at farmers' markets, through community-supported agriculture (CSA), and other direct-to-consumer channels; it is also in demand in schools, hospitals, restaurants or any place where food is purchased. In a meeting organized by the Somerset Economic Development Corporation in October 2013, the need to increase the penetration of local foods and to increase sales to high disposable income customers were specifically identified as key needs of the developing local food hub. In this exploratory study, buyer outreach research in the Somerset County region explored local food consumption and expenditures and factors that influenced local food purchase decisions including: desired use of local foods, types of produce and quantities demanded by buyers, and preferred time of year. Other requirements including: quality of product, food safety certification

Photo–Local Food Month Display at Hannaford's Supermarket in Skowhegan. August 2015

requirements, price, client preference, and consistency were investigated as well. A written report of our findings will be provided to the growers and businesses connected to the Skowhegan Food Hub and the Somerset County Economic Development organization.

Original project objectives that were met and significant findings:

In this exploratory study, the co-principal investigators conducted buyer outreach research in the Somerset County region and:

1. Developed an interview instrument used to explore local food consumption, expenditures and factors that influenced local food purchase decisions including:
   o desired use of local foods, types of produce buyers demand, quantities and seasons needed, quality of product, food safety certification requirements, price, client preference, and consistency.
2. Identified potential buyers (restaurants, schools, tourist destinations) for purchase of local foods.
3. Selected representative sample of local businesses to insure reflect the Somerset County region.
4. Conducted 10 in-person interviews.
5. Produced a final written report and resource directory.

Original project objectives that were not met:

Project objectives not met - A business viability summary that includes a financial model for expanding local food markets. Insufficient financial data from interviewees made it unrealistic to create a financial model for decision-making. The choice to purchase local foods was based less on finances and more on the ethics of the business owner.

Methods used to evaluate outcomes:

The local farmers expressed the need to know if there was an unmet need for their food products. They needed to know if there was capacity for increased production before committing to increasing production. By conducting a qualitative survey of food businesses likely to desire increased locally produced food in the Skowhegan Food Hub's region, we gained an understanding of the potential unmet capacity for locally produced food. Grouped responses showed a desire for more locally produced food within certain specifications and will be shared with local farmers in the fall of 2015 for their future farm planning. Specific individual requests for access to more local food will be shared in a directory given to local farmers.

Integration of research and extension activities:

The research project goal was to develop a set of criteria that would inform local farmers about the unmet market for local foods. An additional goal was to share the beliefs and attitudes of local food entrepreneurs toward local food purchases. The research project clarified what food products were needed. The quality, quantity, and processing specifications and required certifications were also documented. The attitudes and beliefs about local foods both positive and negative as well as the desired local foods were shared with farmers markets and food hub vendors and with the leaders of the Sustainable Food Research Collaborative from the University of Maine working with local food and a food hub in the Bangor area. This information allows farms to plan for new markets currently not being served.

Photo – Skowhegan Farmers Market and Pick Up CSA advertising sign

External funding both sought and received:

None at this time. A follow-up study on consumer preference for local food is in development.

Educational material, publications, and programs:

A presentation is planned for the Farmers Market Annual Meeting in Skowhegan in January 2016. A presentation is planned for the Board of Directors and staff of the Pick Up CSA http://thepickupcsa.com/. A poster presentation is planned for the National Association of County Agriculture Agents Annual Meeting Professional Improvement Conference.

MAC143:   Preliminary Soil Test Calibration for High Tunnel Production

Principal investigator(s):   Bruce Hoskins, Mark Hutton, Becky Sideman

Background

Routine soil fertility testing programs, as they exist, are calibrated within each state or region to determine the critical test level for each major nutrient. Critical test levels are those above which there is no statistically significant response to an additional increment of application. The typical response parameter is yield and/or quality. Once these critical test levels have been established, recommendations for additional nutrient amendment can be calculated in proportion to nutrient deficit relative to the critical level. All current soil testing calibration is based on field production of vegetables, fruit, and forage crops and have been refined over several decades to be a very useful production management tool.

