Delaware Department of Agriculture

2009 Specialty Crop Block Grant Program

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Below is the final report for the 9 projects that are funded under this Specialty Crop Block Grant.

Project Title: "Marketing Real Christmas Trees"

Project Summary: The Delaware Christmas Tree Growers' Association (DCTGA) designed this project as a marketing initiative to promote the purchase of live Christmas trees. Since Christmas trees are purchased primarily by families, the project was directed to two markets: adult consumers and children, who would become the next generation of Christmas tree consumers.

In order to cultivate the adult consumer market, two media tools were developed: a PowerPoint presentation, which explains the environmental benefits derived from the growing of Christmas trees, and a video, which illustrates the tree growing process and the experience of visiting a Christmas tree farm. DCTGA intended to utilize these tools in presentations to various community groups and organizations as part of its outreach to adult consumers. Excerpts from these media tools were also utilized in a TV advertising campaign which was directed to the general public.

In order to reach the next generation of Christmas tree consumers, DCTGA developed a series of lesson plans, which are used for classroom instruction. These lesson plans were developed to meet the Delaware state science curriculum standards, so that the materials presented by DCTGA members would complement the science instruction that students were receiving at their grade level.

All of the materials developed through this grant were designed to educate and inform the public of the environmental benefits derived from the growing of Christmas trees and to encourage the development of environmental awareness and stewardship.

Project Approach: Project activities were divided into two phases. The first phase consisted of all activities directed toward the development of the PowerPoint presentation, the video, the television advertising campaign and the lesson plans. Phase two consisted of utilizing the materials, which were developed, with the target audiences.

DCTGA formed four committees to handle each of the development tasks. All committee members met together in early 2010 to identify the subject matter, which would be included in the media campaign. The committees then divided and focused on the development of the media tool for which they were responsible.

DCTGA is fortunate to have members who are scientists, educators and business professionals. These members generously gave of their time and expertise to complete the development of the media tools. It was initially anticipated that twenty members of DCTGA would participate in the development phase of the project. In actuality, about half those numbers were actively involved. The smaller committees however, worked effectively to complete their project tasks.

The video content was compiled by DCTGA members, while the video production was accomplished in partnership with Capital School District of Dover Delaware The Video Production Class at Dover High School filmed the video at several DCTGA member farms.

Production of the video required several months longer than anticipated, due to a decision to include filming of a typical family Christmas. With final revisions and editing, this effort required about four months longer than was initially planned.

The development of the lesson plans was accomplished by a committee of three members. Copies of the Delaware State Science Curriculum Standards were obtained and lesson plans were constructed to meet grade level specific instructional guidelines and subject matter.

Phase Two of the project began in 2011 and it consisted of demonstrating the media tools, which had been developed during Phase One. This second project phase would demonstrate whether the media tools could be effectively used with the targeted audiences.

Goals and Outcomes Achieved: All of the Phase Two activities defined in the project Plan of Work were completed within the defined timeframes. It was anticipated that ten members would volunteer to be Classroom Instructors. Six members actually participated in presenting the lessons to more than 700 students, across five grade levels.

To evaluate the effectiveness of the classroom presentations, the project was designed to include pre-tests, which would be administrated prior to the classroom presentations, and post-tests, which would be administered after the lessons. The plan was to calculate T-tests to identify whether significant differences existed between the pre-test (before the lesson) results and the post-test (after the lesson) results. This evaluative component had to be excluded due to time constraints, as the schools would not allow any more than 30 to 40 minutes of student access and this timeframe barely covered the lesson plans.

To provide some evaluative indicator of the effectiveness of the classroom instruction, a teacher survey was distributed in 2012. All of the teachers (20), who were invited to take the survey, were present in the classrooms when the lessons were presented. Their responses indicated that the lessons were well-prepared and stimulated student participation, and that the instructional material was highly relevant to the science curriculum which was being studied. These findings suggest that the goals of the lesson development were achieved.

It was estimated that six DCTGA members would be involved in presenting the PowerPoint presentation and the video to various adult groups within the Delaware community. To date, four DCTGA members have made presentations utilizing these tools and the public response has been positive. However, these media tools have been presented primarily in agricultural settings where the audiences have been transient - a group stays for a short period and then moves on. This presentation format made it impossible to administer a follow-up survey to determine the impact of the presentations. A PowerPoint follow-up survey is not accessible at this time, as the person who created it is out of the area.

To determine the response and receive feedback of the DCTGA membership before the development of these media tools was completed, the PowerPoint program was presented at the September 2010 meeting and the video was presented in September 2011. Both presentations were well received by the members and suggestions for some edits and further utilization were received.

The DCTGA Executive Board assumed responsibility for the development and implementation of television advertising campaign. This decision was made because the costs for this program were substantial, and consisted of project funds in combination with DCTGA membership cost matching. The Executive Board had fiduciary responsibility for distribution of project funds and members of the Board wanted the advertising funds to be expended so that each participating farm would receive an equal share of advertising value. To reach all of the Delaware public through television broadcasting would involve dealing with a minimum of two or three stations. The Executive Board felt that they would be in a better position to deal with the issues involved in this process, so they assumed responsibility for this project component.

Beneficiaries: The primary beneficiaries of this marketing project are Delaware growers of the specialty crop of Christmas trees. In 2012, the Delaware State News listed thirty-six (36) Christmas tree growers within the state of Delaware.

Delaware retailers who sell Christmas trees and related products also derived benefit from this project initiative. The 2011 Delaware Farm Market and Agritourism Directory lists thirty (30) On Farm Markets and Retail Garden Centers which market Christmas trees and related items. In total, sixty-six (66) agricultural enterprises derived direct economic benefits from this marketing project. Additionally, all Delaware chain stores and home center retailers, who market Christmas trees and value-added products, also benefited from the marketing initiative funded by this grant.

Three television stations were contracted to broadcast the DCTGA advertising during the months of November and December of 2010 and 2011. WBOC reached 180,000 households in Kent and Sussex counties, while FOX reached an additional 45,000 households in the same area. Comcast TV reached 167,970 households in New Castle County. Therefore, the advertising initiative funded by this grant reached a total of 392,970 households within the state of Delaware over two years.

In order to ascertain the impact of the TV advertising on grower revenues, DCTGA members were asked at a meeting in Sept. 2012, to compare their revenues from the 2009 season (before TV advertising began) to revenues from the 2011 season. The group consensus was that revenues were up a bit (less than 10%). Considering that during the 2010 – 2011 timeframe, the U.S. economy was is a serious recession, and that the purchase of a Christmas tree cannot be considered a “need”, the impact of the TV advertising is viewed as a positive outcome.

From the perspective of educational benefit, all members of the general public who view the media presentations, which this project produced, or participate in the instructional outreach components, will also be beneficially impacted by this project. Additionally, information on this project will be made available to other Christmas Tree Grower Associations upon request.

Lessons Learned: Project outcomes demonstrate that when project activities are conducted by volunteers, a project planner or coordinator can easily overestimate the number of volunteers who will actually participate in the project activity. Within this project, the rate of volunteer participation in the project activities was overestimated by 50%.

Another lesson which was learned was that "life sometimes gets in the way" of the project activities and schedule. To assure the completion of project deliverables, it is advisable to work

in teams. When managing a project, it is necessary to have back-up support for your volunteers when personal issues affect their performance capabilities.

As Christmas tree growers, the months of November and December are filled with farm- related responsibilities, so it is not practical to schedule project activities during this timeframe. Even though teachers may think this time of year would be perfect for a presentation on Christmas trees, most growers would find it difficult to participate in classroom presentations during this timeframe. We have found that many school districts have Science Days in the spring and that this is a good time for our members to conduct classroom instruction.

One of the most significant but unexpected outcomes of this project is the, effect that this effort has had on the overall spirit and cohesiveness of the DCTGA membership. Before undertaking this project, members participated in the association's activities in a casual, social manner. Now, the members are much more interested in what the association is doing and planning. Attendance at meetings has increased, and membership in DCTGA has increased by more than 10% since 2009. Implementation of this project and the involvement of DCTGA members in various project activities have resulted in a change in the membership's perception of the association. DCTGA is now seen as a more professional and achievement-oriented organization.

As Christmas tree growers who are committed to generating a sustainable specialty crop, which is beneficial to our environment, we often wonder if our message is being heard. A recent publication of the National Christmas Tree Association noted that in 2008, 28.2 million Americans purchased real Christmas trees. This publication also indicated that by 2011, 30.8 million American households purchased real Christmas trees. It would appear that American families are beginning to listen to our message.

Contact Person: Linda Schreppler, phone number - 302-697-7396

Additional Information:

Results of Teacher Survey

As part of their 2009 Specialty Crop Block Grant initiative, the Delaware Christmas Tree Growers Association had planned to utilize pre-test and a post-test comparisons to determine the effectiveness of the lesson plans that were developed for Delaware elementary school students. However, once the association began to contact the schools to arrange for presenting the lessons, it became clear that there would not be enough time available to accomplish the pre and post-tests. Schools were receptive to the presentations, but they had to be limited to one forty minute classroom period.

In order to provide some indication of the efficacy of the lessons, which were developed, DCTGA conducted a Teacher Survey (Attachment 1). Thirty classroom presentations were conducted from 2010 — 2011. Classroom teachers were present during the lessons, which were presented by DCTGA members. Of the thirty teachers who received a copy of the survey, twenty responded. Results are summarized in percentages of response.

It should be noted that teachers were free to select more than one response.

Question #1. The content of the lesson presented was...

a. especially relevant to the science curriculum being studied. (50% selected this response.)

b. somewhat relevant to the science curriculum being studied. (50% selected this response.)

c. not relevant to the science curriculum being studied. (This response was not selected.)

Question #2. The presentation helped students understand how Christmas trees...

a. provide many benefits for our environment. (70% selected this response.)

b. are grown on a farm but are different from other kinds of crops. (40% selected this response.)

c. are used for special holiday celebrations. (5% selected this response.)

Question #3. The Christmas tree growers who conducted the classroom presentations.

a. maintained student interest through the use of various materials. (55% selected this this response.)

b. were well-prepared and able to stimulate student participation. (65% selected this response.)

c. provided hands on experiences for learning. (30% selected this response.)

Three teachers also entered special comments. One teacher noted that she/he liked the samples of different evergreens that were brought to class and shared with the students. Another teacher noted that the presenter gave a good explanation of the growing cycles of Christmas trees. A third teacher commented that the children learned where Christmas tree seeds came from and how they were prepared for planting.

PowerPoint presentations:

We are in the process of putting the video that was created for this project on our website www.DelawareChristmasTreeGrowersAssn.com

Project Title: Connecting Specialty Crop Growers with Consumers-A Marketing Proposal

Project Summary: The purpose of this project was to connect more consumers with regional producers of specialty crops through a local print/video/web media “blitz”. This was done by promoting two nonprofit entities: the Bethany Beach Farmers' Market and the Fenwick Island Farmers' Market. These markets featured a combined total of twenty-one local specialty crop producers and continue to provide access to a diverse and abundant array of specialty crops while fostering sustainable agricultural practices with profits and benefits for all stakeholders.

The motivation for this project stemmed from the explosion of farmers' markets throughout Delaware, offering small growers the opportunity for the direct marketing of their produce, thus allowing for a greater profitability margin. With the influx of visitors to these coastal resort areas, marketing targeted at this customer base was both essential and timely.

Project Approach: The promotional activities included completion of the following:

- Comcast Cable shot a 30-second commercial which ran for an 11- week period during the height of the season for the Bethany Beach Farmers' Market and the Fenwick Island Farmers' market from July-Sept. 2010. A total of 824 spots were aired on the Resort Visitors Guide, the Weather Channel, the Food Channel and Headline News throughout the regional viewing areas of eastern Delaware and Ocean City, Maryland.

- Eleven weekly ¼ page color ads in two prominent local newspapers ran all summer. “The Coastal Point” and “Ocean City Today” targeted a large range of customers within the coastal area.

- Two new start-up websites, one for each market, were developed by Delaware.Net.Inc. See www.bethanybeachfarmersmarket.com and www.fenwickislandfarmersmarket.com
  A nonprofit organization rate was charged and the websites provided optimal exposure to the widest possible range of customers.

Additional activities included data collection and market monitoring from three sources:

- Manual tallies collected at each market
- Surveys conducted at each market
- Financial totals collected by the Delaware Department of Agriculture for each market date

The Bethany Beach Farmers' Market partnered with The Fenwick Island Farmers' Market successfully in all promotional efforts regarding the grant. Since many of the same specialty crop growers sold produce at both markets, this was compatible.

Goals and Outcomes Achieved: Performance goals achieved during the period included a three-pronged mass marketing approach using video, print and web technology aimed at a resort environment. Measurable outcomes were obtained through the use of the following:
Tally figures for the Bethany Beach Farmers' Market totaled 11,451 customers from June 27 through August 29, 2010. Attendance crested on July 4th with 1607 recorded patrons. Figures for

the Fenwick Island Farmers' Market followed a similar pattern, peaking on July 9 at 708 customers, with a total of 4306 recorded patrons from July2 to August 27, 2010. Note that Fenwick is a much smaller market. Also note that there were many more customers at both markets than we could tally to provide a firm number but these are close estimates. One of the primary challenges was a lack of available comparable tally data from any prior seasons for either market. This made it difficult to measure the full impact of the “media blitz” over time, as the promotions occurred throughout the summer.

Surveys using the following questions were implemented:

1) What is your home state?
2) Are you a visitor or homeowner?
3) Have you shopped here before?
4) How did you hear about the market?
5) Did you walk, bike or drive to the market?
6) Please rate our market on a scale of 1-5.

According to survey data, approximately 50% of customers at both markets were from Maryland, followed by Virginia, Delaware and Pennsylvania, respectively. This supports the observation that the majority of market customers are resort-based visitors from neighboring states.

Surprisingly, in other survey data, the majority of shoppers, also 50%, said that they had learned about both markets through area signage. The remaining customers did cite newspaper ads, word of mouth and commercials, in that order, as their way of learning about the markets. Most interesting, however, through continued survey data the following summer of 2011, was the description of the newly established websites as the top guide for consumers in locating both farmers' markets. It seems the websites took a year to reach maximum potential which was unexpected but resulted in a long-term positive outcome.

Financial totals collected by the Delaware Department of Agriculture reflected the same trends as the tally data, with significantly increased financial numbers during holiday and peak vacation weeks. The following totals for entire market sales at both markets reflect growth:

Fenwick Island Farmers' Market	2009	$60,091	2010	$73,270
Bethany Beach Farmers' Market	2009	$132,230	2010	$163,508

The above outcomes surpassed the goal of linking customers with growers on a local level, partly because buying and eating locally has never been such a huge part of the public's consciousness as it is now. This grant simply capitalized on that concept.

Beneficiaries: Two major groups benefited from this project: specialty crop growers (21) and farmers' market customers. Also, indirectly, the market communities themselves as new markets are being started in Delaware each year. These markets bring much to a community if they are targeted in key commercial districts. Some communities may be less responsive due to the economic downturn but this is certainly not true of the coastal farmers' markets in this area.

Lessons Learned: The primary lesson from the data taken is that numbers can only show growth when comparing two or more years. In the tally counts, for instance, it is recommended a two-year compilation of data for future studies.

The other surprising lesson learned was that technology in the form of the websites took a year to gain a foothold but remains the primary method of reaching new customers to this day. Without the time or resources to develop their own websites, specialty crop growers can greatly benefit from the market websites.

Contact Information: This Final Report was submitted by Carrie W. Bennett, (302) 732-3358, cbennett1218@gmail.com.

