**Final Report**
**FY 2015 SPECIALTY CROP BLOCK GRANT PROGRAM – FARM BILL**
**AMS Agreement: 15-SCBGP-VA-009**
**Virginia Department of Agriculture & Consumer Services**

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**Final Report**

PROJECT TITLE
Making Food Safety Certification Available and Affordable for Virginia Farmers

NAME OF ORGANIZATION
Appalachian Sustainable Development

PROJECT SUMMARY

There is an ever growing demand from the fresh produce industry that the farmers who supply them obtain and hold some form of food safety certification. Good Agricultural Practices (GAP) certification is currently available from several sources (e.g. USDA GAP, GLOBAL GAP, Global Food Safety Initiative (GFSI)). A compromise effort between these many paths, the Harmonized Food Safety Audit, is gaining traction with many produce buyers. Harmonized with the Global addendum has become a successful "push back" to those wholesale buyers who created their marketing strategy based on GFSI audits being the safest pathway for wholesale fresh produce (e.g. Walmart and Kroger).

Appalachian Sustainable Development (ASD), along with Virginia Cooperative Extension, has been at the forefront of working with wholesale buyers to accept USDA GAP certification plans that are friendly to smaller-scale farmers and set them up for success at higher levels such as the Harmonized audit as well as FSMA compliance. We have also worked with farmers to provide training in food safety principles and actions and assisted them with obtaining their GAP certifications so that they can have continued access to quality wholesale markets.

ASD, through this grant, continued to spearhead these efforts throughout the state, providing:

1. Training and consultation to farmers to prepare them to be USDA GAP or Harmonized GAP certification-ready and integrate such into FSMA compliance.
2. Assist farmers with obtaining USDA GAP or Harmonized GAP certification through audit coordination and technical assistance.
3. Expanded training to include direct-market farmers who may need the certification to sell to restaurants and/or institutions and who meet the threshold numbers to be at the minimum FSMA complaint.

PROJECT PURPOSE

ASD is a not-for-profit organization working in the Appalachian region of Virginia and Tennessee. Formed in 1995, ASD focuses on developing healthy, diverse and ecologically sound economic opportunities through education, training, and the development of cooperative networks and marketing systems. ASD has been a regional leader in following food safety legislation which directly impacts many producers of fresh produce in southwest Virginia.

The primary purpose of this project was to ensure that farmers in Virginia can continue to sell to quality wholesale and retail markets by assisting them in obtaining the USDA Good Agricultural Practices (GAP) certification(s) needed to access those markets. The majority of wholesale grocery and wholesale buyers already demand that their producers hold USDA GAP certification. Many of the larger restaurants and institutional buyers are following that lead. For the average Virginia farmer, obtaining USDA GAP certification on their own can be confusing, costly and, in many cases, so discouraging that it means the end of their farming business.

In 2011, ASD partnered with Virginia Cooperative Extension to explore ways to assist farmers selling through the Appalachian Harvest wholesale network to meet the food safety standards which were just starting to be required by wholesale buyers. Over the years, food safety certification has become mandatory for nearly all wholesale buyers and the ASD/Cooperative Extension partnership has helped hundreds of farmers across the state learn more about food safety standards and prepare their own farms for food safety audits, ultimately assisting many of these farmers in reaching GAP certification for their operations.

In that time, the food safety picture has grown more confusing as a global food safety certifier (Global Food Safety Initiative or GFSI) has attracted the attention of several large produce buyers. GFSI is both more rigorous and much more expensive than the USDA GAP program, making many Virginia farmers fear that they will be priced out of business by having to certify GFSI. In response, the Harmonized food safety certification has been developed as a more affordable alternative, taking from both the USDA GAP and the GFSI to develop a certification program that can be accepted by all buyers.

While it is unclear exactly how the food safety certification confusion will settle out, the fact remains that farmers in Virginia need assistance with understanding and meeting the USDA GAP requirements in order to access quality wholesale and institutional markets. They also need a pathway to be FSMA compliant as this will soon be an FDA requirement. ASD and Cooperative Extension have developed a training course that helps farmers meet their current food safety needs and prepares them for future developments. Currently all of the Appalachian Harvest[1] buyers accept the USDA GAP certification to meet their food safety needs, and in 2018 one broker/buyer will require the Harmonized audit, as their outlets apply increased pressure for their supplies to have a Global equivalency. It is becoming clear that the future of food safety is closer to the Harmonized model, and FSMA compliance will be the driving forces for farmers to meet in order to continue their farming businesses. In recognition of that trend, all farmers participating in the ASD/Cooperative Extension program were trained to a level that prepares them for certification for both USDA GAP and the Harmonized GAP audits. We have also integrated the FSMA requirements (as they stand now) into the training curriculum. This gives each grower the flexibility to respond to changes in the food safety landscape, and certify according to the demands of their markets. Regardless of farm size, scale of production, and or production methodology (conventional or organic) this training is essential to keep Virginia's food system educated, prepared, and qualified to participate in the wholesale market arenas that are necessary for Virginia's family farms' survival.

PROJECT ACTIVITIES & RESULTS

- Appalachian Harvest conducted 20 training sessions, 30% large group setting (20+ attendees), and 70% small group settings (under 20 attendees). Appalachian Harvest also conducted one-on-one on the farm visits and manual reviews to ensure that new and beginning farmers and/or farmers with SOP challenges had detailed and scientific based, hands on learning opportunities with supportive and compliant USDA GAP and Harmonized manual documentation.
- A hands-on manual for understanding USDA GAP regulations and developing solid practices and SOP's to meet them was utilized with direct classroom instruction to help Virginia specialty crop growers make changes to their farm plans to address food safety and access markets that

[1] Appalachian Harvest is ASD's Scott County-based food hub that was established in 2000.

demand USDA GAP certification with Harmonized preparedness. Free manuals were provided to farmers participating in the training programs organized by ASD and Cooperative Extension. Manuals were also made available to others for free (or at minimal cost, if necessary) to assist additional farmers in Virginia and elsewhere.

- 301 Virginia farmers were fully trained in USDA and Harmonized GAP requirements; 82 of these have completed an on-farm visit and/or mock audit with ASD or Cooperative Extension staff (or a trained contractor). These farmers will be certification-ready should their markets require certification.
- 75 direct marketing farmers participated in training sessions. Although most direct markets for specialty crops do not require USDA GAP certification, the habits and procedures implemented by these farmers will increase the safety of Virginia's food supply. If these farmers wish to sell to a restaurant or institution that does require USDA GAP certification, they will be well-educated and in a position to obtain certification to access those markets. These farmers will have a baseline of FSMA knowledge to be compliant if required under the FDA Standards for Produce Safety Coverage and Exemptions/Exclusions for 21 Part 112.
- A specific clarification that Appalachian Harvest must continue to reinforce at every training session is the requirement of Virginia Pesticide Licenses. Conventional farmers, organic farmers, and farmers that don't utilize any field sprays, fertilizers or inputs, MUST obtain a Pesticide License in order to handle 100 ppm chlorine bleach and/or Sanidate as their "kill step" when washing products for human consumption, and/or 10% chlorine bleach to sanitize all contact surfaces. This vital piece of information is explained at all training sessions and reinforced during manual reviews and one-on-one farm visits. Our experience has shown that farmers, especially organic farmers, often interpret this requirement inaccurately, making it vital that they have a complete and accurate understanding that safe handling of any input by the farmer and/or by his or her labor force is essential for full compliance with Pesticide Applicators Licensing as well as any and all certifications that assess Food Safety.

GOALS AND OUTCOMES

**Goal:** Increase Virginia farmers' knowledge of USDA GAP certification as a result of training. Increase the number of Virginia USDA GAP and Harmonized GAP certified farmers.

**Performance Measure:** Administer tests before and after training to measure increase in farmer knowledge. Number of farmers obtaining USDA GAP and/or Harmonized GAP training or number of farmers successfully completing a mock audit without corrective measures and number of farmers obtaining USDA GAP, Harmonized or more costly market demanded Food Safety certification.

**Benchmark:** Pretest before training and round table discussion prior to training.

**Target:** 150 wholesale growers and 100 direct market farmers receive training and gain a 90% increased understanding of farm support and/or access to new technologies and material to help them comply with USDA GAP and/or Harmonized standards.

**Results:** 301 growers were fully trained in USDA and Harmonized GAP requirements; 82 of these completed an on-farm visit and/or mock audit with ASD or Cooperative Extension staff (or a trained contractor).

Pre and post assessments were conducted utilizing a variety of assessment tools as to not make farmers feel inferior and help maintain individual integrity to promote positive energy to attend classes and continue with goals to support the farmers. As we learned in pervious experiences written pre-tests without requirements of farmer identity that were administered were not well-

received by the farmers. The general feeling was that participants were there to learn and requiring that they measure and then turn in tests that showed they did not understand the topics came across as being a bit insulting. Therefore we changed our process and asked farmers to complete the pre and post group oral test and to assess their own increase in knowledge. At the end of the training sessions we asked farmers how many had increased their learning from instruction, open discussions and peer to peer interact. Of the 226 wholesale farmers trained all participants had self-assessed a 90% minimum comprehension of the material
The 75 direct market producers were not given the pre and post-tests due to our lessons learned from our experiences with wholesale market farmers. 100% of the direct market farmers participated at an "end of session" survey demonstrating that 100% of the participants had gained what they considered at least a 90% increase in knowledge of USDA GAP certification processes and requirements from the education opportunities supported by this grant.

SUPPORTING ACTIVITIES AND OUTPUTS
**Objective:** Train at least 150 farmers in Virginia to be certification-ready in 2016 in both the USDA GAP and the Harmonized GAP program. The expectation is that 1/3 of these will obtain certification in 2016. Train at least 100 direct market farmers on USDA GAP processes.

**Output 1:** Appalachian Sustainable Development/Appalachian Harvest trained and prepared 226 Virginia wholesale to retail farmers and 5 packinghouse facilities for the wholesale market arena on GAP certification and/or Harmonized GAP and preparedness for the Produce Safety Rule (section 112.3(c)). Three packinghouse facilities obtained Harmonized GAP certification, and three (2) packinghouse facilities successfully obtained their GAP certification.
**Output 2:** Appalachian Sustainable Development/Appalachian Harvest trained and prepared 75 direct market Virginia farmers in all aspects of Food Safety certification preparedness and expectations of the upcoming FDA changes as defined by Produce Safety Rule (section 112.3(c)). Appalachian Harvest utilized the following "on site" training examples to demonstrate small scale farmer's compliance with food safety regulations: pest management, hand washing stations, product flow, post-harvest handling station (pre-rinse, kill-step, rinse process), affordable and compliant spill kits, safe transport, safe storage, and all relevant SOP's to meet the very small farmer's needs for GAP compliance should they chose that path and/or should their market requirement shift to require farmer GAP certification.

**Output 3:** To ensure VA farmers are able to access large wholesale markets once the new mandatory FSMA requirements are in place, ASD requested and received approval for a no-cost extension of this grant. The extension enabled ASD to train 5 individuals on new FSMA requirements. One of those trainers subsequently became a FSMA Lead Trainer. As a result, wholesale, direct market and farmers market producers will become FSMA educated and compliant to ensure they can maintain their family farm's revenue stream(s). It is projected that the first FSMA training will be held in early 2018.

BENEFICIARIES

**Farmers**

- 301 Virginia farmers were classroom trained in USDA and Harmonized GAP requirements, with 82 receiving an additional on-farm visit and mock audit with ASD or Cooperative Extension staff (or a trained contractor). These farmers will be certification-ready should their markets require certification.

- 75 direct marketing farmers participated in training sessions. Although most direct markets for specialty crops do not require GAP certification, the habits and procedures implemented by these farmers will increase the safety of Virginia's food supply and if these growers wish to sell to a restaurant or institution that does require GAP certification, they will be in a good position to obtain certification in order to access those markets.
- Virginia farmers have the benefit of having access to FSMA training by positioning Appalachian Harvest staff and consultant, AgCon to be qualified Lead Trainers and Trainers from training received under this grant. Three ASD/AH staff members and two regional partners attended and received Certificates of Training for Train the Trainer from the Produce Safety Alliance 16 hour course. One of the five has already taken the written exam and completed the interview process to receive Lead Trainer status, as required by the FDA for FSMA training. As the other 4 team members progress through the Lead Trainer process, this will make FSMA training and compliance more accessible to Virginia farmers, urban, suburban and most of all remote and rural disadvantaged farmers.
- With the support of this grant the GAP and Harmonized training manuals have been updated to include FSMA Sections terminology, requirement updates, and supportive record-keeping tools.

**Buyers**

- Wholesale buyers have access to a wider diversity of growers and products as a result of the training, on-farm auditing and certification of additional Virginia farmers. This has led to greater sales of Virginia grown products and stronger, more vibrant rural communities in rural Virginia.
- **Consumers**

Consumers are beneficiaries from this project because the integrity of food safety has improved and will continue to improve in both wholesale and direct market outlets and a local product stream of Virginia grown specialty crops will continue to be available in local and regional markets

LESSONS LEARNED

With our deepest thanks to the continuous support of the Virginia Department of Agriculture and Consumer Services, all measurable goals for this project were fully achieved with the exception of 100 direct market farmers receiving training. Of the 100 projected direct market farmers, 75 utilized our training, 25% less than projected. However, Appalachian Sustainable Development/Appalachian Harvest did train 226 wholesale farmers which was 76 above our projected goal.

Appalachian Sustainable Development works diligently to continue to be a Food Safety leader serving the very deserving agriculture community for the Commonwealth. We understand the negative impacts that can happen if Food Safety is packaged and presented in a negative manner without the consideration of relevant, accessible and comprehensive materials and tools that have true on the farm application. Over the many years in our role we understand the learning styles, differentiated instruction needs, relationship and trust development across the farming community. We also realize what can transpire if farmers are not ready for market transitions in the areas of buyer's Food Safety requirements.

Additional lessons learned from our farming communities are the many interpretations and misinterpretations of the requirements and implementation of the FSMA Produce Safety Rule (PSR). There are two primary areas that require additional focus to ensure farmers are able to be in compliance. The area that is the most significant change is focused on the farmers' need to establish a water quality profile(s). The PSR defines agriculture water as either Production Water or Post-Harvest Water. Following are some high level details on the areas where clarification, production practices and tools will be necessary for supporting VA farmers. This requirement will more than quadruple farmers' water testing cost, and thus far an equivalent methodology of the T1603 water test has not been identified and/or published. Additionally, current testing facilities are not equipped to provide farmers with the interpretive services and guidance that will be required as a result of FSMA. As such, it is vital for Appalachian Sustainable Development to be steadfast and persistent with an active role and commitment to Virginia's farmers. Appalachian Sustainable Development, AgCon and other support partners will be key in obtaining, disseminating, and educating on the accurate information and to provide the proper guidance to help farmers successfully navigate this upcoming requirement change. The specialty crop farmers who have been supported through this grant have a baseline awareness and will be provided more in-depth awareness as our necessary training programs and partnerships continue.

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ADDITIONAL INFORMATION
According to a 2013 economic impact study conducted by the Weldon Cooper Center for Public Service at the University of Virginia, agriculture and forestry are Virginia's two largest industries with a combined economic impact of $70 billion annually. Agriculture generates more than $52 billion per annum. The industries also provide more than 400,000 jobs in the Commonwealth. The work of making Food Safety Certification attainable and affordable for Virginia farmers is essential for the successful continuation and growth of Virginia's agriculture and food systems.

By working with Appalachian Harvest to help facilitate their training, audit readiness, request for audit process, and on site USDA GAP or Harmonized audit, many rural/remote family farmers saved approximately $500 on the actual audit process. The closest USDA GAP inspector is 5 hours from many of our rural/remote family farmers. For an inspector to drive directly to a single farm and return to his or her office, the travel cost alone is $920 for one farm, plus a minimum of 4 additional hours (at $92 per hour = $368 ) for pre, during and post inspection documentation. This would total $1,288 in GAP costs for one small rural/remote family farm to be inspected. With the training, mock audits, and networking opportunities provided by this grant, small rural and remote farmers' costs were lowered by a minimum of $600, and some lowered as much as $788. This can be attributed to farmers being well prepared through intensive education, mock audited and provided with fluid and accurate information for inspections. It can also be attributed to Appalachian Harvest working with inspectors to group farms together based on their geographic location, and having 4-5 inspections conducted on one travel trip by the inspectors with him or her spending several consecutive days conducting logistically friendly GAP inspections. This allows the grouped farmers to share in the $920/travel costs of the inspector. This effort also demonstrates the willingness of the USDA to utilize collaborative efforts to help make GAP certification more affordable for small and medium scale family farmers and packinghouses.

**2.**
FINAL REPORT
Title: Enhancing the Food Safety and Quality of Virginia Grown Cucurbits: FFY 2015-536
Organization: Virginia Tech
Project Lead: Laura K. Strawn
Co-Project Lead: Steve L. Rideout

**Project Summary:**

*Salmonella* is considered the leading cause of bacterial foodborne outbreaks in the US, which causes 1.4 million cases of illness and 500 deaths every year with total estimated costs of $3.4 billion/year. At least three outbreaks of salmonellosis have been traced back to the Eastern Shore of Virginia (ESVA, part of Delmarva Peninsula). In 2014, a *Salmonella* Newport outbreak associated with cucumbers caused 275 illnesses and 1 death in 29 U.S. states and Washington DC. The source of the outbreak was traced back to cucumbers grown at a farm on the Delmarva Peninsula of Maryland. While not on the Delmarva Peninsula of VA, the industry suffered due to the stigma of Delmarva-grown produce being unsafe, subsequently impacting the VA agriculture economy. Little was known about the behavior of *Salmonella* or other foodborne pathogens (such as *Listeria monocytogenes*) on cucurbits, specifically cucumber and cantaloupe. Additionally, minimal data existed on how the cucurbit industry would be influenced by the Food Safety Modernization Act. Therefore, the goal of this project was to investigate the fate of *Salmonella* and *Listeria monocytogenes* on cucurbits from field to fork (experiments focused on both pre- and post-harvest environments), and communicate "food safety best practices" to stakeholders. For example, one set of experiments evaluated the growth and survival of *Listeria monocytogenes* and *Salmonella* on whole and sliced cucumbers at refrigeration and ambient temperatures. *L. monocytogenes* and *Salmonella* populations survived for 336 h on refrigerated whole and sliced cucumbers. Both pathogens have the potential to grow on whole and sliced cucumbers at ambient temperatures. Due to the ability of *L. monocytogenes* and *Salmonella* to grow on whole and sliced cucumbers in short amounts of time (especially at ambient temperatures) or survive on whole and sliced cucumbers for long durations (up to 14 d at refrigeration temperatures) it is paramount to reduce the likelihood of contamination events throughout the supply chain.

**Project Purpose:**

The US Centers for Disease Control and Prevention (CDC) estimate that each year some 48 million Americans are sickened as a result of foodborne illness, resulting in 128,000 hospitalizations and 3,000 deaths (Scallan et al., 2011). In addition to human suffering, foodborne illnesses also have a substantial economic impact in the U.S. The proportion of foodborne illnesses attributed to contaminated produce and produce related products has increased dramatically from 0.7% of all foodborne outbreaks in the 1970s to 6% in the 1990s to 13% in the 2000s. Of particular interest to Virginia commodities is the foodborne pathogen *Salmonella* that account for 23% of the outbreaks and 31% of illnesses reported by CDC annually (Anonymous, 2011). Additionally, outbreaks of *Salmonella*, in addition to *Listeria monocytogenes*, have been associated with cucurbits, specifically cucumber and cantaloupe (US FDA 2013a, FDA 2013b, McCollum et al., 2013, Angelo et al., 2015). Despite guidance, including Good Agricultural Practices (GAPs; US FDA 1998) during production and harvest, and Good Manufacturing Practices (GMPs; US FDA, 2008) during packing and postharvest treatment, outbreaks of foodborne illnesses and recalls due to pathogen contamination linked to Virginia commodities continue to occur. Additionally, the Food Safety Modernization Act was signed into law with compliance dates for the Produce Safety Rule beginning in 2018-2022. Thus, the implementation of GAPs, GMPs, and FSMA PSR is quickly becoming a non-negotiable requirement to ensure the safety of products for retailers and consumers alike. Currently, very little is known about how to control *Salmonella* and *L. monocytogenes* on cucurbits, especially cucumber. A review of the work previously done indicates a data gap for cucumbers with no data, to our knowledge, on the likely preharvest contamination events or fate (growth and survival) of foodborne pathogens on cucumbers. Therefore, this project sought to provide the scientific-basis for minimizing foodborne pathogen contamination of cucurbits during the growing and postharvest packing; as well as communication of these results to Virginia stakeholders.

**Project Activities:**

All project activities were completed (using the one year no-cost extension). Additionally, all activities were completed within budget.

| Project Activities | Performed By | Timeline | Completed |
|---|---|---|---|
| Acquire research supplies. PI and research team meet to discuss objectives and short- and long-term deliverables | All | Oct-Nov 2015 | √ |
| Objective 3: Determining the fate (growth and survival) of *Salmonella* and *L. monocytogenes* on whole and fresh cut cucumber at different storage/transport/retail holding temperatures (e.g., 4°C, 23°C) over shelf life | LS, T | Jan-Feb 2016 | √ |
| Publications & presentations | LS, SR | Jan-Dec 2016 | √ (papers submitted 2017; see below for details) |
| Objective 1: Start cantaloupe transplants in greenhouse for transfer to field | SR, T | Apr-July 2016 | √ |
| Objective 1: Plant cucumber (seed) and cantaloupe (transplants) for field-trials | SR, T | Apr-Oct 2016 | √ |
| Objective 1: Evaluating the fate of *Escherichia coli* (indicator for FDA FSMA proposed Produce Safety Rule water standards) on the surface of whole cucumber and cantaloupe when irrigated with water of poor microbial quality (i.e., contaminated water) | LS, T | July-Oct 2016 | √ |
| Objective 2: Assessing the risks of contamination with foodborne pathogens from handling practices that are common in cucumber and cantaloupe field-pack and packinghouses; and evaluate the potential for mitigation strategies (simulated field-pack and packinghouse at ES AREC facilities) | LS, T | Jun-Dec 2016 | √ |
| Objective 4: Develop and present outreach programs and materials target to cucurbit growers and packers regarding the safe handling of cucumbers and cantaloupes, with a | All | Several presentations at grower meetings, | √ (see presentations |

| | | | |
|---|---|---|---|
| special emphasis on water quality, cleaning and sanitation, and FSMA regulations | | workshops, invited lectures, etc. | and publications section below) |
| *Final Report (due October 30, 2017)* | LS | Jan-Mar 2017 | √ (Nov. 2017) |

Abbreviations: LS = Laura Strawn, SR = Steve Rideout, T=Technician

Additionally, the following activity outputs were delivered (bulleted below):

**Publications (research and extension)**

- Bardsley, C., R. Pfuntner, L. Truitt, M.D. Danyluk, S. Rideout, L.K. Strawn. 2017. Growth and Survival of *Salmonella* and *Listeria monocytogenes* on Whole and Sliced Cucumbers. International Journal of Food Microbiology. *Submitted.*
- Strawn, L.K., R. Pfuntner, L. Truitt, and S. L. Rideout. 2017. Survival of *Escherichia coli* on cucumbers, cantaloupe, and tomato grown on the Eastern Shore of Virginia. Foodborne Pathogens. *Submitted.*
- L.K. Strawn, E. Gutierrez, and B. Chapman. 2017. Guide to Identifying Hazards in Packinghouse Environments. Publication number Virginia Cooperative Extension FST-279NP.
- L.K. Strawn, R. Pfuntner, T. Pittman, R. Boyer. 2017. Overview of the Food Safety Modernization Act Produce Safety Rule. Publication number Virginia Cooperative Extension FST 270NP.
- Strawn, L.K. and W. Kline. 2016. "Food Safety Concerns", Commercial Vegetable Production Recommendations. Publication number: Virginia Cooperative Extension 456-420.
- Dodson S., R. Boyer*, M. Chase, J. Eifert, J. Eifert, L.K. Strawn, A. Villalba. 2016. Safe Handling and Storage of Raw Fruits and Vegetables. Publication number: FST-216NP.

**Presentations**

<u>Presentations</u>

- Strawn, LK, RP Pfuntner, A Vallotton. "How to Minimize On-Farm Food Safety Risks using a Good Agricultural Practice Program". FreshFarm and Conservation Fund On-Farm Food Safety Workshop. Shippensburg, Pennsylvania, USA. 24Mar 2016. (30)
- Strawn, LK. "How to Begin Writing a Food Safety Plan for your Farm". Richmond Vegetable Conference. Doswell, Virginia, USA. 16Mar 2016. (50)
- Strawn, LK, S Rideout. "Post-harvest Handling". Profiting from a Few Acres-Small Farms Conference. Dover, Delaware, USA. 08Mar 2016. (30)
- Strawn, LK. "Good Agricultural Practices". Northern Neck Small Growers Workshop. Montross, Virginia, USA. 26Feb 2016. (50)
- Strawn, LK. "The Food Safety Modernization Act's Produce Safety Rule – Final Version: Everything you Need to Know and Compliance Dates".
    - 12th Annual Forum for Rural Innovation: Educating for the Craft of Innovative Agriculture. Winchester, Virginia, USA. 11Mar 2016. (75)
    - Southwest Virginia Packinghouse Best Practices Workshop. Hillsville, Virginia, USA. 02Mar 2016. (23)

    - Shenandoah Valley Packinghouse Best Practices Workshop. Dayton, Virginia, USA. 01Mar 2016. (20)
    - Local Food Hub Annual Food Safety Meeting. Charlottesville, Virginia, USA. 25Feb 2016. (25)
    - Hampton Roads Fruit and Vegetable Conference. Chesapeake, Virginia, USA. 24Feb 2016. (45)
    - Vegetable School. Warrenton, Virginia, USA. 23Feb 2016. *(35)*
- Strawn, LK and R Williams. "Cleaning and Sanitizing 101 for the Produce Industry".
    - Southwest Virginia Packinghouse Best Practices Workshop. Hillsville, Virginia, USA. 02Mar 2016. (included in count above)
    - Shenandoah Valley Packinghouse Best Practices Workshop. Dayton, Virginia, USA. 01Mar 2016. (included in count above)
    - Local Food Hub Annual Food Safety Meeting. Charlottesville, Virginia, USA. 25Feb 2016. (included in count above)

## Goals and Outcomes Achieved:

Goals/outcomes are divided by objective with tables or figures to visually represent data collected during the project, as well as major findings described.

### Objective 1: Evaluating the fate of *Escherichia coli* (indicator used for FDA FSMA proposed Produce Safety Rule water standards; will be tested metric) on the surface of whole cucumber and cantaloupe when irrigated with water of poor microbial quality (i.e., contaminated water).

On average, in trials using the "high inoculum" (black lines), populations of *E. coli* declined sharply within 24 h on cantaloupe, cucumber and tomato plants (Figures 1-3). In tomato plants, *E. coli* populations continued a slow die off with recovery for the seven-day study. However, in cantaloupe and cucumber plants, *E. coli* populations fluctuated from day to day over the seven-day study. This finding is most likely due to the effect of various meteorological variables (e.g., temperature, humidity, solar radiation, etc.) on *E. coli* populations. For trials using the "low inoculum" (blue lines), populations of *E. coli* behaved similarly for the "high inoculum" microbial die off on cantaloupe and tomato plants (Figures 1-3). However, populations of *E. coli* on cucumber using the low inoculum were variable. *E. coli* populations on cucumber increased over the first 48 h of the study, before declining during the remaining seven-day study. Interestingly, commodity (or produce) surface played a role in microbial die off (differences observed for cantaloupe (netted surface), cucumber (prickly surface with raised spines) and tomato (smooth surface). For example, *E. coli* was recovered in larger concentrations on cantaloupe, compared to cucumber and tomato. Tomato fruit had the lowest recovery of *E. coli*, likely due to its smooth surface (compared to the cantaloupe's netted surface).

