North Carolina Department and Agriculture & Consumer Services

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2013 Specialty Crop Block Grant Program

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FINAL Report

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PROJECT TITLE: Regional Seed Development Initiative (RSDI)

FINAL REPORT

PROJECT SUMMARY

The lack of seed varieties available to organic producers is an obstacle to the growth and ongoing success of organic farmers in North Carolina. NC farmers have identified solutions necessary to strengthen the organic seed industry including, 1) information about varieties best suited for organic production, 2) information on how to conduct on-farm variety trials, on-farm plant breeding, and seed saving, and 3) opportunities for organic farmers to work with professional breeders to develop regionally adapted organic cultivars through trialing networks and on-farm plant breeding efforts. The Regional Seed Development Initiative addressed those issues by, 1) providing workshops on how to conduct on-farm variety trials, on-farm plant breeding, and seed saving techniques, 2) assisting farmers in conducting on-farm broccoli variety trials, 3) sharing information about organic seed availability, varieties best suited regionally for organic production and varietal field trial data through a published, annual report, and 4) collaborating with North Carolina State University (NCSU) to expand on-farm broccoli variety trials to additional regions/locations across the state.

The Organic Seed Alliance conducted an organic farmer seed survey in 2009 -2010. They received 117 completed surveys from North Carolina producers that provides baseline data indicating the importance and timeliness of this project.

The following facts about the current state of organic seed in the Southeast were identified by the survey:
• 78% said there is a lack of varieties available in organic seed.
• 77% said there is a lack of varieties suited to organic agriculture.
• 76% said there is a lack of information about which varieties are best for organic.
• 60% said there is a lack of information on how to produce seed.

North Carolina producers identified the following needs as critical for strengthening the organic seed system in the Southeast.
• A need to conduct research concerning varieties that perform best on organic farms in the Southeast (97%).
• A need to teach Southeast farmers how to produce seed for on-farm use (91%).
• A need to breed new and improved varieties for organic farms in the Southeast (87%).
• A need to teach Southeast farmers how to breed varieties for their own use (80%).

Additional challenges identified in the State of Organic Seed report published by the Organic Seed Alliance include:
• Better mechanisms for sharing information related to organic seed availability (or lack thereof), identification of varieties associated with specific and/or desirable traits, and varietal field trial data.
• Lack of opportunities for organic farmers to work with professional breeders to speed the development of regionally adapted organic cultivars through trialing networks and on-farm plant breeding efforts.

This project did not build on previously funded SCBGP projects.

PROJECT APPROACH

Workshop Series:

CFSA's Organic Production Coordinator (OPC) organized a 3-location workshop series across NC titled: *On-Farm Variety Trials, Seed Production and Plant Breeding: A Primer for NC Organic Vegetable Growers*. These workshops took place at the Center for Environmental Farming Systems (Goldsboro), NCA&T State University (Greensboro) and the Mountain Horticultural Crops Research and Extension Center (Mills River) on March 17th, 18th and 20th respectively. Content for each workshop was developed and provided by Dr. John Navazio, Organic Seed Alliance (OSA) Senior Scientist and Washington SU Extension Organic Seed Specialist. These four-hour workshops focused on the following specialty crop topics:

- Principles of designing, conducting and evaluating on-farm variety trials using basic scientific methods.
- Choosing appropriate varieties, integrating trials into current production, and crop traits to consider for trial assessment.
- The basics of reproductive biology, harvest timing and seed cleaning using vegetable crop examples that are best suited for seed production in the varied climates of NC.
- Classical breeding methods that can be used to enhance varietal adaptation to farm-specific cultural practices and environmental/market challenges.

Attendees were surveyed to determine to what extent they would make use of the information provided during the workshop. Forty-six percent said they would conduct on-farm variety trials (32% maybe, 15% already doing it), 49% would save seed for their own use (8% maybe, 35% already doing this), 7% said they would consider producing seed commercially (54% maybe, 4% already doing this), 30% said they would begin working towards conducting on-farm breeding projects for a vegetable or fruit crop? (48% maybe, 11% already doing this).

Fall Organic Broccoli Variety Trial:

CFSA worked with five farmers to conduct replicated, randomized organic broccoli variety trials in the fall. Conducting these trials in the Piedmont and Eastern regions of the state expanded on the data from trials currently being conducted by NC Cooperative Extension in Western NC. Staff at the Mountain Horticultural Crops Research and Extension Center provided trial protocol and evaluation methodology. Farms that were involved include: Cottle Organics (Rose Hill), Uncle Henry's Organics (Rose Hill), Down 2 Earth Farm (Rougemont), Redbud Farm (Burlington) and the Small Farm Unit at the Center for Environmental Farming Systems (Goldsboro). The goal of these trials was to assist in determining which varieties perform best for their operation.

Six varieties were included in the trial: Packman, Green Magic, Arcadia, Belstar, Iron Man and Imperial. These were selected for a number of reasons. They are the most commonly used varieties by NC organic farmers according to results of our NC Organic Broccoli Survey. Most of these varieties are already being grown by one or more of our participating farmers. Each variety has promising reviews for fall production. Packman serves as the industry standard or "check" variety in the trial. The trial was divided into 4 blocks (A-D), each with a plot of the selected varieties (1-6) arranged in a random sequence.

The OPC traveled to each of the farms in early July to deliver necessary supplies and seeds in time for starting transplants. The trial design and layout, along with the importance of minimizing confounding variables in both the greenhouse and field was discussed in detail. Due to greenhouse issues that led to transplant loss, two of the trial farms were not able to participate. Growers at the remaining sites evaluated each plot in the trial as the plants reached harvestable maturity. All plots were rated on a

number of qualitative traits (dome, head firmness, bead uniformity, etc.) and quantitative data (date of maturity, crown yield, crown diameter, sideshoot yield) was also collected.

Data from each of the participating farms were collected by the OPC and statistical analyzed with the assistance of Mountain Research Station staff. A detailed description of the trial, including its findings, was included in the *Southeast Organic Seed and Variety Trial Report*. Results of the trials were presented at a workshop at CFSA's Organic Commodities and Livestock Conference. Trial results will also be shared in CFSA's March eNews.

Southeast Organic Seed and Variety Trial Report:

CFSA published the *Southeast Organic Seed and Variety Trial Report* on our website on February 25th. This resource is split into three sections. The first and second sections focus on replicated variety trials and observational trials conducted in 2014. These sections required gathering significant information from the region's farmers, extension staff, university researchers and other collaborators. The OPC sent a call for submissions out on all of the applicable regional listservs and reached out by phone and email to any known variety trial coordinators. The third section provides a listing of regional and national sources for certified organic seed and was compiled by the OCP.

Getting enough material to produce a valuable publication required repeated encouragement of all likely contributors to the report. The OPC formatted all submitted material and organized it into an approachable and user friendly resource for other growers. CFSA's Communication Coordinator provided final editing before publishing the report on our website. The report will be promoted to specialty crop growers through our March 2015 eNews.

All project activities conducted with SCBGP funds were completed with the sole intent of enhancing the competitiveness of specialty crops and their producers. A very small portion of the SE Organic Variety Trial Report included seed sources, variety trial synopses and data for organic agronomic crops (soybean, wheat, rice). However, any staff time dedicated to collecting information specific to commodities relied on funds from other sources.

Project partners include the Center for Environmental Farming Systems (Goldsboro), NCA&T State University (Greensboro) and the Mountain Horticultural Crops Research and Extension Center (Mills River) who helped promote and host the workshop series. Dr. John Navazio and the Organic Seed Alliance (OSA) provided workshop content.

Staff from the NCSU Jeanine Davis research group provided significant information in developing the broccoli variety trial protocol. The participant farmers that agreed to take on the responsibilities of conducting the evaluating the trial were critical to this project's success. As mentioned previously, they included Cottle Organics (Rose Hill), Uncle Henry's Organics (Rose Hill), Down 2 Earth Farm (Rougemont), Redbud Farm (Burlington) and the Small Farm Unit at the Center for Environmental Farming Systems (Goldsboro).

Contributors to the SE Organic Seed and Variety Trial Report included: NC A&T, NCSU, Clemson University, University of Tennessee, University of Georgia, Twin Oaks Seed Farm/Garden, Southern Exposure Seed Exchange, Box Turtle Bakery and Root Down Farm.

GOALS AND OUTCOMES ACHIEVED

The OPC coordinated logistics for three workshops on conducting on-farm variety trials, plant breeding, and seed saving techniques. He worked with OSA senior scientist Dr. John Navazio to develop and deliver technical information on conducting on-farm variety trials and on-farm plant breeding programs at each of the workshops.

To inform the broccoli variety trial portion of this project, the OPC surveyed growers to identify the broccoli varieties currently being used. Five farmers from the Eastern and Piedmont regions of the state were identified to participate in on-farm broccoli variety trials. On-farm research design and data collection protocol for the broccoli trial was developed with the assistance of the NCSU Jeanine Davis research group out of Mills River. Five farmers were assisted in conducting on-farm broccoli variety trials, with three of them able to reach project completion.

The SE Organic Seed and Variety Trial Report was successfully completed and published on CFSA's website.

The only outcome measure that is long term for this project is the number of views of the published SE Organic Variety Trial Report on CFSA's website. Since the finalized report was published in late February, we do not have significant data to report, but will be monitoring viewing data throughout 2015 as we prepare for developing the next annual publication.

Our initial goal of reaching 100 growers at the workshops was not achieved with attendance numbers totaling 76, with 25, 21 and 30 for each of the respective workshops in Goldsboro, Greensboro and Mills River. Attendees were surveyed at the completion of the workshops to determine to what extent they intended to make use of the information provided during the program. Survey responses were encouraging as it seems that the growers in attendance were supportive of CFSA coordinating future trainings on the subjects covered. The following provides some highlights from these surveys regarding growers' intention of actually using the knowledge gained from the training. From these numbers, it can be reasonably inferred that we have met the goal of engaging fifteen growers in variety trial, seed production or plant breeding act ivies on their farms:

As a result of this program, do you intend to:

- *Conduct on-farm variety trials? (Yes: 46%, Maybe: 32%, Already doing this: 15%)*
- *Save seed for your own use? (Yes: 49%, Maybe: 8%, Already doing this: 38%)*
- *Produce seed to sell? (Yes: 7%, Maybe: 54%, Already doing this: 4%)*
- *Begin working towards an on-farm breeding project for a vegetable or fruit crop? (Yes: 30%, Maybe: 48%, Already doing this: 11%)*

We successfully engaged and assisted five farms to conduct the broccoli variety trial, which exceeds our goal of working with at least four. Challenges on two of the farms resulted in only three of the farms being able to see the trial through to final evaluation.

The SE Organic Variety Trial report was completed, published and promoted. It provides specialty crop producer with fourteen project entries summarizing trial results and recommended varieties for regional organic production. Additionally, it includes an extensive listing of organic seed and planting stock sources to help in meeting the National Organic Program requirements.

We reached 76 attendees, with 25, 21 and 30 for each of the respective workshops in Goldsboro, Greensboro and Mills River. At least fifteen participating growers claim that they will conduct on- farm

variety trials, engage in plant-breeding efforts, and/or begin seed saving projects based on our survey results, listed in the prompt above.

We successfully engaged and assisted five farms to conduct the broccoli variety trial, three of which were able to see the trial through to final evaluation.

The SE Organic Variety Trial report was completed, published and promoted. There have been 116 unique views of the report since it was published on CFSA's website on February 25, 2015.

BENEFICIARIES

The workshop series presented at three locations across NC provided the opportunity to specialty crop producers for in-depth learning on the topics of conducting on-farm variety trials, seed production and on-farm plant breeding programs. A total of 76 attendees took advantage of this opportunity, the majority of which were small-scale, direct market fruit and vegetable producers. Survey results, above, indicate that a majority of participants intend to implement some of the concepts they learned during the workshops.

The Fall Organic Broccoli Variety Trial directly benefited the five farmers that were assisted in planning and implementing randomized, replicated trials on their farms. Based on previous USDA Agricultural Census Data and trends of increased production, we predict that over 200 farms are raising broccoli in NC. The results derived from the three farms that were able to continue the trial to final evaluation will benefit these producers. Results of the trial were presented to 38 attendees at CFSA's Organic Commodities and Livestock Conference in February 2015. A report of the study is available on the CFSA website as part of the SE Organic Variety Trial Report.

The SE Organic Variety Trial Report was completed and made publically available for no charge to users on the CFSA website. While number of views of the report will be forthcoming since it was only published in late February 2015, the 3,740 vegetable farms in NC will benefit from the completion of this portion of the project.

LESSONS LEARNED

Much of the information sought by these prompt overlap, so a comprehensive summary that includes all components follows:

Workshop Series:

Inclement weather was an issue the week of the workshop series, with icy road conditions that deterred some of our registered and potential attendees. The workshop at NCA&T had to be delayed 3 hours and began at noon instead of 9 AM. Several growers that had registered ahead of time called to say that couldn't make it. Our initial goal of reaching 30+ growers at each workshop was not achieved with attendance numbers at 25, 21 and 30 for each of the respective workshops. Obviously we cannot control the weather. Our goal was to time these day-long workshops during the portion of the year when it is most feasible for specialty crop producers to take time away from the farm. This is inherently risky given it coincides with the unpredictable weather conditions of winter/early spring and should be considered by future project leaders. Significant effort was made to promote the workshops through regional allies, but this list can always be expanded and refined to better reach our target audience.

Several survey respondents, when asked how the training could be further improved, suggested that the material warranted more time to get sufficient depth (perhaps even a multi-day training). Others stated that an in-field component should have been included. Both the time allotted for the workshops and providing an outdoor demonstration were discussed at length by Dr. Navazio and the OPC. Seasonal conditions were an obstacle for field demonstration as there was very little growing in the field at each location. In the future, we will be certain to be firm in our suggestion that workshops be of sufficient length to fully cover the desired breadth of information. Longer workshop offerings must be balanced with the effect it may have on attendance. An all-day or multi- day workshop may exclude a number of growers who cannot make such a time commitment.

Fall Organic Broccoli Variety Trial:

All of the farmers that we worked with on the fall broccoli variety trial raise their own transplants on-farm with the exception of Cottle Organics. Uncle Henry's Organics, located only a few miles from Cottle, agreed to raise enough transplants for both locations. Growers were given enough seed for each of the six varieties in the trial so that any incidental loss could be accommodated without compromising the strength of the trial. Two full sets of seeds were provided, each with enough to allow a 20% transplant loss to still meet the 40 plant per plot minimum suggested for Brassicas. Growers were instructed to grow the second set of seeds as a backup in the event of total transplant failure of the first.

Uncle Henry's Organics experienced significant issues in transplant production for the trial. The first set of transplants was lost entirely. Owen Rouse, operator of Uncle Henry's Organics, stated that germination was successful but that the plants wilted and perished afterwards. He suspects that it was perhaps due to disease in the plastic trays, although he stated they were sterilized appropriately before use. The second set of transplants suffered from similar symptoms, with only about half of them surviving. This only left enough transplants to conduct a full trial at Uncle Henry's Organics and left Cottle Organics without any to plant, in essence forcing Cottle out of the trial. This is an unfortunate turn of events that could have been corrected if the issue was communicated soon after it occurred. Stipend funds that had initially been allocated for Cottle Organics' participation will be transferred to CEFS to help cover some of the production and labor costs that the projected required.

Southeast Organic Seed and Variety Trial Report:

Potential contributors to the report were concerned about the tentative publishing date in December 2014. Larger trials that were conducted at multiple sites and those involving crops harvested in late fall required a good deal of data consolidation and analysis after the New Year. Therefore, while we spent down the grant funds by Dec. 31, 2014, we had to wait until late February, 2015 to publish and promote the report, after we have received all the data from 2014 variety trials. In future publications of this annual report, we will set more realistic goals for completion given the need for final data analysis that is often completed late in the year or in the early months of the following year.

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PROJECT TITLE: Down East Connect Online Farmers Market

FINAL REPORT

PROJECT SUMMARY

Columbus County has a rich history in agriculture as part of the tobacco belt in southeastern North Carolina. With the collapse of tobacco production, small farmers have struggled to regain economic footing in specialty crop production. Down East Connect aims to help small farmers transition to specialty crop production by connecting rural agricultural communities and hungry customers in local urban centers through an online marketplace using the Farmer's Fresh Market software developed by Timothy Will and modeled after the Foothills Connect project.

The importance of this program cannot be understated. Much of the diversity and variety of local foods available to local markets is grown by small farmers. For small farmers even a slight delay is too costly. As our market grows, so does our responsibility to offer flexibility to small farmers who face a barrage of challenges getting their locally grown specialty crops to market. For example, one participating small farmer who previously relied on farm-stand sales from her home in Tabor City, North Carolina, discovered road improvement crews made access from the highway impossible, just as crops began to be harvested for peak summer harvest. This seasonal slight helped her farm reach sales record-highs on the Farmer"s Fresh Market in 2014! Another small farmer found local markets in contact with Down East Connect receptive to buying his locally-grown corn by the bushel, after a national contract fell through at the last minute. While other farmer's market models take a larger percentage of profits from small farmers, the Farmer's Fresh Market has stayed loyal to the 80/20 split of the original program, to the delight of local small farmers. These small improvements and dedication to project development are vital to returning local agriculture in southeastern North Carolina to its previous height. Without programs like Down East Connect to provide this reliable service that adds value to specialty crops grown-locally by small farmers, local small farmers would have little recourse to compensate potentially devastating losses.

Previously funded in 2012 and 2013 by the SCBGP, the non-profit's mission to increase value and availability of specialty crops grown locally in southeastern NC has continued to attract new specialty crop farmers to the market. By providing a low-barrier-to-entry marketplace, Down East Connect has attracted more than 60 beginning small farmers to the organization who are encouraged to grow more specialty crops because of the program's ease of use, potential for growth and dynamic ability to reach buyers in both underserved and gourmet markets. Having access to local food year-round has helped inform an inquisitive urban base about nutrition and market local products to local businesses that support local non-profit initiatives.

PROJECT APPROACH

Down East Connect used grant funds to provide marketing and delivery services to specialty crop producers on small local farms. Grant funds were also used to support regular outreach and tabling events that increased awareness in urban markets and quarterly farmer meetings that kept producers updated on program timelines. Seasonal farmer interest meetings were held to attract potential new farmers and a satisfaction survey was conducted in fall of2014 to assess the program's strengths and weaknesses.

Down East Connect ensured grant funds were used solely to enhance the competitiveness of specialty crops by marketing content around the value of specialty crops and consistently supporting specialty crop producers. The program's appeal to consumers is based solely on the delivery of a competitive of specialty crop-product that is harvested and delivered the same day; Preserving the quality and competitiveness of locally-grown specialty produce and encouraging patronage of local farms. The availability of other products is complementary to the variety and value of locally-grown specialty crop.

The program is overseen by the Executive Director, founder Joshua Heinberg who continues to develop the program to close gaps between local farmers and retail markets. The board of directors meet quarterly to discuss the program and provide community partnerships. The Extension Agent, Howard Wallace meets weekly with the project manager and participating farmers to provide services to local farmers. The project manager is involved in the daily operation of Down East Connect and provides marketing and delivery services.

GOALS AND OUTCOMES ACHIEVED

Our Expected Measurable Outcomes for 2014/2015:

1. Increase buyer membership (consumers registered on the virtual farmers' market web site) from 500+ to 1000.

In order to meet this goal, Down East Connect has initiated new buyer's clubs at 4 Wilmington locations, held 13 outreach events in surrounding areas including Farmer Meet and Greets, informational tables at local food events, a farmer dinner and a customer focus group.

<u>As of December 2014, the project has a buyer membership of 1,278.</u>

2. Increase the number of farmers actively selling specialty crops from 21 to 50.

Project has advertised for farmers through the Cooperative Extension Service in Columbus County and held 2 farmer interest meetings for new specialty crop farmers. We also increased our presence at local farmer's markets to attract new specialty crop farmers to our program.

<u>As of December 2014, the project has 41 local small farmers selling specialty crops through the website with some regularity</u>.

3. Reach total sales goal of $230,000 by end of 2015.

Project sought to reach sales goal by bolstering membership and increasing the volume and variety of specialty crops sold on the market. Sales from specialty crops amounted to 70% of total sales. Down East Connect sold a total of $30,269.09 in 2014.

<u>Our total sales to date at the end of December 2013 reached $149,128.00.</u>

BENEFICIARIES

Down East Connect has 61 total farmers registered on the website. Of those participating farmers, 41 of those farmers are specialty crop producers who use the website to promote and distribute specialty crops to a large online customer base. In 2014, small local specialty crop

producers earned $23,685.67 through the program run by Down East Connect. This marks a significant amount of revenue generated and entering the economically distressed rural areas from neighboring metropolitan areas.

The program also unexpectedly benefited local small businesses with collaborative promotions they initiated and the distribution of superior products. Local small businesses have seen a rise in sales on delivery days, thanks to the shared patronage of our customer base. Other beneficiaries include local customers who are attracted to the program's ease of use and nutritional benefits of fresh deliveries.

The potential of this program to promote and distribute local specialty crops is enormous. Local customers are demanding sustainably-grown local food in eateries around Wilmington, NC and our program is attempting to meet those demands by providing a worthwhile service and increasing awareness of local specialty crop farmers.

LESSONS LEARNED

In 2014, Down East Connect welcomed a new project manager with a background in farming and experience in marketing after the previous project manager accepted a position in Wake County. Down East Connect also attained non-profit 501 c4 status in 2014. The goals set for 2014 were ambitious and predicated on the attainment of a refrigerated delivery vehicle, provided by grant funds. Our board secured a biofuels partnership that will lower the cost of transportation and increase sustainability, while keeping fresh food refrigerated. We expect growth as a result of updating our delivery vehicle. As of December 2014, the organization is expecting the refrigerated delivery vehicle by February, 2015.

The response from outreach events was incredible. Our community shows great enthusiasm for this program and its ability to provide income for home-grown specialty crops. The local specialty crop growing community has spread beyond rural farms and into urban backyards- making our organization dynamically attractive to urban and rural growers. Much of the enthusiasm spread through promotions by Down East Connect has encouraged many of our seasoned local food customers to grow their own specialty crops- decreasing sales from the website and increasing product variety and quantity sold through the website. The organization welcomes this transformation and hopes to grow our customer base into other urban markets in order to provide substantial opportunity for all growers of specialty crops.

Growth has been encouraging but unsteady. Although Down East Connect's sales are down from previous years, the program has organized behind its successful delivery service and is updating equipment to run a more flexible delivery schedule that will attract and retain more customers with added convenience. Our role in the community is concrete as evidenced by the success of our press releases that were followed by immediate spurs in sales. The organization partnered with other food-hubs and CSA models to offer "add-on" products from our website to offer more variety in local foods. A cooperative "Eat Local strawberry" advertising campaign resulted in increased media awareness during peak strawberry harvests and insight into local shopper's priorities. Similar seasonal campaigns were not as successful and the organization credits the popularity of sweet summer fruit to the increase in sales. The organization intends to capitalize on these lessons by applying greater efforts to advertisements during local fruit harvests, a flexible delivery schedule that reflects optimal harvests, and expanding local customer base to other urban centers in order to sell locally- grown specialty crops to other urban markets so that sales of specialty crops by local small farmers will increase.

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PROJECT TITLE: Developing a High Tunnel Vegetable Calendar

FINAL REPORT

PROJECT SUMMARY

High tunnels are unheated, plastic-covered structures that provide an intermediate level of environmental protection and control compared to open field conditions. North Carolina small farmers have been rapidly adopting high tunnels for season extension of vegetable crops. It had been demonstrated in the Midwest that a single layer polyplastic film on a high tunnel can provide one hardiness zone of protection. However, high tunnel microclimate characters in plant hardiness zone 7&8 of North Carolina had not been investigated. Most North Carolina farmers have limited knowledge of which vegetables can be grown profitably in high tunnels as well as the appropriate time to grow them. This project was established to develop a high tunnel planting calendar for vegetable crops in the north central (Greensboro, zone 7) and southeast regions (Goldsboro, zone 8) of North Carolina; and to characterize environmental factors such as temperature, humidity and solar radiation in high tunnels. Representative cold tender and hardy vegetable species were planted sequentially in high tunnels. Results from this project would provide a general guideline for (organic) vegetable production in high tunnels that will enhance the competitiveness of North Carolina specialty crops and local food production. Growers will increase income by growing high tunnel vegetables at the optimum time to reach maximum yield and market potentials.

PROJECT APPROACH

Research:

1. Two 30’x96’ high tunnels were constructed in Greensboro and Goldsboro. A total of four high tunnels were used in this research project.

2. Cold season green mixes (Ovation Greens Mix, Encore Lettuce Mix and Spinach Mix); transplanted lettuce (Nancy, Rhazes and Spretnak), bok choi (Win Win and Shiro), and Spinach (Flamingo and Emperor) were planted in spring and fall of 2014 and 2015 with three planting dates each season.

3. Transplanted warm season vegetables English cucumber (Socrates and Tyria), tomato (Oregon Spring, Defiant, Big Beef and Rabelski), and bell pepper (Olympus and Sweet Sunrise) were planted in 2014 and 2015 with three planting dates.

4. Microclimate factors of air temperature/humidity, soil moisture/temperature, solar radiation and photosynthetically active radiation, leaf wetness in/outside high tunnels were measured every thirty minutes for two years (2014 & 2015).

5. Data of yield (cull and marketable), produce quality, pest incidence, plant phenology, and vigor were collected for statistical analyses.

6. One graduate student was hired to do a research thesis.

7. Labor and material costs were recorded for economic analyses.

Outreach:

1. Two field days featuring this project were conducted at each research location. Over 200 hundred participants (extension educators and other agricultural professionals) received training through the field days. Survey indicated a knowledge gain of over 90% (pre-and post-event) from the participants. The

majority of participants indicated the future adoption of learned knowledge and skills in their production or training programs.

2. Project at the Greensboro site was used to offer the 2014 Fall Faculty and Staff Institute training for NC A&T Cooperative Extension field agents. The site also received over 60 farmers who were led by their county extension agent and came to learn what the project could offer. This one-on-one training was welcomed by the participating farmers.

3. This project was a big component of the 2014 Small Farm Field Day, which is the annual event from the Cooperative Extension Program at NC A&T State University.

4. Results from project were presented at the 2015 American Society for Horticultural Sciences Conference (one oral, two poster presentations) in New Orleans; the 2015 SE Vegetable and Fruit Expo (three presentations), and the 2016 Southern Region American Society for Horticultural Sciences Conference (one oral and one poster presentations) in San Antonio.

5. PI offered a state-wide extension training on high tunnel microclimate and planting calendar at the State Extension Conference (December 2015. Raleigh)

6. Eight presentations relevant to this research projects have been delivered to grower based conferences or workshops organized by extension agents throughout North Carolina.

Results: please refer to the attached PDF file. It contains results that have been drawn from the data that have been examined.

Partnership: Partners at the Center for Environmental Farming System (the horticulture technician, small farm unit manager and apprentices) have worked closely with this project at the Goldsboro site. This partnership is essential to the success of the project.

GOALS AND OUTCOMES ACHIEVED

All goals and outcomes have been accomplished as planned. Additionally, we conducted an extra season in fall 2015. This set of data would provide a replication of season extension of both vegetable types in the fall. Data from this season are still been processed. The following table is a comparison of planned activities and accomplished activities, which reflecting the goals and outcomes set up for this project. The attached PDF file contains all major findings from this project.

The project has yielded five published abstracts in HortScience. Six manuscripts have been developing and will be submitted to HortScience or HortTechnology for publication by the end of 2016. Four extension fact sheets on high tunnel and high tunnel specialty crops production are under internal reviews.

PROJECT ACTIVITY (planned)	Progress	Proposed DATES	
		Start	End
Hiring a graduate student and a temporary worker	Finished	10/2013	12/2013
Purchase and construct one 30’ x 72’x 8’ single-bay high tunnel at NC A&T University Farm and at CEFS	Finished	10/2013	12/2013
Purchase additional data loggers and Measure environmental factors. Perform data analyses	Finished	10/2013	09/2015
Sequential planting of warm season			

vegetables: purchasing seeds, raising transplants, preparing soil, planting, managing plants, and harvesting. Year one (one season) Year two (two seasons)	Finished Finished	12/2013 09/2014	06/2014 06/2015
Sequential planting of cold season vegetables Year one Year two	Finished Finished	12/2013 10/2014	05/2014 05/2015
Field Days Year one (construction demonstration) Year one (warm/cold season vegetables) Year two (cold/warm season vegetables) Year two (warm/cold season vegetables)	All Finished	11/2013 05/2014 11/2014 05/2015	12/2013 05/2014 11/2014 05/2015
Compose a draft of High Tunnel Vegetable Calendar. Summarize environmental factors Drafting the planting calendar	Finished Finished	10/2013 10/2014	09/2015 09/2015
Measurement of project outcomes Short term: Incorporated in the above activities Long-term: beyond the funding period of this project	In progress as planned	above 10/2015	above 9/2017

BENEFICIARIES

The direct beneficiary from this project is North Carolina small farmers. With the help of the developed high tunnel vegetable calendar and the characterized microclimate in high tunnels, small farmers can make instructed decision on what and when to grow vegetables in high tunnels that would extend their growing and sale season, thus make more profits. Based on our economic analyses, a farmer grow one season of warm season vegetables in a high tunnel would have a potential net income of $16550.50 or $5.75/ft^2; and for cool season greens the number is $899.50 or $0.31/ft^2. The project was conducted in an organic setting which provides additional information for growers who want to do organic production.

For this project, over 300 NC farmers visited the research sites or participated in the field days or workshops. The direct economic impact would be over $1.6M if one third of the participants adopted the practice and conducted one season production with high tunnels.