Project Title: "MAR-DELicious" – Expanded Marketing & Education Project

Project Summary: Mar-Delicious watermelons are grown on the Eastern Shore of Maryland and lower Delaware, an area known for fresh market produce, including watermelons for more than 100 years. According to the National Agricultural Statistics Service in 2006, Maryland and Delaware farmers together harvested 160.2 million pounds of watermelons with a farm gate value of $16.2 million from 4,900 acres. Former MD Agriculture Secretary Roger L. Richardson states that, "consumers who buy Mar-Delicious watermelons purchase a fresh crop that is carefully grown in Delaware and the Eastern Shore of Maryland.

With an identified preference for Shore-grown specialty crops, Delmarva consumers represent an affluent market for products and services. The Mar-Del Watermelon Association promotes the Mar-Delicious brand to local area food stores including Acme, Food Lion, Giant Foods, Pathmark, Safeway, Superfresh, WAL*MART, and Whole Food Markets tapping into consumer's desire to buy locally-grown food and support local farmers. With a history of delivering the freshest, most nutritious produce from the local farming area to larger cities in the northern Delaware and lower Pennsylvania region, this project will use that history to expand marketing and promotional opportunities to increase sales and product consumption to include the Mar-Delicious brand.

The local watermelon harvest occurs annually during late June through late August. The greatest obstacle to local growers is the influx of less expensive melons flooding the market from the southern states of Florida, Georgia, and North and South Carolina. These states have an earlier growing season than the Eastern Shore region. The imported melons, while less expensive and seemingly a food bargain, are actually an inferior product as they are most often overripe, less flavorful, and of a lesser nutritional value. Existing funding has created a media focus that is a consistent reinforcement of the local message therefore maintaining current consumer demand. By increasing marketing resources, Mar-Del will be able to expand the message of the value in buying locally grown melons thus supporting local farms. These increased resources will stimulate demand and movement of product into market channels while allowing an expanded focus on the nutritional value and diversity of watermelons.

Project Approach: It was identified the need to update and maintain the current Mar-Del website allowing a tracking mechanism and to enhance marketing and promotions of MAR-DELicious watermelons, purchase additional air time for promotional ads in targeted market areas, strengthen brand identity, expand visibility at local and regional special events.

Goals and Outcomes Achieved: Goal #1 - Increase MAR-DELicious brand name awareness. Our growers are proud to place stickers on Maryland and Delaware grown watermelons promoting the MAR-DELicious logo and place them in MAR-DELicious printed display bins. Our focus was to help our customers recognize the logo both by hearing the MAR-DELicious name on the radio, as well as, seeing the MAR-DELicious design on billboards.

Funding was used for a Philadelphia, PA/Wilmington, DE radio ad campaign on Mix 106.1 from July 15 – September 4 on Fridays, Saturdays and Sunday. Their coverage map covers the following counties in the metro area: Bucks, Chester, Delaware, Montgomery, Philadelphia, Burlington, Camden and Gloucester. The station's target audience has a core demo of 35 – 54

year old females and surpassed the one million listeners mark. It is estimated that over 100,000 people heard the radio ads on a weekly basis.

Since we had made an investment in two new billboards for the Wilmington area in 2010, we decided to utilize the billboards in 2011. This gave us visual awareness for eight weeks commencing on July 11 (the beginning of our watermelon harvest season, which typically last for eight weeks). The billboards were located on Rt. 1 Wilmington and Concord Pike. It is estimated that the billboard brought visual awareness to over 600,000 people monthly.

Another tool used was web banner ads on WWFG and WQHQ websites which linked visitors to our website. We also used "Video on Demand" on WWGG featuring a 15 second TV ads with the Mar-Del Watermelon Queen.

Our website has reached over 30,000 people which reflect a 10% increase from our last upgrade. We are updating our site with current information as we confirm our plans for the 2013 year.

*Goal #2 – Increase sales of product. The awareness for "locally grown" watermelons has increased significantly over the past three years. This awareness translates into larger purchases from local consumers. Although, national and state statistical production data is not readily available for the 2010- 2011 time period, local growers have seen an increase in demand. We are able to report overall retail sales of watermelons increased from $298,008,693 in 2011 to $362,116,185 during the promotional period of this project. This increase of 22% in 2012 from 2011 surpasses the goal of a 10% increase in sales. Although the sales figures do not specifically represent watermelons from Maryland and Delaware, these states were the main source of watermelons during the dates of the promotion. This data was provided by FreshLook Marketing.

*Goal #3 – Increase education of nutritional value of product. Queen Jordan did an excellent job speaking with the public about the nutritional value of watermelons and the benefits of buying locally grown watermelons. This campaign required the attendance at county fairs, school-based programs, festivals, visits to local produce markets and grocery stores. Grant monies were spent to purchase promotional materials for educational awareness, explain nutritional values and an emphasis placed on looking for locally grown watermelons.

Beneficiaries: The chain of beneficiaries consists of the following links: growers, brokers, retail outlets and the consumer. The economic impact is hard to determine but we can forecast that the demand for locally grown MAR-DELicious watermelons has increased.

Lessons Learned: We feel that our funds were used wisely and we reached a much larger audience. Educational awareness, nutritional values and emphasis placed on looking for locally grown watermelons were goals realized by this campaign.

Contact Person: L. Michelle Wright, Secretary/Treasurer of the Mar-Del Watermelon Association, phone - 410-749-9587, email - mardelmelon@hotmail.com

Project Title: Native Plants – Increasing Demand and Production Capacities in Delaware

This project was a collaboration between Delaware Cooperative Extension, The University of Delaware Botanic Gardens, the Delaware Nursery and Landscape Association and several individual Delaware nurseries to explore the feasibility of growing underused native plants in Delaware nurseries.

Project Summary: The wide-scale replacement of native plant communities with the typical American lawn has created an "ecological disaster" that reduces biodiversity, contributes to global warming through carbon emissions, pollutes aquatic resources, consumes fossil fuels, and encourages the use of pesticides and herbicides (Bormann *et al*. 1993). The scale of this conversion has been massive, and continues to grow annually. As of 2004, 40 million acres of the U.S. (five times the size of New Jersey) was in manicured lawn (Miles *et al.* 2005). Additionally, a number of plants introduced by the nursery and landscape industry (85% on non-native woody species that grow in natural areas in the United States come from the landscape trade – Richard, 1997) as well as by the USDA for erosion control, wildlife value, forage, etc. have proven to be invasive outside their natural habitat. Non-native species now represent 25% of Delaware's flora (Delaware Nature Society, 2009).

A 2007 forum to evaluate the status of invasive plants in Delaware concluded that consumers must be educated about invasive plant problems and the benefits of native species. Voluntary marketing programs were selected as the best way to approach the problem (Kuehn, 2007). The nursery industry thrives on the introduction of new plants (Thompson, 2009). Since many native species have not been traditionally grown in the nursery and landscape industry, they are "new" to the gardening public. Kauffman and Barnes concluded that a greater focus on education would increase nurseries' and consumers' awareness of private benefits of adoption of native alternatives to invasive plants. While it is useful to appeal to consumers' environmental ethic, native plants must be marketed by providing information on other plant characteristics such as adaptability, aesthetic appeal and ability to attract desirable wildlife (Kauffman and Barnes, 2009). Recent studies have shown that the use of native plants by landscape architects and contractors has increased as has market demand for native plants (Brzuszek et. al. 2007). In fact, the demand for native plants exceeds the supply (Smith, 2007). A recent paper published in HortTechnology concludes that to increase the use of native species by the landscape industry there is a need to increase the number of nurseries carrying native plants and the quantities and species currently available. The market for native plants sold could increase if more wholesale nurseries expanded the volume and diversity of commercially available native plants. To further increase the potential of this market, growers suggest that better and more information sources be provided for the general public. (Brzuszek and Harkess, 2009)

The horticulture industry in Delaware is concentrated in landscape design, installation and maintenance ($228 million/year) and has a relatively small production component ($53 million/year) (Hall, 2006). This project will provide opportunities for existing nurseries to expand their product mix and potentially overall sales as well as provide opportunities for new nurseries to enter the market. It will increase the market demand for native plants from consumers, which will provide opportunities for the landscape industry and enhance the supply of native. Consumers will benefit by having a source of native plants readily available from garden centers supplied by Delaware nurseries.

Project Approach: This project was designed to stimulate consumer demand for native plants by developing a fourth publication in the popular Plants for a Livable Delaware series to address ecosystem services provided by native plant landscaping. It included benefits associated with plant and animal diversity, storm water management and other important sustainable landscape strategies. This publication continues to educate consumers about native plants and develops demand that will ultimately drive the economic success of nurseries that choose to grow native species.

This project also addressed the need to develop procedures for the production of native plants that fit into current production practices. By providing rooted cuttings, liners and small plants for three production facilities to "grow on" in their current production systems, we were able to evaluate production adaptability, growth rate, required inputs, harvest-ability and market success of selected native plants currently not widely available in the nursery industry in Delaware.

Finally, in order for this set of native trees and shrubs to become widely adopted by the nursery industry, we must demonstrate landscape success of the selected species. The native trees and shrubs selected for this project were grown at four sites in Delaware--New Castle County Extension Office, Carvel Research and Education Center, Smyrna Outreach and Research Center, and the University of Delaware Botanic Gardens (UDBG)--and evaluated for establishment success, adaptability, and aesthetics. Home gardeners have had the opportunity to view the "trial plants" in their display/demonstration sites and informal evaluations are being conducted during special events, open houses, workshops, etc. The New Castle County Extension Office reported 1,500 visitors and the Carvel Research & Education Center reported 1,200 visitors to the demonstration sites throughout the grant period via workshops, open houses and special events.

Goals and Outcomes Achieved: The goals of this project were threefold:

- Increase consumer demand for native plants by developing a fourth publication in the popular Plants for a Livable Delaware series to address ecosystem services provided by native plant landscaping.
- Increase production of native plants by evaluating production adaptability, growth rate, required inputs, harvest-ability and market success of selected native plants currently not widely available in the nursery industry in Delaware.
- Increase the use of native plants through demonstrated landscape success of the selected species.

This project evaluated the feasibility of native plant production by tracking inputs, growth rate and plant quality on a select set of native trees and shrubs grown in three production facilities in Delaware including: The Sterling Nursery (liner grower), Forest View Nursery (field nursery) and the University of Delaware Botanic Gardens (UDBG) (container plant producers for spring and fall plant sales). Simultaneously, we evaluated the landscape success of the same set of native trees and shrubs in four landscape settings.

Container and bare root plant material were ordered and obtained from three sources after significant research and exploration into availability, cost and size of desired material at nurseries throughout the mid-Atlantic region. Project administrator conducted additional research

and interviews into propagation strategies of plants selected for trial by The Sterling Nursery. On April 26, 2010, the nurseries received the following plant material:

Trees:	Paw Paw	*Asimina triloba* (UDBG, FV)
	Hickory	*Carya glabra* (UDBG, FV)
	Atlantic White Cedar	*Chamaecyparis thyoides* (UDBG, FV, SN)
	Fringe tree	*Chionanthus virginicus* (UDBG, FV)
	Alternate Leaved Dogwood	*Cornus alternifolia* (UDBG, FV)
	Persimmon	*Diospyros virginiana* (UDBG, FV)
	Pond Baldcypress	*Taxodium ascendens* (UDBG, SN)
	Bald Cypress	*Taxodium distichum* (UDBG, SN)
Shrubs:	Spicebush	*Lindera benzoin* (UDBG, SN)
	Highbush Blueberry	*Vaccinium corymbosum* (UDBG, FV, SN)
	Blackhaw viburnum	*Viburnum prunifolium* (UDBG, FV)

Forest View Nursery (FV) received 10 container plants (3 gallon) of 6 trees and 2 shrubs to be planted in the field. The UDBG received 10 container plants (1 gal) of 8 trees and 3 shrubs. The Sterling Nursery (SN) received 200 rooted cuttings and stock plants from which to take cuttings. The nurseries incorporated the trial plants into their normal production practices. Forest View Nursery (field nursery) agreed to plant and care for The Sterling Nursery's *Chamaecyparis thyoides*, *Taxodium distichum*, and *Taxodium ascendens* stock plants. Forest View planted all project material, inclusive of The Sterling Nursery plants, April 29 & 30, 2010. Trial plants were incorporated into their normal production practices. The project administrator (PA) conducted nursery evaluations three times during the 2010 growing season and four times throughout the 2011 growing season (April/May, June, August, October/November). Evaluations assessed plant growth, health and quality as well as recorded inputs (fertilizer, pesticides, water, etc.) required by the trial plants. The PA recorded growers' concerns about incorporating the trial plants into their production system. Data collection concluded at the end of 2011.

Establishment success and plant growth of the same set of native trees and shrubs were evaluated at four sites in Delaware—New Castle County Extension Office, Smyrna Outreach and Research Center, Carvel Research and Education Center, and the UDBG. County horticulture agents, master gardeners and the UDBG interns/staff planted three plants of each species at the respective sites (Spring/Early Summer 2010). The PA recorded data on plant growth, health, quality, insect and disease problems encountered and overall plant aesthetics at regular intervals throughout the 2010 and 2011 growing seasons. An evaluation form was developed (Winter 2010) to facilitate consistent data collection at both the nursery and landscape sites.

The *Livable Ecosystems* brochure was developed, printed (7,000 copies) and distributed. Susan Barton worked with colleagues in Entomology and Wildlife Ecology to write this fourth brochure in the Plants for a Livable Delaware series. This brochure is targeted to home gardeners and designed to develop a demand for native plants. The brochure includes sections that highlight how native plants and sustainable landscape management enhance the environment, including wildlife habitat, storm water management, nutrient cycling and other benefits (http://extension.udel.edu/lawngarden/files/2012/06/live_eco_final.pdf). Brochures have been distributed to Cooperative extension offices and DE Nursery & Landscape members

(garden centers and landscape firms), DE State Parks, University of Delaware Botanic Gardens, Delaware Invasive Species Council, Delaware Urban and Community Forestry Council and Delaware Center for Horticulture for use in educational programming and outreach. Distribution is primarily through educational displays at public events such as Ag Day, A Day at the Farm, The Delaware State Fair, Coast Day, and all DNLA events. Organizations that have a physical site with homeowner visitorship also distribute the publication from their site. Feedback on this brochure has been highly positive with each county extension office requesting additional copies for distribution at Master Gardener and other public outreach events. The brochure has been used as a text at a Longwood Gardens short course (Sustainable Landscape and Design Theory).

This project was featured at a SARE funded UD Sustainable Landscape Tour (June 2010, 73 attendees) and the DNLA's Summer Turf and Nursery Expo (August 2011, 150 attendees). Attendees received a tour of the plants housed at the UD Botanic Gardens and the NCC Cooperative Extension Office and a discussion of the data obtained to date. Native plants were featured in Delaware Gardener columns in the News Journal and in a weekly Native Delaware column. Native plants, their appearance and performance, were featured in multiple talks at the DE Horticulture Industry Expo (DHIE) in both 2011 (377 attendees) and 2012 (493 attendees). Native plant surveys were distributed at the 2012 DHIE.

Beneficiaries: The green industry in Delaware is currently driven by landscape design, installation and maintenance. To date, Delaware's production component had been relatively small. This project has provided opportunities for existing nurseries to expand their product mix and potentially overall sales. The Sterling Nursery has permanently added *Lindera benzoin* and *Chamaecyparis thyoides* to its production schedule. This project has provided opportunities for new nurseries to enter the market. Increased awareness and subsequent demand of native plants by both consumers and landscape professionals can be attributed, in part, to the *Livable Ecosystems* brochure and ongoing educational programming efforts. The increase in market demand for native plants will encourage increased supply of natives. The UDBG continues to expand its native plant listing at their annual sales in response to consumer demand.