Thanks to a generous cost sharing program through USDA high tunnel production is rapidly gaining popularity, with new and established growers adding capacity at a rapid rate (USDA). The Maine Soil Testing Service lab has added, in conjunction with UVM, two enhanced testing packages to address specific soil fertility concerns with high tunnel systems. One testing system uses the routine field soil test plus a check on nutrient salt buildup and monitoring for nitrate carryover. The second system, used for older continuously covered and/or aggressively amended tunnels, uses the saturated media extract (SME) to monitor all essential nutrients and total salts at the water soluble level. Both systems directly address issues of nutrient salt buildup and nitrate carryover that are unique to high tunnel production (Hoskins). Both testing systems have their adherents, though the SME method is somewhat more controversial. Enhanced field soil test systems similar to Maine's have also been adopted in NH, MA, and PA.

After several years of high tunnel soil testing and grower feedback, patterns of nutrient deficiency have become apparent. Potassium deficiency is the most common problem encountered, especially in houses used for tomato production. Nitrogen use efficiency in a high tunnel is very good, with very little nitrate lost to leaching or denitrification, both common problems in open field production. Despite this efficiency, nitrogen deficiency is also relatively common in high tunnel soils.

In a 2011 preliminary study in Vermont, documented tomato yield in an established tunnel was over 3000 lb of fruit on every 1000 sq ft of growing area (Grubinger). This is equivalent to 65 tons fruit yield on a per acre basis. Other studies have documented as much as 75 tons/acre equivalent yield (Becky Sideman, personal communication). According to the New England Vegetable Growers Guide, a very good yield for field-grown tomatoes is 30 tons/acre. Since current fertility guidelines are calibrated to field-grown crops, it is obvious that current recommendation guidelines for tomatoes and other crops grown in tunnels are not adequate to support these greatly enhanced yields. Current recommendation systems are undoubtedly contributing to the chronic deficiencies in soil fertility in high tunnels.

A variable rate tomato yield response experiment is proposed, using the same experimental design in multiple high tunnels in NH and ME. Two tunnels at UNH and two tunnels at Highmoor Farm will be chosen with relatively low fertility status. A factorial combination of five rates of potassium and 2 rates of nitrogen will be applied with replication in each house. The response parameters will be total and marketable yield; final plant fresh and dry weight. Pre-plant and in-season soil tests will be run, using both common field soil tests used in the Northeast, to document reserve nutrient levels. The SME test will be run at each sampling to document short-term nutrient availability during the season.

- Objective 1: Determine the critical soil test levels for potassium and nitrogen corresponding to maximum tomato fruit yield and quality, using modified Morgan, Mehlich 3, and SME testing systems.
- Objective 2: Characterize the yield response relationships to both potassium and nitrogen, for the purpose of developing a recommendation model for these nutrients.
- Objective 3: Validate and/or modify existing interpretation/recommendations guidelines of Witwer & Honma for the SME testing system, as currently used.

Research and/or extension education activities:

Each high tunnel will consist of 6 beds running the length of the house. Beds near the outside commonly show less growth and yield due to temperature and light differences relative to the center of the house. Only the middle 4 beds will be used for the experiment. Each bed will act as one replicate, to be divided equally among all treatments. Six rates of potassium (including 0) X 2 rates of nitrogen ("average" and 2X) will be combined factorially for 12 individual treatments applied to each bed in a randomized complete block design. Treatments will be from organic nutrient sources: natural potassium sulfate as the K source and a combination of soybean and feather meal as the N source.

Each replicate bed will get one composite soil sample prior to applying treatments (4 soil samples per house, 16 total from 4 houses). Soil will be sampled from each plot within one replicate bed in each house at 4 points during the growing season: at bloom, first ripe fruit, 4th cluster ripe, and end of season for a total of 48 samples from 4 houses at each sampling date. To avoid intra-lab variability, all samples will be analyzed at the MAFES Analytical Lab. Total and marketable yields will be taken continuously throughout the season.

All soil samples will be run through the Modified Morgan (MM) and Mehlich-3 (M3) field soil tests by standard methodology, to determine available reserve levels of P, K, Mg, Ca, B, Cu, Fe, Mn, Na, S, and Zn. Nitrate and ammonium nitrogen will be determined colorimetrically in a potassium chloride extract of each soil. A saturated media extraction (SME) using deionized water will be run to determine total soluble salts by electrical conductivity and water-soluble levels of the same nutrients measured in the field soil tests.