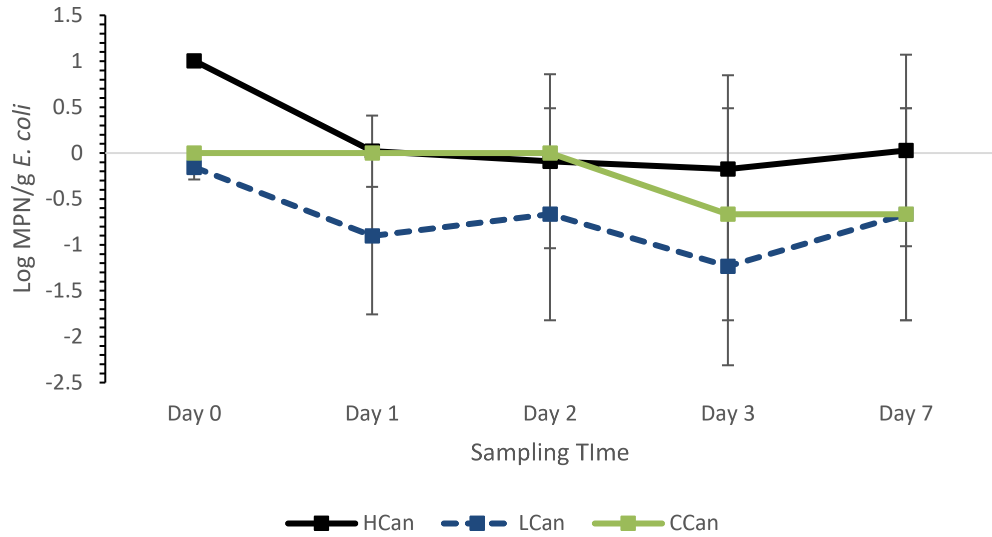



**Figure 1.** Fate of *E. coli* over a week on cantaloupes (Log MPN/g) grown on plastic (Painter, VA). HCan = Cantaloupe with high inoculum (4.88 log), LCan = Cantaloupe with low inoculum (2.53 log), and CCan = Control Cantaloupe. (n=9) (error bars = +/- STD).

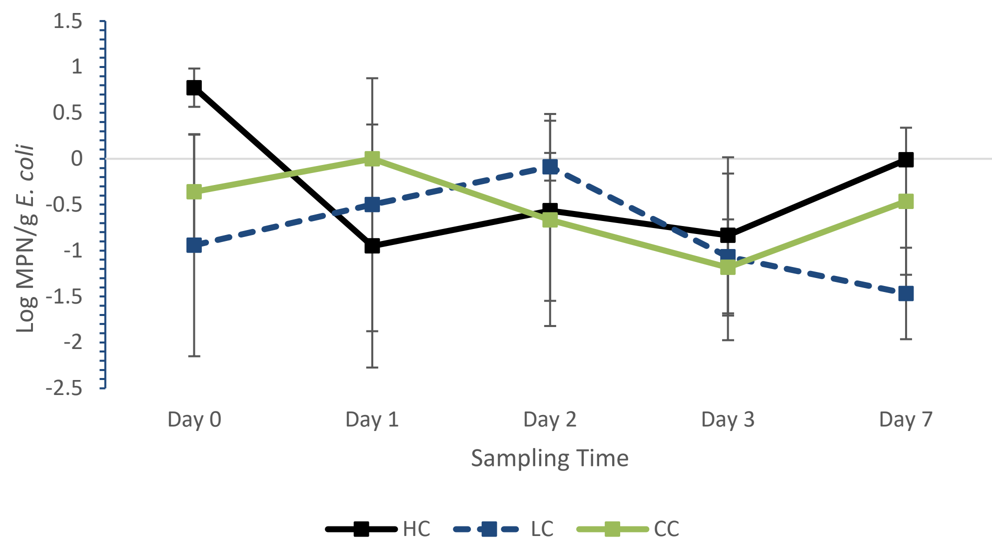



**Figure 2.** Fate of *E. coli* over a week on cucumbers (Log MPN/g) grown on plastic (Painter, VA). HC = Cucumbers with high inoculum (3.45 log), LC = Cucumbers with low inoculum (1.0 log), and CC = Control Cucumbers. (n=9) (error bars = +/- STD).

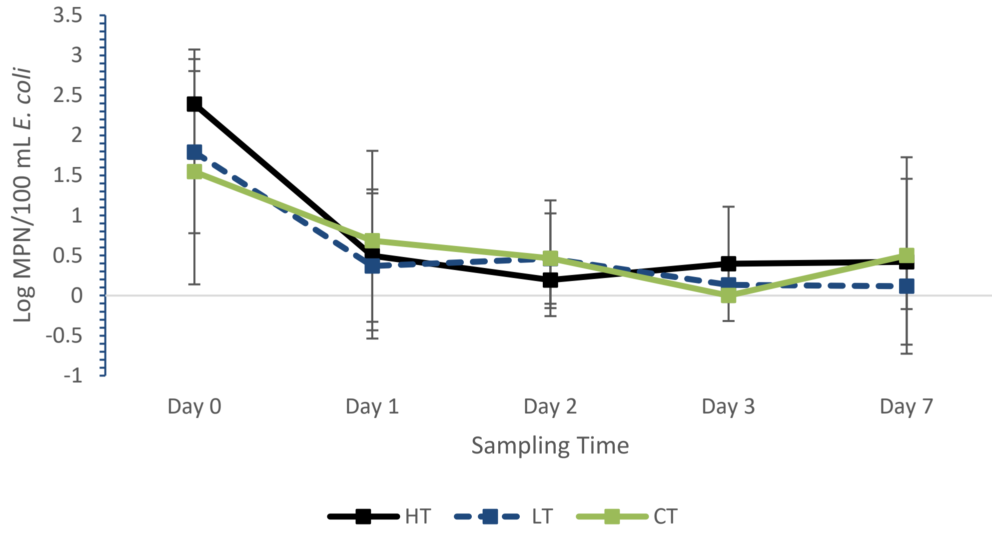



**Figure 3.** Fate of *E. coli* over a week on tomatoes (Log MPN/100mL) grown on plastic mulch (staked) (Painter, VA). HT = Tomatoes with high inoculum (4.87 log), LT = Tomatoes with low inoculum (2.95 log), and CT = Control Tomatoes (n=9) (error bars = +/- STD).

**Objective 2: Assessing the risks of contamination with foodborne pathogens from handling practices that are common in cucumber and cantaloupe field-pack and packinghouses; and evaluate the potential for mitigation strategies.**

Microbial swabbing was performed to develop guidance documents intended to serve as guides for growers that can be used for identification of microbial hazards within field-pack and packinghouse environments. Data was analyzed for the microbial swabbing of the field-pack operations since microorganisms (aerobic bacteria, coliforms, and *E. coli*) were recovered (Figure 4); no detectable levels of *E. coli* were found in the packinghouses tested. Instead potential hazards in packinghouses were described using a flow of food diagram, and collected from an exhaustive search of the literature for microbial risks in produce packinghouses. The flow of food diagram provides the most important areas within a packinghouse, and the potential sources of contamination when handling produce (with mitigation strategies/best practices to limit potential contamination events).

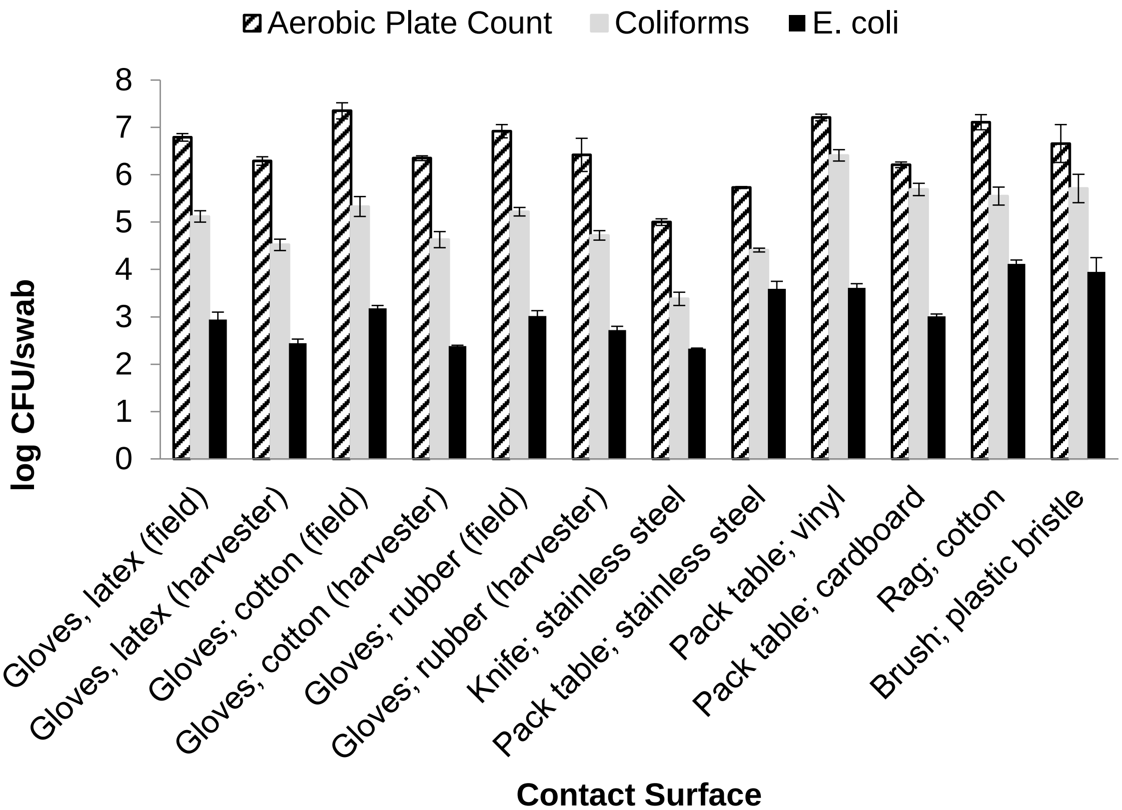



**Figure 4.** Comparison of microbial loads (aerobic plate count, coliforms, and generic *E. coli*) on field-pack contact surfaces collected between 7 and 10 am (morning timeframe). Each contact surface was swabbed if present. Up to three swabs were collected per contact surface for each harvester (n=3); except rags and brushes (n=2 per harvester). As many different harvesters/crews were sampled within the 3 h window (7-10 am) as possible (n=11). Harvesters/crews were tagged to perform an afternoon sampling, but no significant difference was observed in log CFU/swab counts.

**Objective 3: Determining the fate (growth and survival) of *Salmonella* and *L. monocytogenes* on whole and fresh cut (sliced) cucumber at different storage, transport, and retail holding temperatures (e.g., 4°C, 23 degrees Celsius) over shelf life.**

*Behavior of L. monocytogenes on Whole and Sliced Cucumbers at 4 and 23°C.* Whole cucumbers held at 4 °C had an average *L. monocytogenes* population of 5 log CFU/cucumber at 0 h (Table 1). Between 0, 24, 48, and 72 h there was no significant difference ($P \leq 0.05$) in the *L. monocytogenes* populations. *L. monocytogenes* populations significantly increased by 1 log CFU/cucumber between 72 and 168 h, and significantly increased 1.37 log CFU/cucumber between 168 and 336 h. Overall between 0 and 336 h *L. monocytogenes* populations increased by approximately 2.5 log CFU/cucumber. Sliced cucumbers held at 4 °C had an average *L. monocytogenes* population of 3.39 log CFU/g at 0 h (Table 1). Like populations on the whole cucumbers, between 0, 24, 48, and 72 h there was no significant difference in the *L. monocytogenes* populations. *L. monocytogenes* populations significantly increased by 1.26 log CFU/g between 72 and 168 h and significantly increased by approximately 1.5 log CFU/g

between 168 and 336 h. Overall between 0 and 336 h *L. monocytogenes* populations increased by approximately 3 log CFU/g. There was no significant difference in the amount of growth of *L. monocytogenes* populations between whole (per cucumber) and sliced cucumbers (per gram). *L. monocytogenes* was capable of growing on both whole and sliced cucumbers at 4 °C.
Whole cucumbers held at 23 °C had a *L. monocytogenes* average population of 5 log CFU/cucumber at 0 h (Table 1). Between 0 and 24 h *L. monocytogenes* populations significantly increased by approximately 2 log CFU/cucumber. Between 24 and 72 h *L. monocytogenes* populations decreased by approximately 0.5 log CFU/cucumber. There was no significant difference between *L. monocytogenes* populations between 0 and 96 h but there was an overall 0.76 log CFU/cucumber population increase. Sliced cucumbers held at 23 °C had an average *L. monocytogenes* population of 3.39 log CFU/g at 0 h (Table 1). Between 0 and 24 h *L. monocytogenes* populations significantly increased by 3 log CFU/g. Between 48 and 96 h *L. monocytogenes* populations decreased by approximately 1 log CFU/g. Between 0 and 96 h *L. monocytogenes* populations significantly increased by 2 log CFU/g. Populations of *L. monocytogenes* had a significantly higher growth on sliced cucumbers than whole cucumbers between 24 and 48 h. There was no significant difference in the amount of growth or reduction of *L. monocytogenes* populations between whole and sliced cucumbers at 5, 24, 72, and 96 h.

*Behavior of Salmonella on Whole and Sliced Cucumbers at 4 and 23 °C.* Whole and sliced cucumbers were both inoculated with a 4.23 log CFU/ml cocktail of five *Salmonella* strains. Whole cucumbers held at 4 °C had an average *Salmonella* population of 3.14 log CFU/cucumber at 0 h (Table 2). Between 0, 17, 24, 48, 72, and 120 h here was no significant difference in the *Salmonella* populations. Between 0 and 120 h *Salmonella* populations decreased by 0.71 log CFU/cucumber. Sliced cucumbers held at 4 °C had an average *Salmonella* population of approximately 2 log CFU/g at 0 h. *Salmonella* populations significantly decreased between 0 and 17 h by 0.34 log CFU/g and between 17 and 24 h by 0.34 log CFU/g. Between 24 and 120 h there was no significant difference in the *Salmonella* populations. Between 0 and 120 h *Salmonella* populations significantly decreased by approximately 1 log CFU/g. There was no significant difference in the amount of reduction of *Salmonella* populations between the whole and sliced cucumbers between 0 and 72 h. At 120 h the *Salmonella* populations on the sliced cucumber had significantly more reduction than the populations on the whole cucumber.
Whole cucumbers held at 23 °C had an average *Salmonella* population of 3.14 log CFU/cucumber at 0 h (Table 2). Between 0 and 5 h *Salmonella* populations significantly increased by approximately 1.5 log CFU/cucumber. Between 5 and 8 h *Salmonella* populations significantly increased by approximately 1 log. Between 8, 17, 24, and 48 h no significant differences in the *Salmonella* populations. Between 0 and 48 h *Salmonella* populations significantly increased by approximately 3 log CFU/cucumber. Sliced cucumbers held at 23 °C had a *Salmonella* population of approximately 2 log CFU/g at 0 h (Table 2). Between 0 and 5 h *Salmonella* populations significant increased by 1.59 log CFU/g. Between 5 and 8 h *Salmonella* populations significantly increased by 1.33 log CFU/g. Between 8, 17, 24, and 48 h no significant differences in the *Salmonella* populations. Between 0 and 48 h *Salmonella* populations significantly increased by approximately 3 log. There was no difference in the amount of *Salmonella* population growth between whole and sliced cucumbers held at 23 °C.

*Comparison of L. monocytogenes and Salmonella on Whole and Sliced Cucumbers at 4 °C.* The difference in the growth and reduction of *L. monocytogenes* and *Salmonella* populations on whole cucumbers held at 4 °C showed no significant difference between days 0, 1 and 2 (Fig 1A), both populations showed reductions between these days. Between 2 and 3 days *Salmonella* and *L. monocytogenes* populations were significantly different by approximately 1 log CFU/cucumber, the *Salmonella* populations continued to decreased while the *L. monocytogenes* population grew 0.71 log CFU/cucumber. Between days 3 and 7 *L. monocytogenes* and *Salmonella* populations were significantly different by 1.78 log CFU/cucumber, while the *Salmonella* populations continued to decrease the *L. monocytogenes* populations increased by approximately 0.5 log CFU/cucumber. The difference in growth and reduction of *L. monocytogenes* and *Salmonella* populations on sliced cucumbers held at 4 °C showed no significant differences between days 0 and 1, but an increase in *L. monocytogenes* populations and a decrease in *Salmonella* populations was observed (Fig 1B). Between days 1 and 2 *L. monocytogenes* and *Salmonella* populations were significantly different by 0.84 log CFU/g, as *L. monocytogenes* populations continued to increase while *Salmonella* populations continued to decrease. Between days 2 and 3 *L. monocytogenes* and *Salmonella* populations were significantly different by1.21 log CFU/g and significantly different between days 3 and 7 by almost 3 log CFU/g.

*Comparison of L. monocytogenes and Salmonella on Whole and Sliced Cucumbers at 23°C.* The difference in the growth and reduction of *L. monocytogenes* and *Salmonella* populations on whole cucumbers held at 23°C showed no significant differences between 0 and 1 days, though the increase of the *Salmonella* populations was slightly higher than the increase of the *L. monocytogenes* populations (Fig 2A). Between days 1 and 2 *L. monocytogenes* and *Salmonella* populations were significantly different by approximately 2 log CFU/cucumber as the *L. monocytogenes* population decreased. Between days 2 and 3 there was no significant difference between the amount of growth in *L. monocytogenes* and *Salmonella* populations. Between days 1, 2, and 3 the *Salmonella* population was stable showing little to no population changes. There was no significant difference in growth and reduction of *L. monocytogenes* and *Salmonella* populations on sliced cucumbers held at 23°C. Interestingly the *L. monocytogenes* and *Salmonella* populations showed similar trends under these conditions. Between days 0, 1 and 2 both *L. monocytogenes* and *Salmonella* populations increased and between days 2 and 3 *L. monocytogenes* and *Salmonella* populations slightly decreased.

**Table 1.** Behavior of *L. monocytogenes* on whole and sliced cucumbers stored at 23 and 4 °C

| Time (Hours) | 4 °C[a] | | 23 °C[b] | |
|---|---|---|---|---|
| | Whole | Sliced | Whole | Sliced |
| 0 | 5.01±0.08 AB[c] | 3.39±0.05 A | 5.01±0.08 A | 3.39±0.05 A |
| 5 | | | 4.95±0.18 A | 3.63±0.04 A |
| 24 | 4.87±0.10 A | 3.48±0.02 A | 6.85±0.49 C | 5.81±0.65 B |
| 48 | 4.83±0.25 A | 3.56±0.10 A | 6.10±0.35 BC | 6.43±0.29 B |
| 72 | 5.54±0.17 BC | 3.88±0.13 A | 6.20±0.28 BC | 5.82±0.58 B |
| 96 | | | 5.77±0.41 AB | 5.56±0.51 B |
| 168 | 6.07±0.30 C | 5.14±0.41 B | | |
| 336 | 7.44±0.21 D | 6.55±0.63 C | | |

[a] Values expressed as log CFU/cucumber ± standard error; values are the average of duplicate samples from each of three replications (n=6).

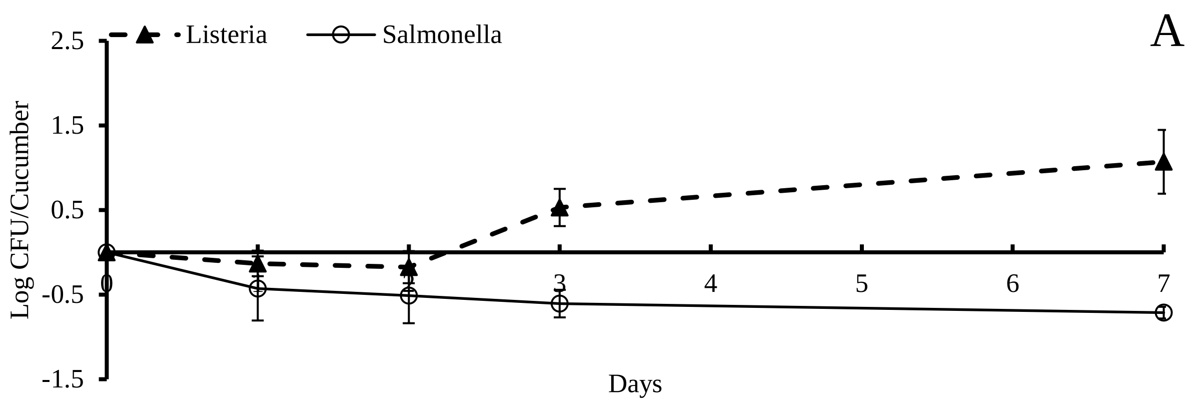
[b] Values expressed as log CFU/gram ± standard error; values are the average of duplicate samples from each of three replications (n=6).
[c] Mean values in columns were analyzed for significant differences (*P≤0.5*) between sampling days.

**Table 2.** Behavior of *S. enterica* on whole and sliced cucumbers stored at 23 and 4 °C

| | 4 °C[a] | | 23 °C[b] | |
|---|---|---|---|---|
| Time (Hours) | Whole | Sliced | Whole | Sliced |
| 0 | 3.14±0.19 A[c] | 1.95±0.15 A | 3.14±0.19 A | 1.95±0.15 A |
| 5 | | | 4.59±0.14 B | 3.54±0.12 B |
| 8 | | | 5.72±0.16 C | 4.87±0.03 C |
| 17 | 2.72±0.36 A | 1.61±0.27 B | 6.07±0.25 C | 4.93±0.16 C |
| 24 | 2.80±0.28 A | 1.27±0.26 C | 6.08±0.13 C | 5.16±0.19 C |
| 48 | 2.54±0.18 A | 1.23±0.20 C | 5.99±0.72 C | 4.85±0.17 C |
| 72 | 2.46±0.09 A | 0.87±0.20 C | | |
| 120 | 2.43±0.22 A | 0.80±0.13 C | | |

[a] Values expressed as log CFU/cucumber ± standard error; values are the average of duplicate samples from each of three replications (n=6).
[b] Values expressed as log CFU/gram ± standard error; values are the average of duplicate samples from each of three replications (n=6).
[c] Mean values in columns were analyzed for significant differences (*P≤0.5*) between sampling days.

**Figure 1.** Behavior of *L. monocytogenes* (triangles, dashed line) and *S. enterica* (circles, solid line) inoculated on the surface of whole (A) and sliced (B) stored at 4 °C. Values are the average of duplicate samples from each of replications (n=6); error bars represent standard errors.



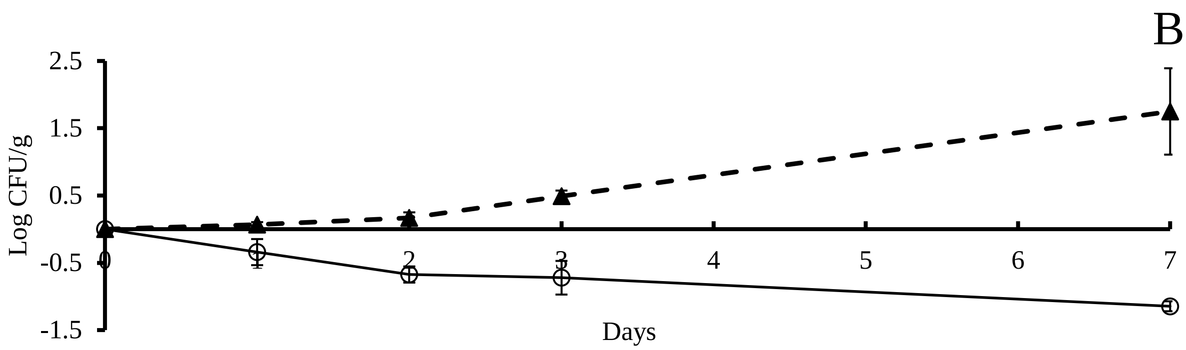
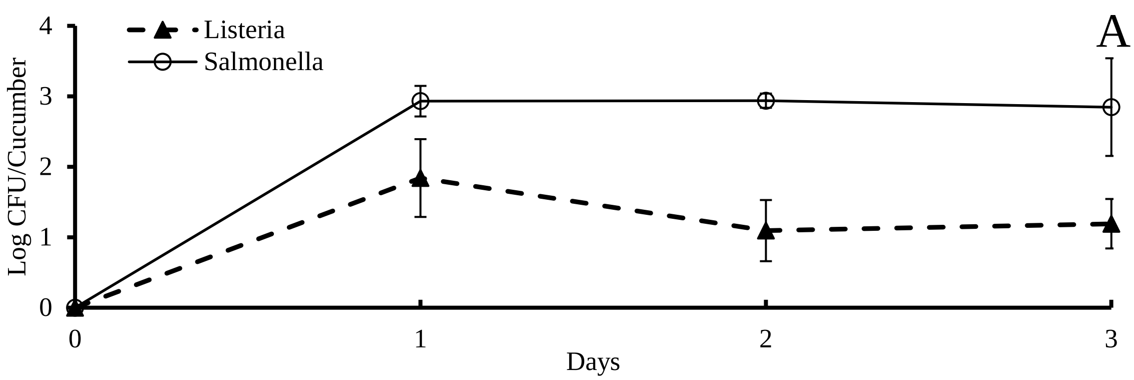
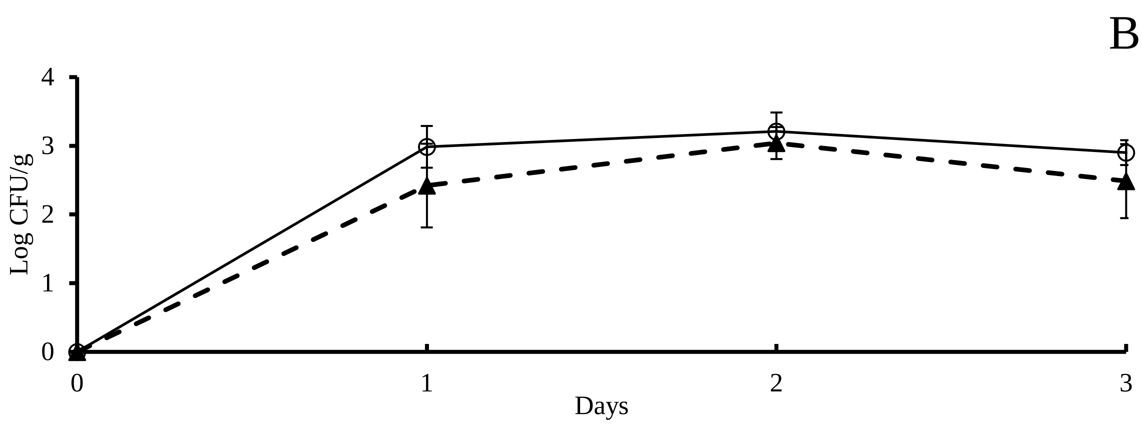



**Figure 2.** Behavior of *L. monocytogenes* (triangles, dashed line) and *S. enterica* (circles, solid line) inoculated on the surface of whole (A) and sliced (B) stored at 23 °C. Values are the average of duplicate samples from each of replications (n=6); error bars represent standard errors.




**Objective 4: Develop and present outreach programs and materials targeted to cucurbit growers and packers regarding the safe handling of cucumbers and cantaloupes, with a special emphasis on water quality, cleaning and sanitation, and FSMA regulations.**

Educational content was developed through publications, fact sheets, and also a number of PowerPoint presentation slide decks (see activities). Two publications were submitted for publication on Objectives 1 & 3 that describe scientific experiments and science-based recommendations. Fact sheets, tailored to the Virginia stakeholder, were created (i) to address hazards/risks in produce packinghouses, and mitigation strategies for limiting contamination events (Objective 2) and (ii) to inform farmers about the FSMA Produce Safety Rule regulations (specifically addressing basics of the rule and compliance dates). Additionally, several PowerPoint presentations were developed to communicate best practices in the pre- and post-harvest environments, as well as presentations on water quality and sanitation programs (cleaning and sanitizing); see activities for list. Feedback from attendees at the meetings were overwhelmingly positive, and several extension agents invited my group back to the same meetings to present again next year (to continue discussion on hot topics, or keep expanding participant food safety knowledge).

**Beneficiaries:**

Cucurbit growers, packers, processors, retailers, and consumers all benefited from the results/findings of this work, with special emphasis on the cucurbits industry: cucumber and cantaloupe. The fresh market cucumber and cantaloupe industry in Virginia represents approximately 1,400 and 1,000 acres (for comparison: cabbage 500 acres, tomatoes 5,000), respectively. This project provided best practice guidance for limiting potential contamination events for cucurbits in the pre- and post-harvest environment, as well as handling. Findings were disseminated through extension venues via presentations, workshops, publications and fact sheets to highlight best practices.

As mentioned above, compliance with current voluntary standards are typically non-negotiable requirements to distribute product through retail and food service entities (e.g., sell wholesale). With release of the final Produce Safety rule under FSMA, these voluntary standards may become mandatory, regulated, minimum requirements for anyone growing or importing products for US consumption (this includes Virginia growers who fall under the regulation). Thus, all produce stakeholders in Virginia benefited from factsheets and presentations on the FSMA Produce Safety Rule (we also provided this information to extension agents for other local grower meetings within the Commonwealth of Virginia that our group could not attend).