LESSONS LEARNED

While the project was accomplished smoothly, there are a few challenges:

- Setting up the account took much longer than expected. When the contract was signed, four months had passed which made the initial purchasing and student hiring difficult.

- Funding agency's timesheet for student and temporary workers has made financial report difficult. MS student is paid monthly at our University, not hourly. Signed contracts from the PI, student, Dean and Graduate School do exist. Extra efforts had to be made in creating timesheets that are used by the funding agency.

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ADDITIONAL INFORMATION

1. A group of farmers led by Extension Agent Taylor Williams and Paige Burns visited the research site in Greensboro (November 12, 2015).

2. Students from HORT610 Season Extension (PI is the instructor) at NC A&T State University were learning harvest of cool season vegetable high tunnels. Two classes of 18 undergraduate and graduate students learned season extension from this project.

PROJECT TITLE: Greening the Green Industry

FINAL REPORT

PROJECT SUMMARY

From 2007 through 2012 the North Carolina green industry had experienced severe losses in sales due to several factors including the economic downturn in 2008 resulting in a slow- stagnant housing market and the influx of discounted nursery items from other states. The growers were discounting items to stay relatively competitive in a flooded market. This led to a decreased income for the nurseries and layoffs of many employee~ in the past few years. As large retailers continually stock non-NC grown products, the average consumer has very little knowledge of locally grown nursery and tree stock. Many consumers were unaware of the availability of the wide varieties of NC produced flowers, trees and landscaping materials.

As we moved into 2013, home sales arid buildings were slightly higher, more homeowners are restocking their yards and more people stayed at home and spent money on increasing their property values. There was no better timing for an increase in consumer awareness. It is 2016 and the tringle home sales have increased significantly with the average home on the market for 45 days. By promoting locally grown shrubs and plants and locally grown Christmas trees during these critical years a significant increase in sales had occurred. The resulting sales generated enough income to expand operations and return a portion of laid-off worker positions

The objectives of the project were:
• Increase awareness of the NC green industry including ornamental crops, landscaping materials, grass/sod and Christmas trees through a targeted marketing campaign.
• Increase sales for local growers by 10 within the next 2 years and up to 15 over the next 5 years by targeting the home builders who are expanding their sales and local buyers of ornamentals.
• Open new market channels or expand current channels for producers and landscape material producers by targeting selected out-of-state wholesale buyers and local NC buyers and consumers.
• Enhance the consumer awareness of water conservation, proper material selection and other sustainable green industry practices through education and promotions designed to encourage consumers to consult with green industry experts. The promotion of new plant introductions and current plant recognition marketing programs will play a key role.

PROJECT APPROACH

The 2014 and 2015 seasons brought a lot of marketing opportunities. Travel and show attendance was a big part of the success of this project. Attendance at the Greening and Growing Show held January in the Greensboro Coliseum introduced the NC plant industry to over 9,000 attendees from 31 states over those 2 years. The MANTS show in Baltimore, Maryland had 11,030 paid registrants of the Green Industry from 44 states and 13 additional countries in 2015. The Winter Green show in Duluth, GA had over 250 booths and over 2000 attendees. The contacts made for the industry from these shows are invaluable and increase awareness and sales throughout the state.

The project also allowed NCDA&CS to purchase promotional items for our growers. T- stakes for flower pots, signs for plants, license plates, and Jute bags were all purchased to be distributed to

growers across the state. These items directed consumers to identify NC grown products that are viable sustainable plants for their homes and gardens. These items reduced the cost to growers who would have purchased them while also creating a comprehensive and ubiquitous marketing campaign that stretched across the state. The campaign simplified into the message: "buy NC grown plants". The sales from the use of these items, compounded with the increase in home landscaping had a very positive effect on the growers.

Finally, the project used traditional promotional efforts to reinforce the message to consumers. Funding for television ads (UNC-TV Digital advertising) (Facebook, radio websites, Pandora, Google ads) further increased awareness of the availability NC grown plants for landscaping and Christmas ornamentation. The ads reached well over 3,000,000 people over the course of 2 years.

GOALS AND OUTCOMES ACHIEVED

It was the intent of this program to increase the awareness and sales of the Green Industry products including ornamental crops, landscaping materials, grass/sod and Christmas trees through a targeted marketing campaign.

The campaign increased sales for local growers by 10 over the past 2 years as reported by a focus group of industry members (Christmas tree growers, sod producers and landscaping material producers). The increase in sales was attributed to the marketing efforts of the department and the increase in demand for housing which has driven the purchases of landscaping. The increase of and up to 15% over the next 5 years through targeting home builders has not been realized at this time. However, the project is only 2 years old and has contributed greatly to the increase in demand and sales for these products.

The campaign also opened new market channels by connecting with those entities that have not purchased from them in the recent past. These markets had been closed/constrained due to limited supplies. However, as production has increased more products are available and the out of state connections made at the recent trade shows have been instrumental. One grower was quoted as saying "this is great I had never thought of him (a buyer) as a person to talk to".

Outcomes were evaluated based on farm income, employment and consumer awareness. Most of the results came from informal communications from growers and producers of NC grown plant, trees and other items.

The informal survey of green industry growers and related services determined the effectiveness of the project. Several growers have increased employment opportunities and acreage in production as a direct result of an increase in demand

BENEFICIARIES

The beneficiaries from this campaign included but is not limited to growers of Christmas trees, ornamental and woody shrubs, trees, sod landscaping and commercial/retail nurseries and related industries; an estimated 62,000 people were impacted in including growers and laborers in the Green Industry.

The expected five-year impact on the green industry and related businesses is an increase in farm

income and employment in nursery and related jobs by 30%, and an Increase in tax revenue in rural counties by 15% over the next 5 years.

LESSONS LEARNED

The lesson that was reiterated was that the housing market has on the landscaping industry. A significant proportion of this industry is dependent on the availability of housing and the demand for new residences. As the market went up during this time an increase in sales went with it. There is a direct correlation, it was not until the market started to move that the correlation was proven.

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PROJECT TITLE: Marketing Support for the North Carolina Nursery Industry

FINAL REPORT

PROJECT SUMMARY

The recent economic recession had a devastating impact on nursery and greenhouse production, North Carolina's largest crop with over $700 million in farm income. Income from nursery crops declined by over $100 million due to the economic recession combined with a flood of deeply discounted plants from other states. While sales are starting to experience some improvement, most growers are still struggling financially. Aggressive marketing support continues to be a high priority to help growers recover lost markets and increase nursery sales to wholesale buyers and consumers. This project will continue the successful marketing campaign initiated in our 2011 SCBG. We have made great progress but in order for nurseries to receive the full economic benefit, the 2011 project must be continued for two more years. In addition, it will provide new sources of nursery income by introducing new plant varieties to the marketplace.

Nursery growers have been forced to transition from a period of unsustainable growth (2000 – 2007) to a time of severe business contraction (2008 – 2011). Farm income from nursery crops is an important part of the economy across the state and replaced a significant amount of the income lost from declining tobacco production over the 10 years from 1997 - 2007. The industry is just beginning to recover and needs a sustained marketing campaign to compete with growers from other states. As demand for plants slowly begins to increase, growers will be able to regain market share and be more competitive through this marketing support.

This project will also assist N.C. growers in being more competitive by introducing new superior varieties of dogwood trees and other new plants. These new plants are being developed through a partnership between NCNLA and NC State Univ. and have the potential to provide $10 - $15million in new income for NC nurseries.

The 2011 SCBG project, "Market Recovery Initiative for the North Carolina Nursery and Greenhouse Industry," ending December 31, 2013. This marketing project has made important progress impacting awareness and demand for nursery plants over the past two years. Our consumer web site has increased 340% from 27,000 visits in 2010 to 120,000 in 2012. Our website for wholesale buyers has increased 75%, from 12,000 to 21,000 visits. NCNLA surveys indicate sales are beginning to improve with a 7% increase in 2012. However, continuing this project over the next two years with this new SCBG project will provide the maximum economic impact to growers and help return sales to pre-recession levels. It will allow NCNLA to continue to expand contacts with wholesale buyers and consumers and promote additional reasons for buying from NC nurseries including new plant introductions and professional certifications. In addition, this project will enhance NCNLA's current SCBG "Improving Nursery Employees Plant Marketing Knowledge". This project began in January 2013 and seeks to improve nursery workers professional marketing and customer service skills through the Certified Plant Professional program. Part of this new grant request will focus on promoting the benefits to consumers of shopping with green industry businesses that have professional certifications. Both projects will complement each other as they are implemented in 2014. This project has not been submitted to or funded by another Federal or State grant program.

PROJECT APPROACH

Task: Survey growers, collect NCDA&CS data from Ag. Statistics division, collect web site traffic data for 2013 to establish benchmark data.
This project has continued to focus on the marketing program planning put forth in the first year of the project. Activities have focused on marketing NC plants to consumers and wholesale buyers. This project continues the efforts conducted with the previous SCBG grant. The two grants overlapped through the first half of the 2014, so the marketing activities are now being fully funded by the current grant cycle.

Baseline Data:
Website baseline data for 2013 includes:
Consumer website: 171,000 visits
BuyNCPlants website: 16,100 visits

October 2014 – June 2015:
Collected website traffic data for BuyNCPlants.com and TarHeelGardening.com. NCDA&CS statistics for 2013 not available as of 11-24-2014.

Task: Plan consumer advertising; develop content, graphics, research media, place ads. Incorporate national "Plant Something" publicity on website
Our statewide advertising campaign included magazine ads in The NC Farm Bureau and Carolina Gardener magazines. These ads provided information to consumers to educate them about the importance of landscaping with NC plants and directed them to our consumer website, TarHeelGardening.com to locate local growers, retailers, and landscapers.

October 2014 – September 2015:
Consumer ads ran in Our State magazine and Triangle Gardener. These ads provided information to consumers to educate them about the importance of landscaping with NC plants and directed them to our consumer website, TarHeelGardening.com to locate local growers, retailers, and landscapers.

Task: Conduct social media marketing for TarHeelGardening.com
NC plants and the benefits of landscaping were promoted through our TarHeelGardening social media including our blog, Facebook, and tweeter. Blog articles were developed posted twice a month.

October 2014 – September 2015:
NC plants and the benefits of landscaping continued to be promoted through our TarHeelGardening social media including our blog, Facebook, and tweeter. Blog articles were developed posted twice a month.

Task: Plan wholesale buyer advertising, conduct trade show promotions, buyers guide distribution, Develop contact lists to target buyers. Place ads targeting wholesale buyers.
Advertising to the trade to promote NC nurseries to landscapers and retailers focused on ads in E-News for Lawn and Landscape and the Buzz. These E-News reach landscapers and retailers throughout the east coast. This is an important market for many NC nurseries that sell plants to buyers in other states.

October 2014 – September 2015:
Continued advertising to the trade to promote NC nurseries to landscapers and retailers focused on ads in E-News for American Nurseryman (Sprout), Landscape Insider, Garden Center, Lawn and Landscape and the Buzz. These E-News reach landscapers and retailers throughout the east coast. This is an important market for many NC nurseries that sell plants to buyers in other states. Ads promoted the BuyNCPlants.com website and the NCNLA Green & Growin' Show.

NCNLA conducted our annual Green & Growin trade show in Greensboro, January 8-9. This event provided an opportunity for NC nurseries to exhibit their plants and meet potential buyers and over 1000 people participated. Also, 850 Buyers Guides were distributed. We also exhibited at the South Carolina Nursery trade show

Task: Compile and print 2015 Buyers Guide.
NCNLA began collecting information from nurseries on the plants that they want to list in our annual Buyers Guide and BuyNCPlants.com website.

October 2014 – September 2015:
Collection of plant and nursery listings for the Buyers Guide was completed. The 2015 Buyers Guide was printed by the NCDA&CS in November 2014 and the BuyNCPlants.com website was updated with the new listings.

Task: Promote new dogwood and other new plant varieties to buyers and growers. Develop marketing materials for new plant varieties.
Planning continued with NCSU plant breeder, Dr. Tom Ranney to develop new patented plant varieties to give NC growers a competitive advantage over other states. Our committee met with Dr. Ranney to review new selections of dogwoods, magnolias, and redbuds that are being developed through our NCNLA research and development agreement with NCSU. We have selected 3 - 4 new hybrids to include in field trials in 2014 and 2015.

October 2014 – September 2015:
Continued with the release of the Carolina Sweetheart™ Redbud and filed an application for this trademark and patent. This plant was promoted to NC nurseries to place orders for liners to begin production in 2015. We also completed a new agreement with NCSU to extend this project for four more years. Agreement with Conard Pyle, a national marketing company, was established for supply chain management and marketing for the redbud and dogwood in production. Process established for future plant releases.

NCNLA represents solely horticulture specialty crops within North Carolina. The Specialty Crop Block Grant Funds awarded in this project were used solely to enhance the competitiveness of specialty crops within our industry.

GOALS AND OUTCOMES ACHIEVED

Goal: Increase the awareness of NC plants among wholesale buyers in NC and also out of state markets and assist them in locating nurseries to source plants.

Advertising the BuyNCPlants.com website to increase awareness for NC plants among buyers continued through E-News ads in Lawn and Landscape and the Buzz targeting landscape contractors and retail buyers. Buyers visiting the website were able to search for NC nurseries that grow the plants in demand.

October 2014 – September 2015:
Advertising the BuyNCPlants.com website and the Green & Growin' Trade Show to increase awareness for NC plants among buyers continued, targeting landscape contractors and retail buyers. Buyers visiting the website were able to search for NC nurseries that grow the plants in demand. Conducted the Green & Growin' trade show to assist nurseries in making contacts with buyers.

Goal: Increase consumer awareness of NC grown plants, new plant varieties being grown by NC nurseries, the benefits of landscaping, and assist consumers in locating sources of NC plants.

Ads were placed in Triangle Gardener and Our State magazines. The ads focused on NC Grown Plants, the TarHeelGardening.com website and the benefits of landscaping to increase awareness for among consumers.

October 2014 – September 2015:
Increased awareness through consumer ads in Triangle Gardener & Our State magazines. Blog articles also targeted consumers. These ads and social media provided information to consumers to educate them about the importance of landscaping with NC plants and directed them to our consumer website, TarHeelGardening.com to locate local growers, retailers, and landscapers

Goal: Introduce new plant varieties grown by NC nurseries to the marketplace. # of new plant varieties introduced to the marketplace:

In partnership with NC State Univ., one new redbud variety and one new dogwood variety were selected for release by NCNLA

October 2014 – September 2015:
A new Cercis was released, trademarked and patented as Carolina Sweetheart™ Redbud.

1. Measurable Outcome: Farm income
Performance measure: Nursery farm income
Benchmark data: 2013 NCDA&CS statistics data
Target: Increase sales by 2% by late 2015, and increase sales an additional 2% by late 2016. By December 2016 our target is to return sales to the $770 million level.
Progress Achieved: 2013 NCDA&CS statistics data not available as of 10-31-15.

2. Measurable Outcome: Wholesale Buyers Engaged
Performance measure: Number of buyers that visit BuyNCPlants.com and number of "Buyers Guides" distributed.
Target: Increase buyer use of this website by 5-10% in 2014 and an additional 5% in 2015 compared to the 2013 visits. Distribute 4,000 Buyers Guides each year.
Benchmark: 2013 visits: BuyNCPlants website: 16,100 visits
Progress Achieved:

October 2014 – January 2015: 10,952 visits to BuyNCPlants.com and 3,000 Buyers guides distributed.

January 2015 – September 2015: 22,235 visits to BuyNCPlants.com and 1,000 Buyers Guides distributed.

3. Measurable Outcome: Consumer Awareness
Performance measure: Number of visits to the website, blog, on TarHeelGardening.com
Target: Increase visits to the website and blog by 10% in 2014 and an additional 10% in 2015 compared to the 2013 visits.
Benchmark: 2013 visits: 171,000 visits
Progress Achieved:
July 2014 – September 2014: 84,245 visits to TarHeelGardening website and blog.

October 2014 – September 2015: 229,533 visits to TarHeelGardening website and blog.

BENEFICIARIES

The beneficiaries of the project were the approximately 1400 nursery growers across North Carolina. Beneficiaries also include approximately 30,000 people employed by the nursery industry and in related rural green industry businesses. In addition, over 1 million consumers and 20,000 wholesale buyers benefited from the information they receive about NC plants and landscaping.

LESSONS LEARNED

No Problems or unexpected outcomes/results.

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PROJECT TITLE: Breeding Resistant Christmas Trees and Ornamentals

FINAL REPORT

PROJECT SUMMARY

Two exotic insect pests, the balsam woolly adelgid (BWA) and the hemlock woolly adelgid (HWA) are threatening the survival of Fraser firs and hemlocks in western North Carolina, in turn negatively impacting the WNC Christmas tree industry and the WNC ornamental tree industry.

These two closely related insects are causing damage and death to Fraser fir, the mainstay of the Christmas tree industry, and two species of eastern hemlocks, Eastern and Carolina hemlocks, which are important trees to the ornamental tree industry. Firs and hemlocks are being rapidly attacked and killed throughout their range. Currently, efforts to deal with these problems have not reduced tree mortality.

A previously funded SCBGP project entitled “Investigating the mechanisms of host resistance to the balsam woolly adelgid as part of an IPM strategy for Christmas trees” specifically researched the mechanisms of resistance. The current proposal will screen for resistance regardless of the mechanism. A common garden has been established at the NCDA Upper Mountain Research Station in western NC near Laurel Springs. We added 18 Turkish fir to this plantation in September 2012. We assessed the health of the other species present in order to plan experiments for the spring of 2013. Cuttings from some of the exotic fir trees in the common garden at the Upper Mountain Research Station were grafted as checks for comparison in our adelgid resistance screening study of improved Christmas tree seed orchard parents.

PROJECT APPROACH

Search for resistance within native and exotic populations of hemlocks and firs: Our approaches to searching for resistance took several forms. One method was through investigation of leads we received from natural resources professionals and the general public. We cultivated leads through the dissemination of information about our search using professional meetings, presentations and invited talks, posters, brochures, multimedia displays at the NC Arboretum and Cradle of Forestry in America, and a website with information and a form for online submission of leads. After appropriately vetting leads received, we conducted site visits to assess potentially resistant trees for their suitability of inclusion in our resistance screening trials. Branch cuttings were collected from trees deemed potentially resistant for subsequent rooting and resistance screening. Through these avenues, we sampled from 72 trees in 2014 in North Carolina, Tennessee, and Virginia, and 18 trees in North Carolina and Virginia in 2015 for further screening. The most promising stand we have sampled from is on private property in Wilkes County, NC, where we have sampled 32 trees representative of the stand for further screening.

A second tactic used to locate candidate trees for testing was actively searching areas of particular interest through ground-based surveys. Due to their ecological and historical importance, we conducted surveys in Great Smoky Mountains National Park (GRSM) and along the Blue Ridge Parkway (BLRI). In addition to being useful in the nursery/ornamental industry, any resistant trees found in these parks would also be of extra value in restoring hemlock stands in the respective national park since utilizing them would not require the introduction of outside genetic material. Our search in GRSM involved surveying the areas surrounding 93 linear miles of trails in the park, with some additional visual surveys using binoculars and a spotting scope from strategic vantage points with

broad view sheds that included former hemlock stands. The areas surveyed in GRSM were selected based on historic information about hemlock stands and vegetation classification maps provided to us by park staff. We also investigated a lead from the park hemlock chemical treatment crew of potential resistant trees in a remote area with no trail access, but unfortunately neither the lead nor the trail surveys yielded any strong candidates for resistance screening. In March 2015, we conducted a survey along approximately 100 miles of the Blue Ridge Parkway utilizing information on hemlock occurrence provided by park staff. This survey resulted in collections for rooting and resistance screening from 12 hemlock trees.

Because there are a large number of Fraser fir trees in natural stands that are the result of regeneration following heavy mortality from the initial infestations of BWA and it is unclear what level of resistance these regenerated trees may have, our search for native Fraser fir adelgid resistance has been primarily limited to screening of improved genotypes in Fraser fir Christmas tree seed orchards. Many genetic factors besides BWA resistance impact the value of Fraser fir grown by Christmas trees producers, so screening the improved breeding populations will help ensure that any resistance identified will occur in trees that already selected for other important desirable characteristics, maximizing their value to commercial growers. We are testing 7 genotypes where material was collected from mature Fraser fir trees in GRSM that survived the initial wave of mortality from BWA.

Root cuttings of hemlocks and firs: We collected cuttings from potentially resistant trees in the winter and spring of both 2014 and 2015 from eastern and Carolina hemlock. In 2014, we stuck a total of just over 7,000 cuttings from 72 potentially resistant hemlock trees located in NC, VA, and TN. Of those trees, 35 had been collected from in a previous with poor rooting success, and 37 trees were new additions to our collections. The cuttings were divided evenly between a greenhouse at the Mountain Research Station (MRS) in Waynesville, NC and a greenhouse in Raleigh at NCSU. This division was done to help reduce the impact of any catastrophic failure in the propagation system, as had been experienced in a previous year prior to the implementation of this policy. Rooting success varied for each of the trees, but generally ranged from around 20% up to 40%. Cuttings in Raleigh did not tend to do as well as those in Waynesville, likely due to higher temperatures. We set up a new mist system in Raleigh, and made incremental upgrades to the system in Waynesville to try to improve uniformity. In the spring of 2015, we collected cuttings from 30 new trees in NC and VA. In 2015, we tried a new rooting technique which involved sticking the cuttings into a bed of rooting media on 4'x8' greenhouse benches, sealed to provide a high humidity environment, and placed in the basement of a building at the MRS in Waynesville. We stuck 1,967 cutting from the trees in this new system, and an additional 1,296 in our traditional system in the greenhouse at the MRS as a backup to the new technique. Rooting success with the new method was lower than hoped at only 6%, but we identified potential areas for improvement in the future, and the cuttings that did root were of excellent quality. The 2015 cuttings in the traditional greenhouse mist setup did better than previous attempts, helping to offset the poorer performance of the experimental system.

Due to the relative ease with which Fraser fir may be grafted relative to hemlocks, we have used grafting instead of rooted cuttings as our propagation technique for screening Fraser fir genotypes for adelgid resistance.

Collect pollen of hemlocks and firs: In spring of 2014, we collected pollen from eastern hemlock, Carolina hemlock, and momi fir from trees in NC for use in controlled crosses. A cooperator in RI attempted to collect pollen from several exotic hemlock species for our use, but was unable to catch the pollen at the correct developmental stage. 2015 was a particularly prolific year for pollen production in hemlocks in western NC, and we were able to collect pollen from eastern hemlock, Carolina hemlock, southern Japanese hemlock, and momi fir, in larger quantities than we have previously been able to

obtain. Our cooperator at the University of Rhode Island was also able to collect Chinese hemlock pollen for us in 2015.

Test hemlocks and firs for resistance: We re-established a test to screen the parent trees that will produce the next generation of improved Fraser fir seed for Christmas tree growers in NC, as well as some genotypes from mature Fraser fir trees that survived the first wave of mortality from balsam woolly adelgid in GRSM. The test was originally initiated in 2012, but failed during the infestation process in 2013 with the loss of all the test trees. In March and April 2014, 1000 bare root Fraser fir liners purchased from a NC Christmas tree grower were transplanted into containers at the MRS for grafting rootstock. Then, in late April, we grafted scion from 30 next-generation improved Fraser fir Christmas tree genotypes, 7 survivors from GRSM, and two exotic firs onto the containerized rootstock for a total of 600 grafts. Following initial higher than expected losses from rootstock mortality and graft failure, related to the quality and size variability of the rootstock trees, the population has stabilized and the material is currently being cultured at the MRS and we plan to begin screening in spring of 2016 for resistance to BWA by intentionally infesting the trees. The most resistant genotypes will be targeted for future controlled crosses made in the seed orchard.

Hemlock cuttings that we have rooted for HWA resistance screening have not yet put on sufficient healthy growth to reliably infest with HWA under controlled conditions, but will tested as soon as they are suitably developed. In anticipation of testing in the near future, with the assistance of other grant funding, we have established a population of HWA wild-collected from several locations on containerized trees at the MRS, to ensure that we have a ready supply of healthy adelgids for use in screening. When we infest the Fraser fir screening test in 2016 with BWA, we will also infest some Fraser fir seedlings to begin raising BWA at the MRS for future screening work.

Maintain and upgrade common gardens at Mountain Research Station and Upper Mountain Research Station: The common garden of hybrid hemlocks from the USNA at the NCDA Upper Mountain Research Station (UMRS) continues to do well. Survival is very high at 98% of the original trees still alive. Height has been assessed during each dormancy period since establishment. As of the most recent measurements taken in December 2014, mean height has increased 53% since establishment in fall 2011. One aspect of adaptability to the southern Appalachians that will be investigated further in future years is the possibility that some hybrids break bud earlier than native species, leaving them vulnerable to damage from late season frosts. In 2014, we observed potentially early bud break on 23% of the trees, with 10% appearing to have broken bud quite early. Repeated assessments of bud break status during the spring will be required to formally evaluate whether this may be a concern, although the current rates of growth do not indicate this is likely to be a major problem. The common gardens at the MRS are in the form of containerized trees taken from cuttings of potentially resistant trees, as well as some exotic hemlocks that have been grown from seed or received from other growers as seedlings, all in a common greenhouse environment. These will be field planted following several iterations of intentional infestation with HWA.

Provide pollinated seed to the University of Georgia for laboratory cloning techniques: In 2014, we provided 44 cones from 15 controlled crosses of hemlocks to the Merkle Lab at University of Georgia for somatic embryogenesis. Of those cones, 28 were from 7 controlled crosses between Carolina hemlock mother trees and pollen from adelgid-resistant/tolerant Chinese or southern Japanese hemlocks, and 16 cones were from 8 crosses between eastern hemlock mother trees and pollen from Chinese, southern Japanese, or western hemlocks. As many cultures as possible were initiated from each cross we supplied, and ultimately three cultures coming from two different crosses of Carolina hemlock by Chinese hemlock, and two cultures from one cross of Carolina hemlock by southern Japanese hemlock produced plants which have been returned to us for continued propagation and eventual resistance screening.

In 2015, which was a tremendously prolific coning year for many hemlocks in western NC, we sent 517 immature cones from 34 different controlled crosses of hemlock and six open-pollinated eastern hemlock parents that are potentially resistant. 239 of the cones were from controlled crosses between Carolina hemlock and various exotic hemlocks, 50 were from controlled crosses between eastern hemlock and exotic hemlock species, and 215 were from open pollinated eastern hemlock trees from our most promising potentially resistant hemlock stand in Wilkes County, NC, from mother trees currently in our resistance screening test. It is too early to yet know what cultures may be successful from 2015.

Report results to the NC Christmas Tree Association and the NC Nursery and Landscape Association at their annual meetings: We have not yet presented results to the NCCTA and NCNLA at their meetings since we do not yet have the results from screening tests, but we will do so when appropriate. In addition, the recently formed Board of Advisors for the Forest Restoration Alliance (named Alliance for Saving Threatened Forests at the time of this grant award) has multiple members who are members of either the NCCTA or NCNLA. The Board of advisors receives updates a minimum of twice yearly on the progress of our projects.

The Christmas Tree Genetics Program at NCSU has provided assistance with the grafting for the Fraser fir resistance screening study as well as some grafting supplies, and provided technical expertise with Fraser fir propagation. Camcore at NCSU has provided technical expertise related to hemlock propagation and infestation with adelgids. The NCDA Mountain Research Station has provided office space and access to research facilities, and assistance with construction of specialized facilities for adelgid research. Unique Places, LLC has provided assistance with collection and sticking of hemlock cuttings for rooting. The Merkle lab at UGA has been working on trying to successfully produce novel interspecific hemlock hybrids through somatic embryogenesis, and develop a system for mass production of hemlock genotypes of interest. They have provided plants produced via somatic embryogenesis from hybrid hemlock crosses for us to propagate and screen for resistance. The Casagrande lab at University of Rhode Island has provided technical advice on the rooting of hemlocks, and attempted to collect pollen from exotic hemlocks. They have also provided a limited number of clonally propagated trees from one of the potentially resistant eastern hemlock the have been testing. The US National Arboretum has continued to collaborate with us on the common garden of hybrid hemlocks at the Upper Mountain Research Station. The US Forest Service has shared technical advice and research results relating to infesting hemlock with adelgids, as well as the loan of some supplies for hemlock propagation.

GOALS AND OUTCOMES ACHIEVED

Our goal is to produce adelgid resistant hemlocks for the NC nursery and landscape industries and adelgid resistant firs for the NC Christmas tree industry. In order to incorporate 102 candidate hemlock trees in our resistance screening pipeline, we conducted outreach efforts to encourage people to report potentially resistant trees to us, and we investigated reports as well as conducted active searches in several high-interest national parks. We then propagated cuttings from the candidate trees so we will be able to screen them in the near future. We have also begun the process of growing a small number of trees provided by collaborators at the University of Rhode Island from a NJ source that appears to be adelgid resistant, in order to eventually determine their adaptability to the southern Appalachians.

In support of our goal to develop adelgid resistant firs, we established through grafting a screening test for important Christmas tree genotypes that are part of a latest generation seed orchard that will produce seed for many of the Fraser fir Christmas trees planted in the future in NC. We then propagated those trees to bring them closer to being ready to screen in 2016.