Total and marketable yield maxima will be statistically compared to all 3 sets of soil test data to determine corresponding critical test levels for K and N. Possible fitting models include quadratic, linear-plateau, and Cate-Nelson. Recommendation systems for N and K will be determined according to the best-fit model.

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Expected outcomes and method for sharing outcomes:

Representatives from ME, VT, NH, MA, and PA have all shared in the design of this experiment and will all have access to the findings. Critical test levels and response models can be used by all to immediately modify high tunnel recommendation systems in each state. Due to the limited scope of this study, further refinements will be needed from on-going experiments in additional locations over more years. Soil test calibration must be undertaken over many site-years to adequately address variations in soils, management techniques, and growing conditions.

Results from this study will be used to leverage additional outside funding for a much more extensive regional project. USDA has placed a high priority on encouraging high tunnel growing. Regional calibration projects such as this are greatly needed to adequately monitor and manage this unique and highly productive growing system.

Final Report

Nontechnical summary:

Tomatoes were grown in high tunnels in 2014 at two location in NH (Durham & N Haverhill) and at Highmoor Farm in Monmouth ME, using the same fertility plot design: 2 rates of Nitrogen (275 or 630 Lbs/Acre) and, depending on location, 6 or 7 rates of Potassium (0 to 1000 Lbs/Acre), using organic nutrient sources. Yield and quality measurements were taken throughout the growing season. Soil and petiole sap nutrient levels were measured early in the season and again late in the season. Soil nutrient levels were very well correlated to treatment levels at all 3 locations at both sampling times. Petiole sap potassium levels were well correlated to treatment levels in late season only. There were no significant relationships between potassium or nitrogen treatment levels and tomato yield or quality at any of the 3 locations. The experiment is being repeated in 2015 at 2 of the locations using a potassium-free nitrogen source and a tomato variety which is more susceptible to deficiency symptoms. This project design was used to successfully leverage a 1-year $11,500 SARE grad student grant and a 3-year $250,000 SARE R&E grant, to continue and expand this study.

Original project objectives that were met and significant findings:

There was a highly significant correlation between K treatment levels and K soil test values for both field soil test methods (modified Morgan and Mehlich 3) for both early and late season soil samples at all three locations. The SME soil test K levels were highly correlated with K treatment levels for early season samples at all three locations and for late season samples from the North Haverhill house.

Soil test K levels for all 3 test methods declined from early to late season, demonstrating significant crop uptake and soil nutrient depletion. Soil nitrate-N levels also showed significant depletion from early to late season.

Petiole sap measurements (early and late season) for both NO3-N and K were added to the original design. Petiole sap K levels were significantly correlated with K treatment levels in 2 out of 3 houses for late season measurements, but not early season measurements. This was the only significant plant response parameter in the project's first year.

Original project objectives that were not met:

This project was designed with an emphasis on correlating tomato yield and quality (yellow shoulder) with soil test K levels. There were no significant yield responses and virtually no defects at any treatment level of N or K at any of the three sites. This was due to two factors.

All nutrient sources were non-chemical fertilizers which contain more than one nutrient. All plots received nitrogen at one of two levels, using blood meal and soy meal. Depending on location, either 6 or 7 levels of K were applied, including a nominal 0 treatment. Due to the K content of blood and especially soy meal, each K treatment received 100 lb/A more K_2O than intended. Because of this, there were no soil K levels low enough to drive yield deficits or deficiency symptom defects.

The second factor causing lack of response was the choice of tomato varieties, Rebelski and Geronimo. These are greenhouse cultivars that were chosen for their high level of tolerance to foliar pathogens. However, both of cultivars have the gene for uniform green fruit which reduces the expression of fruit color defects due to low K levels.

With no significant yield or quality response, we were unable to calibrate any of the soil test methods from the 2014 experiment. The project has been continued into 2015 in two of the original houses and plots. No additional K has been applied beyond the original 2014 treatments. Only N was applied in 2015, using a very low K content fertilizer (Nature Safe). A tomato variety known to be susceptible to yellow shoulder (Big Beef) was chosen. Early season observations have indicated a significant correlation between fruit set/yield and (2014) K treatments. K deficiency symptoms (yellow shoulder) are also very prominent in low K treatment plots. Yield and quality responses will be re-evaluated at the end of the 2015 growing season.