Number of beneficiaries affected by the projects accomplishments (including category of beneficiaries):

Beneficiaries for this project include the VA cucurbit industry, specifically the cucumber and cantaloupe growers/packers. Indirectly; this project will also benefit other cucurbit commodities that are grown in VA, including squash, pumpkin, and other melons. Presentations given to Virginia stakeholders (approximately 383 attendees) by Drs. Strawn and Rideout that addressed safe handling of cucumbers and cantaloupes, with a special emphasis on water quality, cleaning and sanitation, and FSMA regulations are listed above. Number in parenthesis () is approximate attendance at event (listed next to presentations above). Extension publications are online for the general public and anyone can download, or view; therefore, an infinite number of specialty crop producers could benefit from those project accomplishments.

**Lessons Learned:**

A no-cost extension was requested due to field trials for Objective 1 being extended to collect sufficient replication data (also delaying publications). However, with the no-cost extension, all project objectives were completed with no challenges.

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**3.**
**Final Report**
**PROJECT TITLE**
 Sustainable Development of Native Mason Bee Populations for Berry Pollination
 **Old Dominion University Research Foundation**
 Lisa Horth

PROJECT SUMMARY

This goal of this work was to improve Virginia small farmer competitiveness with a timely demonstration that the addition of mason bees *(Osmia lignaria)* on strawberry farms results in larger strawberries than pollination by honey bees alone. The current and severe problem of disease and colony losses in honey bees used for agricultural pollination, warrants remedy. Mason bee cocoons were added to half of each of four farms and the other farm-half was left unstocked. Mason bees were observed on strawberry flowers and moving between plants, allowing for pollination. Berries were larger on the side of each farm where mason bees were stocked by a minimum of 2 grams. We evaluated mason bees for greenhouse pollination and determined that they land on berry flowers and cross pollinated plants. 890 landings were observed on berry flowers and fruits were produced. Three cocoon densities were employed in each of three greenhouses, and berries were similar in size, suggestive that fewer bees may be as useful as less bees in greenhouse settings. To my knowledge, this is the first work to show that these bees prove to be successful pollinators of strawberries in greenhouses.

PROJECT PURPOSE: The primary purpose of this work was to improve pollination of strawberries on small Virginia farms through the use of blue orchard mason bees *(Osmia lignaria)*, given the peril specialty crop farmers face as honey bees continue to die at high rates and colony losses continue to impact crop pollination. We completed this task.

The second goal was to establish sustainable populations of bees and leave farmers with quality bee homes. We created bee homes for farms and used them. However, this area leaves room for improvement. Farmers need solutions that can remain on farms but not interfere with equipment and changing needs. While our homes were placed off crop rows but near to them, sometimes this became complicated, as farmers asked us to move homes to particular places, then events occurred that necessitated change. For example, a freeze came and farmers wanted to cover berries and move homes. Some cocoons drowned as some homes were toppled. Farmers wanted us to remove homes at the end of the season, not leave them on farms. For this experimental work, that turned out to be good news. While it differed from our initial plan, we also started to test mason bees for disease and found that they have deformed wing virus, too. We felt it would be prudent not to leave another generation of bees on farms until we learned more about the deformed wing virus that mason bees carry. A third goal was to conduct greenhouse experiments to determine information about the possibility of pollination in greenhouses with these bees. We completed this work and found that these bees clearly conduct pollination in greenhouses. A final goal was to disseminate information: we list below the talks conducted (in Project Activities) and also established a blog, facebook and twitter feeds, and will share our publication, when complete, with VDACS and any relevant parties (e.g. scientists, Ag. experimental stations).

PROJECT ACTIVITIES: Activities included establishing mason bees on farms and evaluating berries after pollination, constructing homes for bee colonization and deploying them on farms, determining whether mason bees can be used in greenhouse pollination, and disseminating our results to multiple audiences. These were the activities proposed, so all objectives were met. The relevance and timeliness of this work is related to the collapse of honey bee colonies in agriculture and the need for sustainable solutions. Mason bees served as great pollinators in a time when there are no known solutions to honey bee mortality. Recommendations include further research on the use of mason bees on Virginia farms. Caution must be exercised, however, until we know more about bee disease transmission and which bee viruses mason bees carry. Commodity crops were the only ones benefitted.

Several professional presentations were presented related to this work, two of which occurred in 2017:

By Horth, in 2017 'Adding native bees to farms improves berry production, Ecology Society America in Portland, OR.

The published abstract of this talk is entitled: Horth, L. and L. Campbell (2017) Agricultural solutions: Adding native bees to farms improves berry production. *Ecological Society of America.*

As well, in 2016, there was: 'Assessing the effectiveness of *Osmia lignaria* as a greenhouse pollinator of *Fragaria x ananassa'* by Gregory & Horth, presented at the Ecological Society of America meetings in 2016 in Fort Lauderdale, FL.

And in October, 2016, Horth presented, 'Novel mason bee use on farms and in greenhouses for berry pollination' at the North American Pollinator Protection Campaign Meeting in Beltsville, MD.

RESULTS:

Data collected is reported upon in the prior section and the next section. Clearly these bees are pollinating strawberry flowers and producing berries (larger on the side of every farm where mason bees were stocked by a minimum of 2 grams (see outcomes for mean weights), 890 landings observed on strawberry flowers in greenhouses, where fruits were produced no matter how many cocoons were stocked in greenhouses. Talks have been given, as listed above (professionally and to beekeepers) and press coverage has occurred (see below for details). A publication is being worked on imminently (we are collecting final data) and new research collaborations have been initiated related to this work. We also are running public media (fb and blog) about native bees and honey bees.

GOALS & OUTCOMES ACHIEVED:

The **primary goal** of this work was to use native mason bees *(Osmia lignaria)* to pollinate the specialty crop, strawberries. We constructed wooden homes, as planned. These homes were placed on Pungo strawberry farms, then cocoons were placed in them, for emergence onto the crop. We saw bees emerge from cocoons and fly onto the strawberry flowers. We saw bees move between flowers, allowing for the transmission of pollen between plants. We collected quantitative data on berry weight and size for the control (no bee addition) and mason bee addition side of each farm used. Berries were larger where mason bees on the side of each farm where mason bees were stocked (Berry weight for Farm1, mason bee addition farm-side: 19.5g, and no addition farm-side: 17.6 g. Farm 2, mason bee addition: 31.9 g, no addition: 18.1 g. Farm 3, mason bee addition: 16.7, no addition: 12.8. Farm 4: mason bee addition: 22.8 g, no addition 19.7g). We monitored visitation to berry flowers and observed mason bees pollinating berry flowers or flying near to strawberry flowers on over 100 occasions. We saw some colonization of homes, but farmers asked that the homes be removed at the end of the season, so we moved them off farms.

A **second goal** was to conduct greenhouse experiments to determine rates of pollination and optimal pollination regimes for mason bees in greenhouses. We have completed this work, comprehensively. We found challenges regarding the relationship between timing of emerging bees and flowering plants. Nevertheless, we determined that day 14 berry weights for low, medium and high bee density greenhouses (3,6,9 cocoons per greenhouse per trial) were actually similar: Berry weight at 14 days was 0.926 g for low density greenhouse trials (3 cocoons used per trial, 52 total berries weighed), 1.23g for medium cocoon density greenhouse trials (6 cocoons, 72 total berries weighed) and 0.909 for high density greenhouse trials (9 cocoons per trial, 75 total berries weighed). Berry weight at 28 days was 1.24g for low density greenhouses (70 berries), 1.56g for medium density (79 berries) and 1.23g for high density (75 berries). This work suggests that the use of less bees by farmers appears to be as efficient as the use of more bees per greenhouse.

The mason bees used in greenhouse pollination of strawberries clearly landed on one flower, foraged, then landed on another allowing for the cross pollination of plants. To my knowledge, this is the first work to show that these bees prove to be successful pollinators of strawberries in greenhouses. In fact, over the course the time period between 13 June 2018 and 6 August 2018, we observed 890 landings of mason bees on strawberry flowers, cumulatively in three greenhouses (stocked each week, with three, six or nine cocoons). Cocoon stocking density was not correlated with number of pollination events observed. Berries were successfully produced from all greenhouses and the greenhouse (6 cocoon/trial) with the most bee landings also had the berries with the greatest 14 day weight (at 1.2g, as compared to 0.92 for the three cocoon treatment and 0.90 for the nine cocoon treatment) and 28 day weight (1.56 g, as compared to 1.23g for 3 cocoon and 1.24g for nine cocoon greenhouse berries).

Timing bee emergence with floral development is important when there are not scores of berry plants and since strawberry flowers are only open about four days. We have learned that additional control of bee emergence is crucial and relevant for greenhouse work and we are starting to understand this, further. From the work performed, we realized too, that lighting may be an important factor to take into consideration (long periods of overcast skies and rain are challenging for pushing flowering of plants) when using these bees in greenhouses.

A **third goal** was to educate consumers, beekeepers, farmers, other researchers about native bee use. We have established a blog, facebook page, and twitter feed to this effect and are sharing news about our research and our publication and about native bees in general. I will speak to local beekeepers at their meeting this Fall 2018, too.

We also inform farmers before, during, and after experiments about progress and we sent them the results of the work - each communication is performed by email and by snail mail to ensure receipt of this communication.

Recent press on our work includes:

Fall 2018, ODU Dean, College of Sciences featured our current work on COS social media pages (we are pictured in the the experimental greenhouses with strawberries, performing the work of this grant)

'Strawberry Fields Forever' (and Spanish translation), Associate Editor C. Garcia, The Applied Ecologist's Blog (10/17/17)

Bee researchers' groundbreaking work featured in British Ecological Society journal (9/17) News@ODU

'Using mason bees to provide pollinator services on strawberry farms' (8/14/17) British Ecological Society, Press Release, S. Weiss

'Breakthrough with mason bees inspires Horth to push frontiers in pollination research' (2/2017) *News at ODU*

'Mason bees are all the buzz on Virginia Beach berry farms' (10/27/2016) *Southside Daily*

BENEFICIARIES: Beneficiaries have included farmers, who's berries were larger on farms when the bees were added to their farms. Basic agricultural science has also been advanced through this work, which benefits the research scientists in the region (and beyond) indirectly in allowing more knowledge dissemination about how to use these bees in agriculture. A number of students have benefitted directly: Three students will, or have graduated having benefitted from working on this grant: Amanda Norbie will have a chapter of her thesis based on the farm work presented here, Michael Gregory had a chapter of his thesis based upon the initial greenhouse work and Mollie McGee will have a chapter of her thesis based upon the extended effort at greenhouse studies. As well, Katelyn Jao-Santiago gained valuable undergraduate agricultural research experience, as did Jackie Rushley, while assisting on this project. Furthermore, the PI Lisa Horth has gained useful research experience using these bees, which is very helpful is determining optimal paths of future study, that will benefit agriculture in Virginia. She hopes to expand her research to other specialty crops and optimal methods of farming soon.

This work was completed on four farms in Pungo, VA, so those farmers benefitted directly. Other Pungo farmers were aware of this work so could benefit from conversation if they used mason bees on their farms. There is a particular benefit in our region since there appears to be a depauperate wild bee fauna where these farmers are as well, and since they are experiencing a high rate of colony collapse in honey bees.

As well, the data was reported in Journal of Applied Ecology, which has an international audience.
The publication was reported by one of the large mason bee vendors who shares the information with all the berry growers he communicates with, and a few scientists have now asked me about work details. I know that the bee vendor partnered with farmers in TN to use mason bees on berry farms after seeing our results, so a direct impact, as well.

I would estimate that this means >10 direct beneficiaries (Family farmers), with a very positive impact on current science, and current scientists, current bee vendors, and the potential to impact many more farmers and scientists.

**The economic impact:**
We demonstrated quantitatively that berries grew faster and were larger with the use of mason bees.

That was reported in the scientific publication, too. We did not set out to answer this question directly (we did not say we would, nor did we measure ctw, which would allow us to make further statements) , but we did the mathematics to provide the necessary information for future use, and our measurements on berries clearly show two relevant issues: berries were bigger and berries grew faster with mason bees. Here is the information that is relevant:

From an economic perspective, recent National Agricultural Statistics Service, & U.S. Department of Agriculture (2016) reports indicate that 0.404 ha (1 acre) of strawberries in the USA had an average yield of 26,569.6 kg or 523 cwt (hundredweight). Virginia's average yield was 4,165.79 kg (82 ctw). Each cwt returned $80.40 USD. Each 0.404 ha of strawberries in the USA yields $42,000 USD on average in gross returns, with Virginia's yield at $6,592.80 USD.

If 630 cocoons were added to 0.404 ha, at an aver- age cost of $1.47 USD per cocoon, total cocoon cost would be $926USD per 0.404ha, reducing revenue to $5,666.80, if berry production did not increase. So to profit on Virginia farms with mason bees, berry cwt would need to increase at least 12% (or 11.52 ctw) from 82 to 93.5174 ctw per 0.404 ha. While we did not measure ctw, we do know that mean berry size increased much more than 12% on average on our treatment plots, relative to controls.

We also know that growth rate increased.

Average fruit volume with mason bees: 4,481 cubic mm. Average fruit volume without mason bees: 2,919 cubic mm.

Average growth rate of berries with mason bees was greater also: 291 cubic mm / day. Average growth rate for berries without mason bees: 151 cubic mm /day.

This data has all been reported in the Journal of Applied Ecology manuscript, accepted August 2017, entitled Supplementing Small Farms with Native Mason Bees Increases Strawberry Size and Growth Rate.

LESSONS:

There were challenges we did not anticipate, working with farmers, who are always very very busy and sometimes unable to communicate with us. Bee homes, after deployment, were moved on multiple occasions and sometimes this meant cocoons were drowned, as houses were turned over before bees had time to hatch. Changing needs of farmers in quick time-frames may be responsible for this, as well as possible communication gaps between workers and farm heads. It is our job to work harder with farmers on ensuring homes are in good locations and safe (not face down in water) so we know we must improve in this area, which may mean considering a new form of bee deployment.

Our homes were larger than typical mason bee homes, making them valuable for cocoon deployment and recolonization on farms. However, this also makes them heavy. We worked with optimizing a design that would be portable to move around farms, yet sturdy under high winds, freezing rains and snow. Each year, we learn more about how to optimize homes. We still believe that improvement in this area is possible since the situation is not yet perfect for farmers or researchers. Simultaneous with this work we found that mason bees do carry deformed wing virus, so we pulled homes from farms (which pleased farmers, anyway) so as not to contribute to the transmission of disease.

We measured symmetry in these berries, but believe an improved method of measure is necessary, and are in communication with mathematician Dr. John Jungck about improving our method before drawing final conclusions.

We took it upon ourselves to repeat our greenhouse work because bees did fly up toward sunlight often in the first year. With improved lighting and some shade cloth on greenhouses, we remedied much of this issue, allowing for what appeared to be less stressed bees that pollinated plants more often in the second year. Surprisingly, we did find that spider webs in the bottom corners of the greenhouses proved perilous to bees if bees flew into these corners. Something to consider for subsequent work: how to fill small gaps in greenhouse construction so that bees do not escape from them and natural remedies for web building spiders.

We must be able to accommodate student and faculty salary consistent with the demand of the project. Students require a fair amount of supervision even on straightforward tasks. Underestimating labor effort is easy to do and students are not allowed to work more than designated hours. Some tasks that sound trivial to do can take quite a long time to complete (e.g. assembly of greenhouses and making them hole proof to avoid bee escapes, or even routine watering and pruning of the plants throughout the experiment). Timing bee emergence with floral blooms can be challenging so perhaps more cocoons could be ordered. We also found that many shippers (in fact all that we contacted) would not ship berry plants until March (post-freeze) but this makes it challenging to get them blooming and big by the time we want to release bees. Good experiences included the fact that some students quite like greenhouse work and enjoy the bees, so it's a positive life experience for them and they learn an incredible amount about agricultural pollination, which may help with the crisis of who will be our next generation of farmers.

Additional information

The publication for this work is not yet complete since we are still measuring the last few berries. We will send it to you when completed. We did refer to our preliminary greenhouse work in the Horth & Campbell, *Journal of Applied Ecology* paper that was recently published on our very first farm results from a grant funded by VDACS.

There was no project income from this work for the researcher, however there should have been an economic benefit to strawberry farmers from the larger-sized berries produced. This is not something we monitored, we just monitored the berry size.

CONTACT: Lisa Horth, Professor Old Dominion University, (757)683-6508, lhorth@odu.edu

**4.**
Final Report

PROJECT TITLE
**Integrated Peer-to-Peer Training and Community Outreach to Improve Growing, Marketing and Consumption of Specialty Crops on Virginia's Eastern Shore.**

NAME OF ORGANIZATION
**Eastern Shore Resource Conservation and Development Council**

PROJECT LEAD
**Josephine Mooney**

PROJECT SUMMARY
This project was created to meet the growing demand by small farmers on Virginia's Eastern Shore for educational programs directed towards learning best practices for growing specialty crops sustainably. The approach included both Classroom Workshops and Peer-to-Peer/On Farm Training for specialty crop growers. It featured experts from Virginia State University's Small Farmer Outreach Program and Future Harvest Field School/Chesapeake Alliance for Sustainable Agriculture (CASA). Topics presented included High Tunnel Construction, Permaculture, Small Fruits, Honey Making and Pollination Services, Growing Cut Flowers for Profit, value added crops such as Lavender, and various Marketing topics.

**Small Farmer Training Workshops: Total Attendees- 399**

We had a total of 399 attendees at ten Workshops and Peer-to-Peer small farmer training events. Attendance at all our workshops and field meetings greatly surpassed our expectations with classroom presentations often sold out at capacity of 58 attendees in some locations, and one we had to move to a larger location as 110 registered. We ended up with 78 attendees.

**Promoting Increased Consumption of Local Fresh Fruits and Vegetables**

The project also included outreach to the Eastern Shore community on the Benefits of Consuming Fresh Fruits and Vegetables as well as promotion of local farmers' markets and small farmers, to hopefully stimulate increased consumption of local specialty crops.

250 brochures on the Benefits of Consuming Fresh Fruits and Vegetables were distributed at various community events as well as promotions on the local famers' markets and local farmer profiles.

7,500 2-sided full-color flyers with USDA Tips to *Get Kids to Eat More Fruits and Veggies* were distributed directly to all students in the public and privates schools. The flyer also included promotion of the local Farmers' Markets and their respective Double SNAP programs.

The local Extension Nutritionist provided smoothie demonstrations and free tastings during a public Earth Day event in a local park, using fresh fruits available from local farmers. Farmers brought "barnyard animals" for the children to meet during the event. Minority participation was quite pronounced, with approximately 30% of the 150 attendees being Hispanic or African American.

**Total Outreach Numbers**

**Overall Earned and Paid Media Outreach, Email Blasts, and Facebook, Flyers, Reaches/Impressions**

***Eastern Shore News***
We got three **Cover Stories** published in the *Eastern Shore News* on our workshops:
One on each of our two High Tunnel Construction Workshops and one on our Honey Making and Pollinator Services Workshop. Circulation 4,600 x 3 issues
= **13,800 impressions**

**Facebook Paid Boosts** of Posts # people "Reached" = **12,647 impressions**

**Paid Ads** 2 in *Delmarva Farmer* circulation each: 30,000 Mid Atlantic area = **60,000 impressions**
*Lancaster Farming* one ad circulation 50,000 Mid Atlantic area = **50,000 impressions**
*Mail Chimp* Email Blasts 2 for each of 10 events, at 2,000 contacts email blast = **40,000 impressions**
**Email blasts by Future Harvest/CASA** on 1 high tunnel workshop and 4 additional workshops
Total 5 events, 2 email blasts per event = 10 blasts at 3,000 contacts each = **30,000 impressions**

**Printed Flyers** 100-200 per Workshop and Event posted in all Shore Post Offices, community bulletin boards, etc. Estimate 5 persons view each flyer. Total flyers approximately 1500 x 5 "impressions" per flyer = **1,500 impressions**
**Printed flyers** for Smoothie Demonstrations by Extension Nutritionist for Earth Day
Distributed to every student in all the Shore public and private schools, estimate 1.5 impressions per flyer/7,500 flyers printed = **11,250 impressions**

**Estimated Total Outreach Impressions = 217,697**

PROJECT PURPOSE
Many small-scale, new and beginning farmers in Accomack and Northampton Counties do not benefit from exposure to peers with knowledge in the field and classroom that small and beginning farmers have had in other areas of Virginia and nearby Maryland such as the Pocket Farm Programs in Floyd, VA or the Future Harvest Field School in MD. High unemployment, poverty and isolation inhibit access of poor local farmers to peer-to-peer training. The nearest suburban and urban markets with their growing demand for local, sustainably grown food appear to the local farmers to out of reach. These factors have created a demand for more educational programs for small growers in the Shore's two counties not only on the best practices for growing but on economically viable ways to reach these markets with their crops.

America's farmers continue to "age out" of the occupation. According to the USDA's 2014 Census of Agriculture, the average age of farmers in the US is 58 years. The aging agricultural community and the USDA are working toward identifying and supporting the next generation of farmers and rural landowners who will be stewards of our land and produce our food. In stark contrast to recent decades, when few in the younger generation were interested in farming, in recent years interest by young people in locally-sourced food and small-scale agriculture has surged.

PROJECT ACTIVITIES
We presented the following Workshops and Field Meetings for small farmers:
1. Hands-on Two-Day High Tunnel Raising w. Future Harvest & VSU Attendees: 30

2. Skinning A High Tunnel w. VSU Attendees: 23
3. Growing Berries: American Treasure Workshop w. VSU/Hampton Roads AREC Attendees: 58
4. Small Farm/Big Market w VSU, Future Harvest/ Buy Fresh Buy Local Attendees: 38
5. Bee Engaged: Honey Making and Pollinator Services w. Future Harvest Attendees: 33
6. Permaculture Profits w Future Harvest & VSU Attendees: 38
7. Cut Flowers for Profit w. VSU Attendees: 78
8. Growing & Harvesting Lavender w. Future Harvest Attendees: 58

We also collaborated with the VSU Small Farmer Outreach staff on these two Classroom workshops here on the Shore:

9. Whole Farm Planning - Attendees: 25
10. Marketing Techniques for Value Added Products –Attendees: 18

Additional activities included public speaking presentations about the grant programs to various public events and organizations, distributing information while exhibiting at Farm to Restaurant Shows, and other appropriate venues.

GOALS AND OUTCOMES ACHIEVED

Attendance at all our workshops and field meetings greatly surpassed our expectation with classroom presentations often sold out at capacity of 58 attendees and one we had to move to a larger location and had 78 attendees (with signups of 110…some had to cancel due to drastic heat wave.)

**Total Attendees 399**

With regard to Goal 3: increase the consumption of fresh fruits and vegetables by socially disadvantaged communities in Northampton and Accomack Counties of Virginia, neither market experienced an increase in spending by WIC and Senior Bucks over the life of the grant.

The demand for these small farmer training programs greatly outstrips the availability.

BENEFICIARIES

At least 399 attendees at the Workshops and Trainings benefitted. In addition, some farmers travelled from out of town to the Eastern Shore for the first time, as described below. They help increase the awareness of the growing small farm community here and are forming connections.

We also truly surpassed our expected geographic reach with attendees from six states: PA, DE, NJ, NC, VA and MD. Minority participation increased over the two years, and all fee-based workshops offered scholarships and we had between 2 and 6 minority scholarship attendees. Our high tunnel workshops had a particularly high minority turnout with 6 or more Hispanic and/or African Americans out of about 30 attendees.

250 members of the community received brochures on the ***Benefits of Consuming Fresh Fruits and Vegetables***, and 7,500 students received flyers about the local farmers markets and the double SNAP programs.

The new and beginning farmer participants learned tried and true methods and techniques for sustainable farming on a small or medium scale especially suited for the local conditions on the Eastern Shore of Virginia.

LESSONS LEARNED

**GOAL** To increase the number of Virginia Eastern Shore specialty crop growers from socially disadvantaged communities who participate in professional development opportunities at the Future Harvest 3-day Conference in Maryland for small farmers. **Performance Measure:** The number of VA Eastern Shore residents from socially disadvantaged communities who attend **BENCHMARK:** Attendance by VA Eastern Shore resident growers at the 2015 Future Harvest 3-day Conference **TARGET:** Increase attendance by 3 scholarship recipients and at least 2 paid registrations by VA Eastern Shore resident growers each year. We were able to meet this target based on information from Future Harvest's registration data collected electronically on their website annually.

In addition, two of our local farmer have signed up for the year-long Beginning Farmer Training Certificate Program at Future Harvest's Field School in Maryland.

Long Term Post-Project Goal

This project has the potential to become self-sustaining in the near future as we have been in discussions with the leadership at both the Future Harvest/Chesapeake Alliance for Sustainable Agriculture and the Eastern Shore Community College (ESCC) regarding transitioning the program over time to become a satellite location of the Maryland-based Field School. Dr. Thomas Glover, President, and Eddie Swain, Dean of Workforce Development Services, have expressed their support for eventually moving this project to the campus of ESCC as a tuition-based Leadership Development Certification program.

Dr. Glover was the main thrust behind encouraging the development of an ongoing farmer training program at ESCC Workforce Development Services in collaboration with Future Harvest/Chesapeake Alliance for Sustainable Agriculture (FHCASA's) beginning farmer training. Talks were discontinued once Dr. Glover indicated she would be leaving the Shore. There has not yet been a replacement for her and the Acting Interim President will not be doing any planning along these lines.

Not sure how to deal with not being able to rely on partners being able to perform as agreed to unforeseen circumstances or perhaps poor planning/management decisions, or other things that were beyond their control.

Perhaps individual subject matter experts from the private sector are generally more focused and easy to work with compared to a non-profit organization. In the future, I will look for experts such as Lisa Ziegler and Ellen Reynolds, who had deep experience and were terrific presenters.

CONTACT PERSON

- Josephine Mooney
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ADDITIONAL INFORMATION

Visit the Eastern Shore Small Farmer Network's Facebook page at:
https://www.facebook.com/ESSmallFarmerNetwork/

**5.**
**Final Report**
**Strengthen and Develop the Asian Pear Market in Virginia**
**Institute for Advanced Learning and Research**
**Dr. Kedong Da**

## PROJECT SUMMARY

Pears are one of the most popular and well-liked fruits in the world. Two types of pear are now grown in Virginia, the European type and the Asian type. European pears (Pyrus communis) are the variety most commonly seen in supermarkets today. The Asian pear, however, has rapidly increased its market share in the United States due to its attractive appearance and white, crisp, sweet, and juicy flesh. Hence, there exists the potential to increase Virginia-grown Asian pear production and market share. Farm size, soil type and climate differences have restricted technologies successfully applied in the Pacific Northwest from being applied to Virginia's small-to-medium sized farms; especially to Virginia organic farmers whose cultivation practice is quite different from commercial growers utilizing mechanical pruning and chemical thinning. Virginia Asian pear farmers need to develop Virginia Asian pear cultivation protocols to improve Asian pear quality and to strengthen the Virginia Asian pear market. This research facilitated the study of tree training and pruning methodology and fruit bagging technology in Virginia Asian pear orchards to improve Asian pear yield and quality. Our findings demonstrate that bagging improves marketability and quality.

## PROJECT PURPOSE

Virginia has climatic and soil conditions favorable for Asian pear production. Most pear varieties require about 1,000 to 1,200 hours below 45° F in winter to complete their dormant period and most varieties can withstand the low winter minimum temperatures in Virginia. Fully dormant trees can survive temperatures of -20 to -25° F. There are three major growing zones in Virginia: Shenandoah Valley, Piedmont, and Tidewater. Information from five Virginia Asian pear farmers has shown that one of the most important barriers to sustainable farming in Virginia has been improper pruning and fruit protection that caused quality problems due to lack of technical support and knowledge about viable production methods.

It is estimated that 80% of the farmers receive most of their revenues at Farmer's Markets, but in recent years, certain farms have begun to sell their products through chain grocery stores. The market for Asian pears on the East Coast is developing - consumer survey has shown a large potential market share for Asian pear. Internationally, China has agreed to allow all apple varieties produced in the United States access to the Chinese market, and other fruit species like the pear are under discussion as well, which would allow for a potential export market. Strengthening Virginia Asian pear production and developing the market are critical steps for Virginia farmers wanting to capitalize on the growth in the marketplace.

U.S. pear research and production is centered in the Pacific Northwest, Northern California, Oregon and Washington State. Limited information is known about Virginia's pear market and thus, Virginia farmers need to strengthen the production and promotion of their pear products. A report on "Growing Pears in Virginia" compiled by the Virginia Cooperative Extension reveals that Asian pear cultivation requires different techniques than European pear and apple. Pear tree pruning is necessary to: (1) develop a desirable tree shape, (2) maintain the tree at a desirable size, (3) make spraying for insect and disease control easier, (4) improve fruit quality by allowing better light penetration, (5) improve tree strength, and (6) encourage branching. Good shape and balanced trees produce high quality fruits. Fruit bagging is a new technology to U.S. farmers that can reduce chemical use in the orchard, protect fruit damage by hail, disease, pest and animals, increase fruit coloring when the bag is removed, and help produce high quality fruits.