To ensure that as many options as possible are available to the nursery and landscape industries, we have continued to work to develop suitable hemlock interspecific hybrids, which has involved collecting pollen, making controlled crosses, and collecting and providing immature seed to collaborators at the University of Georgia. Those collaborators have so far been able to produce five clonal lines that we will eventually test for resistance once the plants produced are sufficiently large. To further support the effort to provide resistant hemlocks, we have assisted the US National Arboretum (USNA) in evaluating hybrids they have produced for adaptability to the southern Appalachians through the establishment and ongoing assessment of a common garden experiment in NC. Since the USNA breeding program began 18 years prior to our initial hybrid breeding efforts, their genetic material may be available to growers sooner (possibly very limited distribution beginning in 2016) than our hybrids, and our testing in NC will help assure growers in the state that the hybrid hemlocks are viable in this region.
The outcome measures for this project, being able to provide adelgid resistant stock to the Christmas tree, nursery and landscape industries, are long term, but we have made good progress toward being able to identify through testing resistant genotypes. We have deliberately attempted to structure our project in such a way that following identification of resistant genotypes, those genotypes or offspring of them can be distributed as quickly as possible, such as being able to generate clonal copies of hybrid hemlocks through somatic cultures already developed, clonal propagation or open-pollinated offspring of naturally resistant native hemlocks, and collection of seed from more resistant individuals already established in a commercial Christmas tree seed orchard.

While we would have preferred to have begun exposing our hemlock and fir resistance screening tests to adelgids before the end of the reporting period, the health and growth rate of the hemlock rooted cuttings did not allow for this. However, we were able to add 67 new potentially resistant native hemlock genotypes to the screening population during the reporting period, which should increase the probability of identifying resistant genotypes. Our collaborations with efforts at University of Rhode Island and the USNA to produce host plants resistant to HWA have helped move the nursery and landscape industries closer to having resistant stock to propagate. We have been able to successfully produce sufficient hybrid hemlock seed to enable collaborators at University of Georgia to generate hybrid hemlock cultures that pending verification of resistance can be rapidly mass clonally propagated for distribution to producers.

To the best of our knowledge, there are no commercially available adelgid resistant native hemlocks currently available, and no screening has been done of Christmas tree genotypes to identify levels of resistance in breeding populations of Fraser fir. Although the availability of resistant trees will be beyond the scope of the reporting period, we have helped move the affected industries closer to that goal of resistant stock through our breeding and establishment of screening tests as outlined above.

We have identified and begun the resistance screening process on 102 potentially resistant native hemlock trees in the southern Appalachians. The common garden planting of hybrid hemlocks from the USNA we established in NC has had 98% survival, and increased 53% in height after three growing seasons, indicating that once those hybrids become commercially available they will be appropriate to grow in NC, although we will continue to monitor them long-term. In cooperation with the Merkle lab at UGA, we have successfully established at least five clonal lines of hybrid hemlocks (pending verification through DNA analysis) that will be uniquely positioned for rapid distribution through somatic embryogenesis once they are screened for adelgid resistance.

BENEFICIARIES

This project will benefit Christmas tree growers growing Fraser fir trees (the dominant Christmas tree grown in NC, with approximately 1,600 growers producing an estimated 50 million Fraser fir Christmas

trees on over 25,000 acres), nurseries producing ornamental hemlocks (over 750 companies and individuals that could potentially grow hemlocks commercially), and foresters concerned with restoration of natural stands of hemlocks and firs.

Fraser fir serves as one of the most popular Christmas trees in North America and the Christmas tree industry provides an important economic resource for mountain communities. In North Carolina, there are an estimated 50 million Fraser fir trees providing annual cash receipts of well over $100 million. Virtually all Fraser fir Christmas trees require treatment for BWA one or more times during a 5 to 10-year rotation. The threshold for treatment is a single infested tree and chemical insecticides are currently the only effective means for controlling this pest. Treatments require insecticides to be applied with a high-pressure sprayer using 300 to 800 gallons per acre. The entire tree must be wetted and only two or three rows can be treated at a time. Only about half the Christmas tree growers own the type of equipment required and others must hire someone to treat the trees at a cost of $300 to $500 per acre. Treatments for BWA cost the Christmas tree industry over $1.5 million per year.

Developing pest resistant hemlock trees will be a great assistance for our state's nursery industry. Hemlock trees have previously provided a steady source of income to the North Carolina nursery industry. However, HWA has virtually eliminated hemlocks as a marketable ornamental. The development of HWA-resistant hemlocks would be a huge economic benefit to N.C. growers by opening new markets for hemlock sales by nurseries in North Carolina and other states.

LESSONS LEARNED

One of the most important lessons learned and applied is the need for back-up and contingency plans when dealing with plants, environmental conditions, and biological deadlines. For example, we traditionally have used specific plastic containers and trays available from only a single source. We required additional supplies that we did not have on hand at the beginning of the year, but we discovered the containers were backordered when we tried to order the needed supplies. However, biological deadlines required us to collect cuttings for rooting even though we did not have the supplies to process them, requiring us to store them. Once the containers were shipped, the shipping company lost the shipment at their freight terminal, piling on an additional delay. The prolonged storage of the cuttings very likely had a negative effect on rooting success and cutting health, though we have since learned from our more recent experimentation that procedures such as a fungicide dip might enable us to store cuttings longer with less adverse effects. To minimize the effect of future supplier delays, we now try to order supplies in further in advance of needing them when our budget allows. Due to an industry shortage of the size Fraser fir seedlings suitable for grafting rootstock, we were forced to utilize less than ideal stock that very likely was the main contributing factor to poorer grafting success than we have typically enjoyed. We have since begun propagating our own Fraser fir that can be used as rootstock when needed, or for rearing BWA, reducing our reliance on outside suppliers of plants. We have also tried to extend this practice to other areas of the project, growing what trees we can to make us independent of plant supply issues.

An unusual cold spell in April 2014 had a negative impact on our hybrid hemlock breeding efforts, mainly due to the wet conditions immediately preceding the cold, causing us to waste some of our very limited resource of exotic hemlock pollen, and also causing us to miss the window of opportunity for pollination on some of our selected breeding trees. Fortunately, we had learned from prior experience to try to have breeding locations at varied elevations that develop at different rates, so our higher elevation site afforded us a second chance at making some of the crosses that year.

Trying a new technique for rooting hemlock cutting in 2015 allowed us to learn some disease and moisture management practices that we hope will ultimately improve our rooting success, some of which will carry over into our traditional technique. We had fortunately taken the need for a backup plan to heart, so although the new rooting technique was less successful than we hoped, our backup using the traditional methods did better than ever.

With the successful establishment of embryogenic cultures of several hybrid hemlocks, we may be in a position to release meaningful numbers of plants for commercial use sooner than expected, provided resistance screening proceeds smoothly and the hybrids are indeed resistant. The hybrid hemlocks from the USNA that we are growing are doing even better than expected, so we are optimistic that hybrids can be a viable alternative to native hemlocks for the ornamental industry. The plants we have been growing from URI sourced in NJ also seem to be quite well adapted to the southern Appalachians, so those genotypes may also be viable for commercial production here. We will, however, continue to monitor all of the genetic sources long term to ensure there are not unforeseen issues as the trees mature.

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PROJECT TITLE: Cost-Effective Weed Management in Nursery Crops

FINAL REPORT

PROJECT SUMMARY

Weed management in nursery crops can be one of the most costly components of crop production. Reduced profit margins and reduced sales during the recent recession have forced growers to look for methods to reduce costs. Reducing herbicide use in nurseries to save money is counter-productive because hand weeding costs increase as a result. Increasing herbicide use is generally not an option as growers already make multiple applications of residual herbicides, often reaching the maximum number of applications allowed on herbicide labels. Nursery crop producers need alternative strategies for managing weeds efficiently and sustainably. In this project we developed strategies, which if implemented, have the potential to reduce overall weed management costs.

Current "industry standard" weed control practices in container nurseries include three to six applications of preemergence herbicides each year, supplemented with hand weeding. Despite the frequent use of broad-spectrum preemergence herbicides, supplemental hand weeding costs have been estimated to be between $500 and $4,000 per acre per year. Weed management practices that reduce the man-hours required for hand weeding have the greatest potential to reduce overall weed control costs. The objective of this two-year project was to develop alternative and sustainable weed management practices that can reduce overall weed management costs and reduce dependence on broadcast applications of residual herbicides.

The specific objectives were to:

1. Document potential cost and herbicide savings associated with an alternative postemergence weed control strategy that emphasizes sanitation and prevention;
2. Develop guidelines for more efficient and accurate herbicide application;
3. Develop best management practices that minimize crop injury from spray-applied preemergence herbicides in container nurseries; and
4. Produce guidelines and educational materials that will aid growers in adopting these cost-saving strategies.

Nursery and greenhouse crop production is the 4th most valuable agricultural commodity in NC, with over 2,317 farming operations and over $570 million in sales. About a third of that crop acreage is in outdoor container plant production, a management and resource- intensive system that maximizes crop growth and quality. The wholesale value of those crops is estimated to be about $93,000,000. Weeds can cause significant economic losses in container nursery crop production. Fretz (1972) reported that as few as one large crabgrass (*Digitaria sanguinalis*) plant per container can reduce dry weight of Japanese holly (*Ilex crenata* 'Convexa') by up to 60%. Even seemingly non-competitive weeds like bittercress (*Cardamine flexuosa*) have been shown to reduce spirea (*Spirea x* 'Gold Mound') growth by 25% and result in 22% greater water loss compared to weed free pots (Neal, 2012 unpublished data). Consequently, weed control in container nurseries is an essential part of crop management. However, economic forces have resulted in shrinking profit margins and a need for more efficient weed management strategies.

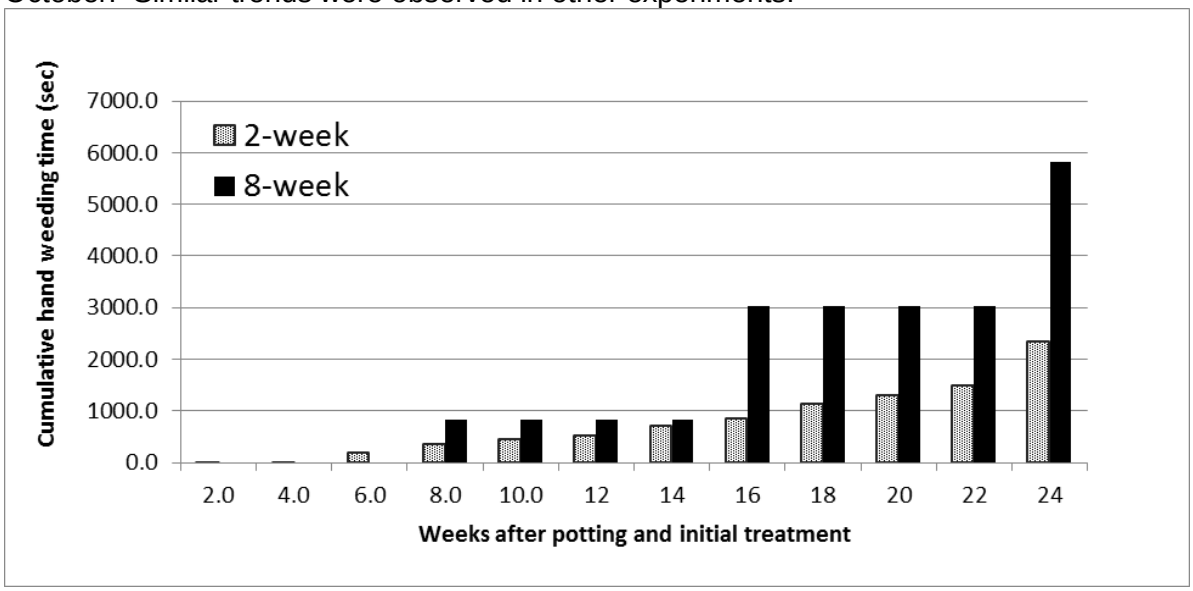
PROJECT APPROACH

Objective 1: Cost comparisons of hand weeding strategies in container nursery crops.

Tests were conducted in 2014 and repeated in 2015 to compare the labor costs associated with two weed removal strategies: hand weeding every 2-weeks or hand weeding every 8-weeks. In 2014, two experiments were conducted, one at the Castle Hayne research station and one at Johnson's Nursery, a cooperating container nursery in eastern NC. The next year, experiments were repeated at the research station and Johnston nursery, plus two additional cooperating nursery sites were added. Methods were similar at all sites both years while plot size, species composition, and size of pots varied. All study sites received applications of an industry standard preemergence herbicide (Snapshot TG) at manufacturer's recommended rate. The herbicide was applied every 8 weeks, after pots were hand weeded. The time required for hand weeding each block of plants and the biomass of weeds removed were recorded. Cumulative man-hours required to hand weed pots and cumulative weed biomass were calculated. At the conclusion of the experiments, data were analyzed and the unit cost per pot and cumulative cost per acre were calculated for each of the treatments assuming $15/hour in labor costs. Additionally, the incremental hand weeding costs ($ per pot per wk) for each study were calculated and compared. The percent difference in cost between the two weeding strategies was calculated as well as the differences in weed biomass.

Overall trends were similar in each study site and supported the hypothesis that increased weeding frequency reduced weed populations and biomass. The research station experiments serve as the "controlled repetition" of the on-farm tests. The time required to remove weeds from pots increased over time. Few differences in weeding time were observed in the first 8 weeks following potting and treatment (Figure 1). However, weed growth and fedundity in the 8-week weeding treatments resulted in much greater time required to remove weeds at 16 and 24 weeks (Figure 1).

Figure 1. Cumulative time (sec.) required to hand weed plots every 2-week vs every 8 weeks in the Castle Hayne research station experiment, 2015. The experiment was initiated in April with preemergence herbicides re-applied at 8-week intervals. Experiment was terminated after 24 weeks, in October. Similar trends were observed in other experiments.



Cumulative hand weeding time and costs for each experiment are summarized in Table 1. The research station experiments (CH14 and CH15) were initiated in April of each year, and were maintained through three 8-week weeding cycles (24 weeks duration). Hand weeding plots every 2

weeks resulted in a 41% to 60% reduction in man-hours required compared to weeding every 8 weeks (Table 1). At Johnson's nursery, frequent weeding reduced weed control costs by 16% in 2014 and 60% in 2015. Reasons for the differences between years could be associated with different staffing or different weed populations or both. At Smith's nursery frequent weeding provided a 32% savings. The Carrol's Plant Center site saw the least benefit from frequent weeding with a savings of only 10% which was not statistically significant. This site was started later in the season and saw some weeds controlled by frost between the 8-week weeding cycles. This suggests that growers might adjust weeding intervals when killing frosts are expected.

The duration of on-farm experiments were either 16 or 24 weeks depending upon the growers' schedules. Due to the differences in duration of experiments, the incremental hand weeding costs ($ per 1000 pots per week) were calculated. The incremental costs between sites were variable but differences between weeding treatments were consistent with the other cost estimates.

Table 1. Cost Comparisons of Weeding Strategies for each study site and year. Labor costs are estimated based on the cumulative man-hours required to hand remove weeds. Costs per unit, per area and incremental costs ($ per 1000 pots per week) were calculated.

Location and year	Weeding Schedule	Ave. # pots per plot	Cumul. Man hours / 1000ft^2	Cumul. Cost ($/1000 ft^2)	Unit Cost ($/pot)	Cum. Cost ($/A)	Study Dura-tion (wks)	Incremen -tal cost ($/1000 pots/wk)	% Diff.
Resarch Station 2014	**2 wk**	**176**	**20.94**	**$314.06**	**$0.114**	**$13,681**	**24**	**$4.76**	**41****
	8 wk	176	35.63	$534.38	$0.194	$23,277		$8.10	
Resarch Station 2015	**2 wk**	**153**	**10.00**	**$150.00**	**$0.064**	**$6,534**	**24**	**$2.66**	**60****
	8 wk	153	24.92	$373.85	$0.159	$16,285		$6.62	
Nursery A 2014	**2 wk**	**1133**	**1.38**	**$20.67**	**$0.016**	**$900**	**16**	**$1.03**	**16**
	8 wk	1133	1.63	$24.50	$0.019	$1,067		$1.22	
Nursery A 2015	**2 wk**	**1133**	**3.38**	**$50.67**	**$0.040**	**$2,207**	**24**	**$1.68**	**60***
	8 wk	1133	8.37	$125.50	$0.100	$5,467		$4.15	
Nursery B 2015	**2 wk**	**658**	**1.15**	**$17.20**	**$0.023**	**$749**	**16**	**$1.42**	**10**
	8 wk	658	1.27	$19.09	$0.025	$832		$1.58	
Nursery C 2015	**2 wk**	**774**	**2.65**	**$39.74**	**$0.015**	**$1,731**	**16**	**$0.96**	**32**
	8 wk	774	3.92	$58.79	$0.023	$2,561		$1.42	

Costs were calculated assuming $15/hour labor costs.
% Difference is calculated as ($/A for 8 wk - $/A for 2 wk) / $/A for 8 wk)*100.
*, ** represent statistically significant difference at α = 0.1 and 0.05, respectively

Hand weeding every 2 weeks resulted in dramatic reductions in weed biomass in every experiment. In the Castle Hayne research station tests, hand weeding every 2 weeks reduced total weed biomass 81% to 92% compared to weeding every 8 weeks (Table 2). At Johnson Nursery in 3-gallon container grown holly plants, weeding every 2 weeks resulted in a 51% to 84% reduction in weed biomass (Table

2). Similar reductions in weed biomass were observed at the other sites. The magnitude of differences in weed biomass removed between 2-week and 8-week weeding events were greater than the differences in labor. This is because each 2-week weeding event included walking each bed and looking for weeds – even if few or no weeds were present.

Table 2: Comparisons of weed biomass (fresh weights) removed for each study site and year. Percent difference between the 2-week and 8-week weeding intervals were calculated.

Location/Year	Weeding Schedule	Plot area (ft^2)	Ave. # pots/plot	Weed biomass g/plot	% Diff.
Resarch Station 2014	**2 wk**	**64**	**176**	**2159**	81**
	8 wk	64	176	11184	
Resarch Station 2015	**2 wk**	**65**	**153**	**360**	92**
	8 wk	65	153	4748	
Nursery A 2014	**2 wk**	**900**	**1133**	**6736**	51
	8 wk	900	1133	13713	
Nursery A 2015	**2 wk**	**900**	**1133**	**10404**	84*
	8 wk	900	1133	66763	
Nursery B 2015	**2 wk**	**872**	**658**	**2340**	73
	8 wk	872	658	8532	
Nursery C 2015	**2 wk**	**300**	**774**	**1790**	64*
	8 wk	300	774	4951	

% Difference is calculated as (Kg/plot for 8 wk – Kg/plot for 2 wk) / Kg/plot for 8 wk
*, ** represent statistically significant difference at α = 0.1 and 0.05, respectively

Within the first 8 weeks the differences in weed biomass removed from 2-week vs 8-week weeding treatments was small or not significant (Figure 2). This trend is reflected in the weeding time required to remove weeds (Figure 1). However, as a result of increased populations and rapid growth rates in summer months, weed biomass increased dramatically and the "legacy" effects of 2-week weed removal was evident. Weed populations (as measured by weed biomass removed) increased throughout the summer. However, when the experiment was continued into late fall, killing frosts can alter the outcomes. At one site, a frost in mid-November killed existing summer annual weeds, thus reducing the biomass of weeds in containers (Figure 3). This suggests that under certain circumstances growers might gain further cost savings by waiting for frost to kill weeds, thus reducing the need for some hand weeding.

Figure 2. Cumulative weed biomass removed from plots weeded every 2 weeks vs every 8 weeks. Castle Hayne 2015 experiment. Results in other experiments were similar.

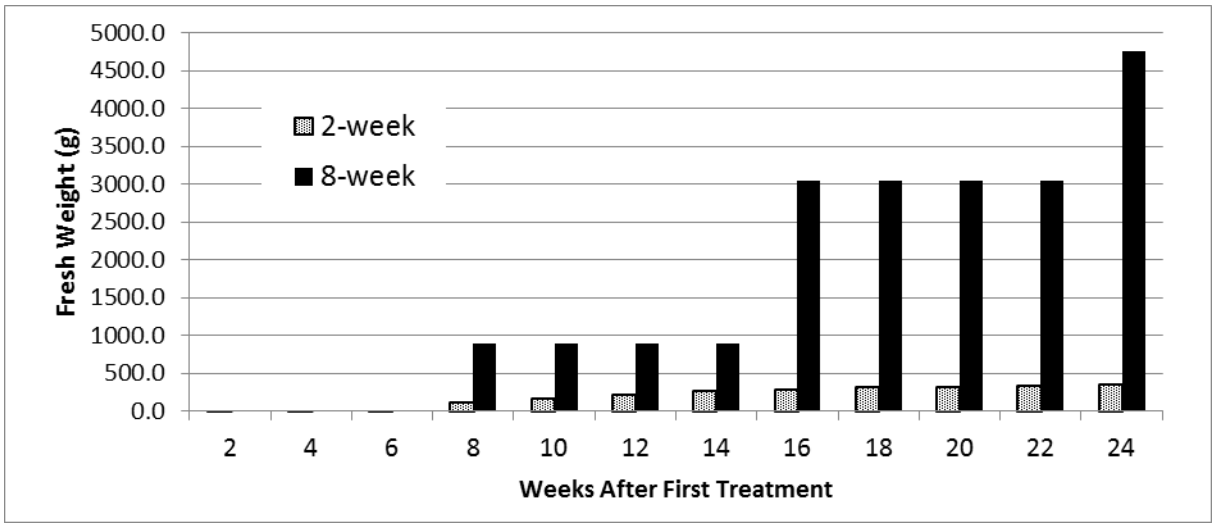
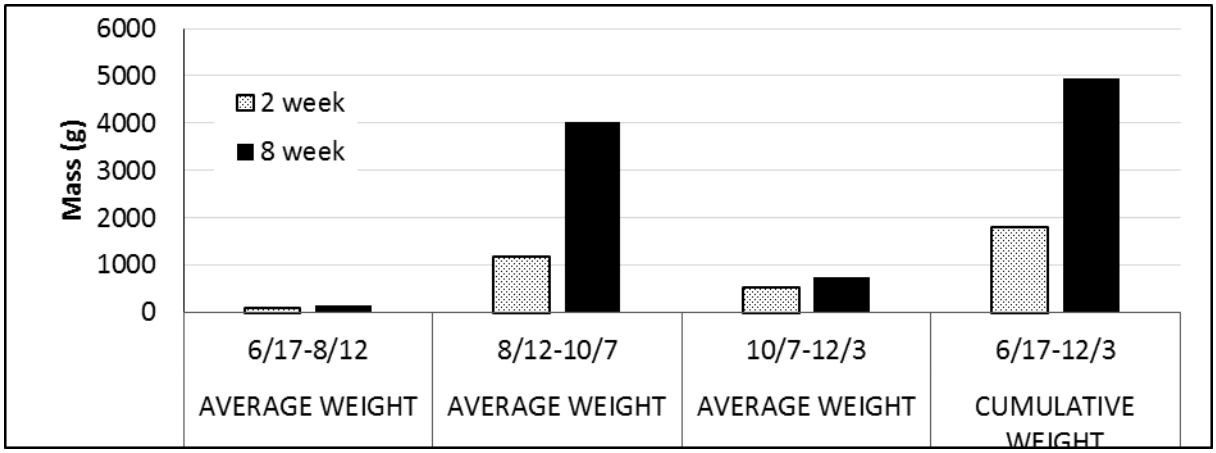


Figure 3. Weed biomass removed from plots weeded every 2 weeks vs every 8 weeks for each "8-week segment" and cumulative for all 24 weeks at Smith's Nursery. Following the 10/7/15 weeding, warm weather resulted in weed emergence then a killing frost occurred before the 12/3/15 weeding. Thus, weed biomass in the 8-week weeding treatment was dramatically reduced compared to the previous weed removal date.



Effects of weeding treatments on plant growth.

When not controlled, weeds suppress crop growth, but weed competition does not affect all crop species equally. Figure 4 shows the effects of eight weeks of uncontrolled growth of eclipta (*Eclipta prostrata)* on the fresh weight of nandina compared to the hand-weeded control. In this illustration neither treatment received herbicide application. In the hand-weeding experiments reported herein, all treatments received a standard herbicide treatment. Consequently, even when pots were only weeded every 8 weeks, little impact was observed on crop growth.

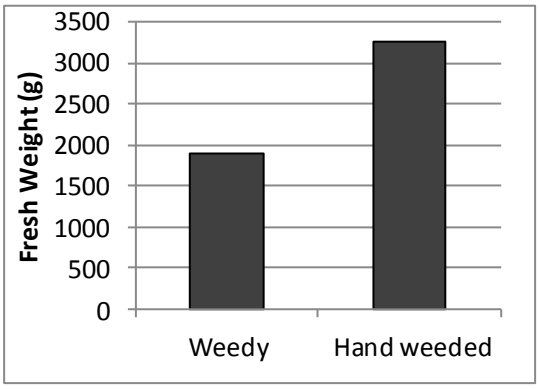


Figure 4. Effects of 8 weeks of eclipta competition on growth of 'Firepower' nandina

In the on-farm studies, no differences in crop growth

were observed between 2-week and 8-week hand weeding intervals. The crops included in these studies were hollies (*Ilex cornuta* hybrids*, Ilex crenata* hybrids, *Ilex vomitoria nana,* and *Ilex glabra*). In the research station experiments no differences in growth of azalea (*Rhododendron obtusum* hybrids) were observed in either year. However, in one of two years there was a difference in the height of 'Green Giant' arborvitae with trees in the 8-week weeding treatment being several inches shorter than those being weeded every 2 weeks (data not shown). Thus, the effects of weed competition on plant growth may vary between crop species, weed species, and the biomass of weeds present.

Weed growth and fecundity. In conducting these experiments the importance of understanding how rapidly weeds reach reproductive maturity was highlighted. In other words -- *just how frequently does one need to removed weeds to prevent seed production?* Thus, in late May 2015 an experiment was conducted to evaluate germination and growth of common nursery weeds in containers pots. This experiment was repeated in 2016. The purpose of this experiment was to understand the time it takes for a weed seed to go from germination to seed dispersal and how weed development intervals impact weed management strategies.

The study captured the time to weed germination, first true leaf, number of branches, number of flowers, and number of seed pods for three common container crop weeds: spotted spurge, long-stalked phyllanthus, and bittercress. Half of the plants were grown in full sun and the other half under shade cloth. Developmental data were similar across species in both 2015 and 2016. Spotted spurge and long-stalked phyllanthus had higher emergence levels and produced more flowers in full sun than in partial shade, while bittercress had higher germination rates and produced more flowers in the shade versus full sun (Figure 5). This is not surprising considering that spurge and phyllanthus are warm-season annuals and bittercress is a cool- season weed.

The most dramatic growth was exhibited by spotted spurge. Branch development in spurge was documented around 15 days after seeding and once branch development occurred, spurge plants grown in sun experienced exponential growth. Spurge plants produced flowers within 21 days of seeding with a very rapid increase in flower production between 21 and 25 days (Figure 6). Seed pods were formed within 7 days of first flowering (data not shown).

These data illustrate that under optimum conditions spotted-spurge may produce viable seeds within four to five weeks of being seeded and less than 4 weeks from emergence. The 8 week weeding schedule would allow time for multiple generations of spurge, greatly increasing the number of seeds and seedlings in and around the plots. The more frequent 2 week weeding schedule should catch seedlings before they set seed, reducing weeding in the future by preventing the buildup of seed banks.

Figure 5: Cumulative weed seedling emergence in sun and shade. Weeds seeded to containers on May 24, 2016.

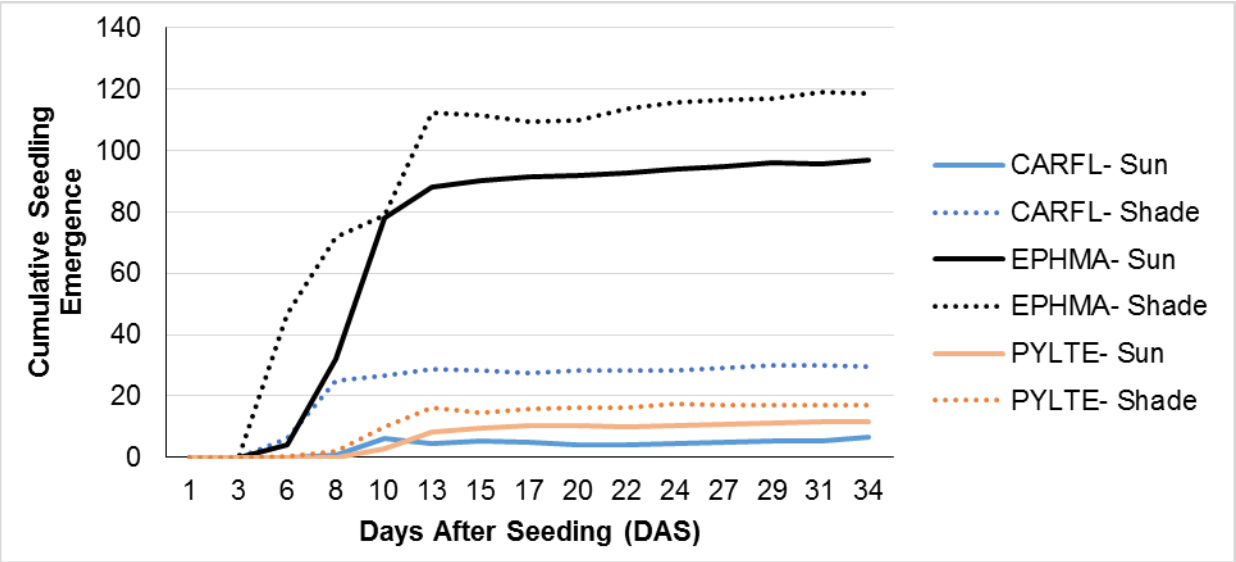
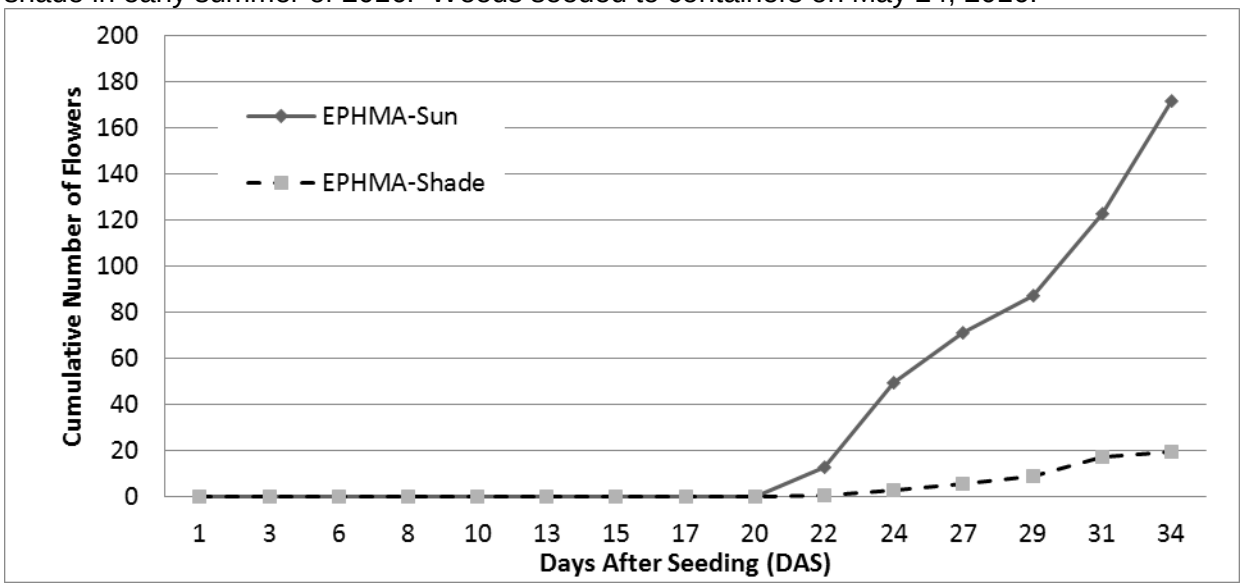


Figure 6: Cumulative number of flowers per plant on spotted spurge (EPHMA) grown in full sun or 50% shade in early summer of 2016. Weeds seeded to containers on May 24, 2016.