Lessons Learned: Weather was the most significant factor impacting installation, plant establishment, and health. Planting was delayed at the UDBG and in Sussex County due to heat and safety of the volunteers that would eventually assist in the planting. Accessibility of water at all sites was an issue. Gator bags were placed on some material at both the NCC and UDBG sites. Water was trucked out to all UDBG landscape trial plants. Five plants died prior to, or immediately after planting. In both 2010 and 2011, The Sterling Nursery lost the *Taxodium* cuttings they were rooting after the shade cloths were removed to allow more light. More than 250 *Chamaecyparis thyoides* cuttings were lost in 2011 due to the late timing of transplanting them into the field. The Carvel Research and Education Center lost eight plants due to drought stress. Other drought-related deaths occurred at all sites throughout the grant period.

Space constraints became problematic for New Castle County. They were unable to accommodate the *Taxodium ascendens* and *Taxodium distichum*. Those plants were given to the University of Delaware Grounds department, and were incorporated into an existing UD landscape.

Vandalism was an issue at the UDBG site, which is surrounded by UD's football parking/tailgating fields. Four plants were broken, pushed over, or ripped out of the ground during the season.

Animal browse was a minor issue faced by NCC and UDBG's nursery. New Castle County master gardeners caged their *Asimina triloba* (paw paw) to protect from further animal browse. Once caged, the paw paws almost doubled in size from their original height.

Weed pressure sometimes made it difficult to obtain accurate measurements for the smaller plants such as *Vaccinium corymbosum* and the *Viburnum prunifolium*. Weed pressure was most significant at the UDBG landscape trials and Forest View Nursery. This was despite Forest View's application of Princep and Surflan (March 2011) and Princep, Surflan and Honcho (September 2011) to prevent or limit weed growth.

To date, Forest View Nursery (field nursery) continues to care for Sterling's *Chamaecyparis thyoides*, *Taxodium distichum*, and *Taxodium ascendens* stock plants. Sterling Nursery takes cuttings from these plants as needed. *Diospyros virginiana* and *Chamaecyparis thyoides* proved to be vigorous growers with an average growth rate of 30.5" and 27.5" respectably. *Vaccinium coryumbosum* and *Cornus alternifolia* have been the most difficult to establish (see table). As of 2012, the nursery has not begun to sell the trial plants.

Nursery	Latin Name	Common Name	Avg. Health (1-5 scale)	Avg. Overall Appearance (aesthetics; 1 to 5 scale)
Forest View	*Asimina triloba*	Paw Paw	3.44	2.39
	Carya glabra	Hickory	3.64	2.69
	Chamaecyparss thyoides	Atlantic White Cedar	3.8	3.47
	Chionanthus virginicus	FringeTree	3.6	2.33
	Cornus alternifolia	Alternate Leaf Dogwood	2.8	1.53
	Diospyros virginiana	Persimmon	2.86	2.27
	Taxodium ascendens	Pond Bald Cypress	3.7	2.79
	Taxodium distichum	Bald Cypress	3.75	2.86
	Vaccinium corymbosum	Highbush Blueberry	1.82	1.4
	Viburnum prunifolium	Backhaw Viburnum	3.23	2.14

Adjustments were needed in the Sterling Nursery's planting procedures to accommodate the field planting of their rooted cuttings of *Chamaecyparis thyoides.* Plants were topped in order to get them through the planting equipment; subsequently the plants have a wider habit. They have been unsuccessful in their attempts to establish *Vaccinium corymbosum*, *Taxodium ascendens*, and *Taxodium distichum*. *Chamaecyparis thyoides* and *Lindera benzoin* have been successfully integrated into their production cycle. Bareroot *Lindera* has been reordered twice and field-planted for resale. Both will be permanently added to The Sterling Nursery plant listing. Both are/were sold at $2.40/liner.

University of Delaware Botanic Gardens (container nursery) fertilized plant material on a weekly basis from May through September. Plants grew at a rate that required transplanting to larger pots. Some material also required staking. Top performing plants for the UDBG are *Viburnum prunifolium*, *Carya glabra*, *Chionanthus virginicus*, and *Chamaecyparis thyoides* (see table). Plants garnering the lowest overall ratings were the *Vaccinium coryumbosum* and *Cornus*

alternifolia. Plants were offered for sale at the 2012 spring plant sale. All available units of *Asimina triloba*, *Chionanthus virginicus*, *Lindera benzoin*, *Vaccinium corymbosum*, and *Carya glabra* were sold. As a result, the UDBG will continue to expand the native plant assortment for future sales.

Nursery	Latin Name	Common Name	Avg. Health (1-5 scale)	Avg. Overall Appearance (aesthetics; 1 to 5 scale)
UDBG	*Asimina triloba*	Paw Paw	3.75	2.85
	Carya glabra	Hickory	3.97	3.37
	Chamaecyparss thyoides	Atlantic White Cedar	4.17	3.64
	Chionanthus virginicus	FringeTree	4.26	3.72
	Cornus alternifolia	Alternate Leaf Dogwood	3.09	2.39
	Diospyros virginiana	Persimmon	3.57	2.69
	Taxodium ascendens	Pond Bald Cypress	3.94	3.01
	Taxodium distichum	Bald Cypress	3.76	3.1
	Lindera benzoin	Spicebush	3.64	3.1
	Vaccinium corymbosum	Highbush Blueberry	3.3	3.13
	Viburnum prunifolium	Backhaw Viburnum	4.19	3.84

Top performers in the landscape trials include *Chamaecyparis thyoides*, *Carya glabra*, *Chionanthus virginicus*, *Diospyros virginiana*, and *Viburnum prunifolium* (see table) Plants that struggled in all landscapes were *Vaccinium corymbosum*, and *Cornus alternifolia*. *Asimina triloba* and the *Taxodium* are proving to be extremely resilient plants. Both had fallen victim to animal browse or vandalism and have grown back from the base at an astounding rate.

Landscape Trials:

Latin Name	Common Name	Avg. Health (1-5 scale)	Avg. Overall Appearance (aesthetics; 1 to 5 scale)
Asimina triloba	Paw Paw	2.95	2.41
Carya glabra	Hickory	4.06	3.83
Chamaecyparis thyoides	Atlantic White Cedar	3.66	3.32
Chionanthus virginicus	FringeTree	3.8	3.37
Cornus alternifolia	Alternate Leaf Dogwood	2.65	1.94
Diospyros virginiana	Persimmon	3.67	3.24
Taxodium ascendens	Pond Bald Cypress	2.68	2.23
Taxodium distichum	Bald Cypress	3.42	2.89
Lindera benzoin	Spicebush	2.94	2.38
Vaccinium corymbosum	Highbush Blueberry	2.83	2.23
Viburnum prunifolium	Backhaw Viburnum	3.68	3.38

Green Industry members are becoming enthusiastic about native plants. Seventy-eight percent of those who responded to a survey at the 2012 Delaware Horticulture Industry Expo said they are more likely to propose a native vs. non-native plant when recommending plants to a customer. Sixty-seven percent stated that they have changed the product mix they carry or grow to include more native plants. Customers are requesting natives. Ninety percent of respondents stated the information they learned via various educational events and publications from 2010-2012 influenced their decision to recommend, carry or grow native plants.

Businesses are beginning to adjust their product mix to accommodate this shift in demand. However, there's still room for improvement in highlighting native plants via displays, signage, etc. in their place of business. Many of the plants trialed by this project were carried or used by approximately 50% of the respondents. However, given the trial results, approximately 75% of the respondents are more likely to utilize them in their businesses. Two of the three participating nurseries are selling the trial plants. As a result of the initial sales response and anticipated future demand, they have permanently added some of them to their production practices.

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Project Title: Produce Food Safety

Project Summary: The purpose of this project was to continue and expand produce food safety programs in Delaware as well as to conduct appropriate applied research and demonstrations in produce food safety. Growers reported that wholesale produce buyers were requiring at a minimum that source farms have personnel trained in Good Agricultural Practices (GAP) and Good Handling Practices (GHP) for produce food safety. Many buyers were also requiring that their farms have GAP/GHP certifications verified by an audit. New federal food safety legislation was also passed and regulations were being developed that would impact produce growers that sell into wholesale channels. It was critical that the University of Delaware in cooperation with the Delaware Department of Agriculture and the Fruit and Vegetable Growers Association of Delaware continue GAP/GHP training programs and adapt training to fit any new industry requirements and government regulations put forward.

In addition, buy local programs were growing and there was increased direct market sales of produce. More direct marketers and small scale wholesalers (such as restaurant sales) of produce needed to be targeted with appropriate food safety training in Delaware.

Applied research was needed in the area of irrigation water microbial loading and the potential to treat water for microbial contaminates of concern on farms. Demonstrations were needed on how to build produce traceability programs. This project included research and demonstrations in these areas to provide information for training purposes.

This project built on a smaller grant received in 2008 which established initial GAP/GHP training certification programs in Delaware.

Project Approach: The project had several aspects. Appropriate experts in produce food safety were brought in for staff trainings and to speak to growers at the Fruit and Vegetable Growers Association of Delaware annual educational meetings at Delaware Agriculture Week. Recertification guidelines for those already having received GAP/GHP training were developed and implemented in 2010. Recertification update sessions for those growers were held in January each year at Delaware Agriculture Week that included the experts previously described. We conducted produce food safety training certifications in 2010, 2011, and 2012 for those not already trained. Trainings included both wholesale grower (6 hour trainings) and small farm/direct market sessions (3 hour trainings). Specifically targeted were wholesale watermelon growers, farm market owners, farmer's market masters/organizers, and small growers that were largely direct market or small scale wholesale.

Applied research and demonstrations in microbial loading of irrigation water and irrigation water treatment to reduce microbial loading were conducted in 2010 and 2011. In 2010, water tests were taken prior to the irrigation season, during the growing season, and after at least one storm event during the growing season on 10 farms during the summer months. Samples were analyzed by the laboratory of Dr. Kali Kniel at the University of Delaware Department of Animal and Food Sciences. This led to the development of a cooperative agreement between the

Fruit and Vegetable Growers Association of Delaware and the Delaware Public Health Service Laboratory to run irrigation water source tests at a reduced cost to growers.
From this on-farm testing, a surface water source that had high risk of contaminating produce was identified on a farm. A chlorine water treatment system was installed on that system in 2010. During the 2011 growing season water was sampled for pathogen reductions at different levels of treatment. Economics of the treatment system was calculated using the costs incurred.

One portion of the project that was not adequately achieved was in the area of produce traceability. Originally, three wholesale growers in Delaware were to be identified to develop produce traceability programs based on the industry standards being proposed and mock tracebacks were to be conducted. Inadequate funds were put into the grant initially to achieve these goals due to cost of software and equipment. However, basic traceability plans were developed and implemented for five farms. By the end of the grant, costs for traceability systems had decreased and we were able to buy one system to use for demonstrations and trainings in the future.

By the end of the project, several partners had made significant contributions. The Delaware Department of Agriculture issued training certificates and provided expertise for recertification sessions and with information on USDA GAP/GHP audit preparations for training sessions. They also helped to set up a GAP training session for those participating in farmer's markets. The Fruit and Vegetable Growers Association of Delaware served as a sponsor of trainings and recertification sessions and outreach to their growers. They also provided a venue for recertification sessions at their annual meetings in January each year. The laboratory of Dr. Kali Kniel in the Animal and Food Sciences Department at the University of Delaware analyzed water samples from irrigation water sources on farms and Dr. Kniel served as an expert resource in produce food safety. The Delaware Public Health Service Laboratory issued a Memorandum of Understanding with the Fruit and Vegetable Growers Association of Delaware to conduct irrigation and packing area water testing for farmers as a result of needs determined by this project. Delaware cooperative extension partners included agricultural and family and consumer science educators who conducted GAP/GHP trainings and the Fruit and Vegetable Extension Specialist (Dr. Gordon Johnson) and Extension Food Safety Specialist (Dr. Sue Snider) who developed and did yearly revisions on GAP/GHP training curriculum.

General Education and Recertification Activities - Yearly Educational and Recertification Sessions at Delaware Agriculture Week.

Experts were identified and spoke at the Fruit and Vegetable Growers Association of Delaware Annual meeting in 2010 in a dedicated produce food safety segment. Over 100 growers, University and industry representatives were in attendance. These sessions also served to train Extension Agents, Extension Specialists, DDA representatives, and FVGAD representatives involved with produce food safety (11 in attendance in 2010). In addition, a meeting of the Delaware Produce Food Safety Working group was held 2010 and modifications were made to training materials prior to the new round of GAP/GHP education sessions in 2010 (16 in attendance).

2010 Produce Food Safety Session Details at DE Agriculture Week

Research Update—Dr. O Sue Snider, Extension Specialist, Food Safety, University of Delaware, Animal and Food Sciences Department
Extension Produce Food Safety Program Updates— Gordon Johnson, Extension Fruit and Vegetable Specialist, University of Delaware

Delaware Department of Agriculture Program Updates—Ed Kee, DE Secretary of Agriculture
Legislative & Regulatory Update—Kathy Means, Legislative Affairs Director, Produce Marketing Association.

Irrigation Water Treatment for Reducing Microbial Loads – Dr. Wes Kline, Rutgers University

Experts were identified and invited to speak at the Fruit and Vegetable Growers Association of Delaware Annual meeting in 2011 in a dedicated produce food safety segment. Over 70 growers, University and industry representatives were in attendance (see program below). These sessions also served to train Extension Agents, Extension Specialists, DDA representatives, and FVGAD representatives involved with produce food safety (9 in attendance in 2011). In addition, a meeting of the Delaware Produce Food Safety Working group was held 2011 and modifications were made to training materials prior to the new round of GAP/GHP education sessions in 2011 (16 in attendance).

2011 Produce Food Safety Session Details at DE Agriculture Week
Updates from the Delaware Department of Agriculture Food Products Section and USDA Third Party Audit Program - Dr. Kaye Wachsmuth, Food Products Administrator, DDA; Nathaniel Taylor, Federal Program Manager, Mid-Atlantic/North East BIQMS Territory, USDA, AMS
Updates on Delaware Produce Food Safety Education Certification Program; Water Testing Research - Gordon Johnson, Extension Fruit and Vegetable Specialist, UD
Produce Traceability – Gordon Johnson, Extension Fruit and Vegetable Specialist, UD; Grower panel

Produce Food Safety Science Updates – Dr. Kali Kniel, Assistant Professior Microbial Food Safety, Department of Animal and Food Sciences, UD

Experts were identified and invited to speak at the Fruit and Vegetable Growers Association of Delaware Annual meeting in 2012 in a dedicated produce food safety segment. Over 70 growers, University and industry representatives were in attendance (see program below). These sessions also served to train Extension Agents, Extension Specialists, DDA representatives, and FVGAD representatives involved with produce food safety (8 in attendance in 2011).
2012 Produce Food Safety Updates at Delaware Agriculture Week
Updates from the Delaware Department of Agriculture - DDA GAP/GHP audits.
Updates from the University of Delaware – Dr. Gordon Johnson, Extension Fruit and Vegetable Specialist
Lessons from outbreaks with produce in 2011 – Dr. Sue Snider, Extension Food Safety Specialist, University of Delaware

<u>GAP/GHP Training Certification Sessions</u>

GAP/GHP training program consisted of 3 hours for direct marketers and low volume local wholesale growers and 6 hours of training for larger volume wholesale growers with potential need of a produce food safety plan for future audits.
The 3 hour training consists of the following segments:
Microbial Risks
Good Agricultural Practices
- Water safety
- Manure and biosolid use; preventing contamination from animals and wildlife
- Worker hygiene and personal practices
- Field sanitation and harvest procedures

Good Handling Practices
- Produce handling procedures
- Worker hygiene and personal practices
- Packing house sanitation

The 6 hour training has these additional segments

Record Keeping
Writing Your Produce Food Safety Plan (farm and packing house)
Preparing for an Audit
Worker Training
Packing house visit (optional)

A total of 5 GAP/GHP certification sessions were held in 2010: 2 in New Castle County, one in Kent County, and 2 in Sussex County. Smaller growers that direct market were specifically targeted – 2 training sessions were tailored for farm stands, farmer's market vendors, and other direct marketers. A total of 58 growers went through these trainings.