We propose to improve Asian pear yield and quality by developing a standard Asian pear training, pruning and bagging system for Virginia farmers. Quality improvement methods that we will test include: (1) different training and pruning technology in Virginia orchard conditions to increase fruit quality by improving tree growth, and (2) testing different fruit bagging technologies to improve fruit quality by reducing insect, disease, and hail damage.

Standard practice for fruit tree pruning on small farms is by hand work mostly performed by seasonal workers, and the knowledge requirements and pruning techniques are quite varied. Proper training of the orchard owner and familiarity with contemporary pruning and fruit quality control technology is important for standard operation. There is not a bagging technology that has been tested systematically in the U.S. to date. IALR's mission is to help these farmers strengthen their foothold in the Asian pear market by developing a detailed pruning protocol covering different stages and soil/climate types of Asian pear growth in Virginia. We will test different pruning methods and use different colored bags to test the effects on fruit quality improvements in Virginia.

Two farms representing two climate-soil types (Piedmont and Shenandoah Valley) in Virginia will be selected; nine mature trees will be selected from each of the participating farms; three tree shapes (vase-shape, Christmas tree shape and modified leader shape) and three colors (white, brown and black) of fruit bags will be tested on the selected trees.
This project is timely and we are optimistic for the outcomes and use of pruning and bagging technology in Virginia pear farms. Our research group has essential knowledge of techniques to make the same results happen in Virginia as in Asian pear farms in Asia. Group members will not only meet regularly during the growing season, they will also be connected online by video. Additionally, to support collaboration and marketing of Virginia grown Asian pears, a Virginia Asian Pear Growers Association web site will be established.

**PROJECT ACTIVITIES**

Project progress successfully based on work plan:

1. PI, Dr. Kedong Da, visited Virginia Gold Orchard in Rockbridge County and Saunders Brothers Orchard in Nelson County on April 13th and 25th 2017 respectively, and discussed with the orchard owners last year's sales results and the anticipated flower date of this coming year. Kedong talked with Bennett Saunders, owner of Saunders Brothers orchard, about problems in the recent year's pear production. Bennett suggested a research direction based on last year's late frost damage to flower and caused some farm flower damage and zero harvest. Kedong agreed with Bennett to plan and collect materials from freeze damage of the fruit and possible preventive measure. Plans are to submit a research proposal to VDACS in the future. Fruit sales, flower time, fire blight disease damage, stink bug control, variety performances and breeding was discussed with the Virginia Gold Orchard owner

2. Dr. Da presented a bagging technics seminar to IALR technicians who participated in this past year's Asian pear bagging in orchards on May 18th, 2017.

3. Fruits were bagged at Saunders Brother Orchard on May 30th and31st and at Virginia Gold Orchard on June 5th and 6th. This was a repeat of an experiment from2016 and similar fruit bags were used to treat marble size fruits. Three repeats for each treatment and 100 fruits were bagged on each tree. 1200 fruits were treated at each farm. The variety "Autumn Sweet" was bagged at Virginia Gold and "Shinko" was bagged at Saunders Brothers.

4. Dr. Da remains in frequent email communication and regular conference calls with the growers, and an additional visit was made to Saunders Brothers Orchard and Virginia Gold Orchard on July 27th, 2017 and August 4th 2017, respectively, to collect fruit setting and bag loss data.

5. Bag treated fruits were harvested at Virginia Gold Orchard on August 17th 2017. Bagging is such an efficient treatment to growers, orchard owner Sue Estabrook plans to bag treat her fruits herself next year. Dr. Da promises to coordinate bag order and provide technical support.

6. Experimental fruits were harvested at Saunders Brothers orchard on August 30th, 2017. Three generations of Saunders showed their interest in the experiment results. Orchard owner Bennett Saunders would like to continue to collaborate in Asian pear research in the future.

## GOALS AND OUTCOMES ACHIEVED

1. Tree pruning. All experimental trees in the Virginia Gold Orchard (VGO) were pruned in the vase shape and experimental trees were pruned to modified central leader shape in the Saunders Brothers Orchard (SB). Trees at Virginia Gold Orchard are approximately 11 years old and trees at Saunders Brothers Orchard are approximately 6 years old. Virginia Gold Orchard cultivation practices are more like an organic farm, while Saunders Brothers Orchard is more systematically managed by scheduled pesticide, fertilizer and irrigation.

2. Bag treatment improved fruit growth and fruit mean weight increases, with single layer white bag treatment showing the best results (Figure 1).

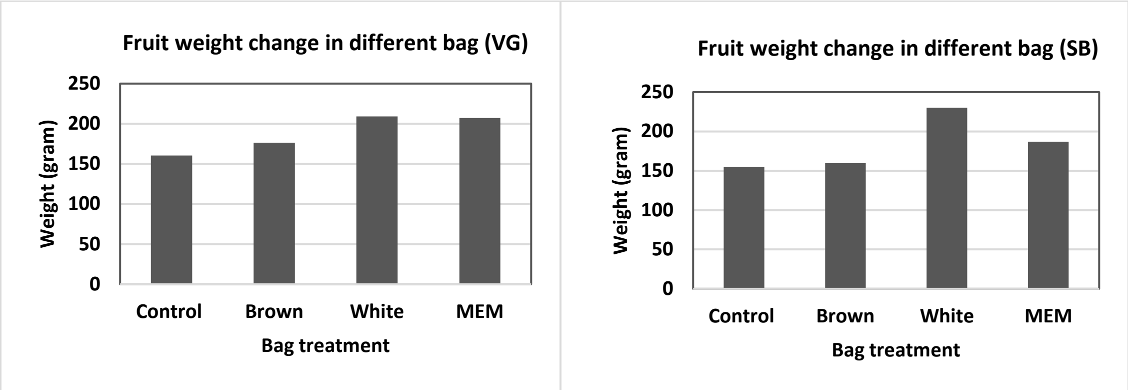



Figure 1. Bagging effect on fruit weight. Virginia gold orchard 2017 (left), Saunders brother orchard 2017 (right)

3. Bagging treatments greatly improved the visual quality of the fruit. (Figure 2). The best result in improving the visual quality of the fruit among the three different bag treatments was the double layer brown bag treatment, which produced golden fresh fruits,while the control and other bag treatments resulted in brown to green-brown fruits. Brown bag treated fruits were also found to have the best taste. Lab tests showed that white bag treated fruits had a higher sugar content (Figure 3).

Figure 2. Brown bag treatment (right) showed healthy, attractive golden color; control fruit (left) showed greenish brown color and some damaged fruits. Saunders brother orchard 2017.

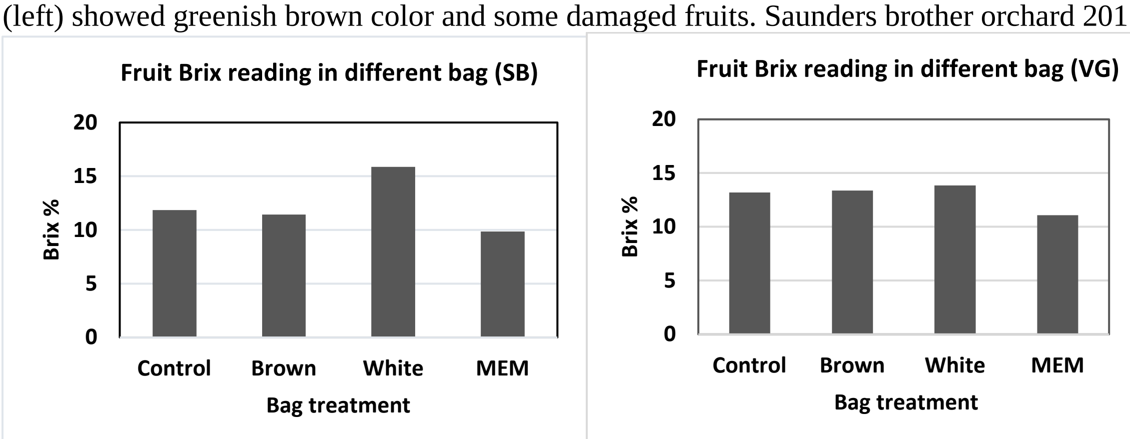
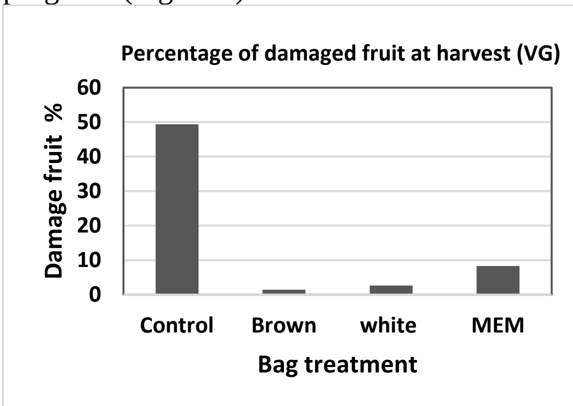



Figure 3. Fruit suger content evaluation in different bag treatment in two farms. Virginia Gold (right) and Saunders brother (leaft) 2017.

4. The two experimental orchard used different cultivation practices. Virginia Gold Orchard practices more organic, lower maintenance techniques, which resulted in a greatly increased percentage of marketable fruit using the bag treatment versus the control. Results from the bagging treatment showed marketable fruit rate at 99% for the brown bag, 97% for the white bag and 92% for the membrane bag; while marketable fruits rate from the control trees at only 49%. Data from Saunders Brothers showed similar trends in bag protection of fruit damage and inhancement of marketable fruit percntage The lower damage percentage in

Saunders Brothers orchard resulted  from the application of a systematic pest/disease contral program. (Figure 4)



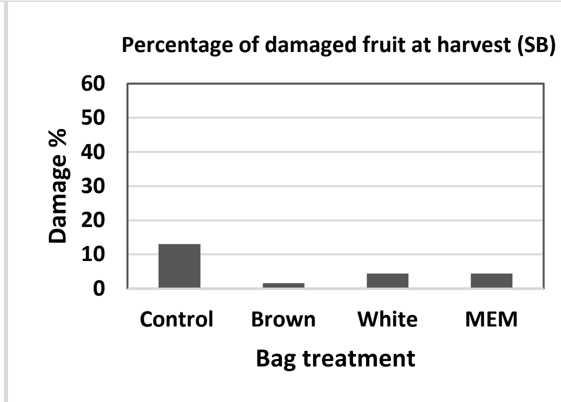




Figure 4. At both farm, brown bag treatment resulted the lowest damage (1-2%) and highest percentage of marketable fruits among the different bag treatments. As high as 49%  of the fruit contained  bug damage in the control at Virginia Gold Orchard (left) while 13% of the fruit was damaged in control at Saunders Brothers Orchard (right).

Second year conclusions:

A. Brown bag treatment is the most efficient quality improvement method in Asian pear.
B. Brown bag treatment provides the best visual quality fruit.
C. Brown bag treatment produces the highest percentage marketable fruits.

**BENEFICIARIES**

Two Asian pear growers directly benefited from the project. Approximately  40 people participated in workshops to learn more about the project and Asian pear production.

**LESSONS LEARNED**

A period of higher temperatures during the months of January and February in the 2016 grant period induced premature flower bud formation, and subsequent flowering in all trees at both orchards utilized in the experiment. Later periods of frost in March - April of 2016 damaged flowers and fruit formation reducing the number of viable fruit. Populations of fruits designated for bagging in 2016 were half of the original anticipated number in the experimental design.

**CONTACT PERSON**

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**ADDITIONAL INFORMATION**

**VADACS ASIAN PEAR MEDIA EXPOSURE, ASIAN PEAR EDUCATION**

1. VDCS project Asian pear research exposure at VSU small farm symposium. November 6, 2016, Danville VA.

2. VDACS Asian pear project visit. Lab day, June 11, 2017. Danville VA

3. VDACS project Asian pear lunch and learn. September 19, 2017. Danville VA

4. VDACS Asian pears project at Institute improving yield, appearance. Danville Register and Bee.

http://www.godanriver.com/news/danville/asian-pears-project-at-institute-improving-yield-appearance/article_e5032fb8-a091-11e7-8802-ebc58d9b0fe9.html

5. VDACS Asian pear project presented at Career Expo 2017 including students from the Cities of Danville and Martinsville as well as Halifax, Henry, Patrick and Pittsylvania Counties. September 27-28, 2017. Olde Dominion Agricultural Center. Chatham, Virginia

6.

**Final Report**

**PROJECT TITLE:** Increasing Yield of Virginia-Grown Hops (*Humulus lupulus* L.): Nutrient Management and Selection for Disease Resistance

Laban Rutto
Virginia State University

## PROJECT SUMMARY

A two location trial was conducted to study the response of select hop varieties to different levels of nitrogen fertilization under Virginia conditions. At Petersburg, Cascade and Nugget were planted and fertilized at 75, 100, and 150kg N/acre while in Blacksburg, Chinook and Nugget were supplied with 50, 100, and 150kg N/acre. Plant performance data including yield were collected and compared. At Petersburg, Cascade yielded more than Nugget, but there were no within variety differences in growth and yield in response to N treatment. Similar results were reported for Blacksburg with no significant differences in growth and yield data in response to N rate. A marked improvement in performance in 2017 relative to 2016 suggests that the crop will continue to change as it matures and future reporting will further clarify varietal and treatment effects on crop performance. Lack of significance in plant performance between N rates suggests that other production factors may have a greater impact on hop growth under Virginia conditions. Climatic data collected at Petersburg and two other Virginia locations confirm the dangers of hop downy and powdery mildews in the region. Significant Japanese beetle damage was also observed at both experimental sites.

## PROJECT PURPOSE

Hops (*Humulus lupulus* L.) is an emerging specialty crop in Virginia and the Southeastern United States. The recent interest in the crop is driven largely by a burgeoning craft beer industry that continues to demand more of specialty ingredients including hops. However, Virginia farmers interested in growing hops are faced with a lack of critical information on variety selection, recommended cultural practices, and market conditions.

In this project, we addressed two key research questions, the answers to which will make Virginia farmers better informed and prepared to grow hops as a cash crop.

i.) Trials were conducted to determine optimum nitrogen (N) levels for hop production under Virginia conditions using select varieties. Nitrogen is a key element in hop production and its management is critical for ensuring a good quality crop.

ii.) We monitored pest and disease interactions to determine the most important challenges to hop production in Virginia, and the period during the growing season when growers should be on the lookout for potential infection or infestation.

As intended, information generated through this project has been disseminated to Virginia farmers at field days and other venues, and to wider audiences through online media.

## PROJECT ACTIVITIES

At both sites, project implementation was preceded by hop yard construction. At both institutions, this was done using in-house resources and expertise, which yielded valuable experiences and data that has been shared with potential hop growers and other stakeholders. For example, we found that the trellis system for a half-acre hop yard costs upwards of $ 6,000 in supplies in addition to considerable labor and specialized equipment (augur, scissor lift etc.).

Actual project implementation was accomplished as per objectives outlined in the proposal. Experiments were established at research and demonstration hop yards in Petersburg (37$^{o}$ 23' 26" N; 77$^{o}$ 44' 33" W) and Blacksburg (37$^{o}$ 21' 77''N; 80$^{o}$ 46' 29" W), VA to test hop nutrient demand-focusing on nitrogen (N), and to observe pest and disease interactions among selected hops varieties. At Petersburg, Cascade and Nugget were planted and fertilized at 75, 100, and 150kg N/acre while at the Blacksburg site, Chinook and Nugget were planted and fertilized with 50, 100, and 150kg N/acre. Planting material obtained from Great Lakes Hops (Zeeland, MI) was used at both locations.

Plant performance data including yield were collected and compared at both sites, and weather monitoring and scouting for pests and diseases conducted. The research sites were also used as venues for training and sensitizing growers and other stakeholders.

**GOALS AND OUTCOMES ACHIEVED**

Data on plant performance and yield as affected by N rate was collected and analyzed with the objective of determining optimum levels to be recommended to hop growers in Virginia and the greater mid-Atlantic. Recommendations for N fertilization in hops obtained from the Pacific Northwest range from an average of 100kg N/acre to as high as 200kg N/acre (as per anecdote). Application rates will vary depending on the age of the crop and also in relation to residual N usually determined after soil analysis.

In this study, rates of 75, 100, and 150kg N/acre (Petersburg) and 50, 100, and 150kg N/acre (Blacksburg) were compared. Yield data at both sites were comparable, ranging from per acre wet weights of 500-700lbs for Cascade and 300-500lbs for Nugget in Petersburg, and 800-1000lbs for Chinook and 250-300lbs for Nugget in Blacksburg. However, there were no treatment-related variations in yield at both sites. This preliminary finding calls for more work on determining optimum hop fertilization rates for the Southeastern United States.

Yields were significantly lower than those reported for Michigan (1500lbs/acre dry weight). This was attributed partly to plant age although latitude also plays a significant role suggesting that yields will remain lower than in the northern regions even at plant maturity.

Pest and disease interactions were also monitored and it was observed that growth conditions at the two locations favor both downy (*Pseudoperonospora humuli*) and powdery mildew (*Podosphaera macularis*) infection. Growers are advised to implement a spray program using products listed for the region and to constantly scout for disease outbreaks from mid-May to early July. The pest of note reported at both sites was the Japanese beetle (*Popilia japonica*) which caused significant leaf damage in June/July.

The two hop yards were quite successful as resources for extension and outreach. Owing to strong interest in hops in the region, both hop yards hosted field days and tours and served as venues for training and exchange of information on the agronomy, postharvest handling, and marketing of hops. In total, the hop yards, and by extension the current project have received more than 600 visitors in the three years they have been in existence.

Data from this project was also presented at the South Atlantic Hops Conference held March 24-25, 2017 in Asheville NC (240 attendees) and March 2-3, 2018 in Blacksburg, VA (230 attendees from 18 states). The annual meeting is organized jointly by Virginia State University, Virginia Tech, and North Carolina State University.

## BENEFICIARIES

The current project is part of a greater effort to generate research-based guidelines for growers in Virginia and the region. At both locations, the project has been used for teaching and demonstration involving different stakeholders including growers, brewers, and partners from other institutions of higher learning. The following are specific activities and events that were served by the project:

*Petersburg Site:*

- The first ever hops field day at the VSU Randolph Farm was held on August 10, 2016 with 25 attendees.
- On October 1, 2016, the VSU hops research and demonstration program hosted the October business meeting (20 attendees) of the Old Dominion Hops Cooperative (ODHC) followed by a hop yard tour and discussion of research prioritization. The ODHC brings together hop growers and other interested parties from Virginia, North Carolina, Tennessee and Maryland.
- The hops research and demonstration program participated in the June 15, 2017 "Ag. Innovations for Small Farmers" field day at the VSU Randolph Farm (33 attendees).
- The program hosted a hops research and production workshop at the VSU Randolph Farm on May 15, 2018 with 30 attendees.
- The project, once again, was featured during the June 7, 2018 "Ag. Innovations for Small Farmers" field day at the VSU Randolph Farm (40 attendees). During this event, we also hosted a research and extension delegation from North Carolina Agricultural and Technical University (NCAT).

*Blacksburg Site:*

- The first annual Virginia Tech Hop Yard Open House was held June 27, 2016 with 32 attendees.
- A hop yard tour and discussion of research goals was presented to the Virginia Beginning Farmer & Rancher Coalition September 7, 2016, with 28 attendees.
- The hop yard was a featured site during the April 2016 meeting of the Old Dominion Hops Cooperative (18 attendees) and the annual Virginia Statewide Master Gardener College in June (42 attendees to our session).
- The second annual Virginia Tech Hop Yard Open House was help August 4, 2017 with 28 attendees.
- Virginia Tech hosted the 3rd annual 2018 South Atlantic Hops Conference at the Skelton Conference Center and Inn, Blacksburg, March 2-3, 2018. There were 230 total attendees representing 18 states. Dr. Holly Scoggins served as primary organizer/convener.

During the field days stakeholders learned about hop research programs at the two Virginia land-grant institutions and obtained data on hop production e.g. estimated costs of hop yard construction, sources of clean planting material, agronomic practices including pest and disease management, and guidelines for postharvest processing and handling of hops before delivery to market. Meetings that brought together growers and brewers included information on brewer needs, and wide ranging discussions on future direction of the regional hops industry.

## LESSONS LEARNED

The following represent key project findings:

- Hops can be grown in Virginia, but nutrient management levels may need to be adjusted to account for lower growth and biomass yield as compared with results obtained in the Pacific Northwest and the US Northeast where the crop benefits from longer days during the summer.
- Other factors including pest and disease interactions, terroir, and weather fluctuations may play as large or even greater role in hop husbandry than nutrient management.
- Significant variation in growth and yield between hop cultivars growing under the same conditions (including fertilization) underlines the need for large-scale variety trials to identify cultivars most suited to Virginia conditions.
- One of the shortcomings of the current project is the duration of the grant period (two years, extended to three). Hop plantings take four to five years to reach maturity and full production potential and the kind of nutrient study proposed should be conducted on mature plantings in order to obtain consistent and comparable results.

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## ADDITIONAL INFORMATION

As part of implementing the project, the following resources and support sites have been developed or identified for growers and other stakeholders in Virginia:

- Estimated trellis construction costs http://www.agriculture.vsu.edu/files/docs/agricultural-research/trellis-construction.pdf
- Information on growing hops in Virginia VCE website http://www.ext.vt.edu/topics/agriculture/commercial-horticulture
- "Hops at Virginia Tech" Facebook page https://www.facebook.com/HopsVT
- Old Dominion Hops Cooperative http://www.olddominionhops.com/
- Loudoun Hops Association https://www.facebook.com/LoudounHops/

**7.**
**Final Report**
**PROJECT TITLE**
Developing Markets & Processing Capacity for Specialty Crop Seconds & Value Added Products

**NAME OF ORGANIZATION**
Appalachian Sustainable Development

**PROJECT SUMMARY**
Most specialty crop farmers struggle to find viable markets for their seconds, particularly in rural areas of VA where there is little processing infrastructure that could be used to convert these low value crops into high value products. Appalachian Sustainable Development (ASD) has worked with a co-packer and Appalachian Harvest farmer to provide its wholesale and retail buyers with access to value added products. These value added products represent a significant market opportunity for farmers in Southwest VA. Unfortunately, few farmers in Southwest VA are able to take advantage of this opportunity due to a lack of processing infrastructure.

This grant will demonstrate the viability of using value added products to increase farmer profitability in Southwest VA by:
1. Increasing demand for value added products among retailers, wholesalers, and end customers
2. Identifying the most efficient and cost effective means of processing seconds for small and medium scale farmers in Southwest VA

**PROJECT PURPOSE**
Objective 1: Increase market opportunities for specialty crop seconds from small and medium scale farmers by increasing sales of value added products in retailer establishments and online.

Objective 2: Identify the most cost effective, efficient means of increasing the amount of seconds produce incorporated into value added products.

The purpose of this project was to increase demand for specialty crop seconds and provide viable market opportunities for farmers by identifying the most cost effective and efficient means of processing seconds from Virginia producers.
Specialty crop producers in remote rural areas often rely on markets for their products that are larger in scale, such as grocery store chains and produce brokers, because locally available direct markets are too small to represent viable opportunities. These more distant markets present large volume opportunities but also have the highest quality and certification requirements and the lowest pricing. Depending on the crop, weather, and farmers' experience, farmers selling into the wholesale market (particularly organic farmers) report that 20 to 50% of specialty crop harvests are graded as U.S. No 2. There is a great opportunity for farmers to process these seconds and create "value added products," providing them with additional income for what can often be a waste product, and expanding the growing season and farmer cash flow.

In 2014 ASD developed a relationship with a specialty crop farmer who is working with ASD to facilitate co-packing beets, pickles, salsas and butters under the Appalachian Harvest brand. The co-packer is located in northern VA, making it very costly to transport products to that location. Additionally, the packer is limited in how much primary processing they are able to do. The products are being very well received and ASD is currently developing markets for them through Appalachian Harvest. Appalachian Harvest, a food hub that serves large scale buyers such as regional grocery store chains and produce brokers, has worked with Ingles Supermarkets which is now purchasing value added products for 50 of their 200 stores. The purpose behind developing these markets is to fulfill a long-term goal of ASD's of providing farmers in the region with an outlet for their seconds. ASD has had numerous requests over the last 10 years to implement a processing facility at its Appalachian Harvest location. Unfortunately, the lack of a strong product line to serve as the base client for such a line of business made it prohibitively expensive and quite risky to attempt such a venture. The value added products line is providing ASD with the opportunity to analyze the best way of processing seconds for incorporation into these products.

This project is important and timely because the demand for the Appalachian Harvest branded products is providing an opportunity to increase the use of specialty crop seconds from Southwest VA farmers. This comes at a time when consumer interest in learning the source of their foods is driving interest in purchasing local food, including value added products. In 2014 local foods generated $14 billion in sales and is projected to generate $20 billion by 2019. However, a lack of local processing infrastructure makes it very difficult for local farmers to benefit from this opportunity. ASD is uniquely positioned to bring all of these pieces together – markets, farmers, and processors – to increase the viability of specialty crop farmers in VA.

## **PROJECT ACTIVITIES**

Over the course of the grant period ASD performed several activities as we sought to find ways to increase demand for specialty crop value added products and position farmers in Southwest VA to participate in this value chain. Following are details on the strategies and opportunities we explored along with the results of that exploration and the different paths we pursued in efforts to accomplish the project goals.

Early in the project we identified that there were two different avenues that farmers and specialty crop value added food entrepreneurs could pursue: 1.) large scale production serving large wholesale buyers, and 2.) small batch production serving smaller retailers, farmers markets and restaurants. We view these two different avenues as being connected over the long term, as a percentage of new specialty crop food entrepreneurs will seek to scale up to serve expanded markets. The lack of specialty crop value added products in Southwest VA can be tied to little infrastructure available for commercial product development in the region, the original motivation for ASD submitting this proposal to VDACS. This lack has resulted in Southwest VA not being at the forefront of value added product development, as the long term impacts of limited infrastructure means that there is no pipeline of value added product developers who are on a path to being able to produce at a large scale which translates into opportunities for specialty crop farmers in the region. ASD's work with the Appalachian Center for Economic

Networks (ACEnet), which has been supporting value added processors in its Athens, OH based facilities since 1993, has demonstrated the economic impact and significant opportunities available to farmers in the region when the infrastructure and services are in place to fill a pipeline of emerging and mature value added product developers. For example, some successful graduates from ACEnet facilities include Frog Ranch Salsa, Shagbark Seed & Mill Co., The Herbal Sage Tea Company & Nature's Magic. Businesses often work with ACEnet partners at the Athens County Economic Development Council to find a suitable and affordable location for their business once they outgrow ACEnet facilities.

This final report shares details of what ASD learned over the course of the last 3 years in exploring these opportunities and our plans for supporting specialty crop producers in this value chain going forward.

Large Scale Production Serving Large Wholesale Buyers

In 2015 ASD established a relationship with Shawnee Canning through a connection with a local farmer. Shawnee produces a large suite of value added products using ingredients in various forms (e. g. raw, pureed, frozen) from farmers and suppliers across the country. As a part of this project, ASD worked with Shawnee to identify the supply chain they utilize to incorporate fresh fruits and vegetables into their products. We identified two potential strategies for Southwest VA farmers:

**Strategy 1:** aggregate large quantities of seconds and haul to primary processors in remote locations such as Oregon, Texas or New Jersey (the locations of Shawnee's current suppliers) and obtain a freight backhaul to defray distribution costs – the savings of which would be passed on to farmers.

**Solution 2:** long term strategy of building a primary processing facility in VA that could be utilized by farmers in the Mid-Atlantic and Central Appalachian regions. In addition to Shawnee, ASD worked with the Dutch Kettle/Relish Barn about the possibility of using their services to co-pack Southwest VA farmers' seconds. Like Shawnee, they purchase frozen puree in bulk and then use it as an ingredient. Ultimately, ASD was able to speak directly with Food Guys whose headquarters are located in Oregon. Food Guys has established relationships with vendors, transportation, and warehouses that span globally, allowing them the ability to supply a significant percentage of the larger scale commercial canneries in the country with low cost ingredients. Our communications with Food Guys determined that they would require Appalachian Harvest (AH) to sell 40,000 lbs of produce per sale.