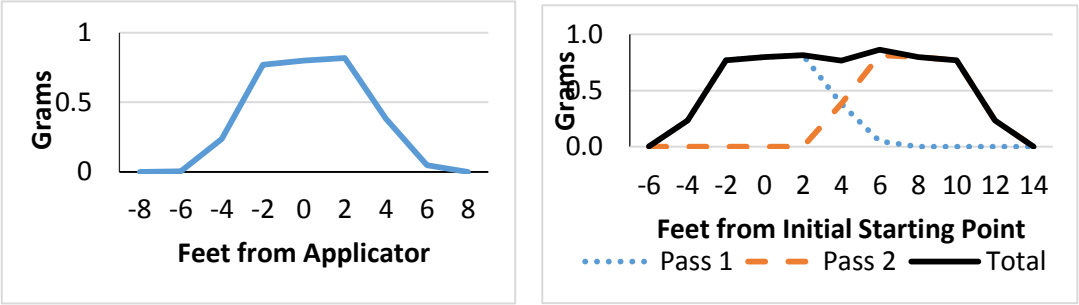
Objective 2: Herbicide application efficiency.

Tests were conducted to document patterns and uniformity of granular distribution using two hand-cranked, hand-carried rotary spreaders commonly used in container nurseries. Research has demonstrated the standard method for applying granulated preemergence herbicides in nurseries is inherently inaccurate and imprecise, yet few guidelines are currently available to the public. The purpose was to create specific guidelines for effective use of hand-cranked, hand-carried rotary spreaders.

The Warren T-7 II and Solo 421S spreaders were chosen as two of the most commonly used spreader. Initial studies used kitty litter as a herbicide substitute but this material proved to be a poor surrogate. Therefore, "formulation blanks" for several commercial herbicides were obtained for the experiments. To eliminate wind as a variable, the experiments were conducted within a large barn. Collection bins from Olympic Horticultural Products (OHP) were used to collect granules. Preliminary research had found these collection bins to be more accurate compared to other collection devices. Granules used in the studies included Freehand G blank, Biodac 10/30, Biodac 12/20, Biodac 20/50, and Verge G blank granules. Walking speed and handle rotation speed were kept constant for all experiments using a metronome. Tests were run with the spreaders positioned to throw granules to the left, center, or right of the applicator with the spreader fully open for all passes. The granules collected in each bin were weighed and ideal swath widths were calculated using a software analysis program: SPREADEREZ.

Granular spreaders typically have a distribution pattern with most granules directly in front of the applicator and tapering off farther away from the applicator (Figure 7). In order to apply a uniform amount over an area, some overlap between passes is required. Overlapping each side of the distribution pattern by 30-35% for a total of 60- 70% overlap, creates the most even application. How close together the passes are, and as a result how much the passes overlap, is called the effective swath width.

Figure 7. A typical pattern of granular distribution from a "belly-grinder" spreader (Left) and the pattern provided by 30 to 35% spreader overlap (Right)



Based on this research we established the following guidelines that are explained in greater detail in a fact sheet to be posted on Dr. Neal's web site: http://www4.ncsu.edu/~jcneal/. By following these guidelines, the coefficient of variability for the granular herbicide distribution may be minimized.

Tips for using Warren T-7 II and Solo 421S spreaders

- Size of the beds matters! Keep nursery beds between 6 and 8 feet wide (for an 8 to 10 ft swath width).
- Center rudder position only. Do not use the spreader held at an angle.
- Spread granules in one direction using parallel passes.

- Maintain consistent walking speed. Use a metronome.
- Maintain consistent cranking speeds. Use a metronome.
- Refill the hopper when the level drops to about 25% full. Don't wait until it runs out.
- Start walking and cranking before opening the hopper.
- If the wind is 5 mph or more, don't make the application. Wait for a calmer day.
- When possible, apply herbicide before spacing out containers to reduce herbicide losses between pots.

Objective 3: Spray applied herbicide safety and efficacy.

The goal of objective 3 was to compare crop injury and herbicide efficacy of dry granular preemergence herbicide applications against liquid preemergence herbicide applications. Generally, liquid / spray applications are more uniform and lower in cost compared to granular formulations. However, liquid / spray applications cause more injury to crops.

Two tests were conducted at the research station beginning in late April 2015. The first test evaluated the efficacy of liquid applications compared to granular applications. The second test evaluated the crop safety of liquid applications compared to granular applications. The tests included four chemical herbicides in both granular and liquid formulations. The herbicide chemicals included: pendimethalin and dimethenamid-P, prodiamine and isozaben, flumioxazin, and indaziflam. One on-farm test was also conducted, beginning in early May, to evaluate liquid and granular applications using pendimethalin and dimethenamid-P. This experiment was repeated in 2016.

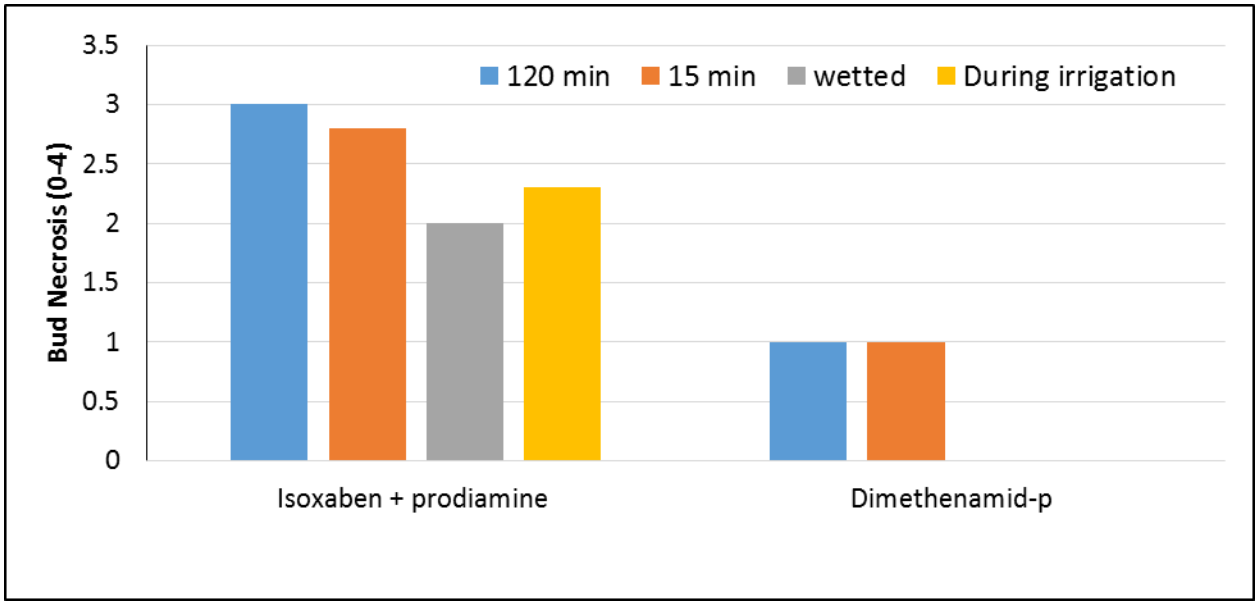
Results from these experiments confirmed that spray applied herbicides provided generally better weed control compared to the same active ingredients applied on granular carriers. However, crop safety with granular herbicides was better than with spray applications. The results of the crop safety experiments are summarized in table 3.

Table 3: Crops with greater injury from spray-applied herbicides compared to the same active ingredients applied on granular carriers.

	Pendimethalin & Dimethenamid-P	Isoxaben & prodiamine	Flumioxazin	Indaziflam
Abelia			X	
Loropetalum			X	X
Chinese holly		X	X	X
Azalea	X		X	
Hydrangea	X	X	na	na
Rose			X	

Separate experiments were conducted to evaluate the potential to mitigate crop injury from spray-applied herbicides by manipulating the treatment to irrigation intervals. Applying preemergence herbicide sprays to pre-wetted foliage or during an irrigation cycle did not mitigate injury for herbicides that cause severe injury to the crop. For example: spray applications of isoxaben + prodiamine cause severe bud necrosis to hydrangea. This injury is reduced but not eliminated by applications to pre-wetted foliage (Figure 8). However, when a herbicide causes mild symptoms, this injury can be mitigated by pre-wetting the foliage before treatment or applying the herbicide during an irrigation cycle (Figure 8). These results support other reports that spray applied herbicides may be a more effective alternative to granular herbicides but care must be taken in product selection.

Figure 8. Severity of bud damage on *Hydrangea macropylla* 'Endless Summer' 13 days after treatment. Herbicides were applied to dry foliage 120 minutes or 15 minutes before irrigation, or to pre-wetted foliage, or during the irrigation cycle. Severity of bud injury was evaluated on a 0 to 4 scale where 1 = slight yellowing, 2 = some tip necrosis, 3 = necrotic buds and 4 = necrotic buds and damage to other foliage.



Objective 4: Outreach

Results were summarized and presented:

- At the Johnston County (NC) Nursery Association meetings, the Northeastern Weed Science Society, and the Weed Science Society of America.
- In a webinar for growers and extension professionals was conducted on April 27th with 147 participants.
- An article was published in the NC Nursery and Landscape Association newsletter.

Fact sheets for each of the major tasks and conclusions were developed and are to be submitted for peer review for publication through NCSU Cooperative Extension. Draft versions of these fact sheets are available on the PI's web site https://weeds.ces.ncsu.edu/cost-effective-weed-control-in-container-nurseries/

Publications:

Harlow, C. D. and J. C. Neal. 2015. Comparison of two weeding strategies in container nurseries. Proc. Northeastern Weed Sci. Soc. 69:35

Neal, J. C., B. LeBlanc, and C. D. Harlow. 2016. Preliminary studies on the germination, early growth and flowering of *Chamaescyce maculata* in containers. Proc Weed Sci Soc. Amer. (#159)
http://wssaabstracts.com/public/38/proceedings.html

Neal, J. C. and C. D. Harlow. 2016. Mitigating PRE herbicide injury in container grown *Hydrangea macrophylla* Proc. Northeast. Plant, Pest, Soils Conf. 1:80 36

Neal, J.C. 2015. All preemergence herbicides injure *Hydrangea macrophylla*. Nursery Notes 49(1):17-21 https://ncnla.memberclicks.net/assets/nln%20january%20february%20march%202015%20web.pdf

Additional outreach:
An Extension IPM grant was received to conduct on-farm demonstrations and field days to educate growers and extension professionals in NC, Virginia and Florida on the principles developed through this project. As part of that extension project, on grower field day was conducted in Pikeville, NC on August 23rd and a second is scheduled in Hickory NC on September 7th.

Results will be published in peer review journals and the NC Nursery and Landscape Association newsletter.

Due to the many unique aspects of outdoor container nursery crop production, the impacts of this research are generally limited to nursery crop production. The principles of sanitation for weed management will be useful to greenhouse crop producers and may have utility for other specialty crop producers who rely heavily on hand-labor for weed control.

PI, Joseph C. Neal, provided overall leadership and coordination, and supervision of project technicians.

PI, Ron Heiniger, provided advice and guidance on objective 2 – herbicide application efficiency.

Project Technicians, Harlow and Barker, conducted the experiments under the direction of Dr. Neal. Harlow conducted research station experiments and on-farm experiments associated with Objective 1. Barker assisted with coordinating on-farm experiments in 2015, growth and fecundity tests, all experiments associated with objective 2, and data analysis. PI and technicians contributed to outreach fact sheet development.

GOALS AND OUTCOMES ACHIEVED

Outcome 1. The goal of the first objective is to document cost advantages of an alternative weed management strategy. Our original goal was to demonstrate strategies to reduce weed control costs by at least 10%. Results of this experiment demonstrated an average cost savings of over 35%. Under certain conditions hand weeding costs may be reduced by as much as 60% compared to current industry practices. Other growers may not experience significant cost savings, but in no study did frequent weeding result in increased labor costs. Thus, growers adopting this sanitation practice may consider it a “risk reduction” strategy with no “down-side”.

Outcome 2. The goal of objective 2 is to improve herbicide application efficiency. Research has demonstrated that the standard method for applying granulated preemergence herbicides in nurseries is inherently inaccurate and imprecise, with up to 250% variation in herbicide deposition between pots. Our experiments confirmed that granular herbicide applications in container nurseries are inherently imprecise. However, through this research we have developed user guidelines that may reduce the variability of herbicide applications. Some strategies are obvious and easily implemented – such as walking at constant speed, avoiding applications in windy conditions, and turning the spreader “crank”-handle at a constant speed. Other user-guidelines will require more effort from growers. In particular—

changing the spreader swath width to between 8 and 10 ft will dramatically improve the uniformity of spread.

Outcome 3. Strategies to mitigate crop injury from spray applications of preemergence herbicides will be investigated. Compared to dry granular formulations, spray applications of herbicides are generally more uniform and lower cost, but more injurious to crops. Spray applied herbicides provided better overall weed control but were more injurious than the same active ingredients applied as dry granules. Crop injury associated with spray-applied herbicides may be mitigated by pre-wetting crop foliage with irrigation before treatment, then irrigating immediately after treatment to prevent foliar absorption of the herbicide. The effectiveness of this strategy is limited to herbicide / crop combinations in which the crop is generally not severely injured by spray applications of the herbicide. This irrigation strategy does not protect plants when the herbicide applied generally causes severe injury to foliage or root growth.

Outcome 4. Produce guidelines and educational materials that will aid growers in adopting these cost-saving strategies. The results from this research have been shared with research and Extension peers at scientific meetings. Results have been shared with growers and Cooperative Extension agents via webinar and presentation at multiple grower meetings of the Johnston County (NC) Nurserymen's Association. Outcomes have been incorporated into extension fact sheets published on the PI's web site. Use metrics for these fact sheets will be monitored.

An additional grant was obtained from Extension IPM to extend the results of these studies within NC and the Southeast Four grower field days are planned, 2 in NC, 1 each in VA and FL.

All results from these experiments will be reported in scientific literature, Cooperative Extension publications, and industry newsletters such as the NC Nursery and Landscape Association's "Nursery Notes". Nursery Notes is distributed to over 1200 nursery and landscape professionals. Educational materials developed though this project will be posted on the NCSU Nursery Crops Extension Portal and site-use metrics will be monitored. Workshops and educational programs promoting these new methodologies will be conducted in conjunction with the NCNLA annual conference, Johnston county nursery association and Blueridge Horticulture Association. Educational programs at the NCNLA annual conferences annually reach over 1000 industry professionals, and the Johnston County Nursery Association and Blue Ridge Horticulture Association are comprised of over 25 member nurseries each. Workshop attendees will be surveyed to determine their current practices and likelihood of adopting new methodologies developed by this research. The methodologies developed through this project will be incorporated in Neal's on-going outreach educational programs and publications beyond the termination of this grant cycle.

Actual change of practice among NC nursery crop producers, as a result of this project, cannot yet be documented. Grower perspectives and inclination to adopt these practices will be assessed at the 2016 grower field days.

Long term adoption will be measured in future industry surveys (after the termination of this project) as part of Neal's on-going Extension Program on weed management in nursery crops.

Our original goal was to demonstrate strategies to reduce weed control costs by at least 10%. Results of this experiment demonstrated an average cost savings of over 35%. Under certain conditions hand weeding costs may be reduced by as much as 60% compared to current industry practices

- Experiments were conducted to demonstrate labor savings of 10 to 60%.

- Granular herbicide application methods were evaluated and guidelines for improved application uniformity were developed
- Data demonstrate that crop injury from spray-applied herbicides can be reduced but not eliminated by managing irrigation cycles.
- Outreach materials were produced to inform peers, Cooperative Extension educators, and growers of these findings.

BENEFICIARIES

Nursery crop producers in NC will directly benefit from this research. Container nursery crop producers throughout the Southeastern US should obtain similar savings if they adopt these procedures.

The most important quantifiable outcome of these research is a demonstration of the potential cost savings associated with frequent hand weeding. Although counter-intuitive to many growers, hand weeding more frequently actually decreased the overall hand weeding costs by an average of 39.9% compared to common grower practice. If only a fraction of growers in the state could adopt this practice

The 2005 green industry economic impact study reports about 36,000 acres of nursery crops are grown in NC, and about 1/3rd of this acreage (~8900 acres) is in container production. Assuming average costs for supplemental hand weeding to be about $2250/acre (reported by Mathers, 2013), and further assuming this procedure can be adopted on 1/3rd of the crop acreage; then the potential savings to NC nursery crop producers would be about $2.7 million annually. Impacts to individual nurseries will vary depending on their current weed control practices and costs.

LESSONS LEARNED

One of the important factors that will influence the success or failure of this project is the “human element”. Informal surveys of the hand-weeding crews at two nurseries provided interesting insights into their perspectives of the hand-weeding strategy. One crew preferred hand weeding only when the pots became “weedy”. They disliked frequent weeding when there were few weeds. At a 2nd nursery, the weeding crew expressed the opposite opinion, disliking the amount of time it required to clean up “weedy pots; preferring to maintain the frequent weeding. Another “human element” is managerial perceptions of the challenges of implementing these recommendations. To fully implement these guidelines there must be a change of philosophy about how labor is allocated within the nursery. Weeding crews must be allowed to continue weed removal and this must be perceived as “an important task”. Also, plant bed spacing will need to be changed to allow for uniform herbicide applications. This is a change of practice that was adopted for other reasons.

Although we encountered several staffing challenges in the first year and a half of this project, we were successful in completing all tasks.

These data illustrated the need for more information about the reproductive biology of weeds in nursery crop production systems. Limited information exists on the rates of germination, early growth and development, flowering or fecundity of the most common weeds of this production system. This information has direct bearing on the successful implementation of cost-effective weed management practices.

We were surprised also by the variability in the incremental costs between nurseries and between years. Even at the same nursery, different “weeding crews” resulted in different costs. Again, this highlights the importance of the “human elements” in crop production systems.

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ADDITIONAL INFORMATION

Outreach fact sheets from this research are available on the PI's web site:
https://weeds.ces.ncsu.edu/cost-effective-weed-control-in-container-nurseries/

PROJECT TITLE: Developing Blueberry Cultivars for Mechanical Harvest

FINAL REPORT

PROJECT SUMMARY

Most blueberries grown in North Carolina are sold fresh, with 50% hand-picked for the fresh market, 25% machine-picked for the fresh market and the remaining 25% machine-picked for processing. Labor to pick blueberries is becoming increasingly difficult to find. Harvest labor is also the biggest annual expense ($6 for every 9 lb. flat) for blueberry growers in producing their crop. Our objective was to determine the machine harvest capability of advanced blueberry selections from the North Carolina State University (NCSU) breeding program, compared to cultivated commercial standards. Methods will include utilizing a mechanical harvester, detecting the percentage of non-blue fruit, soft fruit, ground loss, and determination of post-harvest shelf life. Our findings were published in the annual blueberry proceedings in 2015, and was presented at grower meetings and demonstrated at field days.

The proposed project will increase the competitiveness of North Carolina's approximately 80 blueberry farms. NC has the seventh largest blueberry crop in the US valued at $71 million dollars on about 5700 acres (USDA/NASS, 2013). Blueberry production and demand is also driven by health interest, which has increased worldwide production from 50,000 acres in 1995 to 190,000 acres in 2010. North America remains the market leader producing 57% of the world's fresh blueberries with a projected increase to 1.4 billion pounds produced by 2015 (Mainland, 2013).

The work proposed in this grant application will continue research initiated during a Specialty Crops Research Initiative grant entitled: Advancing Blueberry Production Efficiency by Enabling Mechanical Harvest, Improving Fruit Quality and Safety and Managing Emerging Diseases (2008-2013).

PROJECT APPROACH

The data from the 2014 summer trial was analyzed and presented at the annual North Carolina Blueberry meeting in January 2015. After analyzing the harvest data on the 16 cultivars machine harvested in 2014 and talking with respected blueberry researchers and growers it was determined that because none of those cultivars had all of the traits needed to be a machine harvested commercial cultivar that they would not be picked in 2015. However, 2 of the cultivars were used as breeding parents. All of the bushes in the mechanical harvest trial were pruned in February 2015 to shape the bushes for machine harvest. In the spring of 2015 the plants were walked to determine flower opening and ripe fruit dates. In May and June of 2015 16 cultivars were harvested by machine. The weather was very favorable for harvesting this summer. Data similar to last year was collected with one exception. Ms. M Schaber, the former PI of the project, was able to purchase fruit sorting equipment from another grant. We upgraded a building into a commercial packing shed similar to blueberry growers. Fruit was harvested and cooled. Once cooled to 65 or lower it was put on a conveyor belt that moved the fruit through a blower to remove leaf litter, a soft sorter to remove soft bruised fruit or over ripe fruit, and a color sorter that removed non blue fruit.

During the summer of 2015, another 15 advanced blueberry selections along with control cultivar Reveille were mechanically harvested using a Little Blue harvester. Data collected included total yield

and fruit firmness, weight, size and post-harvest longevity. Data were statistically analyzed. One accession, NC4992, was determined to be significantly different from the control cultivar Reveille and other accessions in the experiment. This accession, has the potential of being released as cultivar amenable to mechanical harvest.

Overall the project was more relevant to specialty crops and in particular blueberry production industry.

The workers at the Horticultural Crops Research Station in Castle Hayne were invaluable to this project. They made sure that the plots were sprayed weekly for insects and diseases to mimic a commercial grower location. They also assisted with harvest by driving the tractor that pulled the Little Blue Harvester by BEI. They helped to build the packing shed and installation of the new fruit sorting line. The sorting and packing line was designed to mimic near-to growers' conditions. This helped us to measure fruit firmness related traits more accurately than before.

GOALS AND OUTCOMES ACHIEVED

The goal of this project was to determine the machine harvest capability of the 16 cultivars trialed this year. Overall 2015 was a great blueberry season because of the small amount of rain. Little rainfall decreased the amount of disease pressure and fruit softness due to water as well as causing fewer cracks in the skin of the fruit. From the raw data there appears to be a stand out cultivar (NC 4992) that has all of the characteristics a grower needs in a variety to mechanically harvest (high yield, medium fruit size, firmness, and good storage qualities). Besides having the fruit pick well with a machine it needs to taste good to consumers. The data were analyzed with SAS/STAT® software.

The data illustrates the importance of continuing to harvest new selections from the breeding program using a machine. Analysis indicates that the cultivars trialed possess some of the traits needed to be a commercial mechanical harvested variety but not all of them and very few cultivars have all of them. Additionally, a mechanically harvested berry is only as good as a consumer thinks it is. In addition to the other data collected it is important to continue to select for flavor as well. This data will ultimately help breeders make informed decisions regarding the release of new commercial cultivars. The identified promising accession through this research can be used as parent to further exploit the genetic mechanism underlying firmness trait. For instance, to pursue this project in future we are planning to understand the genetic bases of firmness by incorporating genomic data. This can be achieved by creating segregating populations in which progenies segregate for firmness and other fruit quality related traits. These segregating populations can be used to map the genes that are playing a role in fruit quality.

In 2015 we were able to construct a packing shed and a fruit soft sorter in our experimental field. By using a mechanical harvester and fruit sorter we mimicked grower's conditions. The data that were collected in 2015 represented a more realistic measurement and which were closer to what actually happens in a commercial field. In 2014 we did not have this system and all fruit quality related traits and yield data were based on a cup of fruit that we harvested for each cultivar in that year.

The data was analyzed by SAS software and herein is a snap shot of average fruit softness after storage in our mechanical harvest trial (please see additional information section). We measured 32 different variables in 2015 among which fruit firmness, total harvested fruit weight, amount of fruit loss, and softness after storage were the most important attributes of fruit for mechanical harvest.

By conducting the proposed experiments, we were able to identify one promising accession with least amount of soft fruits that has the potential of being released as a cultivar amenable to mechanical harvest.

BENEFICIARIES

All highbush blueberry growers in the country from FL, GA, NC in the south to OR, and CA in the west will eventually benefit from the results of this research if our potential cultivar performs adequately in their climatic conditions.

Fruit softness after cold storage was among the variables that we measured. NC 4992 was the only accession that outperformed our control cultivar, Reveille. Only 10.5% of the fruits of NC 4992 were soft vs. Reveille with a good reputation as being firm at 22.1% soft.

LESSONS LEARNED

By performing this experiment, we gained experience to rethink about the design of the future experiments. For instance, the length of each row, plant spacing and the minimum distance between two adjacent blocks and the spaces in both ends of the field for the harvester to be able to make a turn are detrimental to collect data more accurately. Due to the length of a blueberry breeding program, execution of an experiment like this requires a long-term planning. Therefore, in future we will improve the design of our experiment.

We expected to see more superior cultivars over the control cultivar. This was not due to the inappropriate design of the experiment or the way we conducted the experiment. This indicates prior to make replicated trials we need to be more stringent in selection of promising accessions that we are supposed to test in this kind of experiments.

To conduct this kind of experiment one needs to know the type of mechanical harvester that is going to be used in his/her experiment well in advance to design the experiment accordingly. Precision measurement is critical to have reliable data, therefore having state of the art equipment for fruit quality analysis and firmness measurement is critical.

We learned that it is much more efficient to use a mechanical harvester to collect data pertain to firmness, than harvesting the fruit by hand and then measuring the firmness. This way we can mimic the grower's conditions and collect a more realistic data. The length of row in which blueberry plants are planted to be trialed should be long enough to allow mechanical harvester collect enough fruit for analysis. There also need to be enough space between the cultivars on the same row to allow technicians have time to clean the machine between each plots.

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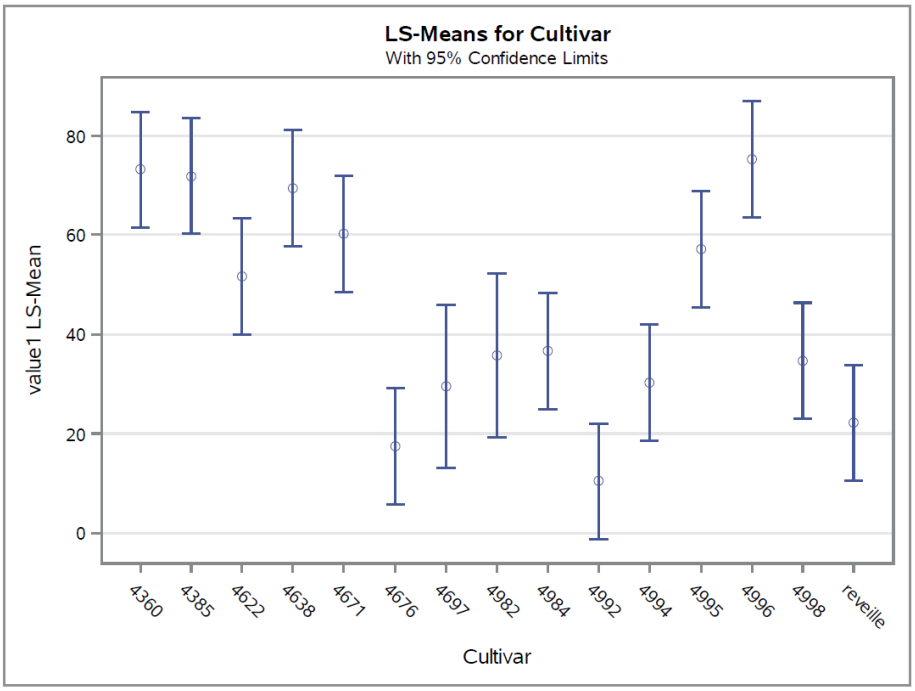
ADDITIONAL INFORMATION

The following graph depicts the percent soft fruit after storage in the cold room for one week. Tukey Kramer grouping (data not shown) indicated that NC 4992 is significantly different from the rest of accessions in the experiment.