Methods used to evaluate outcomes:

- Economic yield and quality response to applied nitrogen and potassium.

Integration of research and extension activities:

- Highmoor Farm field day demonstrations – July 2014 and July 2015.
- Twilight meeting, Grafton County Farm, N. Haverhill NH, Sept 2014.
- Research field day at UNH Woodman Farm, Durham NH, June 2015.
- Master gardener visits to UNH Woodman Farm, Durham NH, Sept 2015.

External funding both sought and received:

1. Connor Eaton, Masters degree student at UNH, was awarded a 1-year $11,500 SARE Graduate Student grant (GNE14-077) 'Potassium Management and Soil Testing in High Tunnel Tomato Production' to continue the experiment through the 2015 growing season.
2. Our High Tunnel Tomato Team was awarded a three-year SARE R&E grant (LNE15-343) 'Improving Nutrient and Pest Management in High Tunnel Tomato Production'. The design for this project uses similar K and N fertility levels, with improved nutrient sourcing, as our MAC Grant project. Foliar testing and petiole sap testing were added to the design as additional plant response parameters. Additional collaborators, including Margaret Skinner from UVM, designed the IPM (biological control) component, which will be a house by house overlay on the fertility plots.

The overall award is $250,000, with $58,000 budgeted for Highmoor Farm and $35,000 budgeted to the MAFES Analytical lab for soil and plant tissue analysis over the three years of the project. The project includes multiple outreach components, including 2 intensive high tunnel grower workshops, grower twilight meetings, MOFGA Farmer to Farmer conference presentations, and online videos and training materials. The design, implementation, and continued refinement of the MAC Grant experiment has been invaluable in helping us obtain and implement this 3 year project.

Educational material, publications, and programs:

A poster was presented by Connor Eaton at 2015 ASHS conference "Effects of varying potassium levels on yields and petiole potassium levels for organically fertilized high tunnel tomato"

Research publications, abstracts, and presentations:

The publication and presentation component of this project will be rolled into the 3 year SARE project, with its extensive outreach pathways.

MAC144:   Maine Agricultural Weather Center Evaluation of Interpolated Weather Data for use in Agricultural Management Decisions

Principal investigator(s):   Glen Koehler, Seanna Annis

Background

Maine blueberry, apple and cranberry growers face management decisions that are directly dependent on recent and forecast weather. There are quantitaive weather-based models that interpret weather data into actionable management advisories to help growers inegreate weather into the decisions. Two examples of this methodology are the UMaine Cooperative Extension blueberry mummy berry forecast http://umaine.edu /blueberries/blog/2012/05/07/mummy-berry-forecast-monday-may-7-2012/ and the UMExt Apple Orchard Radar system http://pronewengland.org/AllModels/DecisionModels.htm

Research and/or extension education activities:

For lowbush blueberry growers, weather data is being used to provide timely information to growers on the potential occurrence of important diseases and pests. This information is used by growers to more accurately time their scouting and pesticide applications to obtain the most effective control of diseases and pests with the fewest pesticide applications. Currently 10 weather stations that are connected to the internet through cellular modems are used to gather data on various weather parameter from 10 locations around Maine. This data is then used to provide information on possible infection periods for mummy berry disease which is the widest spread and potentially most devastating disease of blueberries in Maine. This summer, Annis will be providing information on possible risk of Botrytis blossom blight infection to growers. Annis is also providing the weather data to Dr. Frank Drummond, Entomologist at the University of Maine, to assess models predicting the emergence of two important pests of wild blueberries, the Spotted Wing Drosophila and the Blueberry Maggot fly.

Weather data gathered from the weather stations over the growing season will be correlated to data collected on severity and incidence of various leaf spot diseases in lowbush blueberry to determine if certain weather conditions (humidity, rain fall, temperature, and drought) affect the incidence or severity of particular diseases,

The weather stations have performed well in the past two years, but there is a concern on the cost of deploying and retrieving the stations, maintenance, replacement costs, and yearly cost of internet access and database management. The weather stations can only be deployed after the ground has thawed but also firmed up enough that a vehicle can get into the fields, which is not until mid to late April, and they need to be taken down before October to allow growers to prune their fields. Annis would like to compare the gathered real weather data to virtual weather data provided by detailed weather prediction models to see if the virtual data will be a viable, lower cost alternative to the physical weather stations. Some weather stations will be deployed to the same location as we will gather physical weather data and the weather parameter data and model predictions from that data will be compared. The information on disease infection will be ground-truthed by measuring disease at pertinent times during the growing season.