Next Steps:

One of the core product lines Shawnee sells uses peaches grown on their farm. For the last few years Shawnee has been interested in working with a large scale primary processor that they would like to see located in VA and to which they could send their peaches for primary processing, as they have determined that that aspect of their work is very costly. We believe that the next step in the evolution of this value chain is to explore the possibility of bringing a large scale processor to VA. This will require public and private investment and a feasibility study and analysis on the best location for such a facility. This is beyond the scope of ASD's ability to manage successfully but we see great opportunities for farmers in central and southern VA (and surrounding states) should VDACS be able to facilitate this effort.

Small Batch Production Serving Smaller Retailers, Farmers Markets and Restaurants

As ASD identified prior to submitting this grant proposal to VDACS, there is very little value added product development being done in far Southwest VA due to a lack of infrastructure and support. There are numerous ways that small scale processing infrastructure can be implemented: standalone incubator kitchens, commercial canneries, culinary schools, certified home kitchens, co-packers and others. ASD explored a number of these opportunities and, through the course of this grant, we were able to work with two efforts that have become available to Southwest Virginians.

Grocery store interested in adding value added product line: Recognizing that there were no canning or facilities for creating commercial value added products, a small retailer in Glade Spring VA, Glade Green Grocer, chose to work with ASD on a project to implement equipment at their facility to create value added products, focusing initially on frozen fruit and vegetable purees. ASD and the owner of Glade Green Grocer worked together to explore necessary equipment, staff needs, and the knowledge and certification they would need to implement this commercial production at their store. Unfortunately, the store closed in the summer of 2016 when the economy in Glade Spring took a turn for the worse. Prior to closing, the store struggled financially and eventually decided that they would need to seek grant funding to assist with implementation costs.

County Cannery #1: Virginia Food Works in Farmville, VA:

Virginia Food Works is a non-profit organization that works with existing and prospective producers of value-added foods, providing expertise and guidance on the steps involved from product development to final production. They also offer contract packing services ("co-packing"), specializing in the creation of value-added foods from locally grown ingredients. Their pricing structure is an escalating scale based on residency and location. Their model was informative and has potential for Southwest Virginians long term, but it was clear that in the short term, it was not cost effective to partner with them due to the high logistical costs.

County Cannery #2: Russell County Cannery:

The Russell County Cannery became certified for commercial production in the summer of 2017. (Previously, they operated as a cannery for the citizens of Southwest VA.) ASD worked with them to help get an approved scheduled process, a co-packer, insurance coverage, and certification for commercial canning. ASD intends to continue to support the cannery as they expand their offerings.

Next Steps:

ASD plans to work with Russell County Cannery, county administrators, and economic developers to help grow the cannery and increase business and awareness of the opportunities available. ASD will continue to help connect farmers and food entrepreneurs who can take advantage of the cannery. We also believe that the cannery needs to focus on their business model and develop more aggressive and targeted marketing to raise awareness of the services they offer and intend to assist them with

Kitchen Incubators:

The kitchen incubators studied were ACEnet in Athens, OH and Blue Ridge Food Ventures in Chandler, NC. These two kitchen incubators were modeled for food entrepreneurs specifically. All of the entrepreneurs needed a scheduled process and usually focused on one unique product to fill a niche in the marketplace. The chart below demonstrates why processing facilities need to be closer to farmers and food entrepreneurs who are seeking to make value added products at a smaller scale.

| **Blue Ridge Food Ventures** | | | **Total Cost** |
|---|---|---|---|
| **Co-packing services** | $115 per Hour | 8 labor hours | $920 |
| **Distance from Appalachian Harvest** | 114 Miles | $2.34 per Mile | $266.76 |
| **Distance Back to ASD** | 118 Miles | $2.34 per Mile | $276.12 |
| **Cost of Materials** | | | $16.40 per dozen jars |
| **Total Cost of Use:** | | | $1,479.28 |

| **ACENet** | | | **Total Cost** |
|---|---|---|---|
| **Co-packing services** | $120 per Hour | 8 labor hours | $960 |
| **Distance from Appalachian Harvest** | 258 Miles | $2.34 per Mile | $603.72 |
| **Distance Back to ASD** | 275 Miles | $2.34 per Mile | $643.50 |
| **Cost of Materials** | | | $16.40 per dozen jars |
| **Total Cost of Use:** | | | $2,223.62 |

Mountain Harvest Kitchen (MHK): MHK is a commercial kitchen located in Unicoi, TN, which recently opened its doors and is currently supporting 9 commercial processors at their facility. It is estimated that each processor works with between 1 and 4 local farmers to source local products. MHK and Russell County Cannery are both viable options to connect local food entrepreneurs and local farmers. ASD will continue to promote both facilities and use them as a connection for farmers and food entrepreneurs.

Increasing Demand for Value Added Products

In addition to identifying the most appropriate/cost effective infrastructure to process and develop value added products using SWVA specialty crop products, ASD also expended effort to promote the Appalachian Harvest line of canned goods to develop and prove the market. Following are the various market development activities we pursued.

Tastings at various stores and events: Multiple taste testings were conducted at each of the local retail locations to raise awareness of the products. The taste testings gave customers a chance to taste the product without committing to purchasing and gave ASD a chance to talk with customers about the importance of supporting local farmers, businesses, producers and their products. One example of these efforts is [Barter Theatre](), which attracts thousands of tourists per week, and which began carrying the product line and also approved ASD and the product line to be a part of their curtain speech. Before each show the product is mentioned and the person who traveled the longest distance to attend the play wins a free jar. Taste testing were also held at the "Love Local Food Tastings" at Ingles markets to raise awareness with customers and help direct them to our products in the stores. These events increased online sales when Ingles stores weren't fully stocked. ASD staff also sold the product line and held taste testings at multiple ASD events throughout the grant period. The taste testings proved that there is significant demand for locally sourced value-added products in this region.

Media: ASD appeared on WCYB (a local news station) to promote the value added product line. Marketing materials such as rack cards and advertisements were developed and used to promote the Appalachian Harvest value added product line. The product line has been promoted via social media as well - current social media standings are: Facebook 4,111 likes and Twitter 502 followers. Advertising for the product line was also included in ASD's Local Food Guide (annual publication produced by ASD). ASD produces and distributes 15,000 printed copies of the food guide each year. These efforts will continue after the grant period.

Display development: ASD worked with a local woodworker to build a display for retailers to use to display the value added product line at their retail locations. Currently Heartwood uses the display at their retail location. More displays will be built as retailers want/need them.

Sales to a large wholesaler and to small retailers to explore the opportunities at markets at different scales: Over the course of the grant, ASD worked with a variety of business owners, farmers, food entrepreneurs, incubators/canneries, and others to determine what was needed to convert low value crops into high value products. ASD cultivated relationships with various local retailers to increase interest in these products. It was determined that small, locally owned businesses have customers that are more interested in supporting these products. Currently the product line can be found in 6 small, local retailers and one large grocery retailer (products are in 50 of their stores).

Next Steps:
ASD will continue to be the sales representative for the Appalachian Harvest value added product line. An order policy has been implemented for small retailers which will allow delivery to these small retailers to continue as well as helping the program to be financially viable. Taste testings, advertisements, social media marketing, and sales of goods at events will continue. ASD was awarded a POWER grant through the Appalachian Regional Commission. This $1.5MM grant was focused on creating a Central Appalachian Food Enterprise Corridor which included promoting a selection of value added products to small, medium, and large scale wholesale buyers. Value added producers from OH, WV, KY, VA and TN were included in a product catalog which is being provided to wholesalers in support of their interest in procuring unique value added products through one source. ASD will continue to work with its partners in the Central Appalachian Network to increase our knowledge and understanding of how we support local specialty crop farmers' access to value added processor markets.

**GOALS AND OUTCOMES ACHIEVED**

**Expected Measurable Outcomes**
**Goal**: Farmers in Southwest VA have access to profitable markets for their specialty crop seconds.
**Performance Measure**: Sales of value added specialty crop products through Appalachian Harvest and Rooted in Appalachia.
**Target**: The target for this project is to increase sales to $60,000 in Year 1 and $120,000 in Year 2
**Outcome:** Total sales for the grant period (10/1/15-9/30/18) equal $104,018 however, sales will continue after the grant period. In year 2 of the grant period some of the small local retailers that carried the Appalachian Harvest canned goods closed, resulting in ASD spending time cultivating new partnerships with other retailers. Currently the products can be found at 6 local retailers and there are plans to expand to more local retailers in the near future.
ASD will continue to promote and serve as sales representative for the product line and online sales will continue. A cost analysis was conducted and from that a policy was implemented to help with the cost of delivering the products to local retailers. This change in policy will enable us to continue expansion of the product. The products will also continue to be in 50 Ingles stores. Promotion will continue through activities such as social media promotion, taste testings, advertising, events, and more.

**Performance Measure**: Farmers and/or food processors/entrepreneurs obtain knowledge of how to sell their specialty crop seconds for use in value added products.
**Target**: At least 20 farmers are able to sell their specialty crop seconds into the processing market and understand the financial impacts to their bottom line.
**Outcome:** Throughout the grant period ASD has worked with farmers to help them utilize their seconds. ASD worked with and supported two new processing facilities that opened/became commercially certified during the grant period: Mountain Harvest Kitchen (MHK) and Russell County Cannery (obtained commercial certification in Summer of 2017). Both of these facilities have proven to be viable options for food entrepreneurs and ASD will continue to use them as a means to connect farmers and food entrepreneurs. To date, MHK has 9 commercial processors

utilizing their facility, each producer sources from local farmers, connecting approximately 18 local farmers with food entrepreneurs.

**Performance Measure**: ASD has analyzed the most cost effective, efficient means of incorporating specialty crop seconds into regionally produced value added products.
**Target**: Three different options for incorporating seconds into value added products are analyzed for the impact on farmer profitability. (e.g. research is conducted on micro-processing equipment and its efficacy as an option for distributed processing assessed.) ASD will use the data collected through this project to create a recommended course of action for farmers in southwest VA and northeast TN.
**Outcome:** ASD has analyzed a variety of different models throughout the grant period. Small scale value-added production at the county or small regional level has proven to be the best option at this time. This allows small scale producers to work with local farmers to produce products that can be sold at farmers markets and small local retailers. The processors can also take advantage of local commercial kitchens and canneries. In order to be able to incorporate seconds produce into value-added goods in a large arena, a large scale processing facility is needed in VA. This will require public and private investment and a feasibility study and analysis on the best location for such a facility. This is beyond the scope of ASD's ability to manage successfully but we see great opportunities for farmers in central and southern VA should VDACS be able to facilitate this effort.

## BENEFICIARIES

Specialty crop groups and other stakeholders that benefited from the completion of this project's accomplishments are local farmers, regional commercial kitchens/canneries, local processors, local retailers, local community colleges

Six retailers plus their customers, value added producers, 9 commercial producers at MHK along with approximately 18 farmers, a wide variety of customers at events and taste testings, 50 Ingles markets and their customers.

The project afforded local farmers another outlet for their seconds produce. Regional commercial kitchens/canneries were able to become certified and operational. These facilities also gave local processors a space to produce without having to spend the money to convert their kitchens to commercial. Local processors were able to connect with local farmers and therefore use local ingredients in their products making quality local products. Russell County Cannery was able to obtain certification and a better understanding on the process of working with VT on a scheduled process. Local retailers are able to obtain a product that consumers want and support local farmers/economy.

## LESSONS LEARNED

- Many farmers who use their crops in value-added products grow specifically for that purpose. Knowing this ahead of time allows the farmer to accept much less for the crops, due to the reduction in harvesting and packaging costs. This makes the resulting value added product affordable for the consumer.

- Distribution and processing are major components to being able to use local crops to create a product that is priced affordably. A large processing facility in the region is needed to get pricing where it needs to be to be able to work in the large wholesale arena.
- One of the biggest barriers to getting local farmers' produce into value added products is that large packers that can provide price points that are attractive to larger wholesalers (e.g. Shawnee Canning Company), purchase the bulk of their ingredients from large primary processors vs. utilizing whole produce. Since there is no large primary processor in our region, that limits farmers' ability to supply these markets.
- Small local retailers have more of a customer base that supports local product lines and can command higher prices with lower margins. These retailers are an excellent outlet for new value added producers.

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**ADDITIONAL INFORMATION**
Here is the link to the 2018 Local Food Guide that has an ad promoting the value added product line - https://asdevelop.org/food-guide-locator/

8.
Final Report
Title: Balancing Microbial Safety and Disease Management of Virginia Fresh Herbs
Organization: Virginia Tech
Project Lead: Laura K. Strawn
Co-Project Lead: Steve L. Rideout

**Project Summary:**

The market for fresh herbs, such as cilantro, basil, and dill has been steadily increasing at a rate of 10% per year. Virginia is well suited for the production of fresh market herbs, and more farms have begun producing various herbs for commercial sale. Therefore, understanding the safety and quality of VA-grown herbs in fields and greenhouses is essential for the growth of the VA fresh market herb industry. While no outbreaks have been traced back to VA-grown herbs, several herbs (basil, cilantro) have been implicated in both *Salmonella* and *Escherichia coli* outbreaks elsewhere. Additionally, herbs (cilantro, basil) can be affected by different plant pathogens that can have severe impacts on quality and result in substantial economic loss. Minimal research has been performed on the balance between microbial safety and disease management in VA, especially herbs. Therefore, the project sought to evaluate the risk of (i) *Listeria monocytogenes* (human foodborne pathogen) contamination, (ii) basil downy mildew and septoria leaf spot (plant pathogens) infection, and (iii) the combined effect of such plant pathogen infections on foodborne pathogen contamination in fresh market herbs by a series of both field and greenhouse experiments. In general, *L. monocytogenes* did not grow on herb plants grown in a greenhouse environment, *L. monocytogenes* was able to survive up to 28d post-inoculation for all plants, excluding parsley, which fell below the limit of detection on 7d. Since *L. monocytogenes* exhibited long-term survival on the herb plants studied, the need for greenhouses to implement best practices (e.g., Sanitation, Good Agricultural Practices) is fundamental to minimizing the introduction of contamination. On the other hand (plant pathology side), it was shown mandipropamid and cyazofamid were the most effective conventional fungicides suppressing levels of basil downy mildew, while copper containing products provided the best control of BDM in organic settings. However, resistant cultivars may prove the most effective means of achieving control of basil downy mildew and septoria leaf spot infection. Eleonora and thai-type basils were shown to be resistant to both infections (although not immune). Lastly, while not conclusive, light interruption during night hours was a promising strategy to inhibit sporulation.

**Project Purpose:**

Outbreaks of human diseases caused by foodborne pathogens have increasingly been associated with fresh vegetables and fruits. *Salmonella* has been reported to be the leading cause of these outbreaks in the United States, as well as the main bacterial foodborne pathogen of concern in Virginia (especially the Eastern Shore of VA). The Center for Disease Control and Prevention studies indicated it causes 1.4 million cases of illness and 500 deaths in the US every year, with total estimated costs of $3.4 billion/year (Scallan et al., 2011; Scharff 2010). Not only does foodborne pathogen contamination impact the agricultural economy of VA; but also, loss from plant diseases, such as basil downy mildew and septoria leaf spot (caused by the fungal pathogens *Ocimum basilicum and Septoria sp., respectively)*. If plant diseases are not prevented or minimized in the field or greenhouse during production, growers may have to forfeit harvesting of a crop due to disease infestation so severe that the product is not acceptable for market (i.e., unable to make a profit in the marketplace, poor quality). Both diseases severely limit productivity of herbs in Virginia. Moreover, fresh market herbs are commonly consumed raw, or with minimal processing making them a high-risk crop in terms of food safety risks. Additionally, the delicate nature of herbs also makes them susceptible to plant diseases, such as basil downy mildew and septoria leaf spot. Thus, the balance between microbial safety and disease management is critical.

**Project Activities:**

All project activities were completed in the project timeline (all tasks completed on-time and within budget).

| Project Activities | Performed By | Timeline |
|---|---|---|
| Acquire research supplies. PI and research team meet to discuss objectives and short- and long-term deliverables | All | Oct-Nov 2015 |
| Greenhouse trials: Plant cilantro, basil, and dill | SR, T | Nov 2015 |
| Greenhouse trials: Foodborne pathogen experiments on each fresh market herb | LS, T | Jan-Mar 2016 |
| Greenhouse trials: Infect plants with Septoria Leaf Spot (perform plant pathology experiments) | SR, T | Jan-Mar 2016 |
| Greenhouse trials: Interaction between diseased plants (Septoria Leaf Spot) and foodborne pathogen | All | Jan-Mar 2016 |
| Field trials: Plant cilantro, basil, and dill | SR, T | Apr/May 2016 |
| Field trials: Infect plants with Basil Downy Mildew (perform plant pathology experiments) | SR, T | Jun-Aug 2016 |
| Develop materials<br>Guidance/breakout sessions/case studies | LS, SR | Aug/Sept 2016 |
| Publications | LS, SR | Sept 2016 |
| *Final Report (due October 30, 2016)* | LS, SR | Oct 2016 |

Abbreviations: LS = Laura Strawn (PI, Virginia Tech ES AREC), SR = Steve Rideout (Co-PI, Virginia Tech ES AREC), T = Technician Rachel Pfuntner (Personnel Virginia Tech ES AREC).

ACTIVITIES PERFORMED

Several activities were performed during this reporting period. Activities are divided by food safety and plant pathology with tables or figures to visually represent data collected during the reporting period, as well as major findings described.

Objective 1: Determine the risk of L. monocytogenes (human foodborne pathogen) contamination in fresh market herbs (cilantro, basil, and dill).

*Temperature and Relative Humidity*

The temperatures (□C) and relative humidity (%) were measured in the greenhouse following the inoculation of each herb and for the duration of the study. The average, maximum, and minimum temperature and relative humidity for each herb were calculated (Table 1). There was no significant difference (P <0.05) in the average greenhouse temperature between the herb trials. The average relative humidity of the greenhouse during the basil study was significantly lower than the average relative humidity of the greenhouse during the cilantro, dill, and parsley studies, but did not appear to influence the pathogen survival dynamics on the basil.

Table 1.

| Herb | Avg Temp | Max Temp | Min Temp | Avg RH | Max RH | Min RH |
|---|---|---|---|---|---|---|
| Basil | 25±8°C | 57°C | 15°C | 55±19% B | 96% | 6% |
| Cilantro | 26±7°C | 58°C | 15°C | 63±17% A | 98% | 6% |
| Dill | 26±7°C | 53°C | 17°C | 66±22% A | 97% | 10% |
| Parsley | 26±8°C | 58°C | 18°C | 67±22% A | 98% | 10% |

*Fate of* Listeria monocytogenes *on Basil, Cilantro, Dill, and Parsley plants*

Basil plants had an initial *Listeria monocytogenes* inoculation level of 4.6 log CFU/g which decreased significantly in the first five hours to 2.2 log CFU/g (Table 2). After 24-hour there was an observed 3.3 log CFU/g reduction. Between days 1 and 2 of the study there was an observed 0.8 log reduction and between days 2 and 3 there was a significant growth of 1.4 log CFU/g growth (Figure 1). On day 21 of the study, *L. monocytogenes* levels fell below the limit of detection (<0.5 log CFU/g), but was not below the limit of detection on day 28 of the study.

Cilantro plants had an initial inoculation level of 4.9 log CFU/g (Figure 2). There was a significant 1.6 log CFU/g reduction 5-hours following inoculation and a 2.4 log CFU/g reduction 24-hours after inoculation. There was a significant 1.2 log CFU/g reduction between two and seven days of the study. On day 21 of the study, *L. monocytogenes* levels below the limit of detection (<0.5 log CFU/g) and remained below the limit of detection for the rest of the study (28 days).

Dill plants had an initial inoculation level of 4.1 log CFU/g (Figure 3). There was an observed 2.7 log CFU/g significant reduction 5-hours after inoculation but was only a 2.5 log CFU/g reduction after 24-hours. *L. monocytogenes* levels fell below the limit of detection (0.7 log CFU/g) for days 14 and 21 of the study, but was not below the limit of detection at day 28 of the study.

Parsley plants had an initial inoculation level of 5.1 log CFU/g (Figure 4). There was a significant 3.1 log CFU/g reduction 5-hours following inoculation and a 3.2 log CFU/g reduction at 24-hours after inoculation. *L. monocytogenes* levels fell below the limit of detection at day 7 of the study and remained below the limit of detection for the rest of the study (28 days).

Table 2: Fate of *L. monocytogenes* (Log CFU/g) at 5-hours on basil, cilantro, dill, and parsley (n=6) (error bars = +/- standard error). Letters indicate significant differences.

| Herb | Time | | |
|---|---|---|---|
| | Initial | 5 hours | 1 day |
| Basil | 4.6±0.1 B | 2.2±0.3 BC | 1.3±0.4 B |
| Cilantro | 4.9±0.1 A | 3.3±0.2 A | 2.5±0.2 A |
| Dill | 4.1±0.1 C | 1.4±0.2 C | 1.6±0.2 AB |
| Parsley | 5.1±0.1 A | 3.1±0.3 AB | 1.85±0.9 AB |

Figure 1. Fate of *L. monocytogenes* (Log CFU/g) over a month on basil (n=6) (error bars = +/- standard error).

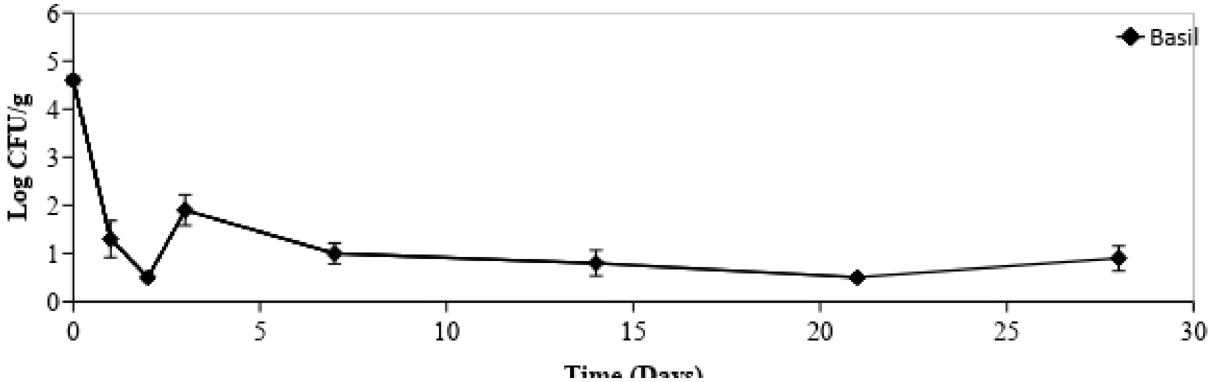



Figure 2. Fate of *L. monocytogenes* (Log CFU/g) over a month on cilantro (n=6) (error bars = +/- standard error).

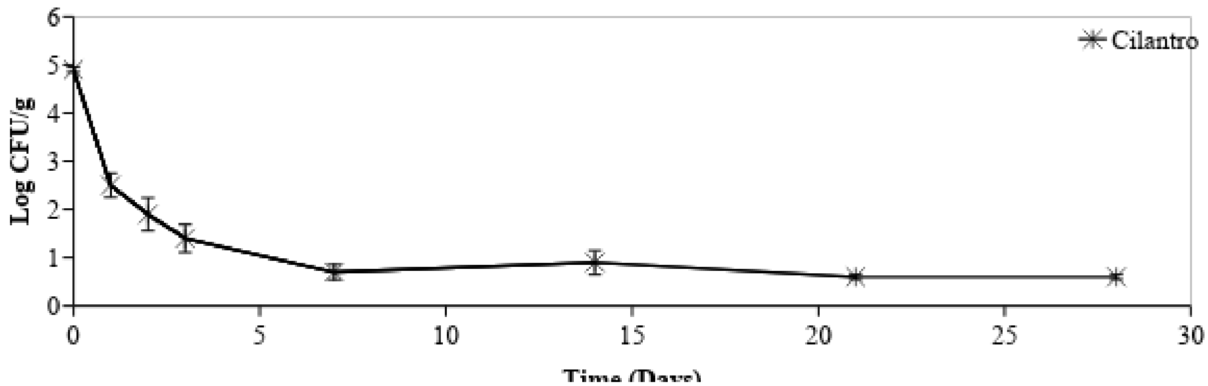



Figure 3. Fate of *L. monocytogenes* (Log CFU/g) over a month on dill (n=6) (error bars = +/- standard error).

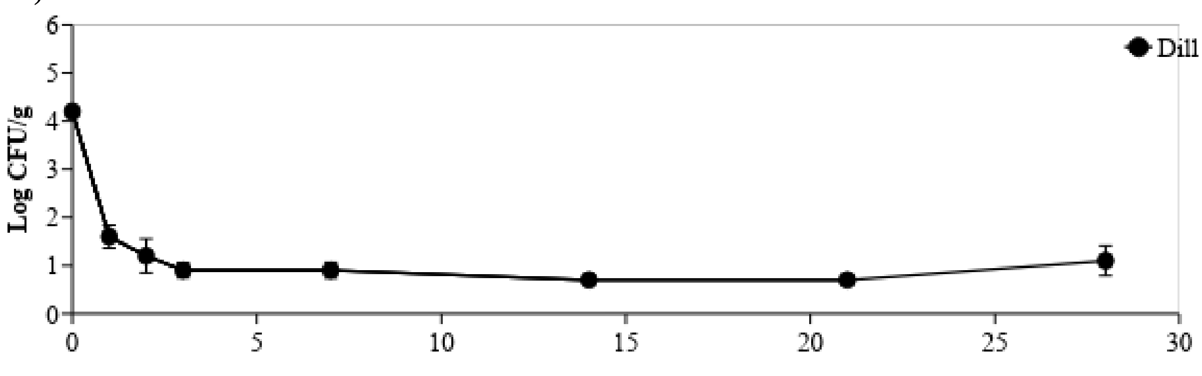
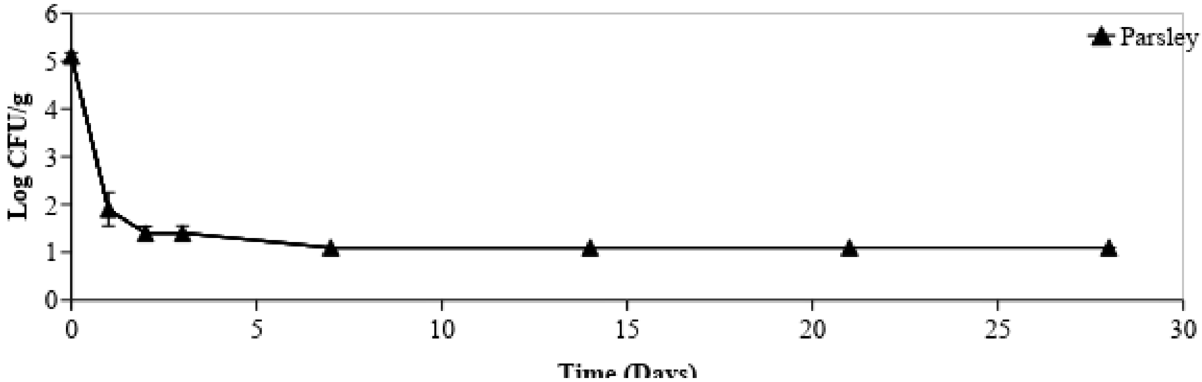


Figure 4. Fate of *L. monocytogenes* (Log CFU/g) over a month on parsley (n=6) (error bars = +/- standard error).

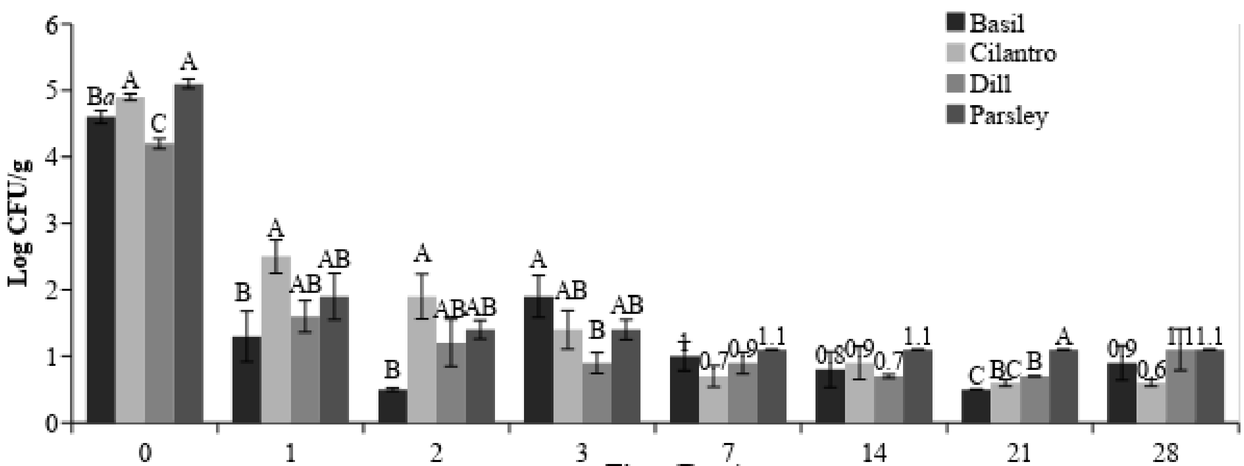



*Between Herb Comparison*

When comparing the *L. monocytogenes* initial inoculation concentration of the herbs, parsley and cilantro were significantly higher than the other herbs, while dill was significantly lower than all the other herbs (Table 2). Five-hours following inoculation, the *L. monocytogenes* concentration on the cilantro was significantly higher than basil and dill. The *L. monocytogenes* concentration on the parsley was significantly higher than on dill. Twenty-four hours and two-days after inoculation, the *L. monocytogenes* concentration on the cilantro was significantly higher than the basil (Table 3). Three days following inoculation the *L. monocytogenes* concentration was significantly higher on the basil than the dill (Table 3). On day seven and for the rest of the study there was no significant difference between herbs and concentration of *L. monocytogenes* (Table 3). All the herbs demonstrated a similar biphasic curve (Figures 1-4).