PROJECT TITLE: Developing The NC Pecan Industry

FINAL REPORT

PROJECT SUMMARY

Pecans have been grown for decades in North Carolina. Historically, pecans were planted on family farms across eastern NC and with minimal input but provided income. However, with changes in the international marketing and increasing demand for pecans, along with the interest in local food, the economic opportunity for North Carolina pecan growers to commercially plant and intensively manage pecan orchards is significant for both retail and wholesale markets. New orchards have been planted due to an interest in growing pecans as a new venture, part of a diversified farming operation, or as a source of income for retirement 8-10 years down the road. However, in many orchards there are some major issues, due to a lack of knowledge by those planting the orchard that seriously decreases the profitability and long-term economic sustainability. Educational programs have been provided in the past 10 years to address this lack of knowledge. This project was designed to help support the present and develop the future pecan industry with educational training and resources for growers. The need and direction of this proposal and activities were developed by NCSU campus and county extension faculty, the NC Pecan Growers Association, interested pecan growers and national pecan expertise. Educational programs were developed and presented to commercial growers through state annual meetings, regional meetings and field tours in addition to the production of educational videos and web-based and printed publications.

The specific objectives of this proposal were:
- To design, develop and shoot educational videos on pecan orchard establishment and maintenance in North Carolina.
- To revise and print publications on successfully growing pecans in North Carolina. The publications would also be developed for web-based distribution.
- To provide county, regional and state-wide pecan programs on in-depth pecan production, through the local Cooperative Extension Centers and the NC Pecan Growers Association.
- To fund and bring in out-of-state pecan expertise to speak to the growers/industry at the NC Pecan Growers Annual Meetings.
- To conduct on-farm demonstration/research trials on issues of importance to NC pecan growers.

PROJECT APPROACH

This project was projected to start in January 2014 with a significant amount of work proposed in the first 4 months. However, funding was not available until Spring 2015 which delayed certain aspects of the project since this project is growing season dependent. However, all of the Activities of this project were accomplished over the life of this grant with the 6 month no-cost extension. Educational programs were coordinated and conducted primarily with the NC Pecan Growers with the most recent program being the NC Pecan Growers Annual meeting in Greenville in March 2016 with 130 people in attendance, the largest grower attendance in the history of this organization. In addition, in October 2015 approximately 600 second graders in Columbus County were educated on growing pecans in NC and the healthy benefits of including pecans in a healthy diet cooperatively with the NC Museum of Natural Sciences- Whiteville and the NC Pecan Growers Association. Three educational videos on planting and pruning pecan tree of varying ages a well as the review, update and printing of the "Growing Pecans in NC" publication and the "North Carolina Production Guide for Smaller Orchard Plantings" was achieved. Research/demonstration trials were also established at 5 locations of new

pecan varieties, and rootstocks, for NC pecan growers with the potential for increased disease resistance.

All aspects of this proposal were conducted to make information related to pecan information available in multiple formats for NC growers. The goal of this project is to maximize orchard productivity and profitability and increase orchard life and economic sustainability. Recommendations and notices of new educational resources are being presented at grower meetings, newsletter articles, and field tours of these plantings.

GOALS AND OUTCOMES ACHIEVED

The projects that this proposal conducted were:

- **Pecan Production Related Videos**- Three videos were developed for NC pecan growers on designing, planting and managing pecan orchards. These will be posted to the NC Pecan Growers website, the NCSU Horticultural Science website and the NCSU You Tube channel. The videos developed were: "Planting Pecan Trees", "Pruning Pecan Trees", and "Managing the Mature Pecan Orchard".
- **Growing Pecans in North Carolina Publication**- This widely distributed publication was first printed in 1994 with several printings since that time. It was expanded, edited, updated and reprinted for hard copy as well as formatted for use on-line. In addition, to benefit smaller pecan growers a publication entitled "North Carolina Production Guide for Smaller Orchard Plantings" was written and available as a web-based publication and in hard copy.
- **Out-of-State Educational Speakers**- Bringing in experts from outside the region to speak at grower meetings is a very useful tool. Experts from the USDA (Texas A&M, College Station, TX), a Texas commercial grower and UGA (Tifton, GA) who are actively involved in pecan research were invited to participate in educational programs in NC.
- **Grower Educational Programs**- Multiple educational programs at the county, region and state level for growers have been conducted on successfully growing pecans in NC. In addition to the annual meetings and field days of the NC Pecan Growers, regional county based programs were also utilized. The meetings were coordinated by the county extension staff and presented by NCSU campus faculty. The Annual Meetings of the NC Pecan Growers had attendance in excess of 100 annually). The Field Day conducted in 2015 in Sampson County had grower attendance in excess of 60. Regional pecan programs were also conducted across the state (Rockingham County, Chowan County, Franklin County, Wayne, Duplin, Johnston and Wilson Counties) with attendance totaling more than 150 for these programs
- **On-Farm Research and Demonstration Trials**- In on-going discussions with the NC Pecan Growers and input from Dr. LJ Grauke, the USDA Pecan Breeder at TAMUS in Texas, a long-term pecan variety and rootstock trial was designed. Trees were ordered of varieties and rootstocks suggested for NC by Dr. Grauke and Dr. Lenny Wells, UGA, and planted at four grower locations in eastern NC and at the Sandhills Research Station in Jackson Springs, NC to determine the long-term survival, productivity and nut quality of eight cultivars and three rootstocks.

BENEFICIARIES

Results and information generated from this project will benefit all the pecan growers currently in North Carolina in addition to new growers. There will be significant financial and social benefits from increasing the sustainability of the production systems as well and providing a greater supply of pecans for NC citizens. With an estimated current economic impact of $10 million annually, it is not

inconceivable to see this number double in the next 10-15 years if pecan production increased annually by a conservative 10%. In addition, many new orchards have yet to start production and with new orchards that are established this number would drastically increase. There is also a trend for new pecan growers to emerge because of interest in local foods and associated profitability which would further increase the value of the pecan industry in NC.

Pecan production is a long-term venture and the components of this educational proposal are long term (1 0+ years) in nature. The short-term goals of this project are to educate growers in NC on proper orchard design, implementation and management, which is very difficult to measure. However, grower attendance at educational meetings is one way to gauge this as well using pre and post meeting questionnaires. Meeting attendance has increased significantly over the past two years and when administered, those in attendance stated that their knowledge of pecan production increased significantly from these programs. The medium term goals, is easier to quantify, and new orchards are being established and current orchards are being expanded, in addition to evaluating the orchard practices implemented. This is evaluated by surveying growers in attendance at meetings on the size, or number of trees, of their operation and from surveying the horticultural extension agents for pecan orchard establishment and management in their respective counties. The ultimate long-term goal of this project is to increase the pecan production in North Carolina and maximize the profit potential for the growers involved in this business. In addition, there are many benefits to eating pecans on a regular basis and this could/would increase the health of those consumers that regularly eat this NC product.

LESSONS LEARNED

Although this project is composed of many individual educational and demonstration components, they are all interlinked as part of a long-term project. It is exciting to see a demand for educational programs and individual consultation, educational material developed and accessed by clientele and new orchards being established. However, the ultimate impact of this project is orchard survival and productivity which will be initially evident over the next 5-10 years. All of the goals of this project were achieved (Harvest video is currently being edited to its final form) and have provided a firm educational basis on which the NC pecan industry can build.

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ADDITIONAL INFORMATION

North Carolina Production Guide for Smaller Orchard Plantings
http://content.ces.ncsu.edu/north-carolina-production-guide-for-smaller-orchard-plantings

Growing Pecans in North Carolina
http://content.ces.ncsu.edu/growing-pecans-in-north-carolina

PROJECT TITLE: Expanding NC Markets Using Seedless Cucumbers

FINAL REPORT

PROJECT SUMMARY

Seedless cucumbers can be produced using a new trait 'parthenocarpy' and are higher quality than traditional seeded cucumbers. The objective of this study is to develop methods for producing seedless (parthenocarpic) pickling cucumbers in NC for improved yield for grower profitability, and for improved quality products for processors. Seedless varieties will be tested at multiple planting densities at NCDA/NCSU research stations over several environments for yield and quality. Potential new varieties from the NCSU breeding program and seed companies will also be evaluated for yield and quality under varied growing conditions. Fruit quality for processing will be assessed in brining evaluations with Mt. Olive Pickle Company. Another objective of this study will be determining the economics as it relates to use of more costly parthenocarpic seed at various seeding rates in relation to yield.

Seedless cucumbers can be cut more easily on processing machines, without the usual damage from seeds tearing the flesh when processed. A major potential advantage of seedless cucumbers is higher yield, an important consideration since growers often choose other crops that are easier or more profitable to produce.

PROJECT APPROACH

Three studies with parthenocarpic pickling cucumbers were run at the Cunningham Research Station in Kinston, NC in the summer of 2014 and 2015. The studies are described below.

Parthenocarpic Pickling Density, Once-Over or Mechanical Harvest

The objective of this study is to determine the effect of density, harvest stage, and variety on parthenocarpic pickling cucumber yield and quality in a once-over (mechanical) harvest system.

Two varieties were evaluated in this study (Puccini from RijkZwaan and Merengue from Seminis). The planting densities of 10,000, 20,000, 40,000, 80,000 and 160,000 plants per acre were evaluated at both a spring and summer planting in 2014. In 2015, the densities of 60,000, 100,000, and 120,000 plants per acre were added to the list for evaluation. This trial was harvested at three dates to determine the effect of earliness on yield. The experiment was a split-plot in a randomized complete block with three replications.

We used 4-row plots, with the center 2 rows harvested for data collection. The border rows allowed simulation of competition in a normal field condition. The plots were 10’ long with 30” row centers.

All data were collected at harvest. Vines were counted and percentages of vines with 0, 1, or 2 or more fruit were noted. Fruit from each plot were graded into No. 1, No. 2, No. 3, No. 4 (oversize), and culls (crooked or nubbined). Fruit from each grade were weighed and counted. In 2015, fruit from each grade were also counted. Quality of fruit was also evaluated. The length-diameter ratio of five No. 2 fruit was measured, and the fruit firmness of three No. 3 fruit were measured for each harvest.

In 2014, the highest density resulted in mostly fruitless plants. The density of 80,000 PPA was near-optimum for each harvest date, while the density of 40,000 PPA yields were slightly lower. Fruit quality was affected by harvest date. The latest harvest yielded less desirable length to diameter ratios and more mature fruit. In 2015, we found similar results. The higher densities yielded more fruitless plants. The last two harvest stages resulted in the greatest yields. The optimum density for yield ranged from 40,000 to 100,000 plants per acre depending on cultivar, harvest stage, and season. The economic analysis for both years is in progress.

An overview of the 2014 experiment was presented to growers and industry representatives at the Southeast Vegetable and Fruit Expo (cucumber session) in Myrtle Beach SC in December 2014. An overview of both the 2014 and 2015 experiments were presented at the Pickle Packers International meeting (pickling cucumber improvement session) in Fort Worth, TX in October 2015.

Optimum planting densities for once-over harvest will be determined with collected data and economic analysis.

Parthenocarpic Pickling Density, Multiharvest or Hand Picked

The objective of this study is to evaluate the effect of planting density and variety on yield of parthenocarpic pickling cucumbers on yield and quality in a multiple/hand-picked system.

Two varieties were evaluated in this study (Puccini from RijkZwaan and Merengue from Seminis). The planting densities of 5,000, 10,000, 20,000, 40,000, and 80,000 plants per acre were evaluated at both a spring and summer plantings grown using a bare-ground system. In 2015, the planting densities of 30,000, 50,000, and 60,000 plants per acre were added to the list and evaluated. This trial was harvested 8 times for the spring planting and 6 times for the summer planting.

The plots were 3 rows from which the center row was harvested for data collection. Again, the border rows simulated field production conditions. The rows were 20’ long with rows on 30” centers.

In 2015, the plots were planted on black plastic mulch in the spring and white plastic mulch in the summer.

All data were collected at harvest. Each plot’s harvest was graded into No. 1, No. 2, No. 3, No. 4 (oversize), and culls (crooked or nubbined). These categories were then weighed and counted. Quality of fruit was also evaluated. The length-diameter ratio of five No. 2 fruit was measured and averaged, and the fruit firmness of three No. 3 fruit was measured and averaged at 3 separate harvests. Data are being analyzed.

Parthenocarpic Pickling Cucumber Variety Trial

The objective of this study is to evaluate the effect of parthenocarpic pickling cucumber variety on yield and quality of fruit for both fresh market and pickling purposes.

The trial had 17 cultivars of parthenocarpic pickling cucumbers from RijkZwaan, Bejo Seeds, Nunhems, HortAg, US AgriSeeds, Seminis, and NC State that were evaluated for yield and quality, in 2014. This year, 26 varieties were evaluated. These varieties were planted at a spring and summer date. There were three replications per variety. The plots were 20' long, with one row on 60" centers.

In 2015, the variety trial was planted on black plastic mulch in the spring and white plastic mulch in the summer.

In 2014, the spring planting was harvested 8 times and the summer planting was harvested 6 times. In 2015, there were 8 harvests in both seasons. The data were collected at harvest. Plot yield was graded into No. 1, No. 2, No. 3, No. 4 (oversize), and misshapen culls and the categories were weighed. The length-diameter ratio of five No. 2 fruit was measured and averaged, and the fruit firmness of three No. 3 fruit was measured and averaged at 3 separate harvests. At those three harvests, the 17 or 26 varieties were bagged in burlap sacks, labeled and sent to Mt. Olive to be brined.

On October 30, 2014, the spring harvest of the 17 varieties was evaluated at Mt. Olive for brined quality. The same event occurred on November 10, 2015 for the spring harvest of 26 varieties.

Drs. Schultheis and Wehner have provided planning and operation of field trials. Prof. Bullen ran the economic analysis in the fall of 2015. Ms. Arteman has carried out the field trials and coordinated the field crew.

GOALS AND OUTCOMES ACHIEVED

- Run experiments on once-over and multiple-harvest systems for parthenocarpic cucumbers. The experiments had 2 years (2014, 2015), 2 seasons (spring, summer), 8 densities, 2 varieties, 6 harvests (3 stages for once-over), and 3 replications.

- The project has finished as scheduled. Economic analysis is completed. The graduate student will be publishing several journal articles. These were our original goals.

- Industry has increased the acres planted to seedless cucumbers, and is at 15% of total this year.

- We determined the optimum planting density for production of parthenocarpic cucumbers for once-over harvest, and for multiple harvest. We also identified cultivars that performed well in North Carolina production systems, including brining.

BENEFICIARIES

Beneficiaries included cucumber growers, pickle processing companies, and seed companies.

Optimum density for once-over harvest is 60,000 to 80,000 plants/A; optimum density for once-over harvest is 20,000 to 40,000 plants/A; Puccini was a good variety to use in North Carolina.

LESSONS LEARNED

Weather was a problem for the spring planting of 2014, but cultural management improvements were made to improve success in 2015.

Weather was a problem for the spring planting, causing stand problems in 2014. We relied more strongly on the two studies conducted in 2015 to more accurately reflect the goals and outcomes of the studies.

More attention to production details was given to 2015 studies. Use of raised beds was incorporated into the 2015 once-over harvest studies to alleviate flooding caused by heavy rainfalls. In addition, black and white plastic mulch were used to optimize production practices for the multiple harvest studies.

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PROJECT TITLE: Exploring Stevia for Western North Carolina

FINAL REPORT

PROJECT SUMMARY

Stevia *(Stevia rebaudiana)* is an increasingly popular natural sweetener that has been embraced by health conscious consumers around the world. Presently, most stevia is grown in China, India, and Vietnam. In recent years, however, several large corporations have begun production of stevia in the United States, including eastern North Carolina. There are reasons to believe that there could be benefits to growing stevia in western North Carolina, both production and final product-wise. This project explored the feasibility of growing stevia commercially in western North Carolina.

The United States consumes roughly 65% of the global market for stevia. As this market expands, consumer and practitioner concerns about stevia's traceability and authenticity will emerge consistent with established trends in other adulterated ingredient scares (e.g., melamine, DEG, ethoxyquin). Currently 80% of stevia for sweetener markets is produced in China, which has experienced myriad problems with quality, authenticity, and especially purity. This project is in line with wider NC rural economic development efforts to add value to locally-sourced specialty crops, e.g., the Golden LEAF Foundation-sponsored Blue Ridge Naturally branding project (http:/fwww.blueridgenaturally.org). which can provide traceability, purity, and regional branding benefits to all WNC-grown stevia and stevia extracts.

Little was known about how stevia would produce in western North Carolina. How the plant grows. how many leaf cuttings per year can be taken, yields, disease and insect challenges, and whether the plant overwinters and how these factors affect the quality and sweetness of the raw material was unknown.

Dr. David Shew and Dr. Reberg-Horton at NC State University collaborated on stevia research in eastern North Carolina. They were very supportive of this complimentary project in the western part of the state which might have benefits due to climate and soils.

PROJECT APPROACH

The overall scope of the project was to determine if stevia can be grown commercially in the mountains of western North Carolina. It was determined that the primary issues were overwintering capabilities of the plants, weed control, and maximizing yield. Two field trials were conducted at the Mountain Research Station in Waynesville, NC in 2014 and 2015. The 2014 field study was a randomized split-split plot design with stevia planted in double rows on raised beds on five foot centers with drip irrigation. The main treatments were black plastic mulch, white plastic mulch. and bare ground. Sub-plots were three in-row plant populations of 6", 12" and 18". The sub-sub plots were a one-time harvest compared to two harvests per season. There were four replications.

Transplants for the field studies were grown by Sweet Green Fields, a private company that contracts with growers in North Carolina, South Carolina and Georgia. Transplants were planted on June 6, 2014 using a water wheel transplanter. Data were collected throughout the season on plant growth, harvest timing, and total yields including fresh and dried weight, and disease and insect pressure. Plants were watered and fertilized as needed, and weeds managed manually. Fertilizer

recommendations were provided by Dr. David Shew and Dr. Reberg-Horton at NC State University who were collaborating on stevia research in eastern North Carolina.

Specific criteria were developed to decipher optimal harvest timing in con junction with industry standards. The leaves and stems were cut at 6" above the ground to ensure a second flush of growth. The twice over harvest plot treatments were harvested, all plots at the same time, on July 22nd and September 4th. The once over harvest plot treatments were harvested when each individual plot had 15% of the plants within at the flower button stage; this occurred in late July through early August fresh weights were taken, and a subsample was collected to be dried and analyzed.

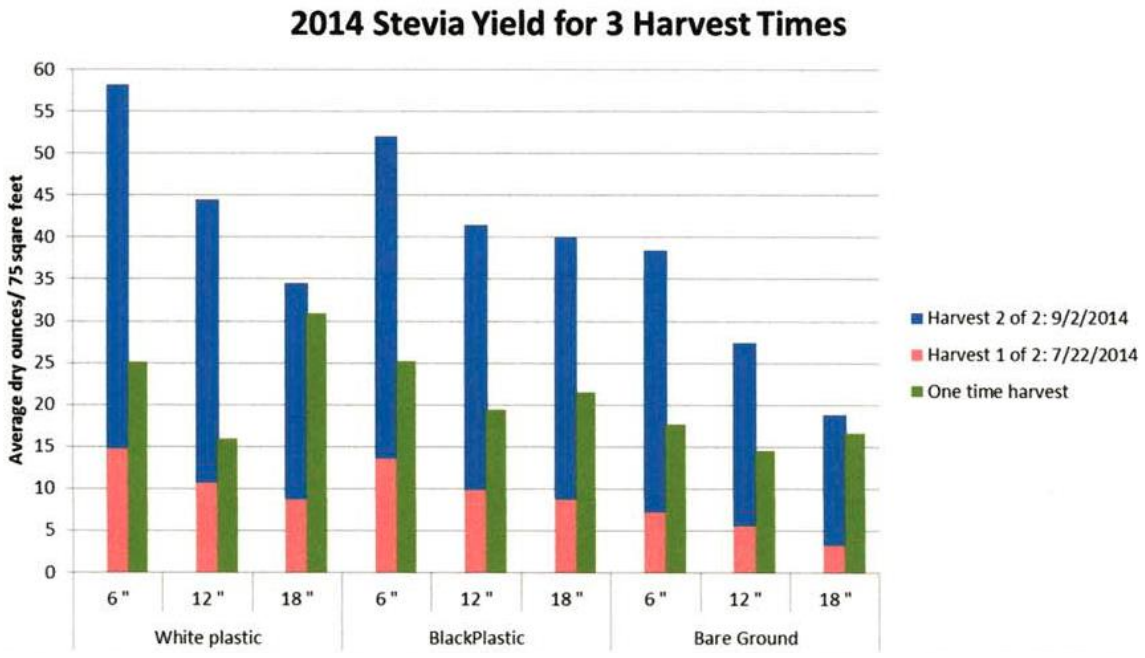
As this project evolved, it became clear that one of the most important factors of economic concern is the overwintering capabilities of this crop. In order to increase the chances of survival, straw mulch was applied to the plots in mid- November. By late April, there were no signs of life and the field was set to be tilled under. After removing the plastic and straw mulch on June 1. We noted that some plants were beginning to sprout The plots that had been mulched with black or white plastic showed 17% survivability. the bare ground plots exhibited no regrowth.

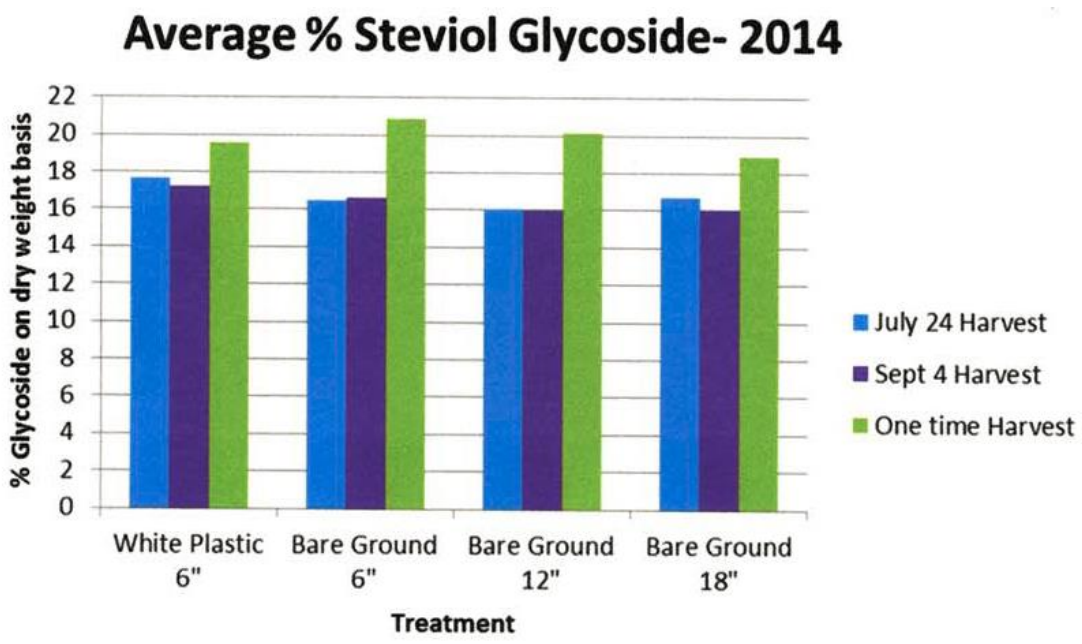
The 2015 field study was supposed to be a replicate of the 2014 field study but due to high grower demand and a short supply of stevia transplanted we were forced to modify our study. After consul ting with our Raleigh based colleagues, the researcher and field man at Sweet Green Fields we chose to compare bare ground plots with 6", 12" and 18" in-row spacings with white plastic mulch with 6" spacing (main plots) and two harvests to three harvests (sub plots) with four replications. Transplanting took place on May 20th for the bare ground plots and June 1st for the white plastic mulch plots.

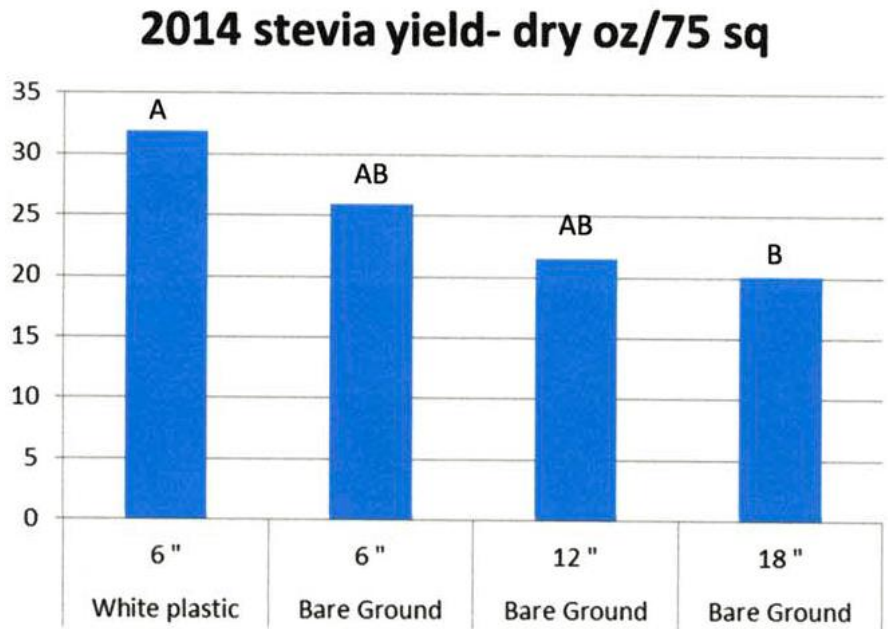
The field was irrigated, fertilized, watered, and scouted weekly for presence of insects and disease. In early July, Septoria leaf spot was observed and confirmed by the NCSU plant Disease and Insect Clinic. The initial infection was minimal but the outbreak soon affected all plants in the field. We learned that many stevia fields i n the Southeast were infected with the disease that year and that it likely originated on the seedlings in the greenhouse. As stevia is a new crop in the region, there was not a management protocol, so a rapid course of action was not an option.

In the first year of the study, two harvests were conducted and we deduced that we could probably have obtained a third harvest. This was the plan for 2015, but plant growth was much slower than in 2014 and with the compounding factors of Septoria and a damaging wind storm; we were only able to conduct one harvest. All plots were harvested on August 24th when 15% of the plants were i n the button stage of flower. Fresh weights were recorded and subsamples were dried and sent to be analyzed for steviol glycosides.

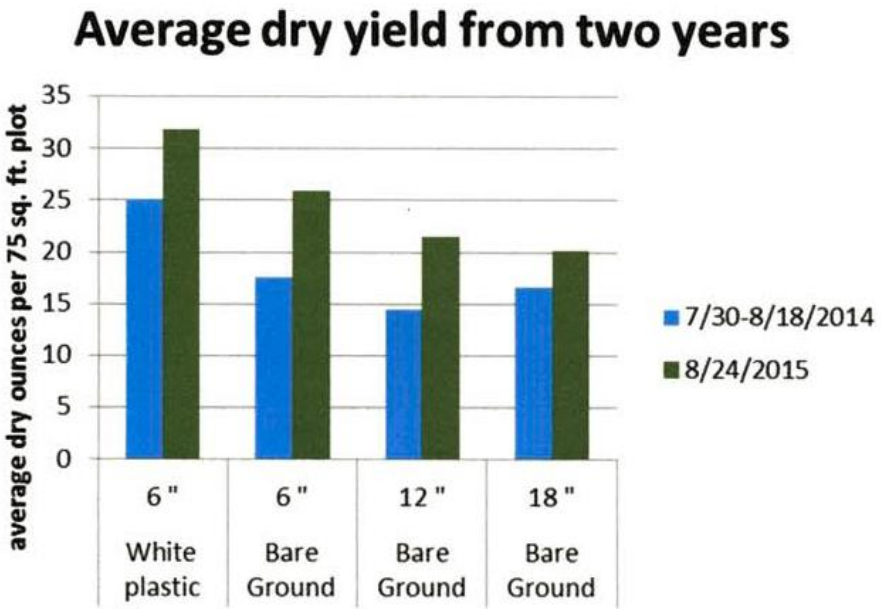
In 2014 stevia biomass yields were significantly increased by utilizing both black and white plastic mulch and the closest in-row spacing of 6 inches compared to the bare ground treatment and the two wider spacings of 12 and 18 inches. No difference was detected between the two plastic types or between the two wider spacings. The double cutting produced almost twice the biomass yield of a single harvest The stevia glycosides were not affected by mulch or plant spacing. Plants harvested one time per season, however, had significantly more glycosides per unit dry weight than plants harvested twice per season.


2014 Stevia Yield for 3 Harvest Times
Average dry ounces/ 75 sqare feet
60
55
50
45
40
35
30
25
20
15
10
5
0
6 "
12 "
18 "
6 "
12 "
18 "
6 "
12 "
18 "
White plastic
BlackPlastic
Bare Ground
Harvest 2 of 2: 9/2/2014
Harvest 1 of 2: 7/22/2014
One time harvest


Average % Steviol Glycoside- 2014
% Glycoside on dry weight basis
22
20
18
16
14
12
10
8
6
4
2
0
White Plastic 6"
Bare Ground 6"
Bare Ground 12"
Bare Ground 18"
Treatment
July 24 Harvest
Sept 4 Harvest
One time Harvest



The plants grew much slower in 2015 than in 2014 and reached optimal once over harvest stage, button stage of flower, too late for there to be multiple harvests. Because of this the first and only harvest in 2015 occurred on August 24. Comparatively, the once over harvest dates in 2014 were July 30 to August 18. The once over harvests in 2015 harvest yields were larger than in 2014. Because of the heavy disease pressure, glycoside results from 2015 are questionable and not reported here.