The monthly operational cost of maintaining cell phone data transfer alone costs more than what it cost to purchase complete weather data service from SkyBit Incorporatred. If using interpolated weather data from SkyBit results in the same decision advice relative to need and timing for fungicide application to prevent mummby berry disease in lowbush blueberry, then there is no reason to incur the much greater expense of operating our own hardware weather station network. In addition, the SkyBit data includes ten days of hourly forecast values. This would greatly augment the mummy berry forecast system by enabling it to use not just retrospective weather observations but also forecast values to help growers plan ahead. This function is currently done "manually" by the system operator reviewing forecast and intergrating it into a disease forecast on a weekly basis. With the SkyBit data, the forecast mode can be operated twice daily automatically.

The Apple Orchard Radar system already has a system developed to automatically capture SkyBit Inc. weather data, ingest it into models, and autogenerate model output as web pages. (See Orchard Radar website link above for examples).

Two or three project websites are close enough to both apple orchard and lowbush blueberry sites to allow their use for a parallel on-site vs. SkyBit comparison for apple pest and horticultural model performance.

In addition to the model performance functions of the project, we will also conduct end user feedback surveys to better understand which weather models are most useful to growers, how they like to have the information presented (e.g. charts vs tables vs. text summary).

The existing Apple Orchard Radar system needs to move to a new server because the existing machine is no longer going to be available. We have enlisted the support of Tanner Kelleter, Network Administrator to provide the expertise to make that transition at no charge to the project.

We have enlisted the expertise of Dr. Seanna Annis to perform the lowbush blueberry model comparisons at no charge to the project. We have enlisted the expertise of Glen Koehler to operate the data management system and to perform the apple model comparisons at no charge to the project.

All we are asking from Maine Agricultural Center is support to leverage these assets by providing us with funds to access the weather data needed, and small amounts to operate the website and to communicate the results to our respective professional colleagues.

Project results will be available by September 2015. All results will be communicate the Maine agricultural community through the final project report, at the Maine Agricultural Trade Show, through Extension outreach via newsletters and grower education meetings.

Finally, establishing and validating this approach provides foundation for developing more model applications to support the dairy (e.g. Silage corn phenology and hay drying models), vegetables (planting and harvest dates, irrigation scheduling, and pest phenology models), and numerous other practical applications. With a founcatoin established, we will use that to seek much larger grants to operate and extend the sytem into a fully functions Maine Agricultural Weather Center. This has the potential to serve as front line of defense for climate change adaptation and Maine agricultural sustainability.

Expected outcomes and method for sharing outcomes:

1. A quantitative evaluation of weather-based model output using weather input from on-site hardware stations and from SkyBit Inc.
2. A system to automate weather data ingestion, model calculation, and model output as web pages for lowbush mummy berry disease. (The apple model output system is already constructed.)
3. Feedback from apple and blueberry growers on how they interact with the information, how to make it more useful for their real time management decisions.
4. Migration of the existing Apple Orchard Radar system to a new web server host by Univerity of Maine Network Services.
5. Communication of project results to Maine Agricutlural Center, Maine blueberry and apple growers, and the respective research and Extension communities for blueberry and apple through newletters and presentations at grower education and research/Extension meetings.

Final Report

Nontechnical summary:

In recent years, Maine blueberry growers have benefitted greatly from weather-based estimates that inform critically important pest management decisions. However, the high cost to operate on-site weather stations to provide input for these estimates may not be sustainable.

Since 1997, the Maine apple industry has used farm-specific weather values based on interpolation between measurements at surrounding professionally-managed weather stations. Data are delivered electronically as hourly observation and 10-day forecasts. These data are translated into publicly available web page grower advisories by an automated computer system. Informal evaluation indicates that estimates for apple bloom date and other easily observable events have been very good. But we need to verify that estimates based on interpolated weather match those made with on-site station observations.