A total of 5 GAP/GHP certification sessions were held in 2011: one in New Castle County, 2 in Kent County, and 2 in Sussex County. Smaller growers that direct market were specifically targeted – 2 training sessions were tailored for farm stands, farmer's market vendors, and other direct marketers. There were 61 growers that went through these trainings.

A total of 5 GAP/GHP certification sessions were held in 2012: one in New Castle County, 2 in Kent County, and 2 in Sussex County. Smaller growers that direct market were specifically targeted – 2 training sessions were tailored for farm stands, farmer's market vendors, and other direct marketers. One special session was conducted for farmer's market vendors and a special session was conducted for a graduate student cooperative at the University of Delaware. A total of 47 growers went through these trainings.

Recertification Training Attendees - Recertification sessions were held at Delaware Agriculture week every year (2010-2012). In 2010, 46 growers received recertification credits. The Produce Food Safety Working Group met in 2011 and came up with revised recertification guidelines for growers already receiving GAP/GHP training. The requirement previously agreed on was that 1 hour of additional training would be required each year to remain certified. In 2011, this was

modified so that growers can obtain these credits over a 3 year period. In 2011, 53 growers received recertification credits. In 2012, 41 growers received recertification credits.

Water Testing and Water Treatment Research and Demonstrations - Irrigation Water Testing

In 2010, ten produce farmers were identified and samples were taken from surface water sources used to irrigate produce throughout the summer on a bi-weekly basis. 2010 was a dry year so there were not as many storm events during the year as in most years. Samples were processed by Dr. Kali Kneil's lab in the Animal and Food Sciences Department at the University of Delaware using. Verbal reports were given to growers and project results were presented at Delaware Agriculture Week. The following is a summary of that work:

Materials and Methods

Two 50-250 ml water samples were collected on a bi-weekly basis from May to September from 10 locations. Samples were collected in sterile containers from the sprinklers of the irrigation system. They were placed in coolers with ice packs and delivered to the laboratory the same day. At the laboratory, the samples were analyzed using the Colilert detection system as per the protocols required for that system. Due to detection limits, some samples had to be diluted (1:10 dilution).

Sample sites included the following:

Site 1 – river

Site 2 - stream fed pond

Site 3 - well fed pond

Site 4 – major drainage ditch

Site 5 - water table fed pond

Site 6 - water table fed pond

Site 7 - stream fed pond

Site 8 – major drainage ditch

Site 9 – major drainage ditch

Site 10 - stream fed pond

Selected Results

POND SITE E. coli MPN/100 ml

May	POND	100
June	POND	53.1
July	POND	310
August	POND	<1

At this site that had a stream fed pond, the site had one sampling period where the water exceeded the established standards for E. coli (Geometric mean of 5 samples - <126 CFU or MPN/100 ml with no sample over 235 CFU or MPN/100ml). This corresponded to a rain event that occurred two days prior to sampling. All other samples were below this level.

POND SITE 2 E. coli MPN/100 ml

June	POND	200.5
July	POND	23.8
August	POND	34.4

At another pond site, the E. coli levels were above acceptable standards at the beginning of the season when there was weekly rainfall but declined during the other months, most likely due to reduced rainfall during those periods.

River E. coli MPN/100 ml

May	<1
June	94.5
July	13.7
July	23.8
August	13.7
August	4.2

At the river site, no dates had values that exceeded irrigation water standards. The highest levels were in June and levels declined during the season. Again, this was most likely due to the extended drought during the 2010 growing season.

Over all sites, 8 of 65 samples exceeded guidelines for irrigation water, the highest levels were associated with rain events or were found early in the year, and dry year effects were evident as levels decreased through the drought period.

In 2011 and 2012, the Fruit and Vegetable Growers Association of Delaware initiated a water testing program for growers who wanted to become GAP/GHP certified (pass an audit). This was in cooperation with the Delaware Public Health Service Laboratory. In tracking these samples, the following results were found: Of the surface irrigation water samples tested, 6 out of 10 had E. coli that exceeded the established standards. Of the wells tested, E. coli was

detected in 4 out of 49. In two of the contaminated wells, one was located next to a manure storage area and three were located near to septic systems or waste handling systems.

Irrigation Water Treatment - A site was chosen where samples had high levels of E. coli in 2010. This site was a large pond that is fed by several streams as well as surface runoff water. An AccuTab chlorine injection system was chosen and installed on this system at the grower's farm. In this system, slowly dissolving chlorine tablets release chlorine and that is injected into the irrigation water stream.

AccuTab system with slowly dissolving chlorine tablets

Materials and Methods

An AccuTab chlorine system was installed at the irrigation pump for a stream and runoff fed pond site on a produce farm in Delaware in 2010. In 2011, the chlorine injection unit was tested with two irrigation systems that it supplied in two separate fields, one with a travelling gun system and one with a center pivot system. The crop that was being grown was cabbage. Water samples were collected at the injection site and in the field from the irrigation sprinklers or gun. Three chlorine injection levels were tested. Free chlorine levels in the irrigation water were checked using test strips.

Results

Field and System	Pump Cl	Field Cl	Pond E. coli	Field E. coli
	ppm	ppm	MPN/100 ml	MPN/100 ml
Pivot	3	<1	330	18
Pivot	6	2	330	<1
Pivot	9	4	330	<1
Gun	3	<1	375	5
Gun	6	3	375	<1
Gun	9	5	375	<1

Cl = free chlorine

In all cases, the addition of chlorine reduced E. coli levels well below irrigation water standards. The 6 ppm rate at the irrigation pump was sufficient to reduce levels to where they were not detected. However, the 3 ppm rate did not totally eliminate E. coli. This was probably due to the inactivation of chlorine by dissolved organic materials in the pond water to the extent that no chlorine could be detected in the field. The pivot had slightly lower levels of chlorine when it reached the field compared to the gun system, most likely due to the shorter length of run through pipes and lower volume of water used.

Economics - Costs for the chlorinator including fittings and installation were $2,800. The chlorine cost for running the unit at 4-6 ppm chlorine was approximately $3.10 per acre inch of water.

Cost for a 40 acre field using 6 acre inches of irrigation water is 40*6*3.10 = $744 or $18.60 per acre.

A liquid chlorine injection system is estimated at $14.40 per acre.

Traceability - As stated previously, the traceability portion of the project was not able to be completed due to costs of implementing those systems. Depending on the farm, the estimates varied from $4,000 to $15,000 for a system fully compliant with the Produce Traceability Initiative standards. Since we had approximately $6,000 we could not implement the system and efforts to seek additional funding were unsuccessful.

However, simplified produce traceability plans were completed and implemented on five farms. These involved creating a unique lot number or lot number and date system that could be stamped on shipping boxes or containers and that could be traced back to specific farms from repackers or from end sellers such as supermarkets. Lot numbers and dates were recorded on all of these farms and mock tracebacks were done during the year 2012 on 3 farms.

Finally, as software and hardware costs decreased, we were able to buy one sample demonstration system (PTI Lite from Redline Solutions) at the end of the project that will be used in future training sessions in 2013 and 2014.

Goals and Outcomes Achieved: Measureable outcomes and targets that were set for this project were as follows: 1) 15 or more extension agents/educators, specialists, and Delaware Department of Agriculture staff will receive continuing education on produce food safety, legislation and regulation, GHP's and GAP's, 2) 75 additional produce growers will be trained and certified, 3) 80 previously trained growers will received enough credits to be recertified, 4) surface water quality used for irrigating produce will be sampled on 10 or more farms at different periods during the growing season, 5) water treatment research will provide needed information on what will work on Delaware farms and costs involved and 6) a traceability program will provide details on costs, time, materials, and expertise needed to implement a traceability program for wholesale growers.
The following are the measured outcomes for these goals:

Goal: Bring in experts in produce food safety to speak to growers at Delaware Agriculture week and bring in experts to provide continuing education to Extension Agents, Extension Specialists, DDA representatives, and FVGAD representatives on produce food safety and incorporate new information into training materials.

Experts were identified and invited to speak at the Fruit and Vegetable Growers Association of Delaware Annual meeting in 2011, 2011, and 2012 in a dedicated produce food safety segment. These sessions also served to train Extension Agents, Extension Specialists, DDA representatives, and FVGAD representatives involved with produce food safety. In addition, a meeting of the Delaware Produce Food Safety Working group was held 2010 and 2011 and modifications were made to training materials prior to the new round of GAP/GHP education sessions in 2011 and 2012. A total of 18 staff were trained and received updates in the 3 years (1 FVGAD, 3 DDA, 3 DSU extension, and 11 UD Extension). See Project Approach Section Above for numbers attending training sessions and the Working Group sessions each year.

Goal: Offer additional initial produce food safety certification trainings (GAP/GHP) targeting those that did not attend previous trainings.

A total of 14 training certification sessions were held in 2010, 2011, and 2012 in all three counties. Wholesale watermelon growers and smaller growers that direct market or do limited wholesale were specifically targeted. A total of 6 sessions were specifically tailored for farm stands, farmer's market vendors, and other direct marketers.

Over the 3 years, a total of 166 additional growers went through these trainings. While the initial goal was on 75 in 2010, we extended the trainings beyond that year. Of the 166 that attended, 143 were from the targeted groups. This exceeded grant goals.

Post training surveys to date have been overwhelmingly positive. From these surveys, 100% of those attending now understand their role in keeping produce safe from contamination. A detailed survey from 2010 is attached. Evaluations immediately post-training were overwhelmingly positive for all sessions.

See Project Approach Section Above for numbers attending training sessions each year.

Goal: Recertification guidelines for those already having received GAP/GHP training will be developed by November 2009. Recertification update sessions for those growers will be held.

The Produce Food Safety Working Group met and came up with recertification guidelines for growers already receiving GAP/GHP training in 2009. The requirement agreed on was that 1 hour of additional training would be required each year to remain certified. In 2011, this was modified so that growers can obtain these credits over a 3 year period.

Recertification sessions have occurred at Delaware Agriculture week every year (2010-2012). An average of 46 growers received credits each year. In addition 14 growers went through GAP training again. By 2012, 60 growers had enough credits for recertification. This was short of the initial goal of 80, however there are > 60 that were certified that still have at least one year to complete their recertification and we are confident that we will achieve the goal.

See Project Approach Section Above for numbers attending recertification sessions each year.

Goal: Conduct an applied research project looking at water quality on farms using surface water for overhead irrigation of fruits and vegetables. Water tests will be taken prior to the irrigation season, during the growing season, and after at least one storm event during the growing season on a minimum of 10 farms. This will give us baseline information on the potential for surface water contamination of produce in Delaware.

In 2010, 10 produce farmers were identified and samples were taken from surface water sources used to irrigate produce throughout the summer on a weekly basis from June through August. Samples were processed by Dr. Kali Kneil's lab in the Animal and Food Sciences Department at the University of Delaware. Verbal reports were given to participating growers and project results were presented at Delaware Agriculture Week in 2011. Information gathered from this project was incorporated into GAP/GHP training programs in 2011 and 2012.

From this work, the Fruit and Vegetable Growers Association of Delaware decided to offer water testing in cooperation with the Delaware Public Health Service Laboratory at reduced cost. This program has been in place for 2 years and is a significant achievement.

See Project Approach Section Above for specific results of this work.

Goal: Conduct applied research on reducing potential pathogen loads in surface waters. From on-farm testing proposed, a surface water source that has high risk of contaminating produce will be identified. An appropriate water treatment system will be identified and installed and water will be sampled for pathogen reductions at various levels of treatment. Economics of the treatment system will be calculated.

In 2010, a grower with water quality issues was identified and a water treatment system was purchased and installed supplying several overhead irrigation systems that irrigate fresh produce. Sampling was conducted in 2011 starting in May using different treatment levels. This information will be reported at 2013 grower meetings.

See Project Approach Section Above for specific results of this work.

Goal: Conduct a pilot traceability project. We will choose 3 wholesale growers in Delaware and work with them to develop traceability programs for their produce based on the industry standards being proposed. These growers will then serve as examples for the rest of the produce industry in DE.

As detailed previously, the traceability portion of the project was not able to be completed due to costs of implementing those systems. However, simplified produce traceability plans were completed and implemented on five farms. These involved creating a unique lot number or lot number and date system that could be stamped on shipping boxes or containers and that could be traced back to specific farms from repackers or from end sellers such as supermarkets. Lot numbers and dates were recorded on all of these farms and mock tracebacks were done during the year 2012 on 3 farms.

As costs of systems declined, we purchased one sample demonstration system (PTI Lite from Redline Solutions) that will be used in future training sessions in 2013 and 2014 on how to comply with Produce Traceability Standards. While outside the scope of this grant, we will provide reports on the success of those trainings to the Delaware Department of Agriculture.

Beneficiaries: Beneficiaries of the project included 18 staff that were trained and received updates in the 3 years (1 FVGAD, 3 DDA, 3 DSU extension, and 11 UD Extension). Over the 3 years, a total of 166 additional growers went through GAP/GHP training certification. Of the 166 that attended, 143 were from the specially targeted groups. A total of 60 growers completed sufficient credits for recertification. In 2010, 10 produce farmers received the benefit of irrigation water testing on-farm and one grower had an irrigation water treatment system installed on their farm. Simplified produce traceability plans were completed and implemented on five farms. Results from water testing were incorporated in to training materials and provided information on costs of water treatment and this was presented to 108 growers attending trainings in 2011 and 2012.

Lessons Learned: There were many lessons learned from this project. Staff benefitted greatly from training sessions and updates were incorporated into the GAP/GHP training for growers. In particular, the latest food borne illness outbreaks with produce, legislation and proposed regulations, audit guidelines, and industry initiatives were incorporated in to grower training.

From growers attending GAP/GHP training sessions, there was a better understanding of their concerns, particularly the need for assistance in developing produce food safety plans prior to an audit. Smaller growers expressed a need for more information on produce washing. Improvements to these sessions included demonstrations on why certain produce are of more concern than others for contamination and ways to monitor chlorine in wash water.

From the recertification sessions, we learned the importance of yearly updates. We also learned that there was a need for alternative ways to get recertification credits and an electronic version that can be done from a computer will be needed as well at least one additional session where multiple credits can be picked up at a time.

On-farm water testing information demonstrated the potential for surface irrigation water to be contaminated above acceptable levels and the on-farm water treatment information showed how to address this problem and the economics of using chlorine to reduce pathogen loads in irrigation water.

One portion of the project that was not adequately achieved was in the area of produce traceability. Inadequate funds were put into the grant initially to achieve these goals due to cost of software and equipment. Our costs were inaccurate and should have been increased by at least 200% to achieve the goals of the project. However, we did learn what appropriate costs were and as the costs of these systems and software decreased, we were able to purchase a demonstration system for future training. The idea of setting up systems on farms as a demonstration is probably not practical.

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Additional Information: Survey Results

Good Agricultural Practices Survey

Recently, you attended produce food safety training. In order to evaluate the success of the training, your feedback is requested. Please complete this anonymous survey and send it back in the enclosed postage-paid envelope.

In mid-2010, we will be sending a follow-up survey. In order to match future responses to the information you provide in this survey, we are asking you to supply your birth date. No other means of tracking data will be used.