Yields from both years were highest in the white plastic mulch with 6" in-row spacing treatments. That treatment was not significantly different from the 6" bare ground treatment in 2015, but the labor needed to keep the bare ground plots clean was excessive and would not be cost effective without herbicides which are not currently labeled for use in North Carolina. The hypothesis was that disease pressure would be less in western NC than eastern NC. In 2014 there was no disease present, but in 2015 Septoria leaf spot affected all plants. Currently, there are no fungicides approved for use on stevia in NC. In 2014, multiple harvests resulted in higher overall yields but lower glycoside content. In

2015, plants grew too slowly to allow for multiple harvests, but the once over harvest was greater than for 2014.

The highest yield obtained in this study was 58 oz. of dry material per 75 square feet. That translates, roughly into 2,105 dried pounds per acre. This is similar to yields reported from some other research studies (Kansas State), but very low compared to commercial yield reports. Currently, average yields reported fall between 5,500-8,000 pounds per acre with organic production in the lower range. Prices for conventional production average about $0.26 per lb and organic production is $0.34 per lb. Using those figures, reported commercial production would yield gross returns of $1,430 to $2,080 per acre whereas yields extrapolated from our research would only yield gross returns of about $547 per acre.

Our objective was to determine if stevia could be grown commercially in Western North Carolina. With the current germplasm available, our conclusion is that stevia would not be economically viable for large-scale, wholesale production to sell to a manufacturer. There is, however, a local market for direct sales of stevia to small natural product manufacturers. There is also the opportunity for farmers to make their own value-added products with stevia, including extracts and teas. The yields we obtained in this study would be adequate for those purposes.

Our field trials showed that stevia can be grown in western NC but more research needs to be conducted before it becomes a viable crop in this region. Research is continuing in the eastern part of the state to manage disease, control weeds, increase yields, and monitor overwintering capabilities.

There is also interest in developing stevia further. Much of the stevia research and development lines developed unless they are contracted to grow for those companies. We are now in communication with a company that is interested in us breeding stevia and creating improved varieties that will be more readily available to growers. With Dr. Luping Qu, an experienced breeder on our staff, they are interested in having us do that work. Those discussions are currently underway.

The stevia research plots were included in field days and workshops at the Mountain Research Station in Waynesville, NC in both years. At the Alternative Crops and Organics Research Highlights Tour on August 20, 2015, participants were surveyed before and after the event Results show that before the tour, 93% of the attendees knew little or nothing about growing stevia. After the tour 73% stated that they had a moderate understanding or better of how to grow stevia.

The Exploring Stevia for Western North Carolina web page has pictures of the trial, yield data, and project information for interested growers- http:/fwww.ces.ncsu.edu/fletcherjprograms/herbs/Steviafindex.html. Photo documentation was taken regularly to be used to educate growers at future meetings and informational sessions. Growers and Extension Agents have been informed of this project though social media and personal communications as well as through program brochures. Thousands of people have been reached through these means.

Our project and results were displayed at the North Carolina Vegetable Growers Association Winter Meeting in Myrtle Beach, SC. At least 300 people were reached.

Sweet Green Fields, a stevia producer and manufacturer, became a partner after the initiation of the project They provided stevia transplants so we had commercial grade material that could be directly comparable with stevia produced in eastern North Carolina, north Georgia, and other areas. They

also did the laboratory analysis so we could make direct comparisons with other commercial production.

GOALS AND OUTCOMES ACHIEVED

1) To determine if stevia can be grown in western NC (GOAL), stevia was grown in two field trials to compare yields and glycoside contents with stevia grown in eastern North Carolina (BENCHMARK). Data were collected on growth and leaf yield and analyzed (PERFORMANCE MEASURE). Yields of 3,200 dried pounds per acre would be considered a success (TARGET). Yields from the best treatments were only equivalent to 2,105 dried pounds per acre, which was only 65% of the target.

2) To gather information on potential insect and disease pressures for stevia production in western North Carolina (GOAL), we monitored and documented those found in the field trials. The number of pests and diseases (PERFORMANCE MEASURE) were compared to what is obtained with stevia in eastern North Carolina (BENCHMARK). Levels of damage less to or equal that would be considered acceptable (TARGET). In the first year, there was no disease and insect pressure and we exceeded our target, but in the second year Septoria leaf blight caused extensive damage to the foliage, reducing product quality.

3) Stevia must contain high levels of glycosides to be useful as a sweetener and nutraceutical product (GOAL). Leaves were harvested, dried, analyzed for glycosides (PERFORMANCE MEASURE) and compared to industry standards (BENCHMARK). A product with glycosides as high or higher than the industry standard would be considered a success (TARGET). In the first year, glycoside levels met industry standards, but the leaf blight in year two damaged the foliage extensively and prevented any meaningful laboratory analysis.

4) Growers must see successful production of stevia before they will plant it themselves (GOAL). This study was to help growers decide if stevia is appropriate for their conditions currently producing (BENCHMARK). Results from this study was presented at two field days and included on a project webpage on http:/fwww.ces.ncsu.edu/fletcherjprograms/herbs/Steviafindex.html. Surveys concerning information learned were to be offered at the field days and counts of hits on the webpage gathered (PERFORMANCE MEASURE). In the survey given before the 2015 tour, 93% of the attendees knew little or nothing about growing stevia. After the tour 73% stated that they had a moderate understanding or better of how to grow stevia. We estimate that based on physical attendance at field days and private visits, website, blog, and twitter views, and email and phone conversations that more than 5,000 people are more knowledgeable about stevia production (TARGET). This is less than the original target of 8,000 people, but the original company, MelStevia, that triggered grower interest in the region, pulled out of the area about the same time that the project started. This reduced interest and created some skepticism about growers. Sweet Green Fields is the company that is working with growers in eastern North Carolina but has had little public exposure in the western part of the state.

A long-term outcome measure for the project was not stated but logically would be how many growers grow stevia on a commercial scale in western North Carolina. The research results do not support large-scale commercial production, but small-scale commercial production is a reasonable option that we will attempt to monitor in coming years.

Comparison of actual accomplishments with the goals established for the reporting period:

1. To determine if stevia can be grown in western North Carolina, two field trials were conducted that revealed that stevia can be grown in the region but yields were 65% less than the target and winter survivability was only 17%.

2. To gather information on potential insect and disease pressure, insects and diseases were monitored in both field trials. There was no insect pressure, but Septoria leaf blight was severe in the second year study. Currently there are no fungicides cleared for use on stevia i n North Carolina, but we are confident that there are appropriate fungicides available and it would simply be a matter of running some trials and getting regulatory approval to have fungicides available.

3. To determine if western North Carolina grown stevia had glycoside levels that would meet industry standards, leaf samples from the field trials were analyzed. Glycoside levels in year one were acceptable for industry use but foliar disease in year two damaged the leaf material to the extent that analytic results were not useful.

4. Because growers must see successful production before they will grow it themselves, we included the stevia research plots in two field days, presented results at grower meetings, and posted results on a webpage, blog, and on social media. Results do not support large-scale production in the region, but were of interest to some growers who were considering doing small-scale production for making value-added products.

Baseline data gathered and progress toward achieving set targets:

Yield data were collected from the field studies to determine if yields in western North Carolina could be high enough to make stevia production economically viable. Results from the field trials, including winter survivability and yields, were not high enough to be of interest to stevia product manufacturers. They were adequate for small-scale local production for direct sales and making value-added products. Monitoring of diseases and insects in the field trials revealed that insects were not an issue in 2014 or 2015, but a foliar disease was a problem in 2015 and seriously affected the quality of the crop. Fungicides would need to be tested and approved to make it manageable for growers.

Stevia must have high glycoside content to be of value to manufacturers. When disease did not damage the foliage, glycoside content from western North Carolina grown stevia was adequate to meet industry standards.

Growers need to see successful field production of stevia before they will invest in largescale production themselves. Field days gave growers the opportunity to observe stevia growing in a field setting. Many were impressed with what they saw growing in the field, but the resulting dry yields were low. We concluded that with the present germplasm available, stevia production on a large commercial scale would probably not be economically viable but it might present an opportunity for local sales and farmer made value-added products.

Major successful outcomes of the project in quantifiable terms:

The highest yield obtained in this study was 58 oz. of dry material per 75 square feet. That roughly translates into 2,105 dried pounds per acre. This is similar to yields reported from some other research studies (Kansas State), but very low compared to commercial yield reports. Currently, average yields reported fall between 5,500-8,000 pounds per acre with organic production in the lower range. Prices for conventional production average about $0.26 per lb and organic production is $0.34 per lb. Using those figures, commercial production would yield gross returns of $1,430 to

$2,080 per acre whereas yields extrapolated from our research would only yield gross returns of about $547 per acre.

BENEFICIARIES

This project benefited farmers in the region looking for new alternative cash crops that they could use as a rotational crop with other field and vegetable crops including corn and soybeans. it was also of value to conventional and organic vegetable growers who were under the impression that stevia was a high enough value crop to replace crops such as tomatoes, eggplant, cucumbers, beans, and cabbage. The project provided useful information to stevia manufacturers about the potential of this region as a growing region for their companies.

LESSONS LEARNED

Our objective was to determine if stevia could be grown commercially in western North Carolina. With the current germplasm available, our conclusion is that stevia would not be economically viable for large-scale, wholesale production to sell to a manufacturer. There is, however, a local market for direct sales of stevia to small natural product manufacturers. There is also the opportunity for farmers to make their own value-added products with stevia, including extracts and teas. The yields we obtained in this study would be adequate for those purposes.

There is also interest in developing stevia further. Much of the stevia research and development currently underway is proprietary. Growers will not be able to access any of the new varieties or lines developed unless they are contracted to grow for those companies. We are now in communication with a company that is interested in us breeding stevia and creating improved varieties that will be more readily available to growers. With Dr. Luping Qu, an experienced breeder on our staff, they are interested in having us do that work. Those discussions are currently underway.

We did not expect stevia to overwinter in western North Carolina and were surprised when, with the aid of mulch, 17% of the crop did survive a particularly cold winter. This demonstrates that there is germ plasm available that could be used to create a hardier stevia line.

Stevia yields were too low to be of interest to large scale commercial producers but good enough to interest growers producing for the local markets or to make small-scale value-added products such as tea blends. The plants that successfully overwintered could be used as the basis of a stevia breeding program to develop a cold-hardy stevia line.

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ADDITIONAL INFORMATION

PROJECT TITLE: Improving Cucurbit Downy Mildew Disease Management

FINAL REPORT

PROJECT SUMMARY

Cucurbit downy mildew (CDM) is a highly destructive foliar disease of cucurbit vegetables, including cucumber, watermelon, cantaloupe, squash, pumpkin, zucchini, and gourd. Valued at over $1.5 billion in the United States (US) and over $81 million in NC, these crops can be rapidly defoliated by *Pseudoperonospora cubensis*, a fungal-like Oomycete that causes CDM and can travel long distances through air currents. Until 2004, CDM was controlled in cucumber by the use of resistant cultivars and, in other cucurbits, with commonly used fungicides. Nonetheless, pathogen populations overcame host resistance in cucumber, and every year since, widespread crop failures have occurred throughout cucumber fields in the eastern half of the US. Fungicides are currently the only form of control available to commercial cucurbit growers for preventing and managing CDM. However, *P. cubensis* is well known for its ability to quickly develop resistance to fungicides. In NC, *P. cubensis* has been reported to be resistant to mefenoxam, strobilurins, and mandipropamid, and in 2012 fungicide trials revealed poor control of CDM in NC using Presidio (a.i. fluopicolide), the leading product used for CDM control in the past few years.

Managing CDM has been difficult because of the pathogen's ability to travel long distance, to overcome traditional control measures, and to quickly destroy cucurbit crops. Because CDM can destroy entire fields within days, cucurbit growers utilize protective fungicides to prevent initial infection by the pathogen. However, timing the initial protective fungicide applications to periods when CDM is a threat can be difficult, and growers may waste money by applying fungicides prematurely. The USDA CDM IPM PIPE has helped reduce the number of premature fungicide applications by providing growers with forecasts of where CDM has a high probability of occurring next. However, once CDM has been reported in a state, all growers in that state start applying protective fungicides even though their crop may not be infected. In addition, CDM may go unnoticed in some areas because a grower may not be familiar with the disease symptoms, which can be difficult to recognize in non-cucumber hosts like melons and squash. To prevent losses due to late diagnostics or unnecessary application of fungicides, it is imperative to have a quick and efficient identification method for CDM to determine if chemical control should be initiated.

Immediate identification of CDM in the field would allow growers to better plan initiation of fungicide applications. The technology to provide rapid identification of pathogens currently exists using molecular assays. Such assays are not yet available for identification of CDM because the genomic information necessary for developing molecular diagnostics specific for *P. cubensis* is not yet in place. The genome for *P. cubensis* has already been released; therefore, the aim of this project was to fill in the remaining knowledge gaps while providing education tools for extension agents and growers on CDM diagnostics and control.

PROJECT APPROACH

Objective 1: Identify targets for species-specific diagnostics that can be consistently detected by assessing the genetic differences between diverse strains of P. cubensis

We sampled over 2,000 isolates of *P. cubensis* from cucurbit hosts including cucumber, pumpkin, melon, cantaloupe, squash, watermelon, and gourds. Trap plots were planted in research stations in Clinton, Cleveland, and Waynesville, North Carolina, during 2014 and 2015 to have a continuous source of isolates. Plots were scouted for downy mildew and sampled every week. Once downy mildew infection occurred, samples were brought to the lab fur confirmation of infection under the microscope, long-term storage, and further analyses. A subset of seven samples was propagated in the lab under clean conditions on detached host leaves to obtain high quality material for sequencing. Eight hop downy mildew isolates were obtained from several regions for diagnostic candidate filtering. The best isolate samples were used for RNA sequencing and the remaining samples will be used for testing our diagnostic markers.

We extracted RNA from seven *P. cubensis* (cucurbit DM) isolates and eight *P. humuli* (hop DM) isolates after performing a sporangia increase on detached cucurbit or hops leaves (Table 1). Our goal was to include a total of twelve isolates in our study and we were able to include fifteen.

We sequenced single-end RNA libraries of seven *P. cubensis* (cucurbit DM) isolates and eight *P. humuli* (hop DM) isolates (Table 2). For all isolates we obtained high-quality sequencing data, and for most isolates we obtained more than 10 million reads. Our goal was to obtain at least 10-15 million reads per isolate.

Table 1: Downy mildew isolates used for RNA sequencing.

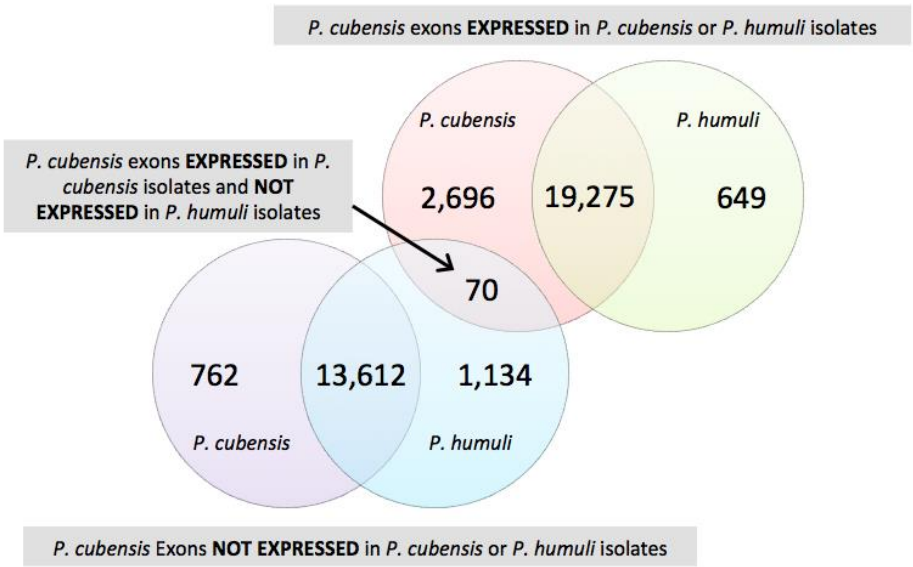
Pathogen species	Isolate	Host	Location
P. cubensis	CA08A1	*Cucumis sativus* (Cucumber)	California
P. cubensis	SC1982	*Cucumis melo* (Cantaloupe)	South Carolina
P. cubensis	NC2013C3	*Cucurbita maxima* (Pumpkin)	North Carolina
P. cubensis	SC2013F2	*Cucurbita pepo* (Acorn squash)	South Carolina
P. cubensis	NCA11	Cucumber	North Carolina
P. cubensis	SCD3	*Cucurbita moschata* (Butternut squash)	South Carolina
P. cubensis	NCWAY2-1	Cucumber	North Carolina
P. humuli	NY482CA	*Humulus lupulus* (Hop)	New York
P. humuli	JP490-5	*Humulus japonicus* (Japanese hop)	Aomori, Japan
P. humuli	JP490	Japanese hop	Aomori, Japan
P. humuli	JP498SA	Japanese hop	Ehoro, Japan
P. humuli	OR501BA	Hop	Oregon
P. humuli	OR502AA	Hop	Oregon
P. humuli	VT503A3	Hop	Virginia
P. humuli	WI510-1	Hop	Wisconsin

Table 2: Summary of quality control analysis of downy mildew isolates used for RNA sequencing.

Pathogen species	Isolate	Number of total reads	Number of high quality reads	Reads mapped to *P. cubensis* (%)	Reads mapped to *Cucumis sativus* (%)
P. cubensis	CA08A1	23,691,206	23,576,348	92.96	0.49
P. cubensis	SC1982	22,117,725	22,049,442	93.6	6.24
P. cubensis	NC2013C3	28,035,867	27,888,243	87.98	0.62
P. cubensis	SC2013F2	16,956,357	16,886,934	79.89	5.8
P. cubensis	NCA11	28,101,878	27,962,061	88.33	0.62
P. cubensis	SCD3	29,304,711	29,218,196	95.08	4.26
P. cubensis	NCWAY2-1	21,038,800	20,974,369	94.58	6.7
P. humuli	NY482CA	15,906,769	15,860,532	91.45	7.54
P. humuli	JP490-5	20,211,068	20,149,698	92.12	4.58
P. humuli	JP490	11,942,671	11,913,949	66.91	6.45
P. humuli	JP498SA	26,977,356	26,866,989	90.01	0.54
P. humuli	OR501BA	14,429,953	14,399,612	88.53	5.55
P. humuli	OR502AA	26,193,148	26,086,672	92.28	0.51
P. humuli	VT503A3	14,576,962	14,543,704	91.75	5.69
P. humuli	WI510-1	29,264,282	29,150,378	88.78	0.68

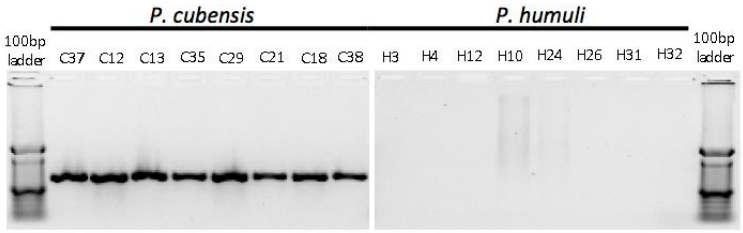
We mapped all the reads from diverse *P. cubensis* and *P. humuli* isolates to the *P. cubensis* genome, which allowed us to identify exons that are always expressed in *P. cubensis* (2,696 exons) as well as 70 exons that are specific to *P. cubensis* (Figure 1). For developing a diagnostics tool, our goal was to identify genomic regions (genes, exons, or SNPs) that are conserved among different *P. cubensis* isolates.

Figure 1: Candidate diagnostic markers for *P. cubensis* identified through comparative genomics with *P. humuli.*



The 70 identified exons were located in 51 genes that were selected for PCR screening in the lab. An initial screen of six diverse *P. cubensis* and six *P. humuli* isolates eliminated another 15 candidates from a subset of 26 candidates selected for validation. Evaluations of the remaining 11 candidate diagnostic regions with diverse isolates including 40 *P. cubensis*, 34 *P. humuli*, 5 *P. belbahrii*, 3 *P. obducens*, 6 *Phytopthora capsici*, 8 *Phytophthora infestans* and 8 uninfected cucurbit, basil and hop plant samples, revealed that 10 diagnostic candidates in 7 genes would be specific and robust enough for CDM-specific diagnostics (Figure 2). A publication has been submitted describing this work to report our findings and make these data available to the public.

Figure 2: Gel electrophoresis images showing one *P. cubensis* diagnostic candidate PCR product for diverse cucurbit downy mildew and hop downy mildew samples. Cucurbit downy mildew samples are C37 (watermelon, NC), C12 (cucumber, NC), C13 (cantaloupe, NC), C35 (pumpkin, NC), C29 (cucumber, MI), C21 (butternut squash, NC), C18 (buffalo gourd, NC), and C38 (watermelon, NC). Hop downy mildew samples are H3 (NC), H4 (OR), H12 (NC), HIO (Japan), H24 (NC), H26 (OR), H31 (WA), and H32 (NY). Primers for candidate A are being re-designed to ensure that they are differentiated by presence in *P. cubensis* and absence in *P. humuli* instead of product size differences for using markers in *P. cubensis* quantification.



Objective 2: Develop web-based education tools for NC extension agents and growers about identification and control of CDM

The Quesada Lab has developed several web-based and mobile-friendly resources to engage stakeholders and publish information related to cucurbit DM diagnostics and control. Our resources include:

- A lab website (go.ncsu.edu/veggiepathology) that includes a CDM fact sheet (http://content.ces.ncsu.edu/cucurbit-downy-mildew).
- An extension plant pathology portal (http://plantpathology.ces.ncsu.edu/).
- Social media sites including Facebook (https:L/www.facebook.comLQuesadaLabNCSU), twitter (https:/./twitter.com/_QuesadaLabNCSU), and LinkedIn (http://www.linkedin.com/in/linaquesadaocampo).

On these websites we have published disease factsheets and disease alerts regularly, and we have developed dedicated website spaces only for DM news (http://plantpathology.ces.ncsu.edu/tags/cdm/). Thirteen articles with educational photos describing how to diagnose cucurbit DM on different cucurbits have been published. In addition, four Plant Disease Management Reports have been published in our website reporting our 2013, 2014, and 2015 fungicide efficacy trials for cucurbit DM control. Our web-based tools have implemented feedback systems to establish the impact of individual posts. The impact of posts is determined by counting the number of people that read the post using the google analytics tool (http://www.google.comlanalytics/) implemented in the NCSU websites. Collectively our cucurbit DM posts from the extension portal and our lab website have had over 3,000 readers. We also have over 3,000 followers on Facebook, Twitter and LinkedIn combined.

The Quesada Lab also updated and co-edited the vegetable disease control sections for the 2014, 2015, and 2016 Southeastern U.S. Vegetable Crop Handbook (http://www.thegrower.com/south-eastvegetable-guide/) and the North Carolina Agricultural Chemicals Manual (http:LLipm.ncsu.edu/agchemLagchem.htm). Both publications are used by growers, extension agents and consultants to obtain updated fungicide and cultural management recommendations for vegetable diseases, including cucurbit DM.

We trained thirty extension agents and approximately 180 growers in cucurbit DM diagnostics and control at four county workshops and during field days. We have also assisted the Plant Disease and Insect Clinic in the diagnosis of 387 cucurbit samples submitted by growers, extension agents and consultants. We also provided technical support for 12 sentinel plots in North Carolina as part of our role as state collaborators for the cucurbit downy mildew IPM pipe. We have received positive feedback about our extension efforts from extension agents, consultants and growers via personal communications, emails directly sent to our department head and evaluations provided at the end of workshops and field days.

GOALS AND OUTCOMES ACHIEVED

Outcome 1: We identified targets for robust, species-specific diagnostics of *P. cubensis*.

One goal of this project was to identify species-specific regions of the genome that are shared among different strains of *P. cubensis*. Our target was to compare genetic differences among 12 *P. cubensis* strains coming from different cucurbit hosts within a year of the initiation of this grant. We were able to sequence seven isolates for whole-transcriptome comparisons and we included another 40 isolates in our PCR screening achieving our target goal.

Outcome 2: We developed web-based education tools for NC extension agents and growers about identification of CDM.

Another goal of this project was to continue to inform extension agents and growers about how to identify early symptoms of CDM and control the disease. Our target was to develop disease factsheets to be posted in the University's portals and the PI's lab website to make materials available to stakeholders. Bellow we list publications and presentations as a result of this work.

Peer-reviewed journal articles

Withers S., Gongora-Castillo E., Gent D., Thomas A., Ojiambo P., and Quesada-Ocampo L. M. (201X) Using next-generation sequencing to develop molecular diagnostics for *Pseudoperonospora cubensis*, the cucurbit downy mildew pathogen. Phytopathology: submitted.

Ojiambo P. S., Gent D. H., Quesada-Ocampo L. M., Hausbeck M. K., and Holmes G. J. (2015) Epidemiology and population biology of *Pseudoperonospora cubensis*: A model system for management of downy mildews. Annual Review of Phytopathology 53: 223-246.

Cohen Y., Van den Langenberg K. M., Wehner T., Ojiambo P., Hausbeck M., Quesada-Ocampo L. M., Lebeda A., Sierotzki H., and Gisi U. (2015) Resurgence of *Pseudoperonospora cubensis* – the agent of cucurbit downy mildew. Phytopathology 105: 998-1012.

Holmes G., Ojiambo P., Hausbeck M., Quesada-Ocampo L. M., and Keinath A. P. (2015) Resurgence of cucurbit downy mildew in the United States: A watershed event for research and extension. Plant Disease 99: 428-441.

Oral presentations

Quesada-Ocampo L. M., Withers S., Gongora-Castillo E., Gent D. H., and Ojiambo P. S. Using next-generation sequencing to develop species-specific molecular diagnostics for cucurbit downy mildew. APS Meeting, Pasadena, CA, August 2015.

Withers S., Gongora-Castillo E., Gent D., Ojiambo P., and Quesada-Ocampo L. M. Developing species-specific molecular diagnostics for cucurbit downy mildew. Oomycete Molecular Genetics Network Meeting, Pacific Grove, CA, March 2015.

Quesada-Ocampo L. M. Cucurbit downy mildew management, diagnostics, and pathogen populations. Pickle Packers International Spring Meeting. Raleigh, NC, April 2016.

Quesada-Ocampo L. M. Managing downy mildew on hops in the south. South Atlantic Hops Conference. Richmond, VA, March 2016.

Quesada-Ocampo L. M. Downy mildew updates for cucurbits. Southeast Regional Fruit and Vegetable Conference. Savannah, GA, January 2016.

Wallace E. C. and Quesada-Ocampo L. M. Controlling downy mildew in cucumber. 30th Annual Southeast Vegetable and Fruit Expo. Myrtle Beach, NC, December 2015.

Quesada-Ocampo L. M. Diagnostics and management of cucurbit downy mildew. Pickle Packers International Annual Meeting. Fort Worth, TX, October 2015.

Quesada-Ocampo L. M. Management of cucurbit downy mildew and tomato late blight. Winter Vegetable Conference. Asheville, NC, February 2015.

Adams M. L. and Quesada-Ocampo L. M. Vegetable disease control methods. Vegetable Growers Program. Reidsville, NC, February 2015.

Adams M. L. and Quesada-Ocampo L. M. Identification and management of cucurbit and tomato diseases. PLANT Farm Enterprise Incubator. Hillsborough, NC, February 2015.

Quesada-Ocampo L. M. Control options for cucurbit downy mildew. 29th Annual Southeast Vegetable and Fruit Expo. Myrtle Beach, NC, December 2014.

Wallace E. C. and Quesada-Ocampo L. M. Non-commercial cucurbits and the downy mildew epidemic. 29th Annual Southeast Vegetable and Fruit Expo. Myrtle Beach, NC, December 2014.

Adams M. L. and Quesada-Ocampo L. M. Identification and management of cucurbit and tomato diseases. Northeast Agriculture Agents Association Meeting. Plymouth, NC, December 2014.

Adams M. L. and Quesada-Ocampo L. M. Disease management in vegetable production. Certified Crop Advisor Training. Jacksonville, NC, December 2014.

Quesada-Ocampo L. M. Expanding your toolbox for cucurbit downy mildew detection and control. Pickle Packers International Annual Meeting. Orlando, FL, October 2014.

Adams M. L. and Quesada-Ocampo L. M. Cucurbit downy mildew management in the greenhouse. 42nd Annual Conference of the North Carolina Greenhouse Vegetable Growers Association. Greensboro, NC, October 2014.

Quesada-Ocampo L. M. Organic management of foliar vegetable diseases in high tunnels. High Tunnel Production Workshop. Pittsboro, NC, March 2014

Adams M. L. and Quesada-Ocampo L. M. Identification and management of cucurbit and tomato diseases. PLANT Farm Enterprise Incubator. Hillsborough, NC, March 2014.

Adams M. L. and Quesada-Ocampo L. M. Evaluation of fungicides for control of cucurbit downy and powdery mildew in NC. Winter Vegetable Conference. Asheville, NC, February 2014.

Poster presentations

Withers S., Gongora-Castillo E., Bowman M. J., Childs K., Gent D. H., Ojiambo P. S., and Quesada-Ocampo L. M. Developing genomic resources for species-specific molecular diagnostics of cucurbit downy mildew. APS Meeting, Minneapolis, MN, August 2014.

Production guides

Southeastern Vegetable Extension Workers. Kemble J., Lewis Ivey M., Jennings K. M., and Walgenbach J. F., Eds. (2016) Southeastern US 2016 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2016) Disease control for commercial vegetables. North Carolina Agricultural and Chemicals Manual.

Southeastern Vegetable Extension Workers. Kemble J., Quesada-Ocampo L. M., Lewis Ivey M., Jennings K. M., and Walgenbach J. F., Eds. (2015) Southeastern US 2015 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2015) Disease control for commercial vegetables. North Carolina Agricultural and Chemicals Manual.