Table 3: Fate of *L. monocytogenes* (Log CFU/g) over the course of the study (28-days) on basil, cilantro, dill, and parsley (n=6) (error bars = +/- standard error). Letters indicate significant differences.

*Salmonella* and *E. coli* bacteria behaved similarly as *L. monocytogenes*, likely due to universal pressures in the greenhouse setting (data not shown, pending analyses).



Objective 2: Assess the risk of Septoria sp. and Ocimum basilicum (plant pathogens) infection in fresh market herbs (cilantro, basil and dill).

Parsley, cilantro, dill and basil in Virginia can be devastated by Septoria leafspot and even complete crop losses can occur due customer demand of blemish free produce. Septoria leafspot is caused by fungal pathogens of the genus *Septoria* (numerous species can infect umbelliferous crops). Conventional growers in Virginia have extensively used azoxystrobin (Quadris; Syngenta Crop Protection, Greensboro, NC) over the past two decades to control this disease and have noticed declining efficacy. Azoxystrobin belongs to a group of fungicides (QoI inhibitors) that possess a single-site mode of action and are thus prone to fungal pathogens developing resistance to these materials. In 2015 a research field trial was conducted at Virginia Tech's Eastern Shore AREC in Painter examining alternatives to azoxystrobin for control of parsley and cilantro Septoria leafspot. In both crops, Fontelis (penthiopyrad; DuPont Crop Protection, Wilmington, DE) and Merivon (fluxapyroxad and pyraclostrobin; BASF Corporation, Research Triangle Park, NC) were found to provide efficacy similar if not improved over azoxystrobin alone. This information was inserted into the 2016 Commercial Vegetable Production Guide (Virginia Cooperative Extension Publication 420-456; https://pubs.ext.vt.edu/456/456-420/456-420-pdf.pdf ) and presented at 5 vegetable grower meetings across the Commonwealth in early 2016. Unfortunately, in cultivar screens, all commercially available cultivars were found to be susceptible to Septoria leafspot.

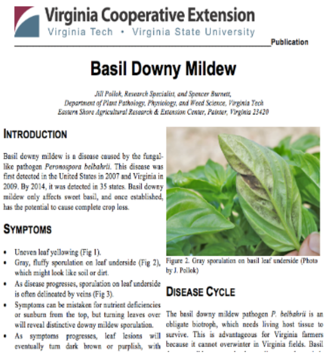
Research identified mandipropamid and cyazofamid as the most effective conventional fungicides suppressing levels of *Ocimum basilicum* (basil downy mildew). Copper containing products, although less effective than the conventional products, provided the best control of BDM in organic settings. Resistant cultivars are the most effective means of achieving control of *Ocimum basilicum*. Eleonora and thai-type basils are most resistant to severe infections (although not immune). Research is ongoing examining the viability of light interruption during night hours as a means to inhibit sporulation of the pathogen. Results are promising, but, inconclusive at this point.

Objective 3: Evaluate the interaction between diseased herbs (cilantro, basil, and dill) infected by Septoria sp. and Ocimum basilicum (plant pathogens) and the likelihood of L. monocytogenes contamination (human foodborne pathogen).

Data on diseased herbs and foodborne pathogens was difficult to assess since herbs had to naturally become contaminated with the diseases of interest. Once an herb was identified as diseased by the Rideout group, the Strawn group would obtain a sample to assess growth and survival dynamics. Samples were inoculated with foodborne pathogens and then held room temperature for 72 hours. An un-inoculated sample was also run in parallel (exposed to same conditions) to serve as the control (for comparisons). Diseased herb samples were more susceptive to pathogen (*L. monocytogenes* and *Salmonella*) growth and survival, compared to herb samples not diseased (control). Pathogen populations increased nearly two times faster than on control herbs, and pathogen concentrations were significantly higher in disease herbs, compared to control herbs. This highlights the importance of growers implementing Good Agricultural Practices (GAPs) which discourage growers from harvesting diseased plants. In general, diseased herbs increase the likelihood of pathogen contamination since diseased herbs promote a favorable environment for pathogen growth and survival.

Objective 4: Develop and present outreach program and materials targeted to VA-grown herbs for fresh market consumption regarding the best production (safety and quality) of cilantro, basil and dill (VA Herb Workshop/Day and VA Commercial Vegetable Production Guide).

Additionally, the following activity outputs were delivered (bulleted below).


Virginia Cooperative Extension
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Publication

Basil Downy Mildew

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INTRODUCTION

Basil downy mildew is a disease caused by the fungal-like pathogen *Peronospora belbahrii*. This disease was first detected in the United States in 2007 and Virginia in 2009. By 2014, it was detected in 35 states. Basil downy mildew only affects sweet basil, and once established, has the potential to cause complete crop loss.

SYMPTOMS

- Uneven leaf yellowing (Fig 1).
- Gray, fluffy sporulation on leaf underside (Fig 2), which might look like soil or dirt.
- As disease progresses, sporulation on leaf underside is often delineated by veins (Fig 3).
- Symptoms can be mistaken for nutrient deficiencies or sunburn from the top, but turning leaves over will reveal distinctive downy mildew sporulation.
- As symptoms progresses, leaf lesions will eventually turn dark brown or purplish, with

Figure 2. Gray sporulation on basil leaf underside (Photo by J. Pollok)

DISEASE CYCLE

The basil downy mildew pathogen *P. belbahrii* is an obligate biotroph, which needs living host tissue to survive. This is advantageous for Virginia farmers because it cannot overwinter in Virginia fields. Basil

**Publications (research & extension)**

- Bardsley, C., R. Pfuntner, L. Truitt, S. Rideout, R. Boyer, L.K. Strawn. 2017. Survival of Listeria monocytogenes on the Surface of Basil, Cilantro, Dill, and Parsley Plants. Food Control. *Submitted.*
- Strawn, L.K. and W. Kline. 2016. "Food Safety Concerns", Commercial Vegetable Production Recommendations. Publication number: Virginia Cooperative Extension 456-420.
- Pollok, J., Burnett, S. and S. Rideout. 2016. "Basil Downy Mildew". Virginia Cooperative Extension. Publication number: PPWS-556NP.
- Pollok, J., Burnett, S. and S. Rideout. 2017. "Septoria Leaf Spot". Virginia Cooperative Extension. *Submitted.*

**Presentations**

- C. Bardsley, R. Pfuntner, L. Truitt, S. Rideout, R. Boyer, and L.K Strawn. Survival of *Listeria monocytogenes* on the Surface of Basil, Cilantro, Dill, and Parsley Plants Grown in a Greenhouse Environment. International Association for Food Protection Annual Meeting, Tampa, FL, July 2017.
- Strawn, LK, R Pfuntner, L Truitt, S Rideout. "Food Safety in Greenhouse Production Environments – Fresh Market Herbs Case Study". Eastern Shore Agricultural Conference. Melfa, Virginia, USA. Jan 2017.
- Shenandoah Valley Herb Best Practices Workshop. Dayton, Virginia, USA. Jan 2016.
- Bardsley, C and L.K. Strawn. 2016. "Pathogen Dynamics of Basil, Dill, Parsley, and Cilantro". FST Seminar. Blacksburg, Virginia. Jun 2016.
- Southwest Virginia Disease Workshop. Hillsville, Virginia, USA. Jun 2016.
- Shenandoah Valley Disease Workshop. Dayton, Virginia, USA. Mar 2016.
- Hampton Roads Fruit and Vegetable Conference. Chesapeake, Virginia, USA. Feb 2016.
- Vegetable School. Warrenton, Virginia, USA. Feb 2016.
- Local Food Hub Disease Clinic and Twilight Tour. Charlottesville, Virginia, USA. Jan 2016.

## Goals and Outcomes Achieved

Goals/outcomes are divided by food safety and plant pathology with tables or figures to visually represent data collected during the project, as well as major findings described.

| Goal | Performance measure | Benchmark | Target |
| --- | --- | --- | --- |

| | | | |
|---|---|---|---|
| Determine the risk of *L. monocytogenes* (human foodborne pathogen) contamination in fresh market herbs (cilantro, basil, and dill) | Metrics on contamination risk of *L. monocytogenes* on each fresh market herb (cilantro, basil, and dill)<br>Data generated; see Objective 1 results in report. Also targets listed in far-right column. | No published metrics on *L. monocytogenes*contamination risk of cilantro, basil, and dill in US (none in VA and herbs is a growing industry)<br>Data will be published in peer-reviewed manuscript; to be submitted May 2018. | Ranking contamination risk in field/green house grown herbs<br><br>Develop specific metrics/guidance for the safe production of fresh market herbs. Data ranking herbs and guidance on best prescript is complete and in review. Anticipated submission is May 2018; as described in report (Future Project Plans)<br><br>Metrics and guidance also presented at three meetings; reaching 180 attendees; see Presentations. |
| | | | |
| Assess the risk of *Ocimum basilicum* and *Septoria* sp.(plant pathogens) infection in fresh market herbs (cilantro, basil, and dill) | Disease control and increased yield though varying practices<br>Data generated; see Objective 2 results in report. Also targets listed in far-right column. | Minimal published data on disease control of fresh market herbs in US<br><br>None in VA<br>Data has been published in Virginia Production Recommendations Guide (discussed in targets column). | Guidance for VA Commercial Production Guide<br>Guidance published on disease control of herbs and also food safety best practices in the Commercial Vegetable Production Recommendations Guide (Publication number: Virginia Cooperative Extension 456-420). Also, distributed Mid-Atlantic wide. |
| | | | |
| Evaluate the interaction between diseased herbs (cilantro, basil, and dill) infected by *Ocimum basilicum*and *Septoria* sp. and the likelihood of *L. monocytogenes* contamination | Odds of foodborne pathogen contamination based on herbs being infected with plant pathogens (herb diseased with Septoria Leaf Spot). For example, does likelihood of contamination increase with plant disease | No published data on interaction between likelihood of foodborne pathogen contamination and diseased plants for selected herbs<br><br>None in VA | Identification of contamination risks based on selected plant pathogen diseases typically observed in VA-grown herbs<br><br>Data and guidance presented at four meetings; reaching |

| | | | |
|---|---|---|---|
| | Data showing herbs contaminated with plant pathogens are more susceptible to Listeria to be published in a peer review journal (Food Control). The draft of the manuscript is complete and in-review; anticipated submission May 2018; as described in report (Future Project Plans). Also targets listed in far right column. | Data will be published in peer-reviewed manuscript; to be submitted May 2018. | 245 attendees (showing importance of controlling plant disease to reduce likelihood of food safety issue); see Presentations section. In addition to publication discussed (to be submitted May 2018 to Journal of Food Control). |
| | | | |
| Develop and present outreach program and materials targeted to VA-grown herbs for fresh market consumption regarding the best production (safety and quality) of cilantro, basil, and dill (VA Herb Workshop/Day and VA Commercial Vegetable Production Guide) | Guidance documents for VA fresh market herbs to balance food safety and disease management of cilantro, basil, and dill<br><br>Best practices for VA herb growers that will be regulated by the FSMA proposed Produce Safety Rule<br><br>Both outreach publications and presentations were given; see Objective 4 results in report. Also targets listed in far-right column. | No documents related to fresh market herbs that balance food safety and disease management<br><br>No FSMA specific documentation for growers/packers of fresh market herbs<br><br>Food Safety section of Commercial Vegetable Production Recommendations updated and published (2016). Also, updated for diseases. Virginia Cooperative Extension fact sheet is in review for Basil Downy Mildew (see Publications in report). | Hold VA Herb Workshop/Day (conduct pre- and post assessments to evaluate benefit to VA-stakeholders)<br><br>Present data and findings to summer 2016 field day or fall specialist day held at the ES AREC (estimated 75/100 people)<br><br>Held Herb Disease Identification workshop (65 attendees)<br><br>Presented herb disease and food safety metrics and guidance at the Eastern Shore field day (>100 attendees including growers, public, agents, specialist, among others) |

## Food Safety

*Greenhouse Temperatures and Relative Humidity*. The temperature (°C) and relative humidity (%) were measured in the greenhouse for each replication of each herb plant of the study (n=9). The average temperature and relative humidity of the greenhouse were calculated (Table 1). No significant difference ($P \leq 0.05$) was observed in the average greenhouse temperature between herb plant replications. The average relative humidity of the greenhouse during the basil plant replications was significantly ($P \leq 0.05$) lower than the average relative humidity of the greenhouse during the cilantro, dill, and parsley plant replications. However, this difference in relative humidity did not appear to influence the survival of *L. monocytogenes* on basil plants, compared to cilantro, dill, and parsley plants.

**TABLE 1.** Comparison of the average, maximum, and minimum temperature and relative humidity conditions for each herb over the three replications

| Herb | Average Temperature (°C) | Average Relative Humidity (%) |
|---|---|---|
| Basil | 25±8 | 55±19 B[a] |
| Cilantro | 26±7 | 63±17 A |
| Dill | 26±7 | 66±22 A |
| Parsley | 26±8 | 67±22 A |

[a] Mean values were analyzed for significant differences ($P<0.05$) between each herb type.

*Survival of* L. monocytogenes *on Basil, Cilantro, Dill, and Parsley Plants.* All herb plants were inoculated with a 6 log CFU/ml cocktail of five *L. monocytogenes* strains. There was an approximately 1.5 log CFU/g initial microbial reduction, on average across all herb plants, after the drying time, which was expected. Basil plants had an average *L. monocytogenes* population of 4.6 log CFU/g at 0 h. A significant *L. monocytogenes* population decline (2.4 log CFU/g; Table 2) was observed within the first 5 h. During the first 24 h, there was a 3.3 log CFU/g reduction in *L. monocytogenes* populations across all basil plant replications. Between 1 and 2 d, there was another significant ($P \leq 0.05$) decrease in *L. monocytogenes* populations. Interestingly, between 2 and 3 d, *L. monocytogenes* populations significantly ($P \leq 0.05$) increased by 1.4 log CFU/g (Figure 1). By 21 d, *L. monocytogenes* populations on basil plants were below the limit of detection (≤0.3 log CFU/g); however, *L. monocytogenes* populations increased by approximately 0.5 log CFU/g between 21 and 28 d post inoculation. Cilantro plants had an average *L. monocytogenes* population of 4.9 log CFU/g at 0 h. *L. monocytogenes* populations significantly decreased by approximately 1.6 log CFU/g (Table 2) within the first 5 h. During the first 24 h, a 2.4 log CFU/g reduction was observed in *L. monocytogenes* populations across all cilantro plant replications. *L. monocytogenes* populations continued to significantly decrease between 2 and 7 d (Figure 1). By 21 d, the *L. monocytogenes* populations declined below 0.6 log CFU/g and remained below this level for the duration of the study (Figure 1). Dill plants had an average *L. monocytogenes* population of 4.1 log CFU/g at 0 h. Similar to cilantro, *L. monocytogenes* populations significantly decreased by approximately 2.3 log CFU/g (Table 2) within the first 5 h. *L. monocytogenes* populations remained stagnant between 5 and 24 h (Table 2). *L. monocytogenes* populations fell below the limit of detection (0.7 log CFU/g) between 14 and 21 d; however, *L. monocytogenes* populations increased to approximately 1 log CFU/g by 28 d (Figure 1). Parsley plants had an average *L. monocytogenes* population of 5.1 log CFU/g at 0 hr. Similar to cilantro and dill, *L. monocytogenes* populations significantly decreased by 1.1 log CFU/g within the first 5 h (Table 2). *L. monocytogenes* populations continued to decrease in the first 24 h (approximately another 1.2 log CFU/g). By 7 d, *L. monocytogenes* populations fell below 1.1 log CFU/g and remained below this level for the duration of the study (Figure 1).

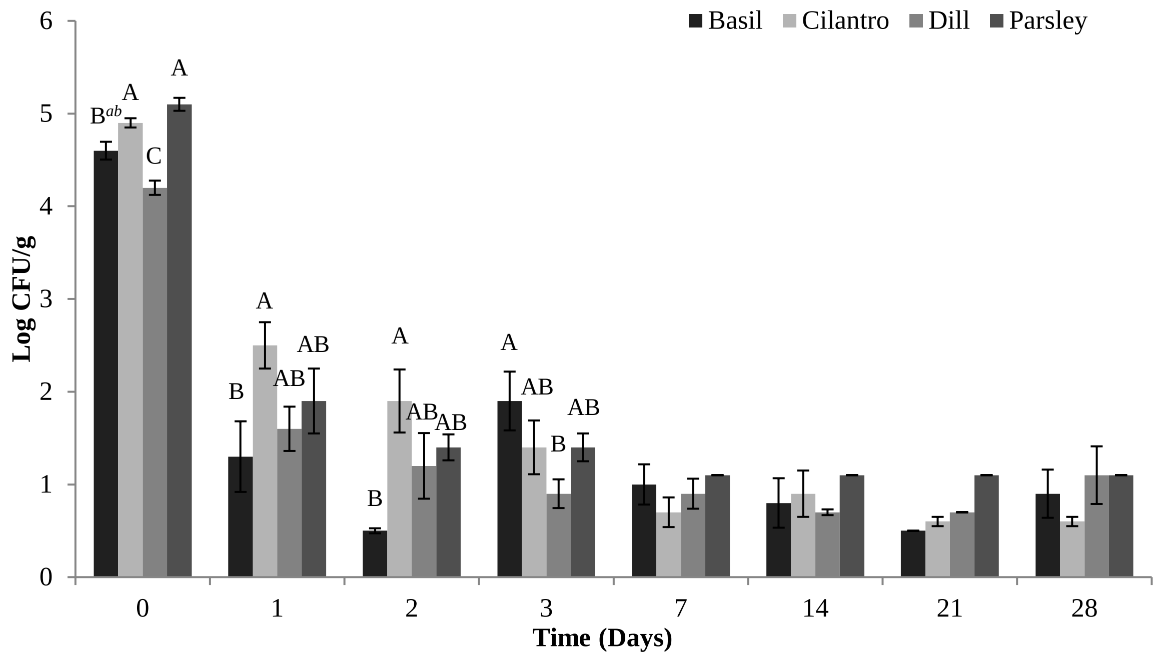
**TABLE 2.** Comparison of the initial die off between basil, cilantro, dill, and parsley at the initial, 5 h and 1 d (24 h) time points

| Herb | Time[a] | | |
|---|---|---|---|
| | 0 h | 5 h | 24 h |
| Basil | 4.6±0.1 B[b], X[c] | 2.2±0.3 BC, Y | 1.3±0.4 B, Y |
| Cilantro | 4.9±0.1 A, X | 3.3±0.2 A, Y | 2.5±0.2 A, Y |
| Dill | 4.1±0.1 C, X | 1.4±0.2 C, Y | 1.6±0.2 AB, Y |
| Parsley | 5.1±0.1 A, X | 3.1±0.3 AB, Y | 1.9±0.9 AB, Z |

[a] Values expressed as log CFU per gram; values are the average of triplicate samples from each of three replications (n=9) ± standard error.
[b] Mean values (log CFU per gram) were analyzed for significant differences ($P$<0.05) between rows (significance represented with A, B, and C).
[c] Mean values (log CFU per gram) were analyzed for significant differences ($P$<0.05) between columns (significance represented with X, Y, and Z).

*Comparison of L. monocytogenes Survival Between Herb Plants.* An evaluation of *L. monocytogenes* survival curves for the four herb plants exhibited each *L. monocytogenes* population demonstrated a similar biphasic curve. *L. monocytogenes* populations on dill plants was significantly lower than all the other types of herb plants at 0 h (Table 2). At 5 h, *L. monocytogenes* populations on cilantro plants were significantly higher than the *L. monocytogenes* populations on basil and dill plants. At 1 and 2 d, *L. monocytogenes* populations on cilantro plants were significantly higher than the *L. monocytogenes* population on basil plants (Figure 1). At 3 d, the *L. monocytogenes* population on basil plants was significantly higher than the *L. monocytogenes* population on the dill plants. No significant difference was observed between the *L. monocytogenes* populations and each herb plant at 7, 14, 21, and 28 d. Additionally, no significant difference was observed between overall reduction of *L. monocytogenes* populations and different herb plants. These results suggest that the type of herb (e.g., basil, cilantro) when grown in a greenhouse environment does not drastically influence the survival of *L. monocytogenes*. This may allow generalized best practices to be implemented to minimize risk of *L. monocytogenes* contamination on greenhouse grown herb plants.

**FIGURE 1.** Comparison of the survival of Listeria monocytogenes on greenhouse grown basil, cilantro, dill, and parsley herb plants.




[a] Mean values (log CFU per gram) were analyzed for significant differences (*P*<0.05) between each herb type of each time point, letters indicate significant differences between herb plants while the absence of letters indicates no significant difference.
[b] Values are the average of triplicate samples from each of three replications (n=9) ± standard error.

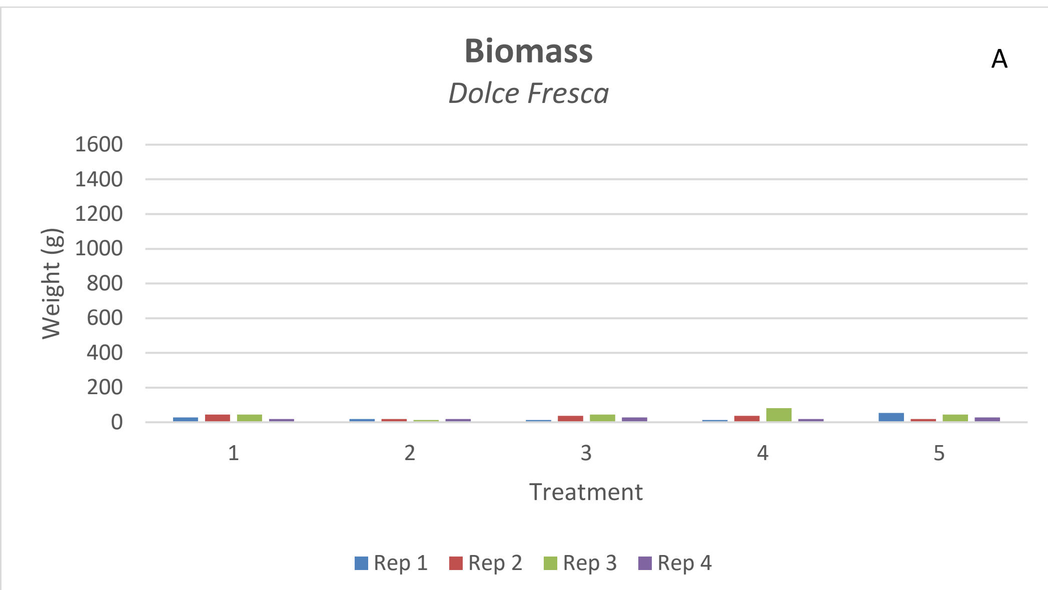
*Summary.* Therefore, in order to limit the risk of *L. monocytogenes* survival on the surface of herbs in greenhouse environments and during postharvest handling, it is important that producers select, maintain and monitor environmental conditions such as relative humidity and temperature. It is also important that producers implement best practices targeted at minimizing the introduction of contamination to greenhouse environments including controlling the microbial safety of irrigation water and soil, sanitation of facilities and tools, proper flow of food (raw to finished product to prevent cross contamination), and implementation of worker health, hygiene and training programs; due to the reported survival of *L. monocytogenes* on the surface of the selected herb plants in this study.

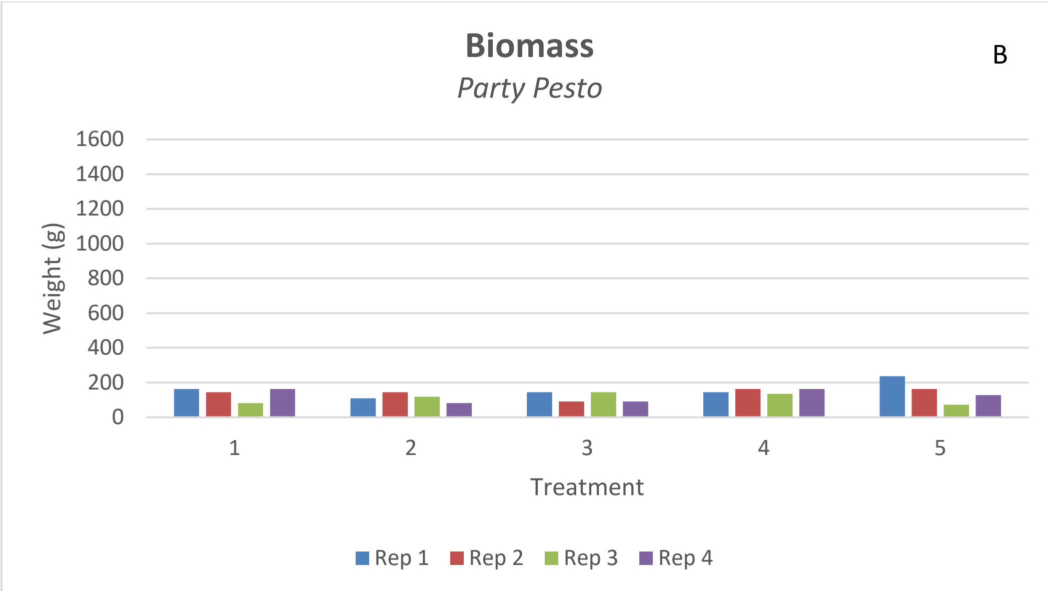
**Plant Pathology**

*Chemical Strategies.* Parsley, cilantro, dill and basil in Virginia can be devastated by Septoria leafspot and even complete crop losses can occur due customer demand of blemish free produce. Septoria leafspot is caused by fungal pathogens of the genus *Septoria* (numerous species can infect umbelliferous crops). Conventional growers in Virginia have extensively used azoxystrobin (Quadris; Syngenta Crop Protection, Greensboro, NC) over the past two decades to control this disease and have noticed declining efficacy. Azoxystrobin belongs to a group of fungicides (QoI inhibitors) that possess a single-site mode of action and are thus prone to fungal pathogens developing resistance to these materials. Research was conducted at Virginia Tech's Eastern Shore AREC in Painter examining alternatives to azoxystrobin for control of parsley and cilantro Septoria leafspot. In both crops, Fontelis (penthiopyrad; DuPont Crop Protection, Wilmington, DE) and Merivon (fluxapyroxad and pyraclostrobin; BASF Corporation, Research Triangle Park, NC) were found to provide efficacy similar if not improved over azoxystrobin alone. This information was inserted into the Commercial Vegetable Production Guide (Virginia Cooperative Extension Publication 420-456; https://pubs.ext.vt.edu/456/456-420/456-420-pdf.pdf ) and presented at 5 vegetable grower meetings across the Commonwealth. Unfortunately, in cultivar screens, all commercially available cultivars were found to be susceptible to Septoria leafspot. Additionally, research identified mandipropamid and cyazofamid as the most effective conventional fungicides suppressing levels of basil downy mildew. Copper containing products, although less effective than the conventional products, provided the best control of BDM in organic settings.

*Cultural Strategies.* Lastly, resistant cultivars may prove the most effective means of achieving control of basil downy mildew and septoria leaf spot infection. Eleonora and thai-type basils are most resistant to severe infections (although not immune). Research was performed to examine the viability of light interruption during night hours as a means to inhibit sporulation of the pathogen. While not conclusive, light interruption during night hours was a promising strategy to inhibit sporulation (Figures 2-A, B, C, and D); as evident in biomass values in the resident cultivar (Eleonora Fig. 2-D).

**FIGURE 2.** Biomass weight (g) of basil cultivars (A, B, C, D) infected with basil Downey Mildew with light treatments (colored bars represent different replications performed during the seasons).