Birth Date (mm/dd/yyyy): _07/31/37 - 06/05/87_ **→70 surveys total**

1. I sell produce primarily through direct marketing in a retail setting.
   __63% (44)_yes _33% (23)_no

2. I sell produce primarily through wholesale channels.
   __39% (27)_yes _46% (32)_no

Overall, how would you rate the training you attended? (Circle Your Answer)

	Strongly Disagree	Somewhat disagree	Neither Agree or disagree	Somewhat Agree	Strongly Agree
3. The information was relevant to me.	1 (2) 3%	2 (2) 3%	3 (3) 4%	4 (22) 31%	5 (47) 67%
4. I will use or refer to the handouts.	1 (1) 1%	2 (3) 4%	3 (4) 6%	4 (26) 37%	5 (42) 61%
5. I will use the information now.	1 (2) 3%	2 (2) 3%	3 (3) 4%	4 (22) 31%	5 (47) 67%
6. I will use the information in the future.	1 (2) 3%	2 (1) 1%	3 (2) 3%	4 (14) 20%	5 (58) 83%

As a result of this program, I better understand (please check all that apply):

7. 96% (67) the need to protect consumers from unsafe produce

8. 100% (70) my role in keeping produce safe

9. 96% (67) the need for record keeping to document good food safety practices

10. 90% (63) the liability associated with selling unsafe produce

11. 96% (67) microorganisms that can contaminate produce

12. 96% (67) how water can contaminate produce

13. 97% (68) how fecal contamination in fields can make produce unsafe

14. 97% (68) how good personal hygiene can reduce foodborne illness

15. 96% (67) the role of Delaware's voluntary food safety certification program

16. 71% (50) the role third-party audits play in differentiating my product and opening my produce to larger markets

As a result of this program, I will:

17. Train my workers in the importance of good personal hygiene practices
36% (25)__yes __0%___no 36% (25)__I already do this 39% (27)___ not applicable (N/A)

18. Provide and maintain toilets and sanitary washing facilities in the field
13% (9)__yes 3%(2)___no 36% (25)__I already do this 57%(40)__ not applicable (N/A)

19. Keep records to document good food safety practices
56% (39)__yes 9% (6)__no 24% (17)___I already do this _19% (13)___ not applicable (N/A)

20. Test packing area wash water (municipal water once yearly, well water twice yearly)
33% (23)___yes 9%_(6)__no 10% (7)__I already do this 57%(40)__ not applicable (N/A)

21. Test surface irrigation water source 3 times per year

29% (20)___yes 21% (15)__no 7% (5)___I already do this 53% (37)__ not applicable (N/A)

22. Establish standard operating procedures for periodic washing and sanitizing of harvest and packing area tools, containers, and transport equipment
46% (32)__yes 4% (3)_no 24% (17)__I already do this _31%(22) not applicable (N/A)

23. Monitor temperature of refrigeration units daily
24%(17)__yes 7%_(5)__no 27% (19)___I already do this 51% (36)__ not applicable (N/A)

24. Monitor temperature of wash water before each packing run
14% (10)___yes 11% (8)__no 6% (4)___I already do this 77%(54)__ not applicable (N/A)

25. Monitor chlorine levels of wash water before each packing run
14% (10)___yes 10% (7)___no 9% (6)___I already do this 73% (51)__ not applicable (N/A)

26. Remove rejects/culls to distant location to eliminate cross contamination
30% (21)___yes 1% (1)___no 51% (36)__I already do this 20%(14) not applicable (N/A)

27. Eliminate potential of field contamination from livestock operation runoff.
19%(13)___yes _0%___no 31%(22)___I already do this 60%(42)__ not applicable (N/A)

28. Compost manure and culls properly to insure elimination of harmful microorganisms
24%(17)___yes 3% (2)___no 47%(33)__I already do this 33%(23)__ not applicable (N/A)

29. Store compost in a way to reduce the potential of cross contamination
26%(18)___yes 1% (1)___no 44%(31)__I already do this 36%(25)__ not applicable (N/A)

30. Develop and implement a farm food safety plan
57% (40)__yes 11% (8)__no 20% (14)___I already do this 17%(12)___ not applicable (N/A)

31. Request a third-party audit
21%(15)_yes 44%(31)__no 4%(3)___I already do this 34%(24)___ not applicable (N/A)

32. Use the voluntary food safety certification to market my operation.
51%(36)__yes 23%(16)___no 10%(7)___I have already done this _17%(12)_ not applicable (N/A)

If you conduct direct sales, please answer these questions. If not, skip to question 36. As a result of this program, I will:

33. Keep cut produce refrigerated, covered, and reduce the opportunity for bare hand contact
_27% (19)___yes 3% (2)___no 14% (10)___I already do this 27% (26)__ not applicable (N/A)

34. Sell produce in pre-packed containers to minimize customer handling
36%(25)___yes 16%(11)_no 16%(11)___I already do this 30% (21) not applicable (N/A)

35. Train sales personnel in good personal hygiene practices
31% (22)___yes 0%___no 20% (14)__I already do this 31% (22)__ not applicable (N/A)

36. I attended the following trainings (check all that apply):

31%	(22)	Kent County Cooperative Extension Paradee Center (2/19/09)
30%	(21)	Fifer Farms (February 24, 2009)
9%	(6)	Profiting From A Few Acres Conference (February 20 and 21, 2009)
16%	(11)	Sussex County Extension Training on (April 2 and 9, 2009
7%	(5)	New Castle County Extension Training (November 10, 2009)
4%	(3	New Castle County Extension Training (November 16, 2009)
3%	(2)	Ag Week Training January 2010
11%	(8)	Sussex County Level 1 Training (March 2, 2010)
7%	(5)	New Castle County Level 1 Training (March 9, 2010)
10%	(7)	Sussex County Level 2 Training March 2010

NOTE: Some attendees attended more than one training session

37. What other food safety topics would you be interested in?

- More on fresh market retail operations such as road-side stand
- Food defense
- Application of GAP to producers who are at different stages of incorporating core principles
- How to keep the momentum for GHP-GAP going
- What we can do to ensure that our product, with our traceability code on the stickers, does not get cross contaminated with other produce at the warehouses.
- Ways of effectively communicating the scope of our efforts in area of food safety to the public.
- Hazardous food safety – what are the guidelines for farmer's markets for products such as cheese, yogurt, honey, and heat treated plant foods (relishes)?
- Division of public health guidelines difficult to find.
- People want to be informed about producers having insurance, limits, etc.
- Pesticides, how long they stay on produce, etc.
- GMO's, are there any studies on long term effects of consumption, etc.
- Any topic related to on the farm food production, including produce, baked goods, preserved products, etc.
- Impacts of future FATFDA requirements on small operations.
- Programs/courses offered by extension.

- Smaller scale fresh market produce operations.

38. Other Comments
    - My operation is too small and cash flow is too small to do all this stuff!
    - Now that we have gotten rid of all the harmful bacteria with all the washing and chlorine, what happens to all the beneficial bacteria?
    - I do not raise crops for sale but have in the past and wanted to update my info.
    - I really learned a lot and enjoyed the hand-washing training with the black light.
    - Excellent program. Should be extended to the consumers because once it leaves our hands, we have no control.
    - This course provided a wake-up call as a grower/farmer's market organizer. Especially starting out with the law firm specializing in food borne illness litigation. Farmer's markets in this state are vulnerable to lawsuits. There seems to be better oversight for non-hazardous foods under DDA and Extension service than hazardous foods under public health.
    - I attended this class so that we at NHPS can speak to schools who are attempting to buy local produce. I can also talk to the producers of the importance of this class.
    - Handouts helped a ton!
    - **The speakers were great!**
    - **What can we do to ensure that our product, with our traceability code on the stickers does not get cross-contaminated with other produce at the ware houses?**
    - **Fresh market operations – Road side stands.**
    - **Excellent program that should be extended to the consumers.**
    - **I especially enjoyed the hand-washing training with the black light.**
    - **After you get rid of the harmful bacteria from washing, what happens to the beneficial bacteria?**
    - This course was eye-opening and hopefully useful down the road.
    - This is going to greatly increase cost.
    - Thank you! (6)
    - Informative, beneficial, worthwhile.

Please remember you can request a mock audit of your operation or
request on-farm food safety training for farm workers
by calling your county local Extension office.

Thank you for completing this survey.
The information you provide will help us meet grant funding requirements and assist in developing future programs.

Funds for this project have come from the
Delaware Department of Agriculture and the North East Center for Risk Management Education.

Project Title: Management of Watermelon Fusarium Wilt through Developing and Deploying Host Resistance.

Project Summary: *Background* - Watermelons are one of the most extensively planted and economically valuable vegetables grown in Delaware. Fusarium wilt is increasing in prevalence and has become one of the most important diseases of watermelons in Delaware. The increase is attributed to the shift to production to seedless watermelon, which generally lack resistance; loss of methyl bromide fumigation; and the increase in acreage infested with the highly aggressive *Fusarium oxysporum* f. sp. *niveum* race 2. A new race, race 3, has also been described on Delmarva, but is thought to exist only on limited acreage. Use of resistant cultivars (resistant varieties) is an ideal tool for disease management. It is low cost to the grower and reduces the need for in-field application of pesticides.

Our objective for this project was to provide tools for growers to manage Fusarium wilt of watermelon through deployment of resistant cultivars. We accomplished this through two specific projects that had measurable outcomes: 1) testing triploid watermelon cultivars and providing information on genetic resistance in currently available cultivars; 2) development of germplasm with known resistance to *Fusarium oxysporum* f. sp. *niveum* that will be utilized by commercial vegetable breeders to develop future commercial cultivars. Our project addressed the following research and extension priorities; new variety evaluation and development and varieties for pest resistance and disease management.

Our project benefited all watermelon growers in Delaware. Fusarium wilt has been observed in a majority of fields and, as noted earlier, 25% of surveyed fields had the highly aggressive race 2 FON, for which there is no resistance.

Project Approach: Cultivar evaluation. We obtained triploid (seedless) watermelon cultivars with purported resistance to FON from Seigers Seed Co., Seedway LLC, Abbott and Cobb, Inc., Seminis Vegetable Seed, Rogers Brand, Syngenta Seed, Inc.

Experiments were conducted at the University of Delaware Research and Education Center, Georgetown in 2010 and 2011. The field had been planted to watermelon for several years and had a moderate level of *Fusarium oxysporum* f.sp. *niveum* race 1. In addition, isolations from watermelon plants in the field in 2009 were confirmed as *F.o. niveum* race 2, which is a more virulent race. The experiments were conducted as a randomized complete block design with three (2010) and four (2011) replications. Plots consisted of single row beds, 40 ft. long with 13 triploid plants, on 7-ft centers, and covered with 1.25-mil black plastic under which a single drip irrigation tube was placed in the center. Plots were irrigated via drip tape as needed. Fertility was supplied according to extension recommendations both preplant and through the drip. Twenty-five and eighteen triploid watermelon cultivars, that had previously been identified as possessing some level of resistance to one or more races (races 0 and 1) of *F.o. niveum*, were evaluated in 2010 and 2011, respectively, along with the susceptible cultivar 'Sugar Heart' or 'Calhoun Grey'. 'SP-4', which has resistance to *F.o. niveum* race 1, was used as the pollenizer. Triploid watermelons were seeded in the greenhouse in early May, and 'SP-4' was seeded approx. one week later. Triploid cultivars were transplanted to the field on 10 and 5 Jun, in 2010 and 2011, respectively, spaced 36 in. apart in the row. Six seedlings of 'SP-4' were planted per plot so that a pollinizer was between every second and third triploid plants. Weeds were managed according

to extension recommendations as well as by hand as necessary. Foliar diseases were controlled with applications of chlorothalonil, Topsin M, Ranman, Inspire Super, Pristine, and Previcur Flex, which do not affect Fusarium wilt. Insects were managed according to extension guidelines. In 2010 Wilt index, where 1 = no wilt symptoms, 3 = yellow and stunted plants, 5 = few dead plants, 7 = stunting and more than one dead plant, 10 = most plants in the row dead; was assessed on 28 Jul. In 2011 the dead and wilted plants (% Fusarium wilt) were counted on 29 Jun. Vine length of the 3rd, 5th, and 7th plant in each plot was measured on 29 Jun. If only one of the three plants was alive, a 4th live plant was measured. All fruit were weighed and counted at harvest. Percent Brix (soluble sugar content) was measured with a hand held refractometer on three randomly selected ripe fruit in each plot. Fusarium wilt incidence, severity, vine length and yield were analyzed with the procedure PROC mixed in SAS. Means were separated using Fisher's protected LSD test.

Fusarium wilt severity was high in the field in both 2010 and 2011 and yield and disease varied significantly among cultivars. In 2010 the best performing cultivars were Matrix, Majestic, ACR6277 and Fascination. The poorest performing cultivar was Ruby Premium from Seedway LL, which ranked lowest in yield. A similar trial was conducted in 2009 on a smaller number of cultivars. In that trial Ruby performed similarly as in 2010, although ACR4674 had lower Fusarium wilt and higher yield in 2009 than in this trial.

2010		Wilt Index*		Vine length (in)		Yield lb/plot	
Cultivar	Seed Company	28 Jul					
Matrix	Seedway, LLC…….	2.0	f	54	abcd	115	abc
Majestic	Seminis Vegetable Seeds, Inc……..	2.0	f	48	abcdefg	93	abcdef
ACR6277	Abbott & Cobb, Inc…….	2.3	ef	52	abcde	85	abcdefg
Fascination	Rogers Brand; Syngenta Seeds, Inc…...	3.3	def	47	bcdefg	122	a
Omega	Seminis Vegetable Seeds, Inc…….	3.3	def	44	cdefg	99	abcde
ACR6897	Abbott & Cobb, Inc…….	3.7	def	40	fg	82	abcdefg
Apollo	Seminis Vegetable Seeds, Inc…….	3.7	def	45	cdefg	78	abcdefg
RWT8229	Rogers Brand; Syngenta Seeds, Inc…...	4.3	cdef	56	abc	113	abc
Indiana	Seminis Vegetable Seeds, Inc…….	4.3	cdef	55	abcd	101	abcde
RWT8228	Rogers Brand; Syngenta Seeds, Inc…...	4.3	cdef	49	abcdefg	86	abcdefg
Sugar Coat	Siegers Seed Co……..	4.3	cdef	60	a	49	cdefgh
Sugar Red	Siegers Seed Co……..	4.3	cdef	48	bcdefg	48	cdefgh
ACR5117	Abbott & Cobb, Inc……	4.7	cdef	43	defg	79	abcdefg
ACR4674	Abbott & Cobb, Inc……	4.7	cdef	41	efg	42	defgh
Cooperstown	Seminis Vegetable Seeds, Inc…….	4.7	cdef	50	abcdefg	36	efgh
Seedless Sangria	Siegers Seed Co…….....	5.0	bcde	57	ab	118	ab
RWT8230 (Fascination)	Rogers Brand; Syngenta Seeds, Inc…...	5.0	bcde	51	abcdef	114	abc
ACR6117	Abbott & Cobb, Inc…….	5.0	bcde	46	bcdefg	105	abcd
Harmony	Seedway, LLC…….	5.0	bcde	52	abcdef	76	abcdefgh
Posha Red	Colorado Seeds, Inc……	5.0	bcdef	43	cdefg	21	gh
Melody	Seedway LLC. & Siegers Seed Co…….	5.7	bcd	46	bcdefg	126	a
Sugar Heart	Siegers Seed Co……..	5.7	bcd	51	abcdef	95	abcedf
Wrigley	Seminis Vegetable Seeds, Inc…….	5.7	bcd	44	cdefg	30	fgh
Sweet Delight	Seedway, LLC…….	7.0	abc	42	efg	51	bcdefgh
Ruby	Siegers Seed Co……..	7.7	ab	46	bcdefg	44	defgh
Ruby Premium	Seedway, LLC…….	9.0	a	38	g	8	h
P>F		0.0062		0.0475		0.0156	

*Wilt index,where 1 = no wilt symptoms, 3 = yellow and stunted plants, 5 = few dead plants, 7 = stunting and more than one dead plant, 10 = most plants in the row dead.
** Mean values in each column followed by the same letter are not significantly different at *P* = 0.05 based on Fisher's protected least significant different test.