Southeastern Vegetable Extension Workers. Kemble J., Quesada-Ocampo L. M., Ivors K., Jennings K. M., and Walgenbach J. F., Eds. (2014) Southeastern US 2014 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2014) Disease control for commercial vegetables. North Carolina Agricultural and Chemicals Manual.

Online publications

Wallace E. C. and Quesada-Ocampo L. M. Cucurbit downy mildew reported in North Carolina. Extension Plant Pathology Portal. June 15, 2015.

Quesada-Ocampo L. M. Cucurbit downy mildew in FL, GA, and SC. Extension Plant Pathology Portal. May 29, 2015.

Quesada-Ocampo L. M. Cucurbit downy mildew found in Franklin County, North Carolina. Extension Plant Pathology Portal. June 24, 2014.

Quesada-Ocampo L. M. Control options for cucurbit downy mildew in North Carolina. Extension Plant Pathology Portal. June 11, 2014.

Wallace E. C. and Quesada-Ocampo L. M. Cucurbit downy mildew outbreak in southeastern North Carolina. Extension Plant Pathology Portal. June 9, 2014.

Quesada-Ocampo L. M. What to expect for vegetable diseases in 2014. Extension Plant Pathology Portal. February 13, 2014.

Field days

Quesada-Ocampo L. M. and Adams M. L. Fungicide control options for cucurbit downy mildew in the field. Cucurbit downy mildew field day. Clinton, NC, October 2014.

Quesada-Ocampo L. M., Adams M. L. and Wallace E. C. Management of cucurbit and tomato diseases. Tomato and vegetable field day. Mills River, NC, August 2014.

Adams M. L., Wallace E. C., and Quesada-Ocampo L. M. Management of cucurbit downy mildew. Mountain Research Station field day. Waynesville, NC, July 2014.

BENEFICIARIES

NC is one of the largest cucurbit producers in the US. This project had a direct impact on cucurbit growers in NC since CDM affects crops every year and we provided disease control support throughout the duration of the project Growers report economic losses as a result of the high cost of disease control and/or inadequate disease management resulting in plant death and decreased yields. As a result of CDM, growers of cucurbit crops face production costs that are no longer predictable. For instance, in 2012, the CDM outbreak occurred in early May and control costs quickly escalated. CDM costs growers and processors $6.4 million based on the processors paying $125/acre in fungicide costs to control disease ($4.8 million) and growers paying $42/acre machinery cost to apply six sprays ($1.6 million).

This project created the framework for a diagnostic tool that can be implemented for field use with additional research to quickly identify CDM, thereby avoiding unnecessary fungicide applications. In addition, by developing educational tools we enhanced the ability of extension agents and cucurbit growers to identify the early symptoms of CDM and control it Because these educational tools were provided over the Internet, they had an expanded impact since growers and agents have continuous access to all materials we developed.

LESSONS LEARNED

Advances in Next Generation Sequencing (NGS) allow for rapid development of genomics resources needed to generate molecular diagnostics assays for infectious agents. NGS approaches are particularly helpful for organisms that cannot be cultured, such as the downy mildew pathogens, a group of biotrophic obligate oomycetes that infect crops of economic importance. Unlike most downy mildew pathogens that are highly host-specific, *Pseudoperonospora cubensis* causes disease on a broad range of crops belonging to the Cucurbitaceae. In this study, we identified candidate diagnostic

markers for *P. cubensis* by comparing NGS data from a diverse panel of *P. cubensis* and *Pseudoperonospora humuli* isolates, two very closely related oomycete species. Overall seven diagnostic markers were found to be specific to *P. cubensis*. These markers could be used for pathogen diagnostics on infected tissue, or adapted for monitoring airborne inoculum with real-time PCR and spore traps after additional research outside of the scope of this project.

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PROJECT TITLE: Managing Rhizopus Sot Rot in Sweet Potato

FINAL REPORT

PROJECT SUMMARY

North Carolina (NC) is the number one producer of sweet potatoes in the United States (US), contributing over 51% of the total production at a value of more than $300 million. Rhizopus stolonifer is a ubiquitous fungus that causes soft rot, the most common postharvest disease of sweet potatoes in NC. Infection occurs due to wounds that routinely happen during harvesting, washing, storage and shipping of sweet potatoes. When conditions are favorable, the pathogen can be devastating and completely destroy roots that have been cured and stored within 3 days. Packers have traditionally used the fungicides Botran (a.i. dicloran) and Scholar (a.i. fludioxonil) to protect roots from Rhizopus soft rot after washing. Nonetheless, since sweet potatoes are the primary component of baby food, the use of fungicides such as Botran or Scholar to control Rhizopus soft rot at the last stage of packing and shipping for market, is undesirable. Also, NC sweet potatoes are gaining increased popularity in European markets. European consumers as well as domestic organic consumers are reluctant to buy foods that contain fungicides such as Botran or Scholar; therefore, identifying alternative control measures to Rhizopus soft rot would make NC sweet potatoes more attractive for both markets.

Integrated pest management of Rhizopus soft rot to reduce grower's reliance on fungicides would also be possible if conditions conducive to disease were characterized. It has been reported that wounding promotes infection by facilitating pathogen entry into the root. Nonetheless, specific temperatures, humidity levels, and amount of inoculum required for disease in sweet potato have not been established. If such conditions were known, growers could modify their practices to achieve environmental conditions that are unfavorable for the pathogen. Likely, reliance on only one control method, such as a fungicide, will not be sustainable in the long term since pathogens frequently develop resistance to fungicides. Thus, it is important to take an integrated approach where cultural practices and chemical control methods are combined to achieve the desired quality of sweet potatoes and promote the growth of this industry. This proposal, if funded, will provide much needed epidemiological information to prevent disease, as well as identify specific control strategies that can be immediately used by growers at the end of this project.

This project also seeks to provide a foundation for establishing if ozone is a viable option for postharvest disease control in sweet potatoes. The use of ozone for postharvest disease control is not a novel concept, and has been successfully adopted by the white potato industry to control diverse pathogens. However, no formal data has been collected to demonstrate its efficacy for disease control in sweet potatoes. Alternative management strategies for Rhizopus soft rot to Botran and Scholar need to be identified to maintain the competitiveness of the NC sweet potato industry. The aim of this project was to identify integrated management strategies for Rhizopus soft rot control that will make the sweet potato industry in NC more competitive for overseas and organic markets.

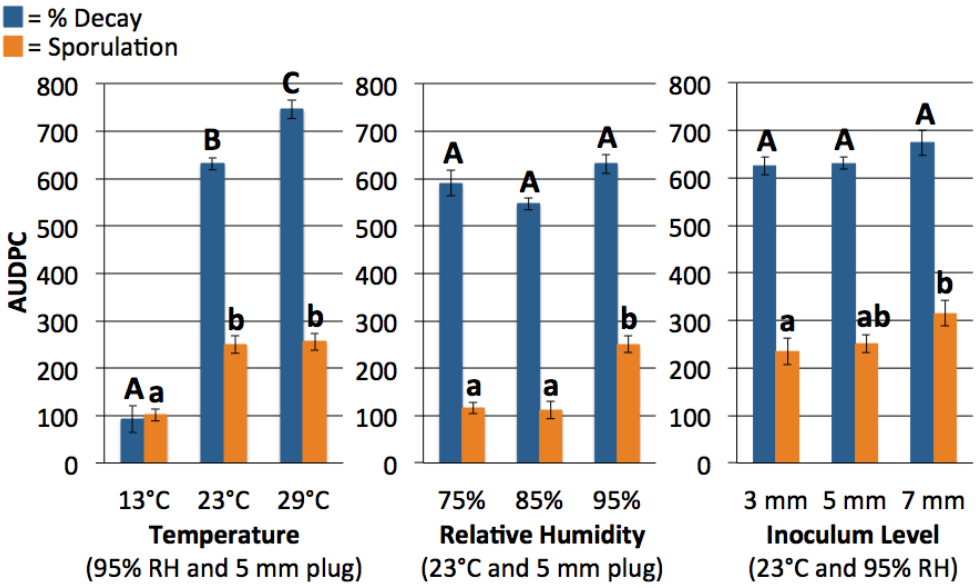
PROJECT APPROACH

Objective 1: Determine epidemiological factors (temperature, humidity and level ofinoculum) influencing disease development

Sweet potatoes are an important food crop around the world, both economically and nutritionally. Sweet potato production is limited by postharvest diseases including Rhizopus soft rot (RSR); however, little is known about the epidemiological conditions that promote disease progression. This study aimed to determine the effects of temperature (13 and 29^{0}C), relative humidity (75, 85, and 95%), and inoculum level (3, 5, and 7 mm diameter mycelial plugs) on progression of RSR of sweet potato, which

are commonly used storage or curing conditions. Six wounded, 'Covington' sweet potatoes were inoculated with an actively growing 5mm diameter agar plug of Rhizopus stolonifer and incubated in the dark for each treatment, except for inoculum level experiments were the size of the agar plug varied. Control roots were included and the experiment was repeated twice. Disease progression was recorded for RSR as percent decay and sporulation every other day, for two weeks. Analysis of AUDPC values revealed significant differences in decay and sporulation among different temperatures ($P<1x10^{-7}$) and differences in sporulation among different relative humidity ($P<0.0001$) and inoculum levels ($P<0.05$). RSR decay was consistently higher at 29C, 95% humidity, and 7mm inoculum level as compared to lower temperatures, humidities, and inoculum levels. Overall, storing sweet potato roots at lower temperatures results in lower disease progression, and storing roots at lower humidity levels and clean facilities with lower inoculum levels, will result lower sporulation and thus, less spread of the disease during storage (Figure 1). These findings will contribute in providing accurate recommendations to growers so that environmental conditions in storage and curing facilities may be optimized to reduce postharvest diseases. This objective has been successfully completed.

Figure 1: Epidemiological factors promoting Rhizopus soft rot in sweet potato. Different temperature, relative humidity, and inoculum levels were investigated as indicated in the horizontal axes of each graph. Disease was assessed as AUDPC values for decay (blue bars) and sporulation (orange bars) as indicated in the vertical axes of graphs. Bars within a color with the same letter are not significantly different from each other.



Objective 2: Examine products for chemical control of Rhizopus soft rot that are acceptable for organic and overseas markets

Experiments with organic and conventional fungicides in the packing line: Sweet potatoes were sampled three to four times from a commercial sweet potato packing facility. Twenty roots were sampled from four points each time (after water tank, after ozone wash, after dryers and at packing) in the order that sweet potatoes travel along the packing line (Table 1). Sweet potatoes were placed in sealed plastic bags by sample location and transported back to the lab. In the lab, sweet potatoes were placed in humidity chambers (90% humidity) by sample location to incubate, stored at room temperature and observed daily. Each humidity chamber contained a beaker of water and moist paper towels, which were changed daily to maintain conditions favorable for disease. After 14 days of

incubation, each root was evaluated for disease incidence and total percent disease per root. Specific diseases observed were noted and included in order of frequency from most frequent to least frequent Fusarium root rot, Black rot, Geotrichum sour rot, and Rhizopus soft rot. Data was analyzed in the software ARM (Gylling Data Management, Brookings, SD) using analysis of variance (AOV) and the Waller-Duncan test to separate the means and compare disease levels along the packing line.

The first experiment evaluated the efficacy of ozone and peracetic acid washes, which are organic options for postharvest disease control (Table 1). Results showed no statistically significant difference between sweet potato disease occurrence before and after the wash, likely due to a negative interaction between ozone and peracetic acid, since ozone by itself performed better in later experiments (Table 4). The second experiment evaluated a wash with Scholar, a conventional fungicide (Table 2). In this experiment there was significant disease control in reps 1, 2, and 3 using a Scholar wash, but not in rep 4 likely due to general low levels of disease observed in that batch of roots.

Table 1: Ozone (4ppm) and peracetic acid wash treatment

	Disease severity* [% disease]		
Location of sample	**Rep 1**	**Rep 2**	**Rep 3**
Water Tank	5.2 a**	3.2 a	3.1 a
Ozone and Peracetic acid	4.4 a	3.0 a	4.9 a
Dryer	5.8 a	3.1 a	2.2 a
Packing	7.2 a	3.6 a	2.7 a

* Disease rating scale based on percent of total area of sweetpotato affected.
** Treatments followed by the same letter(s) within a column are not statistically different (P=0.05, Waller-Duncan k=100).

Table 2: Scholar wash treatment

	Disease severity* [% disease]			
Location of sample	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**
Water Tank	2.9 a**	6.1 a	26.0 a	0.6 a
Scholar	1.7 b	0.1 b	1.1 b	0.7 a
Dryer	1.2 bc	1.1 b	1.2 b	6.0 a
Packing	0.8 c	1.7 b	1.2 b	3.3 a

* Disease rating scale based on percent of total area of sweetpotato affected.
** Treatments followed by the same letter(s) within a column are not statistically different (P=0.05, Waller-Duncan k=100).

Dip experiments with organic and conventional fungicides: Roots were wounded using a rubber band propelled wooden dowel and inoculated with a 5 mm mycelia plug. After inoculation, roots were incubated in sealed, clear plastic containers (40 cm x 50 cm x 17.9 cm) at 23 ^{0}C and 95% relative humidity for 24 hours before treatment. Roots were then dipped into a given treatment (Table 3) for 30 seconds. Inoculated, untreated controls and uninoculated controls were included. Following treatment, roots were placed back into their container and stored in the dark at 23^{0}C and 95% relative humidity.

Ten roots were used per treatment and the experiment was repeated twice. Roots were evaluated 10 days after treatment individually for percent decay and overall for disease incidence. Conventional fungicides Stadium and Botran provided the best control, as well as organic products Storox, Prophyt, and Chlorine dioxide. However, Stadium is not labeled in sweet potato and further testing will be required to pursue a label expansion for sweet potato via the IR-4 project.

Table 3: Results from conventional and organic fungicide dip tests

Treatment	Roots infected with Rhizopus (%)
Uninoculated control	0
Inoculated control	50
Stadium	0
Scholar SC	17.5
Botran 75WP	10
Mertect 340-F	37.5
Stadium	0
Chlorox	20
Zonix	30
Chlorine dioxide	10
Storox	0
Prophyt	10

Objective 3: Explore the use of ozone treatments to control Rhizopus soft rot in sweet potatoes shipped to overseas markets

Experiments with ozone in the packing line: Sweet potatoes were sampled three times from a commercial sweet potato packing facility as described in the previous objective (Table 4).
Sweet potatoes were transported back to the lab and evaluated for disease incidence and total percent disease per root also as described.

Sweet potato diseases were found in each humidity chamber of the three replications in the experiment although disease severity was variable among the reps and sample location. There were no statistical differences in disease levels observed in rep 2 among sample locations. In reps 1 and 3, the water tank had a significantly higher level of disease than any of the other sample locations. The ozone wash significantly reduced disease severity in reps 1 and 3. Rep 1 shows a trend of disease reduction due to the different practices along the packing line (ozone, bad root disposal), however in rep 3, disease levels achieved after the ozone wash were maintained until packing and no further reduction was observed. Levels of disease severity were higher overall in rep 3 when compared to reps 1 and 2. The data in general indicates that while the ozone is helping reduce disease levels, the reduction occurring from the ozone wash at the current concentration (4 ppm) or treatment time (10 seconds) that the ozone is being applied is not consistent or significant in all cases. Nonetheless, some efficacy was observed, which warrants further research in ozone as a control method for sweet potato postharvest diseases.

Table 4: Ozone (4ppm) wash treatment

	Disease severity* [% disease]		
Location of sample	**Rep 1**	**Rep 2**	**Rep 3**
Water Tank	6.6 a**	0.5 a	14.3 a
Ozone	5.2 ab	1.2 a	6.0 b
Dryer	3.9 b	0.9 a	6.2 b
Packing	1.9 c	1.3 a	6.6 b

* Disease rating scale based on percent of total area of sweetpotato affected.
** Treatments followed by the same letter(s) within a column are not statistically different (P=0.05, Waller-Duncan k=100).

Experiments with ozone during storage/shipping: Surveys for RSR were performed in three shipping containers with three different treatments prior to shipping and treated with ozone during shipping (Table 5). Six pallets from the back, middle, and front of the shipping container were visually evaluated for disease severity from photos taken by the receiver. Container 1 did not show decay but presented an average of 5% pathogen sporulation on the stem ends. Container 2 presented a single root with signs of decay and an average of 10% pathogen sporulation on the stem ends of roots. Container 3 had an average of 15% pathogen sporulation on the stem and root ends of sweet potatoes and two pieces presented decay symptoms. Based on these results, it seems that ozone treatment during shipping would not be sufficient for RSR control; however, further replication of this study would be needed to determine the efficacy of ozone fumigation.

Table 5: Survey of RSR in shipping containers treated with ozone during shipping

Treatment prior to shipping	Disease severity* [% disease]
Container 1: Ozone wash	5
Container 2: No treatment	10
Container 3: Biosave	15

* Disease rating scale based on percent of total area of sweetpotato affected.

Dissemination of results

The Quesada Lab has developed several web-based and mobile-friendly resources to engage stakeholders and publish information related to diagnostics and control of sweet potato diseases. Our resources include:

- A lab website (go.ncsu.edu/veggiepathplogy) with a RSR fact sheet (http://content.ces.ncsu.edu/.rhizopus-soft-rot-of-sweetpotato).
- An extension plant pathology portal (http://plantpathology.ces.ncsu.edu/).
- Social media sites including Facebook (https://www.facebook.com/QuesadaLabNCSU), twitter (https:/[twitter.com/QuesadaLabNCSU), and Linkedln (http://www.linkedin.com/in/linaquesadaocampo).

On these websites we have published disease fact sheets and disease alerts regularly. Our web-based tools have implemented feedback systems to establish the impact of individual posts. The impact of posts is determined by counting the number of people that read the post using the google analytics tool (http://www.google.com/anaic) implemented in the NCSU websites. Collectively from the extension portal and our lab website have had over 3,000 readers. We also have over 2,000 followers on Facebook, Twitter and LinkedIN combined.

The Quesada Lab also updated and co-edited the vegetable disease control sections for the 2014, 2015, and 2016 Southeastern U.S. Vegetable Crop Handbook (http://www.thegrower.com/south-east-vegetable-guide/) and the North Carolina Agricultural Chemicals Manual (http://ipm.ncsu.edu/agchem/agchem.htm). Both publications are used by growers, extension agents and consultants to obtain updated fungicide and cultural management recommendations for vegetable diseases, including Rhizopus soft rot in sweet potato.

We trained thirty extension agents and approximately 300 growers in sweet potato disease diagnostics and control at four county workshops and during the sweet potato field days. We have also assisted the Plant Disease and Insect Clinic in the diagnosis of 128 sweet potato samples submitted by growers, extension agents and consultants. We have received positive feedback about our extension efforts from extension agents, consultants and growers via personal communications, emails directly sent to our department head and evaluations provided at the end of workshops and field days.

GOALS AND OUTCOMES ACHIEVED

Outcome 1: Determine epidemiological factors influencing disease development.

One goal of this project was to determine epidemiological factors such as temperature, humidity and level of inoculum that influence Rhizopus soft rot. Our target was to test 2 different conditions for each factor (high and low rate) to establish if disease progresses faster at higher temperatures or humidity, or extensive wounding and levels of inoculum. We tested three different treatments for temperature, relative humidity, and inoculum level. Percent decay due to Rhizopus soft rot infection is significantly reduced ($P<0.0001$) at lower temperatures (13^0C) but is not significantly impacted by changes in relative humidity or initial inoculum level ($P>0.05$).

Outcome 2: Identify effective products for chemical control of Rhizopus soft rot that are acceptable for organic and overseas markets.

Another goal of this project was to identify fungicide products alternative to Botran and Scholar to effectively control Rhizopus soft rot. Our target was to compare 5 organic-friendly treatments with Botran and Scholar for performance of Rhizopus soft rot control. We compared 5 organic-friendly products to 5 conventional fungicides. Dips in aqueous Stadium, Cl02 and StorOx 2.0 significantly (<0.05) reduced disease incidence.

Outcome 3: Explore the use of ozone treatments to control Rhizopus soft rot in sweet potatoes shipped to overseas markets.

The final goal of this project was to explore the use of ozone to control Rhizopus soft rot. Our target was to test different combinations of ozone washes and ozone in transit for control of Rhizopus soft rot for long-periods of time (~25 days). We tested three different ozone washes and three treatments with ozone fumigation during shipping. Ozone washes and fumigation were not consistently effective in reducing sporulation of roots or incidence of Rhizopus soft rot.

Below we list publications and presentations as a result of this work:

Peer-reviewed journal articles

Scruggs, A. C. and Quesada-Ocampo L. M. (201X) Cultural, chemical, and alternative control strategies for Rhizopus soft rot of sweetpotato. Plant Disease: submitted.

Abstracts

Scruggs, A. C. and Quesada-Ocampo L. M. (2015) Epidemiological conditions promoting Rhizopus soft rot and Fusarium root rot of sweetpotato. Phytopathology 105: S4.99.

Scruggs, A. C. and Quesada-Ocampo L. M. (2014) Effect of temperature on disease progression of Rhizopus soft rot and Fusarium root rot on sweetpotato. Phytopathology 104: S3.105.

Oral presentations

Scruggs, A. C. and Quesada-Ocampo L. M. Strategies for disease control in sweetpotato. 30th Annual Southeast Vegetable and Fruit Expo. Myrtle Beach, NC, December 2015.

Scruggs A. and Quesada-Ocampo L. M. Improving control of sweetpotato postharvest disease through integrated strategies. NCSU Masters Symposium, Raleigh, NC, November 2015.

Scruggs, A. C. and Quesada-Ocampo L. M. Epidemiological conditions promoting Rhizopus soft rot and Fusarium root rot of sweetpotato. APS Meeting, Pasadena, CA, August 2015.

Quesada-Ocampo L. M. Management of diseases of sweetpotato. Annual Meeting of the North Carolina Certified Sweetpotato Seed Growers Association. Wilson, NC, February 2015.

Adams M. L. and Quesada-Ocampo L. M. Vegetable disease control methods. Vegetable Growers Program. Reidsville, NC, February 2015.

Scruggs A. C. and Quesada-Ocampo L. M. (2015) Epidemiological conditions that promote Rhizopus soft rot and Fusarium root rot on sweetpotato. National Sweetpotato Collaborators Group Annual Meeting, Nashville, TN, January 2015. *Award for best oral presentation

Quesada-Ocampo L. M. Managing disease in sweetpotatoes. Annual Meeting of the NC Sweetpotato Commission. Wilson, NC, January 2015.

Quesada-Ocampo L. M. Management of sweetpotato postharvest diseases. 29th Annual Southeast Vegetable and Fruit Expo. Myrtle Beach, NC, December 2014.

Adams M. L. and Quesada-Ocampo L. M. Disease management in vegetable production. Certified Crop Advisor Training. Jacksonville, NC, December 2014.

Quesada-Ocampo L. M. Improving detection and control of vegetable diseases in North Carolina. The Sainsbury Laboratory, Norwich, England, July 2014.

Poster presentations

Scruggs, A. C. and Quesada-Ocampo L. M. (2014) Effect of temperature on disease progression of Rhizopus soft rot and Fusarium root rot on sweetpotato. Sweetpotato field day. Clinton, NC, October 2014.

Scruggs, A. C. and Quesada-Ocampo L. M. (2014) Effect of temperature on disease progression of Rhizopus soft rot and Fusarium root rot on sweetpotato. APS Meeting, Minneapolis, MN, August 2014.

Scruggs, A. C. and Quesada-Ocampo L. M. (2014) Effect of temperature and humidity on disease progression of Rhizopus soft rot and Fusarium root rot in sweetpotato. NC State Summer Undergraduate Research Symposium, Raleigh, NC, July 2014.

Scruggs, A. C. and Quesada-Ocampo L. M. (2014) Effect of temperature on disease progression of Rhizopus soft rot and Fusarium root rot in sweetpotato. NC State Spring Undergraduate Research Symposium, Raleigh, NC, April 2014.

Production guides

Southeastern Vegetable Extension Workers. Kemble J., Lewis Ivey M., Jennings K. M., and Walgenbach J. F., Eds. (2016) Southeastern US 2016 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2016) Disease control for commercial vegetables. North Carolina Agricultural and Chemicals Manual.

Southeastern Vegetable Extension Workers. Kemble J., Quesada-Ocampo L. M., Lewis Ivey M., Jennings K. M., and Walgenbach J. F., Eds. (2015) Southeastern US 2015 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2015) Disease control for commercial vegetables. North Carolina Agricultural and Chemicals Manual.

Southeastern Vegetable Extension Workers. Kemble J., Quesada-Ocampo L. M., Ivors K., Jennings K. M., and Walgenbach J. F., Eds. (2014) Southeastern US 2014 Vegetable Crop Handbook.

Quesada-Ocampo L. M., Ed, (2014) Disease control for commercial vegetables. North Carolina Agricultural and

Chemicals Manual.

Online publications

Quesada-Ocampo L. M. What to expect for vegetable diseases in 2014. Extension Plant Pathology Portal. February 13, 2014.

Quesada-Ocampo L. M. Vegetable disease diagnostics report. Extension Plant Pathology Portal. September 20, 2013.

Field days

Scruggs A. C., Adams M. L. and Quesada-Ocampo L. M. Management of sweetpotato postharvest diseases. Sweetpotato field day. Kinston, NC, October 2015.

Scruggs A. C., Adams M. L. and Quesada-Ocampo L. M. Improving control of Rhizopus soft rot on sweetpotato. Sweetpotato field day. Bailey, NC, October 2013.

BENEFICIARIES

NC is the largest sweet potato producer in the US. Postharvest diseases cause severe losses to the sweet potato industry every year, Rhizopus soft rot being the number one problem. This project provides epidemiological information on disease progression, which can be used by growers in the short term to modify cultural practices and create a non-conducive environment for disease. The project also identified specific products that can be immediately used by growers for disease control. Finally, through this proposal we studied the use of ozone for postharvest disease control. Providing consumers consistently with high-quality sweet potatoes is of utmost importance for the long-term profitability of the industry. This proposal addressed integrated control of Rhizopus soft rot, which is an urgent matter to the sweet potato industry in NC, and through the PIs extension role, findings were communicated to growers through demonstrations at sweet potato field days to adjust practices as needed for effective disease control.

LESSONS LEARNED

Rhizopus soft rot, caused primarily by Rhizopus stolonifer, is one of the most common postharvest diseases of sweet potato and is often considered the most devastating. Traditionally Rhizopus soft rot has been effectively controlled using postharvest dips in dicloran fungicides, however due to changes in market preferences use of this fungicide is now limited. This, along with the lack of labeled and effective fungicides for control of Rhizopus soft rot in sweet potato, creates the need for integrated strategies to control disease. The effects of storage temperature (13, 23, and 29^{0}C), relative humidity (80, 90, and 100%), and initial inoculum level (3, 5, and 7 mm-diameter mycelia plug) were examined for progression of Rhizopus soft rot, caused by R. stolonifer on Covington sweet potatoes. Percent decay due to Rhizopus soft rot infection is significantly reduced ($P<0.0001$) at lower temperatures (13^{0}C) but is not significantly impacted by changes in relative humidity or initial inoculum level ($P>0.05$). Sporulation of R. stolonifer is also significantly reduced at lower temperatures. High relative humidity (>95%) significantly increased sporulation of R. stolonifer and sporulation also increased as initial inoculum level increased. Efficacy of ozone fumigation and postharvest dips in ozone and alternative control products were also investigated for control of Rhizopus soft rot. Ozone washes and fumigation were not consistently effective in reducing sporulation of roots or incidence of Rhizopus soft rot. Dips in aqueous Cl02 and StorOx 2.0 significantly (<0.05) reduced disease incidence. Understanding the epidemiological factors favoring Rhizopus soft rot and identifying alternative control strategies.

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PROJECT TITLE: Enhancing Online Outreach for NC Strawberries

Project withdrawn

FUNDING

Total: $0.00
% of Grant: 0%

CONTACT PERSON

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PO Box 543
Siler City, NC 27344
(919) 537-2287

PROJECT TITLE: Increased Marketing Opportunities Through Health Messaging

Project withdrawn

FUNDING

Total: $0.00
% of Grant: 0%

CONTACT PERSON

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PROJECT TITLE: Expanding Specialty Crop Risk Management Opportunities

FINAL REPORT

PROJECT SUMMARY

In North Carolina agriculture, specialty crops, and especially those sold through direct markets, have played an important role in the replacement of income caused by major changes in the tobacco industry since the Master Settlement Agreement in 1998, and the end of the USDA Tobacco Quota program for the 2005 production year. With the end of the Tobacco Transition Payment Program in 2014, access to other segments of the federal safety net becomes increasingly important for specialty crop producers. Both specialty crops in general and direct market sales are underserved by crop insurance and these gaps leave specialty crop producers and the overall state's economy vulnerable.

Strawberries in particular represent a significant portion of North Carolina farm income, $27.3 million in 2011 when this grant was written and $23.4 million in 2015. Strawberry income is also extremely important to the economic viability of producing farms. In a RAFI survey of 54 North Carolina strawberry growers, 36% indicate that strawberries accounted for more than half of their farm income. For 60% of producers surveyed, strawberry income was more than 25% of total farm income. Strawberries also have the highest price per unit among specialty crops, more than double the next highest crop. As a result of the economic importance of strawberries, a strawberry crop loss can be particularly devastating to a farmer.

Despite the economic significance of strawberries there existed no specific crop insurance policy to cover this crop, leaving producers exposed. This is compounded by the fact that strawberries are at the high-end of investment vulnerability; they require significant upfront costs without being able to secure a return on investment until nine months after planting. Strawberries are in the ground from September through April, which is a very long risk window. All of these factors make it incredibly important that strawberries are protected by a risk management policy.