Biomass
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B
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Weight (g)
1
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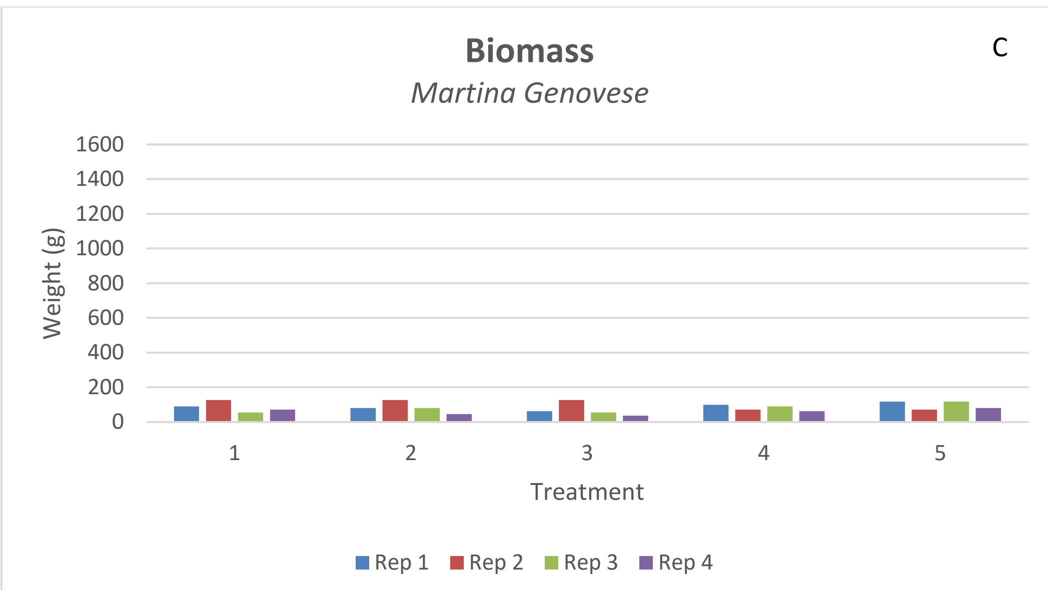
Treatment
Rep 1
Rep 2
Rep 3
Rep 4


Biomass
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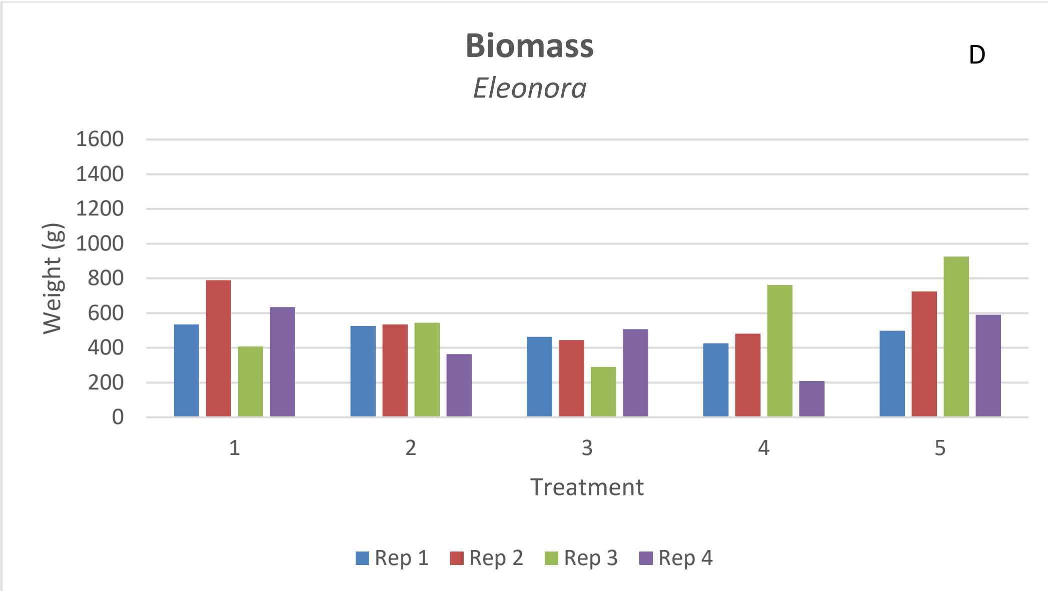


**Food Safety and Plant Pathology**

Data on diseased herbs and foodborne pathogens were difficult to assess since herbs had to naturally become contaminated with the diseases of interest. Once an herb was identified as diseased by the Rideout group, the Strawn group would obtain a sample to assess growth and survival dynamics. Samples were inoculated with foodborne pathogens and then held room temperature for 72 hours. An un-inoculated sample was also run in parallel (exposed to same conditions) to serve as the control (for comparisons). Diseased herb samples were more susceptive to pathogen (*L. monocytogenes*) growth and survival, compared to herb samples not diseased (control). Pathogen populations increased nearly two times faster than on control herbs, and pathogen concentrations were significantly higher in disease herbs, compared to control herbs. This highlights the importance of growers implementing Good Agricultural Practices (GAPs) which discourage growers from harvesting diseased plants. In general, diseased herbs increase the likelihood of pathogen contamination since diseased herbs promote a favorable environment for pathogen growth and survival.

**Beneficiaries**

Fresh market herb producers of cilantro, basil, and dill benefited from the data generated in this project (stakeholder feedback from presentations, publications). Especially in the food safety context, as no data existed on the risks of *L. monocytogenes* growth and survival on fresh market herbs. The data generated from the project provided critical data to facilitate compliance in food safety audits, and potential future inspections (under the Food Safety Modernization Act's Produce Safety Rule). These findings benefited small to large producers of herbs. Also, other herb commodities including parsley and mint. Herbs are a staple on produce farms that are diversified and demand for local-fresh market herbs has increased. Results were disseminated to beneficiaries through extension venues via presentations, workshops, publications and fact sheets to highlight best food safety and quality practices.

Number of beneficiaries affected by the projects accomplishments (including category of beneficiaries):

Beneficiaries for this project include the VA fresh market herb industry, specifically the cilantro, basil, and dill growers/packers. Indirectly this project will also benefit other fresh market herb commodities that are grown in VA, including mint, parsley, and rosemary. Presentations given to Virginia stakeholders (approximately 245 attendees) by Drs. Strawn and Rideout or their groups that addressed the safety and quality of fresh market herbs, with a special emphasis on pathogen growth and survival, best food safety practices, and disease identification are listed above. Number in parenthesis () is approximate attendance at event (listed next to presentations above). Extension publications are online for the general public and anyone can download, or view; therefore, an infinite number of specialty crop producers could benefit from those project accomplishments.

Presentations

- Bardsley, C and L.K. Strawn. 2016. "Pathogen Dynamics of Basil, Dill, Parsley, and Cilantro". FST Seminar. Blacksburg, Virginia. (55)
- Strawn, L.K., C. Bardsley, R. Pfuntner, L. Truitt, and S. Rideout. 2017. "Food Safety of Fresh-Market Herbs". 27th Annual Agricultural Conference (Melfa, Virginia). (80)
- S. Rideout. 2017. "Food Safety and Quality of Fresh-Market Herbs". Local Food Hub Annual Meeting (Charlottesville, Virginia). (45)

S. Rideout. 2017. "Herb Disease Identification". Twilight Tour at Bellair Farms (Charlottesville, Virginia). (65)

## Lessons Learned:

As reported in prior reports, there were no major setbacks and all project activities were completed. Major outcomes and resulting mitigation strategies or lessons were described in each of the sections (Food Safety, Plant Pathology, and Food Safety and Plant Pathology) in *Outcomes Achieved*.

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9.

**Final Report**

**Injury Potential from 2,4-D and Dicamba Spray and Vapor Drift onto Vegetable and Nursery Crops**

**Virginia Polytechnic Institute and State University**
Jeffrey Derr

## PROJECT SUMMARY

The introduction of Roundup Ready crops has given producers of corn, soybeans, and cotton better control of troublesome weeds. These genetically modified crops allow growers to control weeds without crop damage. However, several key weed species have developed resistance to glyphosate, the active ingredient in Roundup. To address these herbicide-resistant weed species, chemical companies have developed through biotechnology varieties of soybean and cotton that are tolerant of 2,4-D and dicamba, two herbicides used for control of broadleaf weeds in grass crops. With the release of this technology, increased use of 2,4-D and dicamba is inevitable, posing a potential hazard to vegetable, fruit, and nursery crops in Virginia and other states. This study found tomato plants were more susceptible to simulated spray drift injury from 2,4-D than dicamba, whiles the opposite was seen with non-GMO soybeans. Tomatoes were injured more by all 2,4-D early season treatments compared to dicamba treatments at 14, 28, and 56 DAT when applied at 1/50, 1/100, and 1/200 the application rate. Early season applications on tomatoes, coreopsis, hydrangea and soybeans showed as much as 50% greater injury for all formulations of 2,4-D and dicamba treatments, compared to late season applications. A volatility study found that the new formulations of 2,4-D (Enlist Duo) and dicamba (Engenia) caused little to no injury in a vapor drift study using tomatoes, coreopsis and non-GMO soybeans, while older formulations of 2,4-D ester, 2,4-D amine, and DMA dicamba caused significant injury. These new formulations do reduce the potential injury from vapor drift but cause similar injury as older formulations in regards to spray drift. Utilizing less volatile formulations and following label directions in regards to wind speed and direction will reduce the potential for injury to specialty crops from 2,4-D and dicamba.

## PROJECT PURPOSE

The planting of Roundup Ready cultivars of soybeans, corn, and cotton has been widely adopted by growers. The resulting increased use of glyphosate, the active ingredient in Roundup, has led to the development of resistance in key weed species. Controlling these resistant weed species has become a major production problem for soybean and cotton growers. To address this production issue, chemical companies have developed through biotechnology cultivars of agronomic crops that are resistant to the broadleaf herbicides 2,4-D and dicamba. In addition, formulations of these two herbicides were developed that were reported to be lower in volatility. Since 2,4-D and dicamba can injure sensitive nursery, fruit, and vegetable crops through vapor drift, lower volatility formulations should pose less risk of offsite plant injury. The objective of this project was to evaluate the injury potential of these newer formulations of 2,4-D and dicamba at different exposure levels to vegetable and nursery crops following simulated spray and vapor drift. The impact of growth stage on sensitivity to these formulations was also tested. Additionally, this project documented injury symptoms from vapor and spray drift to specific crops, providing farmers with tools to identify damage from this group of chemicals.

**PROJECT ACTIVITIES**

This project evaluated spray drift and vapor drift influence on plant injury from several different formulations of 2,4-D and dicamba, including two new formulations Enlist Duo (2,4-D + glyphosate) and Engenia (dicamba) from early and late season spray applications.

*Early season spray application trial.* This study, initiated on May 29, 2017, evaluated spray drift on 4 week-old tomato plants, 2 inch tall coreopsis plants, and newly leafed-out hydrangea plants in 1 gallon containers. For comparison, 4 week-old non-GMO soybeans were also treated. Herbicides were applied at 1/50, 1/100, and 1/200 dilution of 2,4-D at 0.75 lb ae/A, dicamba at 0.5 lb ae/A, and glyphosate at 1.5 lb ae/A. The following formulations were evaluated: 2,4-D amine, 2,4-D ester, dimethylamine salt of dicamba, Engenia (dicamba), Enlist Duo (2,4 D + glyphosate), and Engenia plus glyphosate. Results from plots treated with these formulations were compared to nontreated control plots. Experimental design was a randomized complete block with four replications and one plant per species per plot.

Tomato plants were injured more by all 2,4-D early season treatments compared to dicamba treatments at 14, 28, and 56 days after treatment (DAT) at 1/50, 1/100, and 1/200 the dilution rate (Table 1, 2, and 3). Tomatoes treated at 1/50 the spray concentration of 2,4-D did not bloom or produce any fruit, while leaves and stems were twisted and new growth had ceased. Injury to tomato from 2,4-D ranged up to 45% at 56 DAT. Dicamba-treated tomato plants had less than 16% injury at 56 DAT. No significance difference in percent injury was found between 2,4-D amine, 2,4-D ester, and Enlist Duo formulations on tomatoes.

At 1/50 spray concentration, hydrangea were significantly injured by DMA dicamba, Enlist Duo, and Engenia plus glyphosate treatments at 7, 14, 28 and 56 DAT. The highest injury seen in hydrangea was with Enlist Duo. These plants did not produce flowers for the remainder of the season. However, plants that were over wintered did produce blooms in the 2017 season. Hydrangea were slightly injured at 1/100 spray concentrations; with very little injury found for the 1/200 spray concentration. Coreopsis displayed similar results as hydrangea, with significant injury from DMA dicamba, Enlist Duo, and Engenia plus glyphosate treatments at 7, 14, 28 and 56 DAT. Coreopsis seemed to outgrow the injury faster than hydrangea.

Soybeans were significantly injured by all dicamba treatments at 1/50, 1/100, and 1/200 spray applications. No bean pods were produced at the 1/50 concentration, and only some of the plants in 1/100 concentration were able to produce bean pods. Soybean plants were 1/3 the size of untreated plants at 28 and 56 DAT at the 1/50 spray concentration. Numerically highest injury to soybean occurred with DMA dicamba (36% at 56 DAT)

*Late season spray application trial.* This study, initiated on July 11, 2016 and repeated on July 26, 2017, evaluated spray drift on mature tomato, coreopsis, grapes, and hydrangea plants in 1 gallon containers. The same treatments and experimental design used in the early season trial listed above were applied.

Grapes and hydrangea were not injured during late season spray applications for any formulation of 2,4-D or dicamba at the 1/50, 1/100, or 1/200 application rate. Tomatoes treated late season showed similar injury as early season tomatoes; greatest injury was found with all 2,4-D treatments compared to dicamba treatments at the 1/50, 1/100, and 1/200 rates. Enlist Duo- and 2,4-D ester-treated tomatoes displayed 11% injury at 56 DAT, less than that seen with early season applications. Coreopsis showed the greatest injury at the 1/50 concentration from Enlist Duo and Engenia plus glyphosate, 15% and 19%, respectively. Coreopsis quickly out grew the injury from late season applications; no injury was found at the 1/200 application rate.

*Vapor Drift Study. This trial* was conducted to evaluate vapor drift potential from different formulations of 2,4-D and dicamba on late season spray applications. This trail was initiated on September 12, 2016 and repeated on Aug 14, 2017. Application rates were as follows: 2,4-D at 0.75 lb ae/A, dicamba at 0.5 lb ae/A, and glyphosate at 1.5 lb ae/A. Treatments included: Engenia (dicamba), DMA dicamba, 2,4-D ester, Enlist Duo (2,4-D plus glyphosate), 2,4-D ester, and an untreated control. All plots were at least 40 feet apart. Two plants of each species were placed per plot at either 0 DAT, 2 DAT, 4 DAT, 8 DAT, or 16 DAT. Pots were left on the treated soil for 24 hours. All plants were in 1 gallon containers. No grapes or hydrangea were injured at any exposure date. There was no injury for any treatment when coreopsis, tomato, and soybeans plants were placed either 8 or 16 days after treatment (Table 7). Soybeans displayed the greatest injury from DMA dicamba, 48% at 0 DAT. Tomato had the greatest injury from DMA dicamba vapor (11%) and 2,4-D ester (12%); while Engenia and Enlist Duo caused 0% and 3% injury, respectively, at 0 DAT. Similar findings were observed for coreopsis, with DMA dicamba and 2,4-D ester causing the greatest injury at 17% and 15% respectively. Significantly lower vapor injury from Engenia caused less injury than DMA dicamba and Enlist Duo cased less injury than 2,4-D ester in soybeans. Engenia and Enlist D caused little to no injury to tomato or coreopsis from vapor drift.

Table 1. Mean plant injury from early season spray drift after applying 1/50th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 15 | 27 | 30 | 45 |
| 2,4 D ester | 10 | 22 | 31 | 36 |
| Engenia | 15 | 12 | 10 | 15 |
| DMA | 15 | 15 | 12 | 13 |
| Enlist Duo | 11 | 22 | 28 | 35 |
| Engenia + glyphosate | 12 | 16 | 15 | 21 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 5 | 6 | 10 | 11 |
| **hydrangea** | | | | |
| 2,4 D amine | 1 | 5 | 5 | 8 |
| 2,4 D ester | 2 | 8 | 5 | 5 |
| Engenia | 5 | 5 | 5 | 5 |
| DMA | 10 | 11 | 8 | 5 |
| Enlist Duo | 15 | 11 | 22 | 28 |
| Engenia + gly | 5 | 3 | 5 | 4 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 4 | 6 | 7 | 10 |
| **coreopsis** | | | | |
| 2,4 D amine | 0 | 0 | 0 | 0 |
| 2,4 D ester | 1 | 0 | 0 | 0 |
| Engenia | 3 | 0 | 0 | 0 |
| DMA | 11 | 10 | 12 | 5 |
| Enlist Duo | 20 | 18 | 15 | 5 |
| Engenia + gly | 15 | 12 | 17 | 8 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 9 | 9 | 5 | 6 |
| **soybeans** | | | | |
| 2,4 D amine | 10 | 12 | 15 | 18 |
| 2,4 D ester | 11 | 15 | 18 | 12 |
| Engenia | 13 | 25 | 32 | 30 |
| DMA | 11 | 28 | 41 | 36 |
| Enlist Duo | 15 | 18 | 17 | 15 |
| Engenia + gly | 12 | 28 | 35 | 33 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 5 | 6 | 12 | 13 |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.

Table 2. Mean plant injury from early season spray drift after applying 1/100th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 10 | 11 | 15 | 10 |
| 2,4 D ester | 9 | 7 | 22 | 15 |
| Engenia | 7 | 5 | 4 | 5 |
| DMA | 5 | 7 | 6 | 3 |
| Enlist Duo | 11 | 14 | 19 | 15 |
| Engenia + gly | 12 | 9 | 11 | 11 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 3 | 5 | 9 | 9 |
| **hydrangea** | | | | |
| 2,4 D amine | 0 | 0 | 1 | 0 |
| 2,4 D ester | 0 | 1 | 0 | 0 |
| Engenia | 0 | 0 | 0 | 0 |
| DMA | 1 | 5 | 0 | 0 |
| Enlist Duo | 5 | 8 | 3 | 0 |
| Engenia + gly | 0 | 0 | 0 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 4 | 2 | - |
| **coreopsis** | | | | |
| 2,4 D amine | 0 | 0 | 0 | 0 |
| 2,4 D ester | 1 | 0 | 0 | 0 |
| Engenia | 2 | 2 | 0 | 0 |
| DMA | 5 | 5 | 4 | 0 |
| Enlist Duo | 2 | 10 | 7 | 0 |
| Engenia + gly | 3 | 12 | 6 | 2 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 1 | 2 | 1 |
| **soybeans** | | | | |
| 2,4 D amine | 2 | 5 | 0 | 0 |
| 2,4 D ester | 3 | 6 | 5 | 1 |
| Engenia | 10 | 11 | 15 | 13 |
| DMA | 8 | 20 | 18 | 20 |
| Enlist Duo | 8 | 5 | 3 | 1 |
| Engenia + gly | 3 | 15 | 20 | 18 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 5 | 4 | 3 |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.

Table 3. Mean plant injury from early season spray drift after applying 1/200th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 3 | 5 | 3 | 4 |
| 2,4 D ester | 2 | 7 | 3 | 0 |
| Engenia | 7 | 2 | 0 | 0 |
| DMA | 0 | 0 | 0 | 0 |
| Enlist Duo | 1 | 3 | 5 | 4 |
| Engenia + gly | 2 | 2 | 1 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 1 | 2 | 2 | 3 |
| **coreopsis** | | | | |
| 2,4 D amine | 0 | 0 | 0 | 0 |
| 2,4 D ester | 0 | 0 | 0 | 0 |
| Engenia | 2 | 2 | 0 | 0 |
| DMA | 2 | 2 | 2 | 0 |
| Enlist Duo | 2 | 1 | 0 | 0 |
| Engenia + gly | 2 | 3 | 0 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 2 | 1 | - |
| **soybeans** | | | | |
| 2,4 D amine | 3 | 2 | 0 | 0 |
| 2,4 D ester | 2 | 1 | 0 | 0 |
| Engenia | 5 | 8 | 5 | 5 |
| DMA | 7 | 10 | 5 | 3 |
| Enlist Duo | 5 | 2 | 0 | 0 |
| Engenia + gly | 2 | 6 | 3 | 5 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 3 | 2 | 2 |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.

Table 4. Mean plant injury from late season spray drift after applying 1/50th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 10 | 12 | 3 | 5 |
| 2,4 D ester | 12 | 10 | 5 | 1 |
| Engenia | 5 | 6 | 3 | 5 |
| DMA | 3 | 3 | 3 | 0 |
| Enlist Duo | 8 | 15 | 10 | 11 |
| Engenia + gly | 10 | 8 | 9 | 5 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 3 | 2 | 3 | 4 |
| **coreopsis** | | | | |
| 2,4 D amine | 3 | 3 | 2 | 0 |
| 2,4 D ester | 1 | 1 | 2 | 0 |
| Engenia | 3 | 5 | 3 | 0 |
| DMA | 5 | 6 | 4 | 0 |
| Enlist Duo | 15 | 11 | 7 | 0 |
| Engenia + gly | 19 | 15 | 10 | 2 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 3 | 1 | 1 |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.
Grapes and hydrangea were not injured during late season spray applications.
Soybeans were not included in late season spray applications

Table 5. Mean plant injury from late season spray drift after applying 1/100th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 2 | 5 | 5 | 0 |
| 2,4 D ester | 5 | 5 | 4 | 0 |
| Engenia | 0 | 0 | 0 | 0 |
| DMA | 0 | 0 | 0 | 0 |
| Enlist Duo | 8 | 2 | 6 | 0 |
| Engenia + gly | 7 | 5 | 2 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 2 | 1 | - |
| **coreopsis** | | | | |
| 2,4 D amine | 1 | 2 | 0 | 0 |
| 2,4 D ester | 0 | 0 | 0 | 0 |
| Engenia | 0 | 0 | 0 | 0 |
| DMA | 5 | 7 | 3 | 0 |
| Enlist Duo | 3 | 11 | 7 | 0 |
| Engenia + gly | 2 | 2 | 3 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 2 | 2 | - |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.
Grapes and hydrangea were not injured during late season spray applications.

Table 6. Mean plant injury from late season spray drift after applying 1/200th recommended rate.

| | DAT | | | |
|---|---|---|---|---|
| | 7 | 14 | 28 | 56 |
| **tomato** | | | | |
| 2,4 D amine | 3 | 3 | 2 | 0 |
| 2,4 D ester | 5 | 5 | 4 | 0 |
| Engenia | 0 | 2 | 0 | 0 |
| DMA | 0 | 0 | 0 | 0 |
| Enlist Duo | 0 | 0 | 0 | 0 |
| Engenia + gly | 0 | 0 | 1 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| **LSD** | 2 | 2 | 1 | - |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.
Grapes and hydrangea were not injured during late season spray applications.
No injury was found for coreopsis at 1/200 application rate on late season spray applications

Table 7. Mean plant injury from vapor drift.

DAT

| | 0 | 2 | 4 | 8 |
|---|---|---|---|---|
| **soybeans** | | | | |
| Engenia | 17 | 0 | 0 | 0 |
| DMA | 48 | 15 | 0 | 0 |
| Enlist Duo | 10 | 3 | 0 | 0 |
| 2,4 D ester | 30 | 8 | 0 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| LSD | | | | |
| **tomato** | 15 | 3 | - | - |
| Engenia | 0 | 0 | 0 | 0 |
| DMA | 11 | 0 | 0 | 0 |
| Enlist Duo | 3 | 3 | 0 | 0 |
| 2,4 D ester | 12 | 5 | 0 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| LSD | 3 | 2 | - | - |
| **coreopsis** | | | | |
| Engenia | 5 | 0 | 0 | 0 |
| DMA | 17 | 0 | 0 | 0 |
| Enlist Duo | 3 | 0 | 0 | 0 |
| 2,4 D ester | 15 | 5 | 0 | 0 |
| untreated | 0 | 0 | 0 | 0 |
| LSD | 3 | 2 | - | - |

Plant injury; 0= no injury; 100 = plant death. Gly = glyphosate.

## CONTACT PERSON

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## ADDITIONAL INFORMATION

(see photographs below)

Figure 1. Early season dicamba treatment at 1/50 concentration on tomatoes 14 DAT.

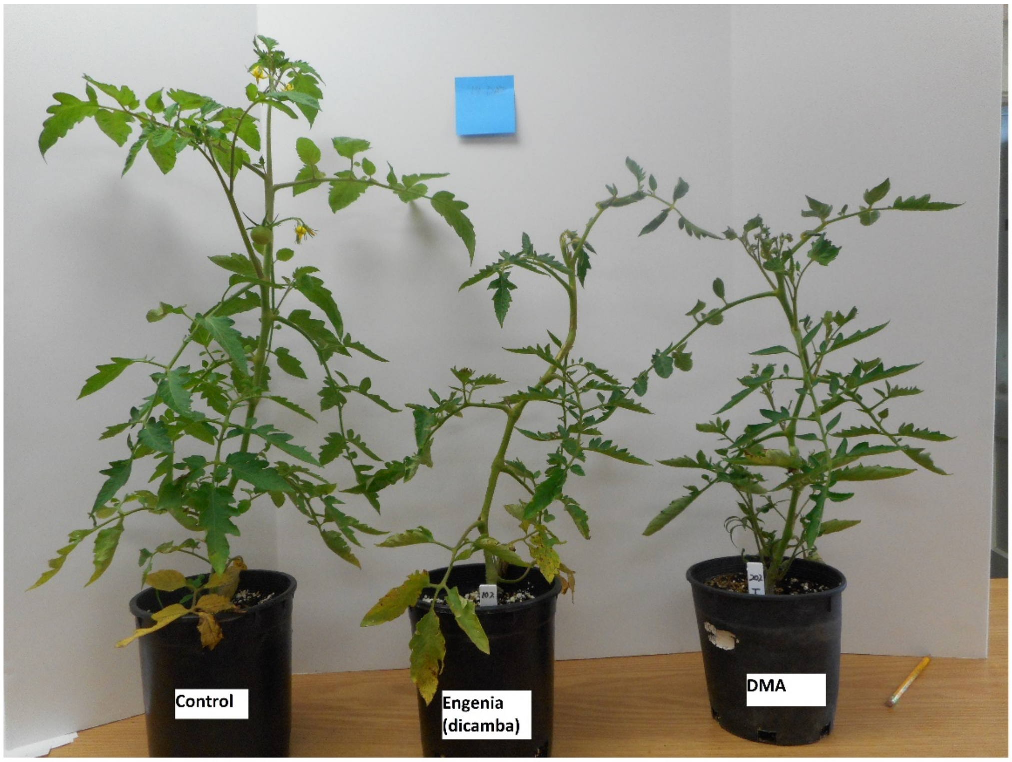



Figure 2. Early season 2,4-D treatments at 1/50 spray concentration 14 DAT.


Figure 3. Early season tomato leaf injury from Engenia, 7 DAT at 1/50 spray concentration.

Figure 4. Stem injury from Enlist Duo 1/50 concentration 7 DAT

Figure 5. Soybean injury from 1/50 spray concentration of Engenia (dicamba), 14 DAT.


Figure 6. Coreopsis injury from Enlist Duo 1/50 concentration, 14 DAT

**GOALS AND OUTCOMES ACHIEVED**

*Project Goal 1:* Determine crop injury potential associated with release of new GM stacked crops to nursery and vegetable producers in Virginia. Target for Goal 1 is to reduce herbicide injury by 50%. All crops tested displayed greater injury from early season applications of 2,4-D or dicamba treatments compared to late season treatments. At 1/50 spray application rate, Enlist Duo caused 28% injury on early season tomatoes compared to 10% following a late season application at 28 DAT. Growers need to be extra careful early in the growing season when applying 2,4-D or dicamba near sensitive broadleaf crops. Overall, applications of 2,4-D and dicamba are safer late season when applied near nursery and vegetable crops. No injury was found on grapes or hydrangea after applying 1/50, 1/100, 1/200 of the recommended rate late season. At 1/50 application rate, coreopsis had 18% injury following early season application compared to 3% for late season application at 28 DAT. Tomatoes suffered 28% injury after 1/50 rate of Enlist Duo rate, compared to 10% injury with Engenia at 28 DAT. The opposite was true for soybeans, after applying 1/50 rate of Enlist Duo 17% injury compared to 32% injury with Engenia, 28 DAT. Chemical selection and adjacent crop species need to be considered. For example, it is safer to spray GMO soybeans with dicamba if tomato growers are in proximity, potential injury reduction by greater than 50%. The converse is true for soybeans; applications of 2,4-D would be much safer to adjacent non-GMO soybeans.