In 2011, Fusarium wilt was severe in plots on 29 Jun, and up to 79% of plants were wilted or had died in the most severely affected cultivar, Wrigley. This contrasted with the diploid resistant cultivar, Calhoun Grey, which had 6% wilt. Omega and Distinction also had low levels of Fusarium wilt that were not significantly different from Calhoun Grey. Fusarium wilt significantly reduced vine length in the field in many cultivars. Majestic, SWT 7138 and Melody had vine lengths that did not differ from Calhoun Grey. Yield was variable across the field and did not differ between cultivars. Omega, Distinction and SWT 7138 had the most fruit and Wrigley, Cronos and HSR 4620 had the fewest fruit/plot. The % Brix was highest in Omega, SWT 7138, WDL 9405, Majestic, Affirmed, WDL 9408, Cooperstown and Apollo, although these differences did not correlate with Fusarium wilt resistance.

We disseminated the outcomes (results) of the trials to Delaware growers at a watermelon field day, posted to the UD vegetable program web page and presented during talks at the Delaware Agricultural Week Program. Thirty farmers or advisors attended the watermelon field day and 100 attended Delaware Ag week. Watermelon growers make decisions on which cultivars to plant based on many factors such as their market demand, quality characteristics, and disease resistance traits. Fifty watermelon farmers are aware of moderate host resistance and 25 growers plant some cultivars that have moderate resistance to Fusarium wilt in our trials. No resistant lines have been released to breeding companies.

2011 Cultivar	Seed Company	Fusarium Wilt (%)[z]		Vine length (in)		Yield lb/plot		No. Fruit/ plot		Brix (%)	
Wrigley	Seminis	79	a[y]	11	f	50	a	8.3	de	10.7	bcde
Cronos	Seminis	71	ab	12	ef	103	a	9.5	cde	10.6	bcde
HSR 4620	Seedway	67	abc	15	def	66	a	6.8	e	10.0	e
Apollo	Seminis	62	abc	14	def	112	a	11.0	cde	11.0	abc
Cooperstown	Seminis	56	abc	19	bcde	124	a	14.3	abcd	11.0	ab
Summer Sweet	Abbott & Cobb	54	abcd	11	f	101	a	13.0	abcde	10.2	cde
Super Seedless	Abbott & Cobb	52	abcd	16	cdef	130	a	13.0	abcde	10.5	bcde
Bold Ruler	Seigers Seed Co.	48	bcd	18	bcdef	90	a	14.5	abcd	10.0	e
Sweet Polly	Seigers Seed Co.	44	bcd	18	bcdef	130	a	14.5	abcd	10.5	bcde
WDL 9408	Rogers Brand/Syngenta	44	bcd	16	def	126	a	13.3	abcde	10.4	bcde
Affirmed	Seigers Seed Co.	44	bcd	15	def	130	a	15.0	abcd	10.7	abcde
Majestic	Seminis	44	bcd	24	ab	99	a	11.3	bcd	10.8	abcd
WDL 9405	Rogers Brand/Syngenta	40	cde	15	def	129	a	12.5	abcde	11.0	abc
Fascination	Rogers Brand/Syngenta	40	cde	12	ef	157	a	16.0	abc	10.1	de
SWT 7138	Seedway	38	cde	24	abc	117	a	19.3	a	10.7	abcde
Melody	Seedway	38	cde	25	ab	83	a	10.8	cde	10.5	bcde
Distinction	Rogers	25	def	21	bcd	170	a	19.3	a	10.6	bcde

Omega	Brand/Syngenta Seminis	13	ef	19	bcde	184	a	18.3	ab	11.4	a
Calhoun Grey		6	f	31	a	176	a	14.3	abcd	10.1	de
P^x>F		0.0012		0.0001		0.0657		0.0480		0.0123	

[z]The percentage of wilted or dead plants per plot.
[y]Means within a column followed by the same letter and not significantly different (P=0.05) according to Fisher's protected LSD test.
[x]P values≤0.05 indicate significant differences exist among treatments.

Previous accomplishments for this project include testing germplasm line USDA-bb101 for *F.o. niveum* race 2 resistance. We were pleased to confirm that USDA-bb101 performed even better than the only previously reported *F.o. niveum* resistant line PI296341-FR. In November 2010, USDA-bb101 and Sugar Baby were planted in the greenhouse at UD-REC in Georgetown, DE and at UM-LESREC in Salisbury, MD.

In winter 2010-2011 USDA-bb101was crossed with 'Sugar Baby'. The F_1 plants were grown in the greenhouse in spring 2011 and an F_2 population was generated through self pollinations of individual plants in a contained screenhouse environment in summer 2011. This F_2 seed will now be tested for the heritability of resistance to *F.o. niveum*. In addition a field trial to compare PI296341, USDA-bb101 and Calhoun Grey was conducted.

Several outreach activities were completed during the reporting period. A Plant Disease Management Report of cultivar trial results from 2010 was published. Results were presented at MarDel Watermelon Growers' Meeting and a University of Delaware Weekly Crop Update article.

Goals and Outcomes achieved: We have accomplished the goals set out in our proposal, specifically we identified specific cultivars that were moderately resistant for Delaware watermelon growers with F. oxysporum f. sp. niveum infested lands. In the fall 2009/Spring 2010 we evaluated the watermelon line USDA-bb1001 in greenhouse. We confirmed that the line was highly resistant to *F. oxysporum* f. sp. *niveum* race 1 and had moderate resistance to race 2. We were able to post information on Fusarium wilt resistance to web (Weekly Crop Update Fusarium Wilt on Watermelons, Thursday, April 8th, 2010, *Kate Everts* and *Emmalea Ernest*. In the summer 2010 we successfully tested commercially available watermelon cultivars in field at UD-REC and identified cultivars that would perform well in Delaware fields that were infested with Fusarium wilt. The information was presented in a talk "Watermelon Disease" at the Mardel Watermelon Meeting. Feb. 2011, Cambridge, MD. This meeting is attended by most of the watermelon growers in Delaware and Maryland.

In the fall 2010 and spring 2011 we conducted more outreach activities. Our cultivar trial was published online as *Everts., K.L., and Hochmuth, M., 2011. Field evaluation of triploid cultivars for resistance to Fusarium wilt of watermelon in Delaware, 2010. Report 5: V175. doi: 10.1094/PDMR05*. We also were able to generate F_1 populations.

In the summer of 2011 we again evaluated commercially available cultivars in the Fusarium-infested field at UD-REC. *Everts K. L., and Hochmuth M.E.,2012. Evaluation of triploid*

cultivars for resistance to Fusarium wilt of watermelon, 2011. Report 5: V175. doi: 10.1094/PDMR05. This information was also presented at the Mardel Watermelon Meeting, Feb. 2012. In the fall and winter of 2011 and spring of 2012 we continued our work on USDA-bb1001 populations.

Beneficiaries: Delaware watermelon growers are the primary beneficiaries of our project. Watermelon is the second largest and largest acreage fresh market vegetable produced in Delaware and Maryland, respectively, where approximately 5,500 acres are planted with a value of $25,000,000 (USDA, NASS, 2010). There are smaller but significant concentrations in southeastern Pennsylvania and southern New Jersey. The benefit of our research extends throughout the Northeast and Southern regions.

Lessons Learned: Because the race structure in Delaware is complex, and includes F. oxysporum f. sp. niveum races 1 and 2, and population density varies across the field, evaluation of resistance is a challenge. Our work taught us that ongoing evaluation of cultivars across years and locations would produce more reliable information on the cultivar performance. The seed companies that we have worked with have expressed that they would like to continue these evaluations.

Growers also have offered suggestions on how to assist them in decisions about fields. Several growers have asked for site-specific information on the presence of FON races in their fields. We developed a proposal for this

Contact Person: Significant contributions of project partners Kathryne Everts PI (420-742-8788; keverts@umd.edu), and Emmalea Ernest, Co-PI. Both PI's have been full contributors in the research and extension portions of this project. Evaluation of USDA-bb101 was completed by Dr. Everts with advice from Ms. Ernest. The field trial to evaluate commercially available triploid watermelon cultivars was a joint effort between Everts and Ernest. Ms. Ernest completed crosses and generated the F_1 seed. Dr. Everts generated selfed-F_2 progeny. In addition, the information on managing Fusarium wilt through host resistance was developed and posted jointly at the following link http://agdev.anr.udel.edu/weeklycropupdate/?p=1785

Additional information: Outreach:

Everts., K.L., and Hochmuth, M., 2011. Field evaluation of triploid cultivars for resistance to Fusarium wilt of watermelon in Delaware, 2010. Report 5: V175. doi: 10.1094/PDMR05.

Everts K. L., and Hochmuth M.E.,2012. Evaluation of triploid cultivars for resistance to Fusarium wilt of watermelon, 2011. Report 5: V175. doi: 10.1094/PDMR05.

Weekly Crop Update **Fusarium Wilt on Watermelons**, Thursday, April 8th, 2010, *Kate Everts* and *Emmalea Ernest*

Extension talks on Fusarium wilt of watermelon and cultivar resistance at the Mardel Watermelon Meeting. Feb. 2011, and Feb. 2012, Cambridge, MD.

Project Title: Herbicide Resistant Weeds – A Threat to Lima Beans and Snap Bean Production in Delaware

Project Summary: Weeds can reduce lima bean (*Phaseolus lunatus*) and snap bean (*Phaseolus vulgaris*) yields through plant competition and severely hamper machine harvest. Lima bean farmers have relied on acetolactate synthase (ALS-) inhibiting herbicides for broadleaf weed control (Pursuit, Raptor, and Sandea). However, smooth pigweed (*Amaranthus hybridus*) biotypes resistant to ALS-inhibiting herbicides (ALS-R) have been confirmed in lima bean fields in Delaware. Currently, no lima bean herbicide can provide effective full-season control of ALS-R pigweed biotypes. Snap bean farmers typically use fomesafen, or Reflex, (a protoporphyrinogen oxidase inhibiting herbicide [PPO]), but Reflex severely injures lima beans. Occasionally, snap bean farmers will use ALS-inhibiting herbicides.

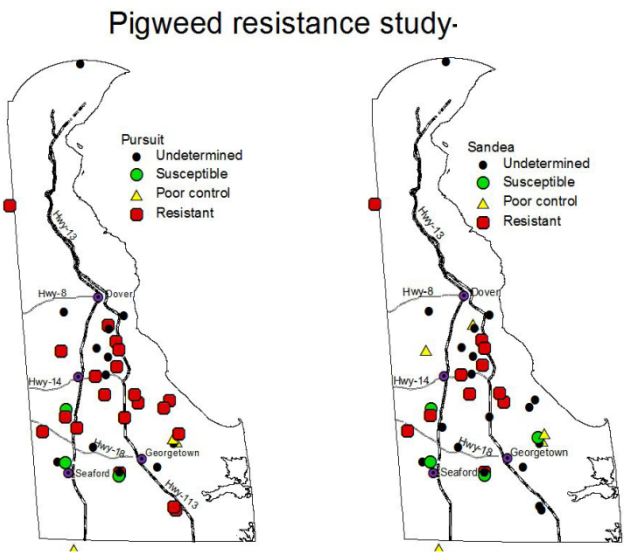
In addition, ALS-R common ragweed (*Ambrosia artemisiifolia*) has been identified in DE; and some of the ALS-R common ragweed is multiple-resistant to PPO-herbicides (PPO-R). At present, no PPO-R common ragweed has been reported in snap bean fields. The lack of effective herbicide control for these weed biotypes places lima bean (and potentially snap bean) at risk in Delaware. The proposed projects will benefit ongoing UD Weed Science research that is screening herbicides for potential use in lima bean and snap bean. While the proposed research can be utilized by producers immediately, identifying an appropriate herbicide and subsequent herbicide registration can take years to approve by federal agencies.

Work Plan:
Objective 1) Document occurrence of ALS-R smooth pigweed

In the fall of 2009 and 2010, we surveyed lima bean fields that had smooth pigweed present and collected seed for sampling. In addition, samples from fieldmen of the processing companies brought us suspected plants. Pigweed samples came from 29 fields and common ragweed from five fields.

Seeds per planted at UD REC greenhouses and seedlings were treated with a range of rates to determine presence of resistant biotypes. Pursuit was tested on all samples and if enough seed/seedlings were available, Sandea was also tested.

	Pursuit	Sandea
No. sites tested	28	27
No. resistant	21 (75%)	16 (59%)
No. poor control	3 (11%)	6 (22%)
No. susceptible	4 (14%)	5 (19%)



All five samples of common ragweed were resistant to ALS-inhibiting herbicides, and two of the samples came from fields with confirmed ALS-R pigweed. While this survey did not attempt to identify what percentage of the fields in DE is infested with ALS-R pigweed or common ragweed, it is evident that if these species escape control, there is a very high probability that it was due to resistance. Furthermore, in 2010, we did not sample fields adjacent or in close proximity to fields testing positive for resistance in 2009. The 2007 USDA census reported 33 lima bean farms in DE. So we estimate that about 20% of the DE lima bean fields were sampled. Twenty-five sites were sampled for resistance to both Pursuit and Sandea herbicides. In four cases, the plants were resistant to Pursuit, but susceptible to Sandea.

Furthermore, the locations of fields testing positive for resistant pigweed was fairly uniform throughout Sussex and Kent Counties. So while some fields maybe more concentrated in one area, the occurrence of ALS-resistant pigweed in DE is wide-spread.

Objective 2) Evaluate the impact of double-cropping or delayed planting on severity of weed infestations.

In the fall of 2009 and 2010, barley was planted at the UD-REC near Georgetown DE and in the spring peas and sweet corn were planted. Following harvest of barley, pea, and sweet corn, lima beans (‘Cypress’) were planted. In addition, lima beans were planted in mid-May as well as mid-June. Thus, there were three planting dates depending on the previous crop (Table 1) (Planting dates were 6-14, 6-28, and 7-16, 2010; and 6-15, 6-30, and 7-13 2011). Dual was applied immediately after planting at 1 pt/A and then a POST application of Basagran, at 1.5 pt/A, was applied approximately 4 weeks after planting. All treatments were replicated four times. All weeds in a 25 sq foot area between the center two rows were counted at flowering and prior to harvest. At harvest only weeds greater than 6 inches tall were included in the counts. The sites received supplemental irrigation, but due to severe drought in 2011, irrigation was not enough for optimal yields.

Results/Summary: Only pigweed and morning glory were abundant enough to include in the data analysis. At harvest, pigweed density was highest for the early and mid-planting dates compared to the late planting date (Table 1). For the early planting date, pigweed density was lower when lima beans followed peas, than with no crop prior to planting lima bean. No other differences were observed for previous crop within a planting date.

The general trend for yields was higher yields with the later planting dates (Table 2). Yields were due to differences in temperature and rainfall rather than weed competition. Cypress was used for all planting dates to be consistent for this trial. The general practice is to plant 'C-Elite' for early planting dates and Cypress for later planting dates.

Objective 3) Demonstrate the utility of in-row cultivation for improved weed management.

This study compared timing of cultivation and cultivation equipment. 'Cypress' lima beans were planted July 12, 2010 and June 30, 2011. Pursuit plus Dual (0.75 oz wt/A plus 0.67 pt/A, respectively) was used in 2010, but only Dual (0.67 pts/A) was used in 2011. Plots were 50 to 80 feet long. An area in front and behind each plot allowed cultivators to reach desired speed prior to entering the plots. Each treatment was replicated four times. Weed density was recorded at flowering and prior to harvest. The sites did not receive supplemental irrigation and yields were lower in 2011 due to lack of rainfall.