In addition to the need to improve risk management policies and options for strawberries, more work also needed to be done in regards to educating specialty crop producers on available crop insurance and risk management strategies, as well as better understanding which risk management options specialty crop producers currently use. Past research by RAFI revealed that 2/3 of surveyed producers didn't know which type of crop insurance policy would best suit their needs.

This 2013 SCBG project was designed to address gaps in the specialty crop safety net by creating a risk management option for strawberries and furthering education and research regarding crop insurance policies and risk management options for specialty crop producers.

North Carolina has seen a significant increase in farm income from specialty crop production and in income from specialty crops marketed through direct markets like farmers markets and farm stands. However, despite the increase in specialty crop production and direct market farm sales these are two areas that remain incredibly underinsured. At the time this grant was written, strawberries represented $27.3 million in NC farm income, and they are still a major component of North Carolina farm income at $23.4 million in 2015. The lack of adequate risk management options increases the economic vulnerability not just to producers, but to the state as well.

Natural disasters and extreme weather events remain a major factor for North Carolina agriculture and a lack of adequate risk management options leaves producers vulnerable not just to losing their crop,

but to losing their entire farm enterprise. During the course of this grant USDA made multiple declarations that designate certain North Carolina counties as Primary Natural Disaster Areas, this is due to the excessive heat and drought in certain parts of the state in Spring of 2015 and the excessive rain and flooding experienced in the Fall of 2015 and hail in the Spring of 2016.

The current vulnerability of specialty crop producers, particularly strawberry producers, highlights the importance of this work to create risk management options and educate producers regarding crop insurance policies and risk management. The regularity and severity of natural disasters underscores the need to address these gaps in specialty crop producers' safety net expediently.

This project built on a previously funded Specialty Crop Block Grant project, "Growing Market Share Through Risk Management". This past project identified specialty crop risk management needs, specifically the critical need for strawberry crop insurance. Many growers who participated in workshops for this past project indicated that strawberries were the crop most in need of an insurance policy. In fact, 100 percent of growers at one of the RAFI hosted workshops stated they were interested in a strawberry crop insurance policy as part of their overall risk management strategy. Growers even indicated that they would grow strawberries if a policy were available.

PROJECT APPROACH

1. Develop Outreach Materials and Conduct Outreach: During the course of this grant, USDA updated two key crop insurance policies for specialty crop producers in North Carolina. First, Whole Farm Revenue Protection (WFRP) replaced Adjusted Gross Revenue-Lite (AGR-Lite). Second, USDA developed a Non-insured Crop Assistance Program (NAP) buy-up option that enables producers to ensure up to 65 percent of their historic yield. The updates were required by the 2014 Farm Bill, and the policies have been available for NC producers since the 2015 crop insurance year.

Seven outreach and education workshops were completed during Fall of 2014 and Winter/Spring 2014, including presentations at the Carolina Farm Stewardship Association (CFSA) Sustainable Agriculture Conference, Southeast Strawberry Expo, Pasture Pork Conference, CFSA Organic Commodities and Livestock Conference, and 3 Appalachian Sustainable Agriculture Project workshops. Average meeting attendance was just under 15 participants. The presentations educated growers regarding new policy developments from the 2014 Farm Bill, mainly reforms to NAP and WFRP. Workshop results provided valuable feedback that allowed RAFI to move forward with developing risk management policy options for strawberry growers.

This information was also presented at four strawberry pre-plant meetings in North Carolina and South Carolina during July 2015 and August 2015. Additional outreach materials were created based on feedback from RAFI's presentation and to support RAFI's decision to pursue a direct-market price option through the Noninsured Crop Disaster Assistance Program. These workshops included guides to applying for NAP, WFRP, direct-market NAP, and how to secure a direct-market price NAP option for other specialty crops.

With support from a Southern Risk Management Education Grant, RAFI also conducted a series of presentations on risk management options and crop insurance policies for specialty crop producers in the Fall of 2015 and Winter of 2016. One of these presentations was held at the Southeastern Strawberry Expo and highlighted RAFI's work on this project working towards a strawberry risk management option. RAFI staff also secured funding to present at the Extension Risk Management Education National Conference. This presentation highlighted RAFI's work on educating specialty

crop producers regarding risk management options and RAFI's work to secure a direct-market coverage option for strawberries.

2. Insurance Policy Research: RAFI conducted an analysis of existing and potential crop insurance programs to determine where new programs might fill gaps in existing risk management programs. The analysis, informed by early indication from RMA that an index-based whether policy would be challenging, compared existing WFRP and NAP with a California ARH policy. Results of the analysis show that a NAP program with higher price options and an ARH program would fill existing gaps at an affordable price per acre.

Figure I illustrates the findings, with boxes in grey indicating where gaps would be filled by new programs.

- Grey boxes in the NAP row indicate where additional coverage could be provided by allowing direct-market prices to be covered under the program.

- Grey boxes under the ARH program indicate that by expanding ARH, a program with a higher liability limit, lower cost, and higher coverage options would serve as an alternative to NAP.

In the example below, WFRP is the cheapest option because the example shows costs for a producer receiving diversification discounts, which would not necessarily be the case for all producers, especially producers growing a high-value crop such as strawberries*. Note: Per acre premiums are only estimates and were calculated using USDA cost estimators for each of the policy options.*

Figure I. Producer Premium, Per Acre

Plan	50%	55%	60%	65%	70%	75%	80%	85%
NAP - Irrigated[1] - FSA price and yield	$539	$583	$628	$673				
WFRP – Highly diverse; 7 crops, 30 acres, All Crops	$25[2]	$30	$37	$44	$53	$66	$113	$208
ARH (CA mid-point estimate, only available for irrigated)	$79	$115	$150	$237	$334	$506		

Figure II represents the same analysis as Figure I but shows per acre cost differences that include the beginning farmer discount for each producer.

Figure II. Producer Premium, Per Acre, Beginning Farmer

Plan	50%	55%	60%	65%	70%	75%	80%	85%
NAP – Irrigated	$223	$245	$267	$290				
WFRP – Highly diverse; 7 crops, 30 acres, All	$12	$15	$19	$22	$27	$33	$74	$161

[1] This has an impact on expected yield, not price or unharvested factor.

[2] Compares insuring a single acre of strawberries to insuring a 30 acre diverse operation. It should be noted that insuring under WFRP means paying this for 30 rather than 2 to 3 acres. It should also be noted that at each coverage level a farmer can insure 30 acres at the WFRP for less than 2.6 (average in NC) of NAP.

Crops[3]								
ARH (CA mid-point estimate, only available for irrigated)	$71	$104	$135	$213	$301	$455		

Results from this policy analysis were presented during the course of 4 strawberry pre-plant meetings in July 2015 and August 2015. These results were also presented in individual meetings with key strawberry growers, including the Board President and Board Vice-President of the North Carolina Strawberry Association. During these meetings feedback was solicited from the growers regarding the feasibility and desirability of these policies. Growers overwhelming cited the need for a policy that covered direct-market strawberry prices and indicated interest in policies that cover revenue for their operations.

3. Online Outreach: SRME funding enabled RAFI to develop a risk management resource web portal http://rafiusa.org/farmer-resources/. Materials that were developed for conference presentations and outreach will be made available permanently on the RAFI Resourceful Farmer website.

4. 522(b) Concept Proposal Development: During the course of this grant RAFI went through many possible iterations of a strawberry insurance policy. Based on extensive outreach RAFI decided to focus on improvements to the NAP program that allow for direct-market price insurance. However, this policy option does not require going through the 522(b) or 508(h) process. RAFI and North Carolina strawberry producers pursued expanded risk management options by collecting data necessary for underwriting and making direct asks of FSA for the new policy options.

5. Full-scale Policy Proposal Development: Full scale policy development was not necessary given the altered methodology for achieving a North Carolina single-crop insurance policy for strawberries. A new policy was not privately developed by RAFI. Rather, existing policies were reformed and expanded to serve direct-market strawberry producers in North Carolina.

6. Data Collection and Support: Historical price information for strawberries from the 2013 and 2014 growing seasons was provided to the FSA North Carolina State Office in September 2015. RAFI in partnership with the North Carolina Strawberry Association gathered additional price data during the Winter of 2016, using a survey sent out to RAFI's farmer database as well as the North Carolina Strawberry Association's database. This data was provided to the State FSA office in March of 2016. The State FSA office was able to use this data to create a direct-market price for strawberries and ask the State Technical Committee for approval in April of 2016. The State Committee approved the price and it moved on to the national level, the Deputy Administrator for Farm Programs office for approval. RAFI has been providing assistance and support to both the state FSA office and the DAFP in order to answer questions regarding the data and direct-market price option. The national office did approve a direct market price of $182 per hundred pounds, but they did not authorize producers to revise their 2016 application to select the direct market price. So while, this does not impact growers directly for 2016 it does provide a precedent for establishing a direct-market price for 2017. The national office also provided feedback to the State Office on the specific data that is needed for this process.

Specialty crops were the only commodities that benefitted from this project.

Contributions and role of project partners in the project:

[3] An unlikely scenario

1. Barry Goodwin: Barry Goodwin provided advising to Selin Guney, NCSU PhD candidate in the Department of Agricultural Economics, who worked as a research assistant during the development of a strawberry Concept Proposal.

2. Selin Guney: Selin contributed comments on the outreach materials for pre-plant meetings, assisted in data entry and analysis of the survey results from workshops, and provided support in analysis of the NAP buy-up option for strawberry producers.

3. Barclay Poling: Barclay was responsible for planning each of the 5 pre-plant meetings in 2014. He was also responsible for assuring that RAFI was included in each agenda and developing advertising and outreach materials to recruit attendees. Barclay was also the organizer for the 2014 Southeast Strawberry Expo and worked with RAFI to developed a Risk Management Breakout Session which included RAFI staff, an FSA NAP representative, and an NCSU expert on the WFRP policy. In addition, Barclay has provided valuable technical insight for preliminary concept proposal development plans. Barclay continued to provide support to the project in 2015 with updates regarding the 2016 growing season and assistance with getting on the pre-plant agendas for 2015.

4. Robert Cerda: Rob Cerda organized and attended two preliminary meetings with RMA representatives in 2014 to discuss the feasibly of an indexed policy to address each of the concerns identified by growers during the pre-plant sessions.

5. Robert Satterfield, Program Specialist at NC FSA: Rob Satterfield aided in the development of the NAP portion of the 2014 pre-plant session presentation. He supported efforts to develop a NAP Premium Calculator for use with NC strawberry growers during outreach events. He has also consulted with RAFI staff on many occasions regarding farmer questions. He has also been a major supporter of securing a NAP direct market price for strawberries. He helped structure our data collection methods and he performed the calculations for the direct-market price and submitted this price to the State Committee for approval.

6. Mitchel Wrenn, President of NCSA 2013-2014: Mitchel provided extensive feedback on the 2014 pre-plant session presentations and the representative farm analysis. He contributed data from his own farm for the pre-plant survey, attended several pre-plant meetings in person, and recruited participants.

7. Grace Tuschak, Education Outreach Coordinator at North Carolina Strawberry Association: Grace provided extensive help with assuring that RAFI was included in each agenda for the 2015 pre-plant meetings and for securing RAFI a spot on the conference agenda for the 2015 Southeast Strawberry Expo. She was also instrumental in providing RAFI with strawberry historical price data and helping obtain price data for the most recent crop year.

GOALS AND OUTCOMES ACHIEVED

There were two measurable outcomes and goals for this project.

Expected Measurable Outcome/Goal 1: Increase grower risk management knowledge through outreach and education with growers about the availability of crop insurance policies, help them identify policies that meet their risk management needs, and help them identify existing policies that meet their risk management needs, and help them identify production-based risk management strategies that will reduce reliance on crop insurance.

RAFI developed outreach materials and conducted outreach to achieve this goal. Seven outreach and education workshops were completed during Fall of 2014 and Winter/Spring 2014, including presentations at the Carolina Farm Stewardship Association (CFSA) Sustainable Agriculture Conference, Southeast Strawberry Expo, Pasture Pork Conference, CFSA Organic Commodities and Livestock Conference, and 3 Appalachian Sustainable Agriculture Project workshops. The presentations educated growers regarding new policy developments from the 2014 Farm Bill, mainly reforms to NAP and WFRP. Workshop results provided valuable feedback that allowed RAFI to move forward with developing risk management policy options for strawberry growers.

In the summer of 2015, four outreach and education presentations were completed during strawberry pre-plant meetings in North Carolina and South Carolina. The presentations educated growers regarding new policy developments mainly reforms to NAP and WFRP. The presentations were also used to educate farmers regarding potential new strawberry insurance policies, specifically ARH and the NAP direct-market price option. These presentations solicited feedback from growers regarding what type of policy they would be most likely to utilize and the best way to collect data. It was through a follow-up conversation with a grower from one of these pre-plants that alerted RAFI to the North Carolina Strawberry Association's annual price survey.

Additional outreach materials were created based on feedback from RAFI's presentation and to support RAFI's decision to pursue a direct-market price option through NAP. These include guides on how to apply for NAP, WFRP, direct-market NAP, and how to secure a direct-market price NAP option for other specialty crops.

Expected Measurable Outcome/Goal 2: Insure North Carolina strawberry income through the development of a direct market strawberry crop insurance policy.

The project team determined, based on strawberry grower input, that this original goal is not realistic. The goal has been changed from development of a new strawberry insurance program to expansion and reform of existing programs, specifically NAP for direct market prices. The decision to pursue an expanded NAP option came about as a result of producer feedback from the workshops held in 2014. Nineteen of the 32 farms surveyed (59%) were enrolled in crop insurance on at least one crop. Sixteen of the farms (50%) were enrolled in crop insurance for strawberries. The most common type was NAP coverage with 13 farmers (41%) using it on any crop and 14 (44%) using it on strawberries. While only 44% of the farms use crop insurance for strawberries, these farms tended to be the larger farms and 62% (106 of 170) of strawberry acreage was enrolled in NAP. In addition to the 14 farmers currently using NAP, 6 more were aware of the program indicating that the majority of farmers interviewed (63%, 20 of 32) had prior knowledge of NAP. Only 4 of the 32 farmers (13%) were previously aware of California's actual revenue history (ARH) policy. This required extensive review of NAP, NAP buy-up, NAP direct-market prices and the ARH policy.

RAFI considered expanding California's Actual Revenue History policy to North Carolina. RAFI reviewed this policy, investigated what data and information would be needed to expand this policy to North Carolina, and had conversations with RMA. RMA has indicated their willingness to work with RAFI and consider the possibility of expanding this policy to North Carolina. Since an ARH policy would preclude strawberries from being eligible for NAP, RAFI decided to focus efforts on developing a NAP-direct market price option based on feedback from growers.

Data collection and coordination was completed to meet this goal. Historical data needed to underwrite this policy was provided to the North Carolina FSA Office and current price data for the 2015 growing season was collected and also submitted to FSA. The State Committee approved the FSA direct-price.

The Washington office approved a direct market price of $182 per hundredweight for 2016, but did not authorize growers to revise their 2016 application to select the direct market price. So while, this does not impact strawberry growers directly for 2016 it does provide a precedent for establishing a direct-market price for 2017. The national office also provided feedback to the State Office on the specific data that is needed for this process.

Comparison of actual accomplishments with the goals established:

Expected Measurable Outcome/Goal 1: Increase grower risk management knowledge through outreach and education with growers about the availability of crop insurance policies, help them identify policies that meet their risk management needs, and help them identify existing policies that meet their risk management needs, and help them identify production-based risk management strategies that will reduce reliance on crop insurance.

Seven outreach workshops were conducted in 2014. Based on feedback from an outreach session; participants experienced an average 58.8% change in knowledge regarding WFRP after the workshop. Prior to the workshop 83.3% of participants ranked themselves as not at all knowledgeable regarding WFRP and post-workshop only 16.7% ranked themselves as not at all knowledgeable. In regards to NAP knowledge there was a 50% change from pre to post workshop. Before the workshop, 66.7% of participants were not at all knowledgeable and then post workshop only 16.7% of participants answered that they were not at all knowledgeable.

Four additional outreach presentations were given in 2015 to further educate strawberry producers and solicit feedback on risk management options. RAFI staff also pursued other avenues for educating producers and others involved in the risk management field regarding specialty crop risk management options.

Expected Measurable Outcome/Goal 2: Insure North Carolina strawberry income through the development of a direct market strawberry crop insurance policy.

We modified this outcome based on strawberry grower input solicited throughout the course of this project. The goal was changed from development of a new strawberry insurance program to expansion and reform of existing programs, specifically NAP for direct market prices. We achieved this modified measurable outcome. We worked with the North Carolina Strawberry Association to collect and provide data to the State FSA Office in order to obtain a direct-market price for strawberries. The State Technical Committee recommended a direct-market price to the national office in the Spring of 2016 and the national office approved a direct market price for strawberries of $182 per hundredweight. The FSA market price is $140 per hundredweight so this is a significant outcome. While, the national office did not authorize this direct-market price to be applied for 2016, it sets a precedent for securing direct-market prices for strawberries and other specialty crops.

Increases in use of WFRP and NAP among specialty crop growers serves as a strong measure of outreach and education success during the reporting period. RMA data for the last five years is updated on a weekly basis, which can lead to corrections and changes in the reported numbers. Based on the RMA Summary of Business for 2015 WFRP sales in North Carolina increased to 23 in 2015 over 3 AGR-Lite policies sold in 2014. In 2016, 58 WFRP policies have been sold. Even more indicative of the improving risk management landscape was an increase in liabilities covered. In 2014, AGR-lite covered $1.1 million in North Carolina agricultural revenue. In 2015, WFRP covered $23.8 million in North

Carolina agricultural revenue.[4] RMA does not break down revenue covered by crop, but given that commodity crops have existing single-crop policies, it is likely that the majority of newly covered revenue is generated from specialty crops or livestock. In addition, 135 additional producers had NAP fees waived in 2015 over 2014, meaning that 135 additional beginning or socially disadvantaged farmers took advantage of the program in the first year of the buy-up.[5] In addition, the number of producers using buy-up NAP coverage held steady during 2015 and 2016, 18 strawberry NAP applications requested buy-up coverage in 2016 and in 2015 19 strawberry NAP applications requested buy-up coverage. The number of NAP applications decreased from 2016 to 2015, in 2016 there were 58 NAP applications for strawberries and in 2015 there were 74 NAP applications for strawberries. This is most likely due to a variety of factors, including the changes to the NAP pricing structure that weren't fully implemented until 2016. It is also reflective of the feedback RAFI heard from farmers during outreach events. During outreach events farmers indicated that they would be more willing to consider NAP if it better reflected the prices farmers were receiving for their direct-market sales.

Major successful outcomes of the project in quantifiable terms:

- An increase in grower knowledge of risk management options was achieved during the course of this project. Seven outreach workshops were conducted in 2014 as part of the outreach and education phase of this project. Based on feedback from an outreach session; participants experienced an average 58.8% change in knowledge regarding WFRP after the workshop. Prior to the workshop 83.3% of participants ranked themselves as not at all knowledgeable regarding WFRP and post-workshop only 16.7% ranked themselves as not at all knowledgeable. In regards to NAP knowledge there was a 50% change from pre to post workshop.

- A direct-market price of $182 per hundredweight for strawberries was approved for the Noninsured Crop Disaster Assistance Program for 2016. This is a significant increase, since the FSA market price for strawberries for NAP is $140 per hundredweight. This is an increase of $42 per hundredweight. Even though the 2016 direct-market price could not be retroactively applied, the real world impact comes in the precedent it sets. Since strawberries are a major direct-market crop and represented $23.4 million in strawberry production in North Carolina in 2015 securing direct-market price coverage will have a significant impact on the strawberry production that can be protected.

BENEFICIARIES

Specialty crop producers will benefit most from this project's accomplishments. The education and outreach conducted as part of this project was geared solely towards specialty crop producers, so they benefited most from the presentations and workshops. Additionally, the outreach materials created were written for specialty crop operations and will best serve this group.

Strawberry growers in particular will benefit from having a direct-market price NAP option. This expanded NAP program allows strawberries producers to obtain coverage for their crop at direct-market prices, instead of the wholesale prices. The strawberry direct-market price NAP option also serves as an example case for other specialty crops. Since there are other specialty crops still lacking

[4] Data accessed through the RMA summary of business: http://prodwebnlb.rma.usda.gov/apps/SummaryofBusiness/ReportGenerator/Results?CY=2015,2014&ST=37&IP=61,76&ORD=CY,IP,ST&CC=S

[5] Data provided by NC FSA office.

adequate risk management options, pursuing a direct-market price NAP option may be a way to obtain coverage for these vulnerable crops.

For 2015 there was $23.4 million in strawberry production in North Carolina. In a RAFI survey of 54 North Carolina strawberry growers, 36% indicate that strawberries accounted for more than half of their farm income. For 60% of producers surveyed, strawberry income was more than 25% of total farm income. Strawberries also have the highest price per unit among specialty crops, more than double the next highest crop.

LESSONS LEARNED

1. RAFI staff has learned the importance of coordinating outreach, education, and policy development work with the Farm Bill. Given newly developed risk management options in the 2014 Farm Bill, RAFI had to modify the outreach plan in order to collect feedback from producers about the adequacy of these programs to fill prior risk management gaps. This was actually a positive development because it provided a new avenue to achieve our goals. Working within the expanded NAP program was a more efficient and feasible solution than creating a new policy.

2. During the course of this project we learned the difficulty of trying to match stakeholder wants with achievable outcomes. While trying to develop a strawberry insurance policy, we went through many different possible policies and approaches. Stakeholder engagement at every part of this process was crucial in order to make sure we were on track to deliver an outcome that met producer needs. This was difficult because stakeholder input did not always match what was feasible. At first in this process producers were inclined toward an index-based weather policy, but RMA feedback indicated a lower chance of success if RAFI pursued that option. Stakeholders also expressed dislike of stringent recordkeeping requirements. So we had to find solutions that met growers' needs and were feasible in our current regulatory landscape, which we did by focusing on NAP. These challenges actually provided a way to be creative and were an opportunity to conduct more education and outreach.

3. During the course of this project we had a very successful partnership with the North Carolina Strawberry Association. Since individual growers were wary of providing data we partnered with the North Carolina Strawberry Association's annual price survey, which was a very efficient use of time and resources.

4. The data analysis phase of this project proved difficult since all of the calculation and approval were done by state and federal agencies and we could only participate minimally. We also had some issues providing appropriate data. Before collecting data, we checked with the state FSA office to ensure we were collecting appropriate data. Then during the direct-market price approval process the Washington office had questions regarding the data that had not come up during the data collection phase. This lack of coordination among offices regarding what data was required made it difficult to ensure that the proper data was collected. Also, since we were focusing on direct-market prices, most of the price data that was collected was provided by the pound or container and the calculations were done in hundredweight.

5. We had difficulty coordinating contracts with the NC SCBG Office. For the Outreach component of our work we wanted to bring on some additional contractual help. Despite, having ample funds in our budget for this piece of work it took months to receive responses from the NC SCBG Program. By the time we did receive responses there was not enough time left on the grant to execute the work. The additional help from a contractor would have greatly improved our work and it would be helpful if the process for approving a contract was more efficient.

When this project initially began we did not expect to pursue a NAP direct-market price option. We had initially planned to develop a private insurance policy for strawberries. However, during the course of the project with the changes from the 2014 Farm Bill and grower feedback we realized it was a much better option to work within the existing policy and program structures.

We had to modify one of our outcomes measures, specifically our goal to “Insure North Carolina strawberry income through the development of a direct market strawberry crop insurance policy.” The project team determined, based on strawberry grower input solicited throughout the course of this project, that this original goal was not realistic. The goal was changed from development of a new strawberry insurance program to expansion and reform of existing programs, specifically NAP for direct market prices, which would achieve the same impacts. We did achieve this goal and it showcases the importance of being flexible with regards to how you achieve your overall goals.

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PROJECT TITLE: Pilot Mountain Pride Operational Assistance

Project withdrawn

FUNDING

Total: $0.00
% of Grant: 0%

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PROJECT TITLE: Farm to School: Crops of NC

FINAL REPORT

PROJECT SUMMARY

Part of the annual review of school nutrition programs addresses nutrition education. School nutrition staff are expected to conduct nutrition education programs in the classroom. Most have no training in education, nor do they have time to develop educational materials that meet the North Carolina Common Core and Essential Standards.

The purpose of this project was to develop four illustrated children's books featuring fruits and vegetables grown in North Carolina. Those chosen to profile were watermelon, apple, tomato and sweet potato, all available through the NC Farm to School program administered by NCDA&CS. Each book tells the story of one crop from the field to the school cafeteria. Students will not only learn how the crop is grown but also how it gets to and is served in school cafeterias. There is an Activity Guide for each story book with activity sheets and information for students to take home. The End of Course standards are identified so school nutrition staff are presenting programs that meet state requirements and objectives.

This project merges the growing interest in farm to school and school food. USDA is emphasizing Farm to School and many community organizations and activists are also interested in schools serving local. These books will help school nutrition staff not only educate students but also promote that they are indeed serving local food in the cafeteria.

The objective of this project is to develop materials school nutrition staff can use to educate students on how their food is grown and to promote buying and consuming locally grown food.

PROJECT APPROACH

NCDA&CS staff researched how each crop is grown in our state and, using this information, developed the story outline and text for four story books- watermelon, sweet potato, tomato and apple. NCDA&CS also visited farmers to get their input and photograph their crops in the fields throughout the season. They chose appropriate images to accompany the text. Working with the illustrator, they finalized the story and decided which photos to feature in the book and which would be illustrated.

The illustrator used the story outline to draft a 28- or 32-page story for each crop. The story tells students how each item is grown in North Carolina and how it travels from the farm to their school cafeteria. The illustrator and NCDA&CS staff also developed activity guides to accompany each story book.

NCDA&CS's print shop printed 10,000 story books and 5,000 activity guides for each commodity for a total of 40,000 story books and 20,000 activity guides. Working with SNA-NC to promote the project, NCDA&CS coordinated delivering books to school districts across the state.
The books have been used during National Farm to School month, National School Lunch week, at nutrition fairs and other events to educate students on where their food comes from and agriculture in North Carolina, including local food served in the school cafeteria. Each has been received well and demand has exceeded supply. There is interest in developing several more books featuring specialty crops grown in our state and served in the school nutrition program.

The North Carolina Department of Agriculture and Consumer Services drafted the story outline, took photographs of the crops during the growing season and compiled these for the illustrator. NCDA&CS worked with the illustrator to edit drafts of each story book and activity guide. NCDA&CS also managed distribution of the story books and activity guides.

Farmers provided information on the production of the commodities, which was used to write the story line. They also allowed access to their farms so pictures could be taken, or contributed their own photos to the project. In addition, they reviewed drafts of each project and offered feedback. The School Nutrition Association of NC managed grant funds and promoted the project to its membership. Members of SNA-NC also provided feedback on drafts of each story book.

GOALS AND OUTCOMES ACHIEVED

Four story books and activity guides were developed and printed. They have been distributed across the state. Sales data for sweet potatoes, apples, watermelons and tomatoes through the NC Farm to School program in 2015-16 has been compiled. This data will be compared to sales for 2016-17 school year.

Data for 2015-16 sales of tomatoes, watermelons, sweet potatoes and apples through the NC Farm to School program has been tallied. Records have also been kept on the number of school districts that have requested materials printed as a result of this grant.

This project had two goals:

- To increase sales of sweet potatoes, tomatoes, watermelons and apples through the NC Farm to School program by 2%.
    - When compared to 2015-16 data, sales of tomatoes and watermelon exceeded the goal. Apple and sweet potato data for 2016-17 is incomplete at this time as sales will continue through the school year.

- Have 65% of school districts utilize materials in nutrition education programs.
    - To date, 85 of the 115 school districts (74%) have requested materials.

Sales data for each of the crops:

Crop	**2015-16 Sales**	**2016-17 Sales (as of 10/20/16)**
Apples	20,275	9,189
Sweet Potatoes	5,688	1,800
Watermelons	7,954	11,291
Tomatoes	2,455	3,322

Forty thousand story books and 20,000 activity guides were printed and distributed to school districts across the state. An additional 3,337 cases of watermelons were sold in the 2016-17 school year. Tomato sales increased by 867 cases.

BENEFICIARIES

The commodity associations of the crops which had story books and activity guides developed each benefited:

NC Watermelon Association

NC SweetPotato Commission

NC Apple Growers Association

NC Vegetable Growers Association

Each association was provided material to distribute to their members. Farms involved in agritourism also requested copies to distribute to teachers bringing school groups to their farm.

In addition, NC Ag in the Classroom also received materials to distribute to the teachers participating in their training courses. Advocates for Health in Action requested copies to distribute during a local foods training for preschools. FoodCorps has also distributed copies of the materials to schools in the counties they have a presence in.

Commodity associations will be interested in sales data. As demand increases, sales of crops will increase. The use of story books to educate elementary school students, combined with promotion of local food in the school cafeterias will drive demand for North Carolina grown tomatoes, watermelons, apples and sweet potatoes.

LESSONS LEARNED

We learned having more people review the drafts early in the development phase means less revisions later in the process. We also learned there are differences in how the same crop can be grown across the state so we need input from farmers representing those areas to write an accurate story line. We also learned how challenging it is to write a book about how a crop is produced at a level children ages 5 to 10 can understand. Initial drafts were too technical for the intended audience.

We realized there is a lack of lesson plans focusing on North Carolina agriculture and what little is available is outdated and therefore does not meet today's standards of learning.

Our initial audience was Kindergarten through fifth grade but realized preschools were also interested.

In the future, it is more realistic to complete two story books and activity guides per year instead of four. We also need to bring in farmers from across the state early in the research stage so the books are representative of production practices across the state in North Carolina.

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