Background Information for this page
Return to Blueberry links for Deblois ME

Weather data for Deblois ME. Forecast values begin October 1, 2014

Monilinia Wetting Period Count	Wetting Period START Time	Wetting Period END Time	Avg Temp. (C) during wetting period	Wetting Period Duration (hours)	Minimum hours required for Monilinia Infection at this Temperature	Monilinia Infection Status
13	Apr 15, Tue. 4 AM	Apr 16, Wed 10AM	8.3	30	7.8	YES, Infection possible
14	Apr 22, Tue. 4 AM	12 PM	7.8	8	8.1	NO
15	Apr 22, Tue. 7 PM	Apr 25, Fri 8AM	5.9	61	9.2	YES, Infection possible
16	Apr 26, Sat. 4 AM	Apr 27, Sun 7PM	5.6	39	9.5	YES, Infection possible
17	Apr 28, Mon. 5 AM	1 PM	6.1	8	9.1	NO
18	Apr 30, Wed. 8 PM	May 2, Fri 11AM	6.8	39	8.6	YES, Infection possible
19	May 3, Sat. 2 AM	11 AM	7.2	9	8.4	YES, Infection possible
20	May 3, Sat. 8 PM	10 PM	9.7	2	7.1	NO
21	May 4, Sun. 2 AM	May 5, Mon 11AM	8.0	33	7.9	YES, Infection possible
22	May 6, Tue. 2 PM	May 7, Wed 6AM	8.5	16	7.7	YES, Infection possible
23	May 9, Fri. 11 PM	May 11, Sun 8AM	11.6	33	6.4	YES, Infection possible
24	May 14, Wed. 5 AM	2 PM	8.8	9	7.5	YES, Infection possible
25	May 15, Thu. 12 AM	5 PM	11.5	17	6.4	YES, Infection possible
26	May 15, Thu. 9 PM	May 16, Fri 11AM	13.5	14	5.7	YES, Infection possible
27	May 16, Fri. 8 PM	May 22, Thu 11AM	12.1	135	6.2	YES, Infection possible
28	May 23, Fri. 12 AM	3 PM	11.2	15	6.5	YES, Infection possible
29	May 23, Fri. 11 PM	May 24, Sat 12PM	10.0	13	7.0	YES, Infection possible
30	May 25, Sun. 1 AM	12 PM	9.9	11	7.0	YES, Infection possible
31	May 25, Sun. 11 PM	May 26, Mon 3PM	12.9	16	5.9	YES, Infection possible
32	May 26, Mon. 6 PM	May 27, Tue 11AM	12.2	17	6.2	YES, Infection possible
33	May 27, Tue. 2 PM	May 28, Wed 3PM	8.6	25	7.7	YES, Infection possible
34	May 28, Wed. 11 PM	May 29, Thu 10AM	5.5	11	9.5	YES, Infection possible
35	May 30, Fri. 5 AM	8 AM	8.1	3	7.9	NO

This project will compare model estimates for the most important blueberry and apple diseases using the two data sources at 10 Maine sites. This project will help determine if costs to acquire blueberry weather data can be substantially reduced, and test the accuracy of the apple orchard advisory system already in use.

Documenting the efficacy of the interpolated weather data would set the stage for developing an economically sustainable and much-needed Maine Agricultural Weather Support Network.

Original project objectives that were met and significant findings:

1. A model to predict infections of lowbush blueberry by the fungus *Botrytis cinerea* was built to run on the Maine Ag-Radar system that had previously only run apple insect, disease, and horticultural models.
2. A model to predict infections of lowbush blueberry by the fungus *Monilinia vaccinii-corymbosi* ("Mummyberry") was built to run on the Maine Ag-Radar system.
3. A model to predict the percentage of lowbush blueberry bloom was built to run on the Maine Ag-Radar system.
4. Existing apple disease models were made more robust to handle a prolonged drought in spring 2014. 5. Weather data from 10 Maine lowbush blueberry locations were obtained from a network of Spectrum weather stations.
5. Interpolated weather data for those same 10 Maine lowbush blueberry locations were obtained from a commercial vendor. The cost for the data service was much less than the cost of operating a network of

hardware weather stations. The interpolated data were ingested twice a day, from April through September 2014 and 2015. The data included observations plus forecast values for the next 10 days.