Trt no.	Rotary hoe	Cultivator	Timing of cultivations	Other
1	None	Standard	Unifoliate + 7 days	
2	None	Standard	1st Trifoliate + 7 days	
3	None	Standard	2nd Trifoliate + 7 days	
4	None	In-row[1]	Unifoliate + 7 days	
5	None	In-row[1]	1st Trifoliate + 7 days	
6	None	In-row[1]	2nd Trifoliate + 7 days	
7	Yes	Standard	Unifoliate + 7 days	
8	Yes	In-row	Unifoliate + 7 days	
9	None	Standard	Unifoliate	Bentazon**
10	None	Standard	7 days after POST	Bentazon***

[1] Bezzerides Bros. Inc., 14142 Avenue 416, Orosi, CA 93647
*Treatments 1 through 8 will receive a second cultivation 7 days after the initial cultivation
**Bentazon will be applied 7 days after cultivation.
***Bentazon will be applied at 1st trifoliate stage.

Weed densities were very low in 2010 and resulted in no significant differences between treatments. Despite using low herbicide rates, Pursuit provided good weed control without cultivation. In 2011, only Dual was used to control grasses and treatment differences were observed (Table 3). Pigweed densities were lowest when cultivation was delayed until the second trifoliate stage. No differences were observed with the in-row cultivator compared to the standard cultivator.

No yield differences were observed in 2010, but in 2011, there was a slight yield reduction when the standard cultivator was used compared to the in-row cultivator. It appears yield differences were due to soil moisture differences, the in-row cultivator caused less soil disturbance and results in less moisture loss.

Goals and Outcomes Achieved: Growers have become very aware of herbicide-resistant biotypes in lima bean fields and the need to preserve existing herbicide mode of action in snap beans as result of this project. A fact sheet on identifying ALS-resistant pigweed was developed and made available on the UD Weed Science Website (see appendix). Due to transition of the website to a new server, we do not have a good handle on number of "hits", but this factsheet has been handed out at various extension meetings and used a part of informational packages handed out to participants at trainings. One such training was a one-day tour on herbicide resistant weeds in the mid-Atlantic Region that I hosted for ~30 EPA officials from Washington, DC. In addition I discussed innovative cultivators and crop rotation for management of ALS-resistant pigweed with this group.

The field plots were demonstrated at various field days and crop tours. At least 80 different people were exposed to this project as part of the weed science field days.

Delaware Cooperative Extension organized a half-day lima bean meeting to discuss pest management. It was attended by ~50 growers, fieldmen, and ag-chemical representatives. This research was discussed as well as other pest management issues related to lima beans.

This information was presented at DE Ag Week at the session for processing vegetables with 150 people in attendance.

Based on conversations with farmers and crop consultants, it appears more processing vegetable acres are being managed with more extensive integrated weed management strategies. Almost all acreage is being cultivated at least once, and most acres are cultivated twice. The successfulness of this approach to prevent new infestations is difficult to judge at this time. Many farmers are moving there lima beans into fields with little or no history of lima bean production as a means of avoiding ALS-resistance pigweed. Field selection is an important component of integrated weed management.

Results have had an impact on extension education for crops other than lima beans. Pickling cucumbers and melons, also rely heavily on ALS-inhibiting herbicides, and the results from sample fields for ALS-resistant biotypes has heightened producers awareness of resistance issues and the need to diversify their weed management programs.

The emphasis on lima beans for the UD Weed Science program has also allowed us to work with potential herbicides on lima beans to assist with herbicide-resistance issues. Working with FMC and DE Department of Agriculture (Mr. David Pyne) we have been able to secure a Special Local Needs (SLN or 24c) label for Spartan Charge for DE lima bean producers. This was not anticipated at the start of this project, but due to our focus on pigweed control we were able to make the appropriate connections and provide the necessary trials to secure the SLN label. In 2012, we estimate at least one-third of the lima bean acreage in Delaware was treated with Spartan Charge.

Farmers and crop consultants have also become aware of the importance of timely cultivation for weed control. While most growers have been practicing row cultivation for lima beans, this project has illustrated the importance of timeliness.

Beneficiaries: This project has benefited all lima bean producers and snap bean growers in Delaware by reinforcing the importance of management for herbicide-resistance. Based on conversations with farmers and crop consultants, over 80% of the lima bean growers in Delaware are aware of herbicide-resistance and take this into consideration in their decisions before planting lima beans.

This project has provided greater insight into integrated weed management for lima beans and snap beans. Other projects have developed as a result of this one, for instance, the interaction of soil-applied herbicides and cultivation; and the utility of a high-residue cultivator for lima beans.

It would have been beneficial to include later cultivation timings in this trial. We should have included treatments that initiated cultivation beyond the 2nd trifoliate stage. Future research projects will take this into consideration.

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Additional Information:

Table 1. Data from objective 2; influence of previous crops and planting dates on pigweed density and lima bean yield.

Treatment Name	Planting date	Pigweed at lima flwr no./25 ft^2	Pigweed at harvest no./25 ft^2		Morning-glory at harvest no./25 ft^2	
Sweet corn No cultivation	Late	4.8	1.25	c	0.13	c
Sweet corn 2 cultivations	Late	3.3	1.38	cb	0.25	c
Barley	Mid	7.6	9.1	a	1.75	ab
No-till (bareground)	Mid	6.8	8.13	ab	1.38	bc
Peas	Early	7.5	3.38	abc	2.13	ab
Early planted limas	Early	7.5	8.5	a	2.88	a
LSD		10	6.8		1.5	
CV		157	126		101	
Pr>F		0.92	0.053		0.0028	

Table 2. Influence of previous crops and planting dates on lima bean yield and yield components. Plump, flat, and dry pods are averaged over 2010 and 2011.

Treatment Name	Planting date	Lima bean plump pods %		Lima bean flat pods %	Lima bean dry pods %		Lima bean Yield - 2010 (lb/A)	Lima bean Yield - 2011 (lb/A)	
Sweet corn No cultivation	Late	67	ab	29	4	bc	3376	1644	a
Sweet corn 2 cultivations	Late	55	c	33	12	a	3129	1085	bc
Barley	Mid	54	c	37	9	ab	3825	1204	b
No-till (bare ground)	Mid	56	bc	33	9	a	4296	891	c
Peas	Early	70	a	28	2	c	4781	322	d
Early planted limas	Early	65	abc	31	4	c	4684	242	d
LSD		11.7		12.6	4.7		2380	279	
CV		19		38.9	69		39	21	
Pr>F		0.0328		0.7007	0.0009		0.60	0.0001	

Table 3. Pigweed density and lima bean yield for treatments examining cultivation in lima bean in 2011.

Treatment Name	Timing	Morning-glory at harvest no./25 ft^2		Pigweed at harvest no./25 ft^2		Lima bean Yield lb/A	
Stnd Cultivator	Unifol + 7 days	1.0	bc	5	ab	1074	bcd
Stnd Cultivator	1st Trif + 7days	1.5	bc	4.3	abc	979	bcd
Stnd Cultivator	2nd Trif + 7days	2.3	bc	0.8	de	871	cd
Inrow Cultivator	Unifol + 7days	1.5	bc	4.5	abc	1379	abc
Inrow Cultivator	1st Trif + 7days	1.0	bc	4.8	ab	952	bcd
Inrow Cultivator	2nd Trif + 7days	1.3	bc	0.3	e	1207	a-d
Rotary hoe Stnd Cultivator	5 DAP Unifol + 7days	2.5	b	2.8	b-e	678	d
Rotary hoe Inrow Cultivator	5 DAP Unifol + 7days	1.3	bc	6	a	1231	a-d
Stnd Cultivator Basagran	Unifol +7 days	2.3	bc	2	cde	1543	ab
Basagran Stnd Cultivator	1st Trif +7 DAT	0.8	c	3.3	bcd	1796	a
Untreated check		4.3	a	4.5	abc	739	d
LSD		1.7		2.7		600	
CV		62.0		54.6		38.4	
Pr>F		0.0008		0.0020		0.0090	

Appendix A. Extension Bulletin developed on herbicide-resistant pigweeds in lima bean fields.

http://extension.udel.edu/factsheet/wp-content/uploads/2012/07/WF20.pdf

Project Title: Improving Irrigation Management Techniques for Drip Irrigated Vegetable Crops using Soil Moisture Sensors

Project Summary: The plasticulture system combined with drip irrigation is the leading production method for high value fresh market vegetable crops in Delaware. The high yields, improved crop quality, and beneficial effect on weed and disease management achieved with plastic and drip irrigation has made this production method essential to the survival of fresh market production of strawberries, watermelon, cantaloupe, tomato and pepper. Unlike overhead irrigation, managing a drip irrigation system is not an intuitive process of balancing inches of daily evapotranspiration with inches of rain or irrigation received. Over irrigation can negatively affect yield, weed management, disease management, causes fertilizer leaching and wastes water. Under irrigation can cause yield loss resulting in significant financial losses for the grower. Continuous soil moisture monitoring has the potential to improve crop yield and quality while encouraging efficient use of water and fertilizer. The overall project objective is to develop guidelines to improve the management of drip irrigation systems and methods for growers to use soil moisture sensors to maximize profits.

Maintaining optimum soil moisture for maximum crop production is complicated. Crops pull water from the soil profile at different rates from day to day and throughout the day. Over the season changes take place in the root zone as the crop grows and crop water use increases. Optimum soil moisture levels also depend on soil texture and overall soil tilth.

Drip irrigation systems can be monitored with continuous logging soil moisture sensors located at multiple depths and distances from the drip line. This information on changes in soil moisture over time documents the effects of irrigations, weather conditions, and crop water uptake. Such information allows for more efficient and effective irrigation.

Delaware vegetable growers face a very competitive national market, while growing their crops in a climate that may be among the most variable and unpredictable. There is great need for both better, more accurate methods to determine soil moisture levels and information on how to irrigate to maintain optimum soil moisture levels. Giving our growers the ability to irrigate more efficiently and effectively would allow them more competitive edge.

All Delaware vegetable growers will benefit from the data collected, which will provide greatly improve drip irrigation management recommendations and demonstrate the effectiveness of soil moisture monitoring and an irrigation scheduling tool. These benefits will come as potentially improved yields, increased fertilizer use efficiency, reduced water use and associated pumping costs, and reduced disease pressure from over watering. The natural resources base of Delaware will benefit as well. Water is becoming an ever important resource and this project has the potential to make more efficient use of that resource

Project Approach: Work began on this project in the spring of 2010 and problems developed immediately after startup. First of all, the soil moisture equipment manufacturer was unable to provide the equipment we specified due to bankruptcy. Plans were adjusted to utilize a less desirable and more expensive sensor made by Decagon that should accomplish the same goal. In the summer of 2010, Decagon 5TE/5TMsoil moisture logging stations consisting of 3 sites per field, with 9 soil moisture sensors per site were installed in the watermelon crops of Mark

Collins, Gary Conaway, Ray Vincent and Wayne Givens. These stations monitored the irrigation patterns of each grower and the resulting soil moisture status. In the fall of 2010 the equipment was installed in the strawberry fields of Travis Hastings, Ellen Magee and Charles Wright for data collection over the winter/spring. These initial installations were only to provide the baseline data to access the current management style for comparison to year 2, where the data would be sent to growers for use in adjusting their schedule.

While we found the data generated by the Decagon equipment to be highly accurate, it performed poorly in terms of product reliability, ease of interpretation, installation and removal. During the winter data collection approximately 50% of the soil moisture sensors and 25% of the data loggers failed to an un-repairable state. Given this high failure rate and poor reliability the decision was made to use the Watermark 950R/T (Figure 1 & 2) system that has proven very affective in other projects.

The primary goal of this project was to collect information regarding the current irrigation practices of drip irrigated vegetable producers in year 1 (2010). In year 2 (2011) the soil moisture information was to be relayed back to the grower, along with an recommendation, on a 3 times per week basis to assist them with irrigation decisions. At the project conclusion, a comparison would be made between year 1 and 2 to estimate the potential value of soil moisture monitoring for irrigation management of drip irrigated vegetable crops. The data interpretation and generation of recommendations was to be performed by the UD Precision Ag. Specialist, Dr. Susan White-Hansen. Unfortunately, Dr. White-Hansen left the university in the fall of 2010. We hired her on a contractual basis to fulfill grant obligations and perform data analysis for this and other projects through 2012. In the late spring of 2011, it became obvious that we could not count on her to provide the timely data analysis necessary to generate irrigation recommendations for the growers. I attempted to teach myself to fill the analytical void, but was unable to do so in the short order needed for the project to be successful in the 2011 season. Therefore, rather than inconvenience the cooperators by installing equipment that would not provide any of the time sensitive data needed to schedule irrigation, I opted to halt the project until the data analysis issues are resolved.

A no cost extension was requested in August of 2011 to essentially start over with a more user friendly, reliable system that could actually be implemented in a production scenario rather than the “only good for research” system originally purchased. Any additional expenses were covered with internal funds and the project purpose was adjusted to provide a recommendation on how to practically use soil moisture monitoring on a whole farm scale.

The Watermark 950R/T system was purchased and installed in 4 strawberry fields in late September 2011 of Bobby Fifer, Ellen Magee, Travis Hastings and Charles Wright. These 4 producers were surveyed on their irrigation protocol and the challenges they face prior to the start of data collection.

These 4 fields consisted of 4 sites per field, with 6 soil moisture sensors per site. The data was collected bi-weekly during the winter months and increased to weekly with the arrival of spring throughout the 36 week duration. Once data was collected, it was evaluated and producers were provided with a summary report and recommendations based on the collected data. At the

conclusion of strawberry harvest, in early June, producers were surveyed again on the data they received and the possible changes that were made.

In mid-June, the same soil moisture systems were installed in the 4 watermelon fields of Gary Conaway, Kevin Evans, Jesse Vanderwende, and Mark Collins. Once again, the 4 fields consisted of 4 sites per field, with 3 soil moisture sensors per site. This time the data was collected weekly during the 12 week duration of the research and concluded in late August at the end of watermelon harvest. The collected data was evaluated and a summary of that data along with recommendations were provided to producers within 24 hours of collection. These 4 producers were surveyed prior to implementation and at the conclusion of the season.

Goals and Outcomes Achieved: The main objective of this project was to create guidelines to improve the management of drip irrigation in vegetable production by using soil moisture sensors. By placing the sensors at depths of 4", 8" and 12" we were able to track the volume of water available at different depths during the growing cycle. Additionally, we could see the benefit of the irrigation cycle and the approximate duration of that benefit through the graphs available with the Watermark 950R/T system. As the project progressed we were able to see producers using longer run times in accordance with the recommendation provided by the collection of the watermelon data. This fact was supported in the final survey with 75% of watermelon producers verifying they used more water and had longer run times. Increased water applications was not noted with strawberry growers due to more available moisture in the spring, cooler temperatures and thus lower crop water demand.

Both strawberry and watermelon growers indicated that they utilized the supplied reports and field equipment with 100% of growers trusting the data according to the survey. No significant increases in yields were noted in the survey. However, the summer of 2012 was extremely dry and no growers reported a decrease in yield.

Beneficiaries: During this project, 4 strawberry growers representing approximately 22 acres and 4 watermelon growers representing approximately 300+ acres benefitted directly by having access to the Watermark 950R/T system and the data which was collected.

As the information gleaned from this project is disseminated at the 2013 Delaware Ag Week and Mar-Del watermelon association meetings approximately 55 growers, representing approximately 3000 acres of drip irrigated vegetable crops will learn the advantages of soil moisture monitoring to direct the irrigation schedule and the significant return provided to high value, drip irrigated crops.

Lessons Learned: The biggest lesson learned from this project was the impracticality of volumetric water content (VWC) sensors as a tool to manage irrigation at the farm level. While very effective as a research tool, VWC requires specific calibration for each soil type and compaction level. Furthermore, the ideal range of soil moisture levels is highly variable depending on soil and crop type. Farmers will not adopt this equipment as it is hard to install and requires considerable time to calibrate before yielding any usable data. Soil tension, despite being considered a rather low tech method to measure soil conditions has the advantage of being easy to install, a direct measurement of the moisture stress on the crop, and relatively

inexpensive. The challenges of maintaining traditional tensiometers have been overcome with the watermark type matric potential sensor and have enabled economical logging of data.

Coming into this project, one of the most common ways growers used to evaluate soil moisture was through the sense of feel. As this project concluded through a very dry summer, growers realized that this type of measurement can vary greatly and in most cases were not very accurate. We could see more growers depending on the project generated reports and using the system directly in the field to determine which zones to irrigate and for what length. Ultimately, using the drip system more effectively and efficiently (Figure 3 & 4).

During the course of this project, one of the challenges using the Watermark 950R/T system is creating line of sight between the Watermark receiver and the individual transmitter. The transmitters must be low enough to allow for ease of pesticide applications and placement of row covers but high enough to expand past plant growth and field topography. By using various heights of PVC piping we were able to arrive at acceptable levels to allow for consistent data collection.

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Additional Information:

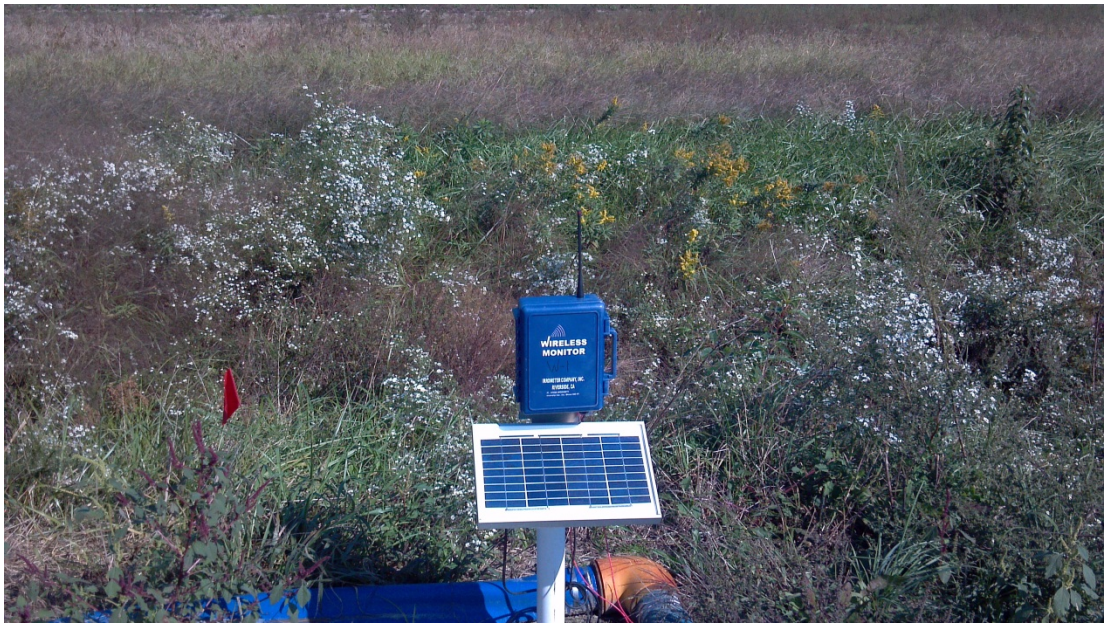

Figure 1: Watermark 950R data logger

Figure 2: (2) Watermark 950T Soil Moisture Transmitters (The 6 attached soil moisture sensors are below ground and are connected via the green wires)

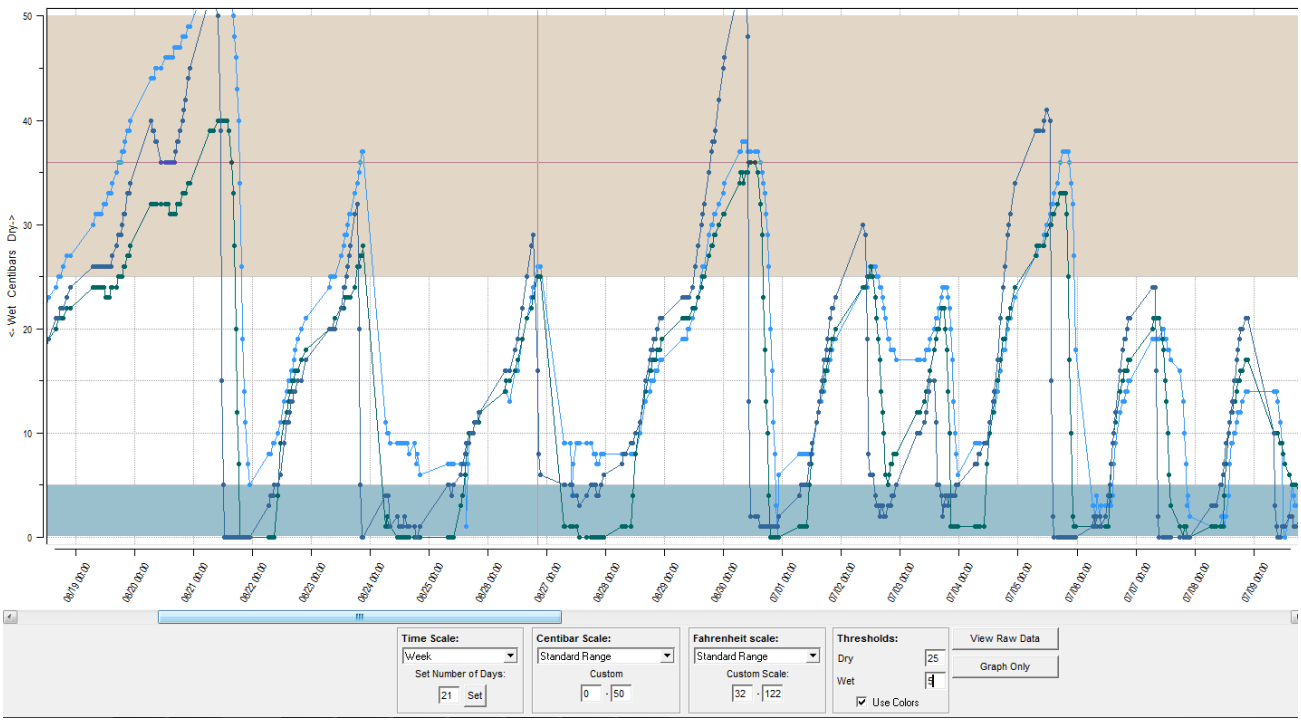

Figure 3: Graph of soil moisture levels before grower trusted the recommendations and data. Ideally, the soil moisture level should be maintained in the white area of the graph. The gray area indicates potential plant stress from insufficient moisture; the blue area is at or near saturation plant stress.

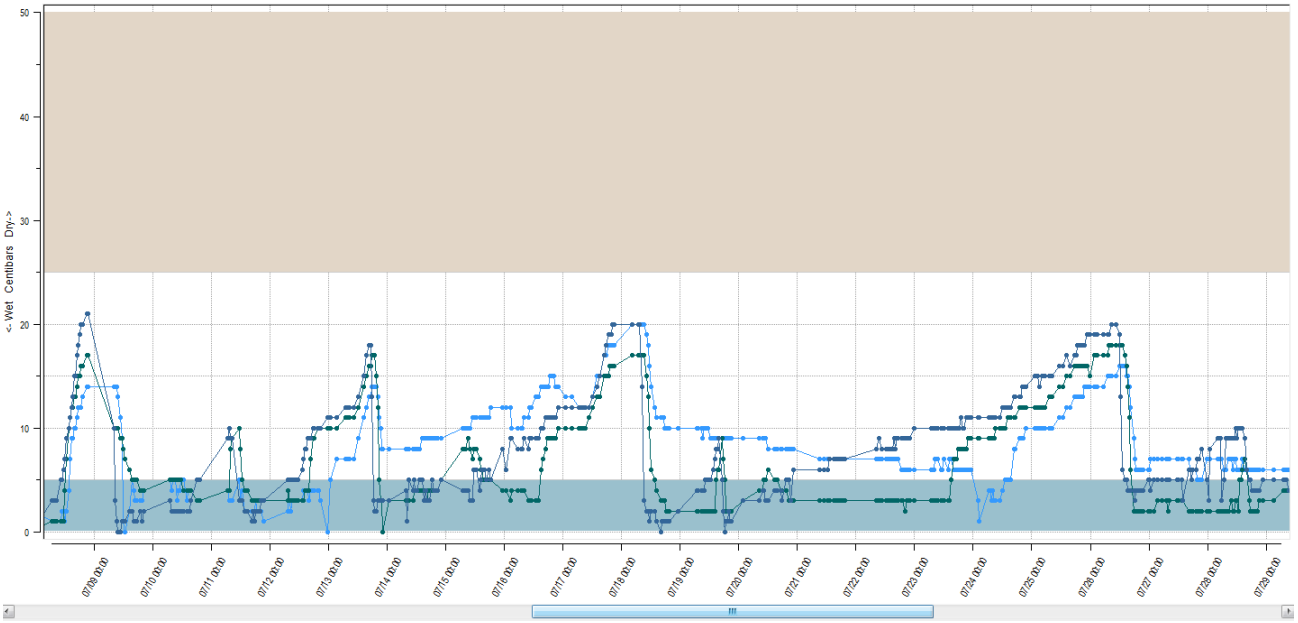

Figure 4: Graph of soil moisture levels after the grower became comfortable with the recommendations and data. Note the reduced number of stress events compared to the previous 3 week period shown in Fig. 3.

Project Title: Genomic Resources Development for Breeding and Gene Discovery in Lima Bean

Project Summary: In this project, 220 individuals belonging to an F_2 population from a cross between lima bean varieties Bridgeton and B2C was screened under field conditions for resistance to race F of *Phytophthora phaseoli*. Leaf tissue was collected from each individual and preserved for DNA extraction. This project has contributed to other projects; the data and resources mentioned above are being used as part of a new, separately funded DDA-SCRI Block Grant project (*Molecular Marker Development for Downy Mildew Resistance Genes in Lima Bean*) funded in 2011.

A major component of this project led to the development and application of a contemporary genotyping technique (genotyping-by-sequencing or GBS) that allows thousands of regions in the lima bean genome ("loci") to be assayed for genetic variation at a relatively cheap cost (the technique is similar to that described by Poland et al. 2012). This represents a major step forward for understanding genetic diversity in lima bean, a genome for which essentially no genomic resources existed at the start of this project. There is no data as such as the goal of this project was to develop a methodology. The development of genomic resources for lima bean will allow lima bean breeders to use diverse germplasm more efficiently and develop molecular markers for indirect selections of important traits, such as disease resistance. In the long term, this will result in higher yielding, stress and disease tolerant varieties available to farmers.

Project Approach: The GBS technique developed in this project was used to characterize sequence variation between Bridgeton and B2C. An additional eight lima bean accessions were also characterized (Table 1). Using all of this data, in this project we initiated the development of a GBS informatics pipeline to process and catalogue genomic loci and genomic variation—these efforts are ongoing and some of the results reported here may change based on improvements to our pipeline. In total, ~8,000 loci were assayed by GBS (note: there was a typo in our second year report [80,000 should have been 8,000]). Among these loci, 370 were polymorphic among the accessions in the panel, which translated into ~1 polymorphism (single nucleotide polymorphism or insertion/deletion polymorphism) every 2,000 base pairs. While this number of polymorphic loci is likely to be enough for a number of studies on lima bean, an advantage of the GBS technique we developed is that it can be easily modified to allow for the identification of many more loci (upward of 2.5 M).

Goals and Outcomes Achieved: This is a proof of concept, a development of a new methodology which will allow for the more rapid development of new varieties of lima bean and other important crop species. The methodology is already being used in our 2011 DDA-SCRI Block Grant entitled "Development of Molecular Markers for Downy Mildew Resistance Race F in Lima Bean" to provide molecular markers in lima bean for resistance to race F of *Phytophthora phaseoli*, the causal agent of downy mildew and the most important epidemic disease affecting lima bean in the humid eastern U.S.. The results of this study provide an expectation for the frequency of loci assayed by GBS that would be polymorphic (~5%), which can be used to guide modifications of the technique to obtain the number of polymorphic loci needed for different projects (e.g., from among 2.5 M loci one would expect ~125,000 polymorphic loci). Furthermore, as originally proposed, we have catalogued loci that are polymorphic between Bridgeton and B2C, the parents of the F_2 population we are using to map

race F resistance in our current DDA-funded project; this data will be used in our mapping efforts and will allow us to determine the parent-of-origin for alleles segregating in the population.

Table 1. Lima bean varieties and plant introductions (PIs) characterized using GBS.

Accesion	**Origin**	**Presumed genepool**	**Seed type**	***P. phaseoli* resistance**
Bridgeton	US	Mesoamerican	baby	ABDE resistant
B2C	US	Mesoamerican	baby	ABCDF resistant
Jackson Wonder	US	Mesoamerican	baby	n/a
PI 189403	Guatemala	Mesoamerican	baby	ABDE resistant
PI 347784	Arizona	Mesoamerican	baby	n/a
Fordhook 242	US	Andean	Fordhook	n/a
PI 257377	Colombia	Andean	Fordhook	n/a
Dr. Martin	US	Andean	big lima	n/a
PI 256906	Peru	Andean	big lima	n/a
PI 256842	Peru	Andean	big butterpea	n/a

Beneficiaries: During this project, we established a collaborating relationship with Dr. Keith Hopper's laboratory at USDA-ARS, Beneficial Insects Introductory Research Unit at the University of Delaware. His laboratory has used GBS to characterize genetic variation in insects. We co-developed the GBS technique and working together to develop a computational pipeline for processing GBS data. Other scientists, both public and private, working in the area of lima bean breeding will benefit from the development of this technique, especially as more of the available germplasm is characterized and molecular markers are developed for valuable traits. Portals for information sharing include: 1) raw sequence data deposition into the short-read archives of NCBI; 2) a project website is being developed as part of a separate, larger projects (USDA-SCRI 0229859); and 3) publications. Ultimately, the Delaware and Maryland lima bean growers and processors will benefit from the development of greater genomic resources using GBS, as improved lima bean varieties are developed using tools and information gained from this project.

Lessons Learned: New sequencing technologies are making it possible to generate unprecedented information that is useful for genetics and breeding. However, these technologies take time for labs to adapt, which is what our (Wisser) lab has experienced over the last several years while engaged in this project and related projects. In the case of exploiting sequencing technologies for breeding, initially much time is spent on establishing a functional 'pipeline' that starts with molecular biology techniques, uses bioinformatics for data processing and data management, and involves genetics for inference, before the information can finally be tapped for breeding. Even with a functional pipeline, species-specific optimization may be required. Thus, the effort needed for individual labs and even small groups of labs to establish such a pipeline are not presently short-term endeavors (e.g. not <2 years) and some time is temporarily

taken away from biological investigation. Ultimately, however, a streamlined process is feasible and is expected to help transform genetic inference and breeding efficiency.

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References: Poland JA, Brown PJ, Sorrells ME, Jannink J-L (2012) Development of High-Density Genetic Maps for Barley and Wheat Using a Novel Two-Enzyme Genotyping-by-Sequencing Approach. PLoS ONE 7(2): e32253. doi:10.1371/journal.pone.0032253