6. Model output was updated three times a day and published as web pages. The lowbush blueberry model output consisted of tables showing both all wetting periods, a second table showing only those wetting periods that met the criteria to be considered an infection period requiring protection by fungicide application, and a third table showing lowbush blueberry bloom percentage by date.

7. A website was built to make the lowbush blueberry model outputs for each of the 10 sites accessible. Because the lowbush blueberry models were still under evaluation and not yet validated, the web pages were protected by password only entry, with the password limited to project staff. 10 websites were created to display the apple model outputs. These models were made visible to users without password protection based on previous experience that the model forecasts provide useful guidance for spray decisions.

8. An analytical spreadsheet was developed to allow direct comparisons of the disease model outputs, from the same disease model, using the two different weather data input sources. These data were directly compared in tables and charts. Ground station data and interpolated data were loaded into the workbook.

## Original project objectives that were not met:

1. Comparisons showed radical differences between temperature measured at the height of the lowbush blueberry canopy and the interpolated weather data which are defined for the standard 2-meter height for temperature measurements.

2. Differences between leaf wetness values were less severe that the temperature differences, but also showed a pattern of difference attributed to the difference in the targeted canopy height for the in-place weather stations vs. the targeted canopy height used for the interpolated weather data.

3. Because of these differences we did not complete the comparative analysis. Instead we began communicating with the commercial supplier of the weather data to clarify exactly how their data values were specified, and how we might resolve the differences in microhabitat between their data and the unique characteristics of the lowbush blueberry crop canopy.

4. The weather vendor agreed that with access to the ground station data and matching interpolated data from the same sites from both 2014 and 2015, he would be able to create a correction algorithm that would allow the interpolated data specified for the standard 2-meter height for temperature measurement to the canopy height of the lowbush blueberry plants. Similarly, he would create a second algorithm to convert the leaf wetness values to the lowbush blueberry canopy. He agreed to do this work without charging us as a development project to expand the portfolio of data types provided by his company, and would do the work in December of 2015.

5. We already have the data from all of the 2014 ground station machines and the paired interpolated data for the same locations. We are currently obtaining data from all of the 2015 ground station machines, will package it with the paired interpolated data and provide these data to the weather vendor so that he can complete that work creating the conversion formulae.

6. Once we have the conversion formulae, they will be incorporated into the software used to generate the model output for the interpolated weather data. Those model outputs will be compared to the output from models fed with data from the Spectrum ground stations.

7. Similarity between the two sets of model output for the lowbush blueberry and apple diseases at each site will be measured by assigning a value to each day during the relevant date range for infection potential (varies for each disease). Each day will be scored for each disease as a member of either:
    a. + for infection by both models,
    b. - for infection by both models,
    c. + for infection by the ground station data and – for the interpolated data,
    d. – for infection by the ground station data and + for the interpolated data.

8. Similarity for the lowbush blueberry and apple first and peak bloom date estimates will be measured as mean difference and absolute difference of the two estimates for each event at each site from the two alternative model outputs. Where available, ground observations will be used to measure model accuracy in the same manner.

Methods used to evaluate outcomes:

1. Upon presentation of the results at grower, meetings, surveys will be used to collect responses from lowbush blueberry and apple farmers.

Integration of research and extension activities:

We operated a system to automatically acquire thrice daily updates of weather data, store them in a database, run analysis to interpret the impact of the weather on infection risk for two key lowbush blueberry diseases, blueberry bloom, three key apple diseases and apple bloom. Though the number of orchards near the lowbush blueberry sites is small, the apple output served as real-time guidance for apple growers with orchard nears the study sites in 2014 and 2015, and will do so again in 2016.

Daily primary scab infection potential as % of yearly total
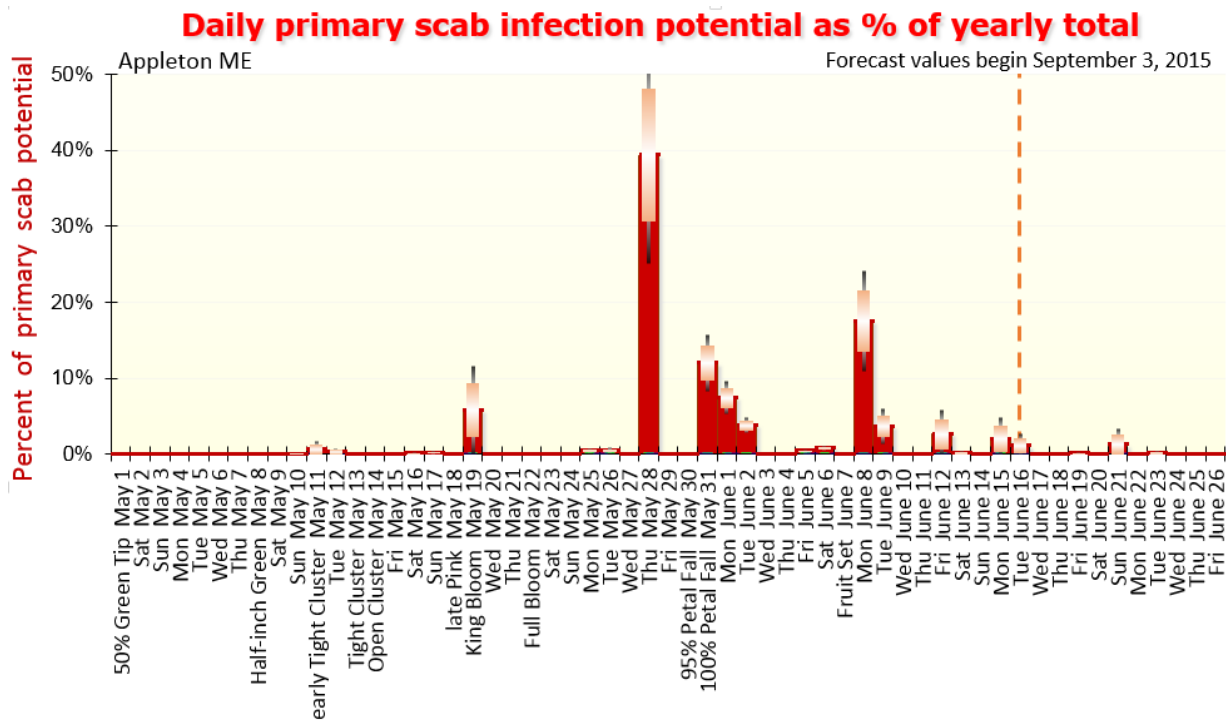
Top of wide red bar shows best estimate of primary scab ascospore infection potential.
White-to-light red shaded narrow boxes overlaid on red bars show range expected to contain the true value most of the time (68% confidence interval). Vertical black bars show wider range of 90% confidence interval.
Vertical green line = today's date. Vertical dotted green line = end of forecast range.
Vertical orange dotted line = date of final siginificant primary scab infection period (estimated 99+% cumulative spore release, and 95% chance of at least 95% cumulative spore release).
Infection potential rating is for scab ascospores (i.e. primary scab) only. Uncontrolled infections can produce secondary scab spores that magnify infection risk beyond what is indicated by this chart 9-17 days after the infection period (number of days depends on temperatures after infection).

External funding both sought and received:

-   Funding was acquired from a USDA – Maine Department of Agriculture Block research grant to pay for operating the network of ground stations and to pay for interpolated weather data and operational costs to run the blueberry and apple disease models in 2015.
-   Funding was acquired from the USDA Northeastern Climate Hub to operate the Ag-Radar system through the winter of 2015-2016 to allow development and publication of dormancy chilling and spring frost models for apples. That work is not directly related to the objectives of the MAC project, but extends the capabilities of the system being evaluated through the MAC project into new areas.
-   Funding has been acquired from the USDA – Maine Department of Agriculture Block research grant to pay for operating the network of ground stations and to pay for interpolated weather data and operational costs to

run the blueberry and apple disease models in 2016. The third year will serve as additional validation of model performance.

Educational material, publications, and programs:

Pending completion of analysis, and validation after year 3 (2016) results will be presented at grower meetings and in written reports.

Research publications, abstracts, and presentations:

Pending completion of analysis, and validation after year 3 (2016) results will be presented at grower meetings and in written reports.