*Project Goal 2:* Recovery potential from exposure to 2,4-D and dicamba. Coreopsis outgrew injury from early season applications of both 2,4-D and dicamba after 56 DAT. However, early season applications of all treatments on tomatoes and soybeans further decreased size and damaged growing points. At 1/50$^{th}$ concentration, neither tomatoes nor soybeans were able to flower. Enlist Duo at the 1/50 concentration greatly injured hydrangea, and after 56 days, plants were unable to recover that season and no flowers were produced. The following year, however, plants were able to flower and produce acceptable foliage.

Both Enlist Duo and Engenia caused significantly less injury from vapors compared to older formulations when pots were placed at 0 and 2 DAT for tomatoes, coreopsis, and soybeans. These new chemical formulations of 2,4-D and dicamba are less volatile and can reduce injury from vapors by 30 to 100%.

*Project Goal 3:* Develop recommendations to corn and soybean growers about application timing and formulation risk potential. Late season spray applications in general, are much safer for GM crops who are in proximity to specialty crops. Drift injury symptoms include twisted and curled shoots and cupped leaves on hydrangea and coreopsis. The new formulations Enlist duo and Engenia pose less risk of injury from vapor drift compared to older formulations.

BENEFICIARIES

There are 700 beneficiaries affected by this project's accomplishments. The results from this report will benefit specialty crop growers that produce nursery, fruit, and vegetable crops in Virginia as well as in other states. With this information, they can inform growers of GMO crops how the choice of herbicide formulation impacts the potential risk of injury to nontarget plants. Using less volatile herbicide formulations and following label directions concerning wind speed and direction can mitigate offsite injury from applications of 2,4-D and dicamba. Growers of specialty crops have greater knowledge of injury symptoms following damage from 2,4-D and dicamba, useful information when diagnosing plant disorders.

**LESSONS LEARNED**

Tomatoes are significantly more sensitive to all formulations of 2,4-D compared to dicamba, while soybeans are significantly more susceptible to injury from herbicides containing dicamba compared to 2,4-D. The greatest risk of injury to vegetable and nursery crops from 2,4-D and dicamba is from spray drift. Growers need to pay attention to wind speed and direction when applying these herbicides near sensitive broadleaf crops. The newer formulations Engenia and Enlist Duo would be better alternatives than older formulations of 2,4-D and dicamba as they pose less risk of vapor rift and damage. These newer formulations still pose a similar risk of injury from spray drift though, compared to older formulations.

10.

**Final Report**

**PROJECT TITLE**

**Understanding Species Complex and Infection Process of Anthracnose and Ripe Rot Pathogens.**

Virginia Tech
Mizuho Nita

PROJECT SUMMARY

Two pathogen-complexes *Colletotrichum acutatum* and *C. gloeosporioides*, are resurging endemic pathogens for VA. Between 2010-14, several growers in southern VA lost more than 30% of their potential crop due to ripe rot of grape caused by these pathogens. In this proposal we have: 1) identify species of *Colletotrichum* isolated from grape, 2) screen for efficacy of fungicides among these species, 3) determine the effect of high relative humidity to the infection process, and 4) Determine cultivar susceptibility. We identified two species in *Colletotrichum acutatum* group (*C. fioriniae* and *C. nymphaeae*) and six in *C. gloeosporioides* group (*C. aenigma, C. alienum, C. conoides, C. fructicola*, *C. kahawae* subsp., and *C. gloeosporioides*). We found that captan, and mancozeb controlled all five *Colletotrichum* species tested. We were also able to prove that all five *Colletotrichum* species tested were able to germinate after 48 hours under 100% relative humidity. *C. aenigma*, *C. fioriniae,* and *C. fruticola* were particularly active. These three species were able to germinate without free water. We also found that among tested cultivars, Vignoles and Petit Manseng being more susceptible to ripe rot than others, and a cultivar Chambourcin seemed to be less susceptible to ripe rot.

PROJECT PURPOSE

Both *C. acutatum* and *C. gloeosporioides* are common pathogens of several crops and non-cultivated plant species [1]. A record of diseases caused by *Colletotrichum acutatum* and *C. gloeosporioides* in VA goes back to an apple fungicide field trial in 1888 by Mr. G. Curtiss in Stafford county, VA [2]. *C. acutatum* and *C. gloeosporioides* cause bitter rot and Glomellera leaf spots on apple, anthracnose in peaches and pears [1] and crown rot and anthracnose fruit rot on strawberries [3]. In 2010-13, our lab encountered several growers who lost 15- 30% of their potential crop due to ripe rot of grape (Fig. 1, Nita, *unpublished data*). The suffering growers all agreed that the wine quality was largely compromised by the infected berries. Additionally, a study by Meunier (2009) indicated that as little as 3% contamination with actively sporulating berries can result in noticeable changes in flavor and color in the resulting wine. Thus, the actual economic damage can be far greater than direct reductions of yield. Discussions with wineries revealed that it is common for winemakers to receive ripe-rot infected berries from vineyards (Nita, *personal communication*). In recent years, sizable outbreaks of ripe rot of grape have been observed in VA, PA, and NC. In fact, during a 2009-2013 state-wide grapevine virus survey, our group found that nearly all visited vineyards had some degree of infestation by ripe rot (Nita, *unpublished*).

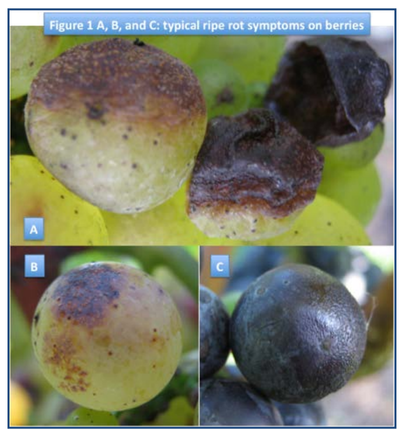
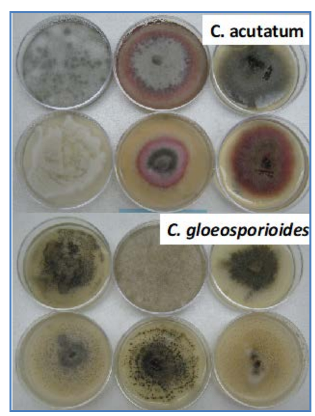


Figure 1 A, B, and C: typical ripe rot symptoms on berries

Typically, our recommendations for chemical management of ripe rot are the use of mancozeb, ziram, captan, and quinone outside inhibitor (QoI) fungicides. However, mancozeb and ziram have a 66-day and 21-day PHI, respectively for grape, thus, we cannot use them in the late season. In addition, there is some evidence to indicate some *C. gloeosporioides* strains are not sensitive to captan [6]. In fact, the aforementioned vineyard with 30% loss relied on captan on their late season disease management; yet, remained unable to manage ripe rot. Thus, the importance of QoI fungicide is high, especially dealing with late season ripe rot outbreak. However, there is a report from South Carolina on QoI resistant isolates from peaches (Schnabel, *personal communication*).

The first question came to my mind when I stepped into the vineyard with 20-30% loss of crop was "why now?" As noted above, *Colletotrichum* species have been causing diseases on fruit crops in VA for a long time, but it was not considered as major players. I believe there are several reasons for the outbreak: 1) selection of species that are not sensitive to some fungicides, 2) lack of understanding on effective mean of control (which lead to reason 1) and 3) change in environmental conditions (via expansion of growing area, and selection of crops/cultivars). Currently, Virginia ranks fifth in the US in wine grape production with 3,500 acres of wine grape acreage (*V. vinifera*, inter-specific hybrids, and *V. labrusca*) and over 230 wineries (Caldwell, 2012, VWB, 2012). An annual economic impact of VA wine industry was estimated to be $740 million in 2010 (VWB, 2012), which represents a 106% increase from 2005. Naturally, expansion also happened in the southern part of the state where there is a big economic potential as a grape production area due to relatively low land. Based on 2014 information, 64 wineries are located in the lower half of VA where ripe rot has historically been considered an issue (www.virginiawine.org). If ripe rot continues to be an issue, it will be a very large roadblock for growers in the southern VA where tobacco and vegetable growers may look into grape as alternative cash crop.

Although these two "species" were loosely classified based on their morphologies, number of new DNA-based studies revealed that both *C. acutatum* and *C. gloeosporioides* are composed of multiple species, rather than just single species [7-12]. Thus, we have collected 400+ isolates mainly from grape, but also from apple and strawberry in 2013-14 seasons. Our culture collections showed wide variety of colony as well as spore morphologies (= indication of different species, Fig. 2), and preliminary DNA-test results revealed that there were at least two *C. acutatum*-type species and 5-7 *C. gloeosporioides*-type species among out samples. Thus, we have at least 7-9 different species causing diseases on grape, apple and strawberry in VA. The question is whether these species differ in terms of their sensitivity to fungicides or not. Contradictory reports from the past suggest that there is a high probability of different sensitivity to fungicides among these species, and we are most likely selecting these species by applying fungicides in the field. In fact, our preliminary results showed that at least 50% of our sample has a gene-mutation [13] that is common among isolates that are resistant to the QoI fungicide.




With a support from previous iteration of SCRI block grant and Virginia Wine Board, our lab has been working to determine the effects of infection conditions (temperature, wetness, and cluster development stage), as well as fungicide efficacy. Our preliminary results showed that both *C. acutatum* and *C. gloeosporioides* can cause infection from bloom to harvest, but symptom development typically happens near harvest (Nita, *unpublished data*). In addition, some of fungicide, which has not been listed previously (e.g., phosphorous acid, tebuconazole), has been identified as potential tools for management (Nita, *unpublished data*). Our studies revealed that clusters need to be protected from bloom until harvest, and there was difference in sensitivity to fungicide between *C. acutatum* and *C. gloeosporioides* isolates we used. In the other words, some fungicides were effective only on one pathogen, but not the others. Thus, knowing with what species we are dealing is a very important factor for ripe rot disease management.

Another finding was the effect of temperature and wetness. Our preliminary results matches with results from other crops, relatively high optimal temperature (~28C or 82F), but at the same time, we accidentally found out that if we did not control humidity after the infection period, the spores could find the way into berries even without the presence of free water, which is often a requirement for fungal infection process. Areas where ripe rot is common in VA (Eastern Shore, Northern neck, and southern VA) are typically experience high humidity in the morning hours, especially close to the end of the season. Thus, it is probably more important to determine the effect of prolonged high humidity on the infection process to understand why these areas experience more ripe rot than other grape growing regions in VA.

There are four objectives:

1) identify species of *Colletotrichum* isolated from grape
2) Screening for efficacy of fungicides among these species
3) Determine the effect of high relative humidity to the infection process.
4) Determine cultivar susceptibility

Since ripe rot of grape affects quality of wine, it does increase the competitiveness of wine grape. With 1.6 million customers coming in every year, we do not want to have a reputation of bad wine.

PROJECT ACTIVITIES

**Objective 1:** In order to identify potential regional differences, growers were selected randomly from each of five major grape growing regions of Virginia (VA). The northern region spans from the Washington D.C./Arlington area west towards the Appalachian Mountains and south to the edge of the Monticello American Viticultural Area, which is the start of the central region that spans to Richmond, VA. The western region of VA contains the Appalachian and Blue Ridge Mountain areas. The eastern region of VA spans the coastline from Virginia Beach up to the Chesapeake Bay area. The southern region of VA is the southern piedmont of Appalachia. Our lab visited 35 growers in 2013 and 7 in 2014 to collect symptomatic ripe rot grape berries. Since some growers had more than one vineyard, we collected from 90 unique locations, and within the same location we were able to collect some isolates.

In the lab, skin from the berry was cut into approximately 5 x 5 mm piece, and the tissue was surface sterilized using 70% EtOH for 10 sec, followed by 0.53% hypochlorite (i.e. 10% bleach) solution for 1.5 min, and rinsing 1.5 min with autoclaved $H_2O$. Then the tissue was placed onto ¼ PDA amended with streptomycin and chloramphicol (both are 100 mg/ml). Once colony growth was observed, a hyphal tip was transferred onto a new Antibiotic ¼ PDA. Once a clean colony was established, single spore isolations were made. Five- to seven-day old culture was flooded with autoclaved $H_2O$, and the media surface was gently scraped with a sterilized toothpick. Then the spore suspension was filtered with two layers of Miracloth (EMD Millipore) to remove mycelium. The spore suspension was plated onto a water agar and individual spore was picked for further culturing. We have collected over 1500 isolates of either *C. acutatum* or *C. gloeosporioides* based on a combination of colony morphology, spore characteristics, and multilocus sequence typing.

Of 500 isolates we sequenced using multilocus sequence typing, we have identified at least two *Colletotrichum acutatum* species within the complex (*C. fioriniae* and *C. nymphaeae*) and six *C. gloeosporioides* species within the complex (*C. aenigma, C. alienum, C. conoides, C. fructicola*, *C. kahawae* subsp., and *C. gloeosporioides*). Additionally, we have identified potentially subspecies or cryptic species within the *C. acutatum* complex that require further investigation. We selected five isolates from different geographic locations per subspecies to conduct experiment. The two *C. acutatum* subspecies and two *C. gloeosporioides* species were found only in one location or a single isolate, thus we are expecting to examine a total of 5 species (30 isolates).

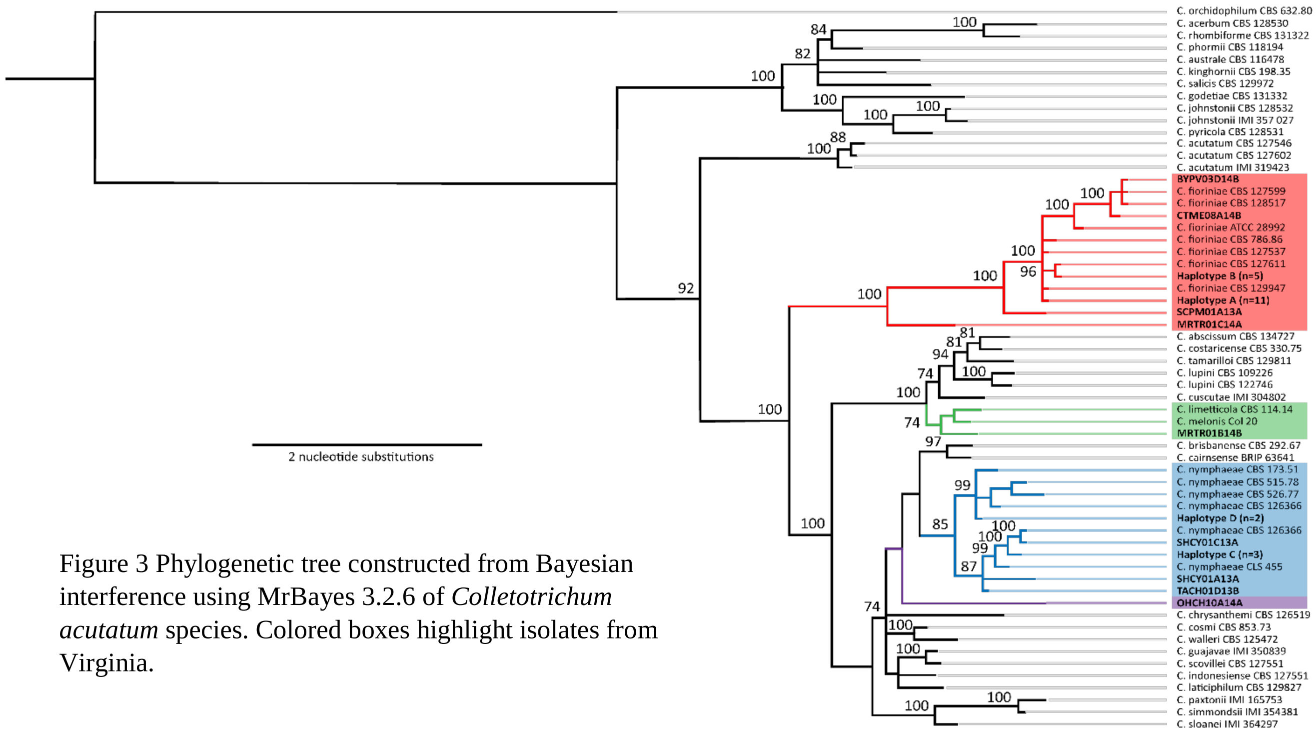



Figure 3 Phylogenetic tree constructed from Bayesian interference using MrBayes 3.2.6 of *Colletotrichum acutatum* species. Colored boxes highlight isolates from Virginia.

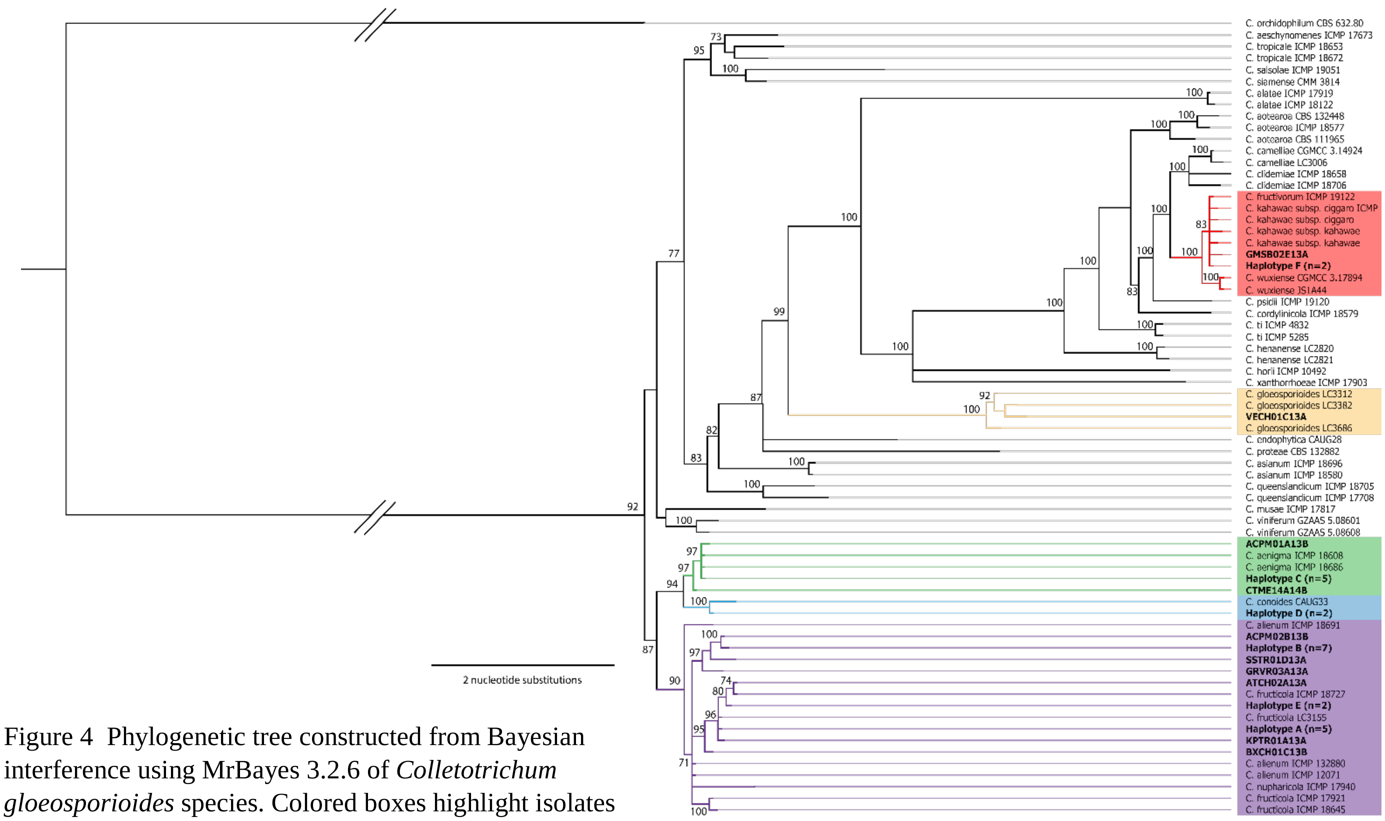



Figure 4 Phylogenetic tree constructed from Bayesian interference using MrBayes 3.2.6 of *Colletotrichum gloeosporioides* species. Colored boxes highlight isolates from Virginia.

**Objective 2:** We employed a two-step method for assay verification. The first step is use of Alamar blue (AB) in the fungicide amended culture plate [14], and then a traditional fungicide amended media assay. The single-spore isolate plates will be flooded by adding 5 ml of clarified, buffered 2 % Potato Dextrose Broth (PDB). Then, the suspension will be filtered using two layers of Miracloth to remove mycelium. Then, 100 µl of a suspension of $10^5$ conidia/ml (adjusted using a hemocytometer) or 100 µl of 2 % PDB with aerial mycelium will be added to test wells of 48-well cell culture plate (Corning Costar), and stock fungicide solutions will be added to give final concentrations of each fungicide (0.0, 0.01, 0.1, 1.0, 10.0, 100.0, and 1000.0 or 0.0, 30.0, 50.0, 150.0, 200.0, 300.0, 500.0 µg/ml). AB dye (AbD Serotec) was added at 10% of the final volume in the test wells [15]. Plates will be covered with sterile plastic plate covers, gently rotated horizontally to mix the well contents, then incubated in the dark at 25°C for 48 h. There was a negative control (200 µl of 2% PDB and 10% AB dye only), and a positive control (100 µl of PDB, 100 µl of $10^5$ conidia/ml, and 10% AB dye). A chemical control plate was also prepared to ensure that the fungicides themselves did not reduce the AB dye (100 µl of stock fungicide, 100 µl of 2% PDB, and 10% AB).

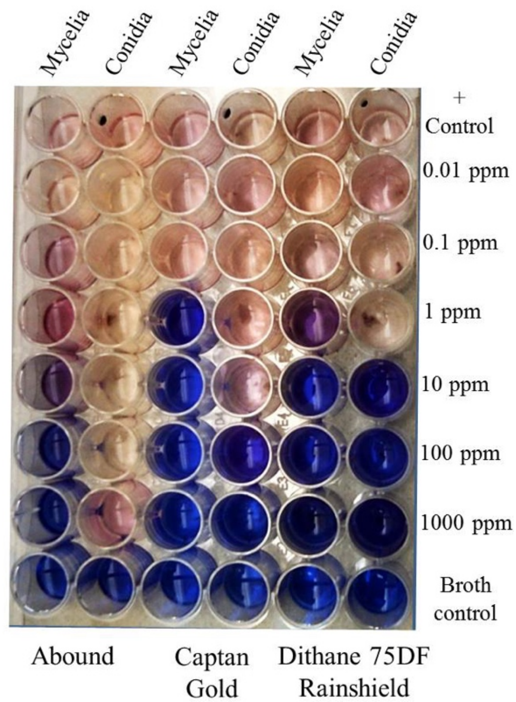
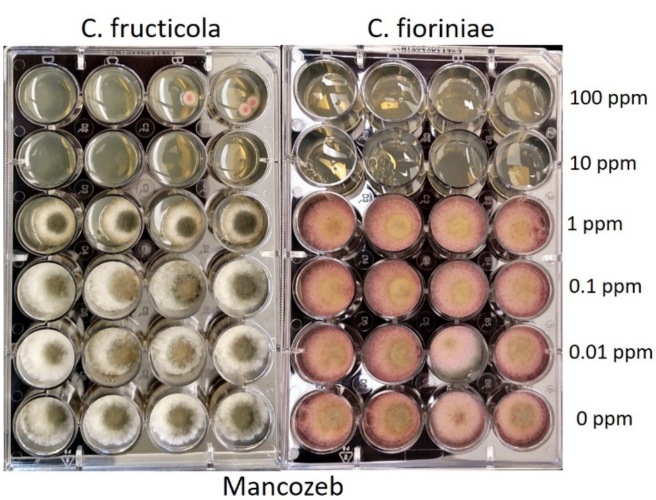


Figure 5 AB plate test example

A positive test result was recorded as a color change from blue to pink, which indicated that the dye had been reduced due to the presence of viable conidia or mycelia (Fig 3). A negative test result will be recorded as no color change or the dye remained blue, i.e., the dye was not reduced. One mean inhibitory concentration (MIC) endpoint was visually determined and defined as the lowest concentration of fungicide that prevented a color change from blue to pink (MIC- blue) after 48 h of incubation.

In 2017, the broth pH for the AB assay was proving to be problematic. Due to the sensitivity of the AB dye, fungicide additions were causing the pH to shift and provide false positives. Therefore, the assay was only completed with two isolates from two separate species. Instead, our lab shifted to a 24-well fungicide amended solid media format for testing of the 30 total isolates. This method allowed for parallel testing of conidia and mycelia, similar to the AB assay method, for a range of fungicide concentrations (0.0, 0.01, 0.1, 1, 10, 100 µg/mL). This method also expanded the range of materials that could be tested (Table 1). Plates were constructed of potato dextrose agar, and commercial fungicide diluted in sterile distilled water (Figure 4).




Fungicides tested by both methods are listed in Table 1. Both assays were repeated four times per isolate/fungicide combination to validate the results. The AB assay results were analyzed by first running a preliminary analysis to determine the effect of *Colletotrichum* species, inoculum type, active ingredient (a.i.) concentration, and their interactions on the color change were examined with ANOVA based on a generalized linear mixed model (PROC GLIMMIX, ver. 9.4, SAS institute, Cary, NC) with a logit as a link function. Since the interaction of inoculum type and a.i. concentration was significant in 50% of cases ($P \leq 0.05$), the effective concentration for which 50% of samples are inhibited (= EC50) was conducted for each *Colletotrichum* species, inoculum type, and a.i. combination individually to describe the effect of a.i. concentration on the probability of no color change (= the inhibition of fungal activity). Three common link functions for binary data (logit, probit, and complementary log-log (CLL)) were used in the generalized linear mixed model. Then the best link function for each *Colletotrichum* species, inoculum type, and a.i. combination was selected based on the comparison of Akaike's Index of Criterion (AIC, a better fit to the data will result in a lower AIC) and deviance (Pearson's chi-square divided by degree of freedom, the better fit to the data will result in a lower deviance) (SAS Institute, 2012). Using the intercept and slope from the best fit model, nonlinear regression mixed model (PROC NLMIXED in SAS) was fitted to the raw data for EC50 estimation. These results are shown in the following figures, Fig. 5 and Fig. 6. The preliminary results for the solid media assay was conducted in a similar fashion using a generalized linear mixed model to observe the effects of *Colletotrichum* species, isolate, inoculum type, and a.i. The effect of isolate was not significant ($P > 0.05$), therefore, the preliminary EC50 calculations are displayed below with isolates combined by *Colletotrichum* species (Fig. 7 & 8).

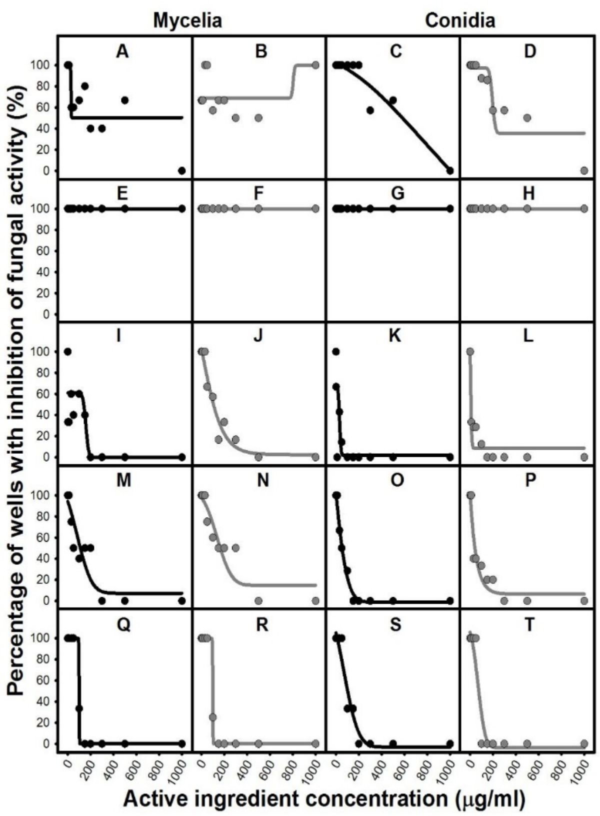



Figure 7 EC50 calculations from thea lamarBlue® assay. The five a.i. are shown horizontally [azoxystrobin (A-D), boscalid (E-H), captan (I-L), copper hydroxide (M-P), and copper octanoate (Q-T)]. The black dots and lines represent *C. siamense* and the gray dots and lines represent *C. fioriniae*.

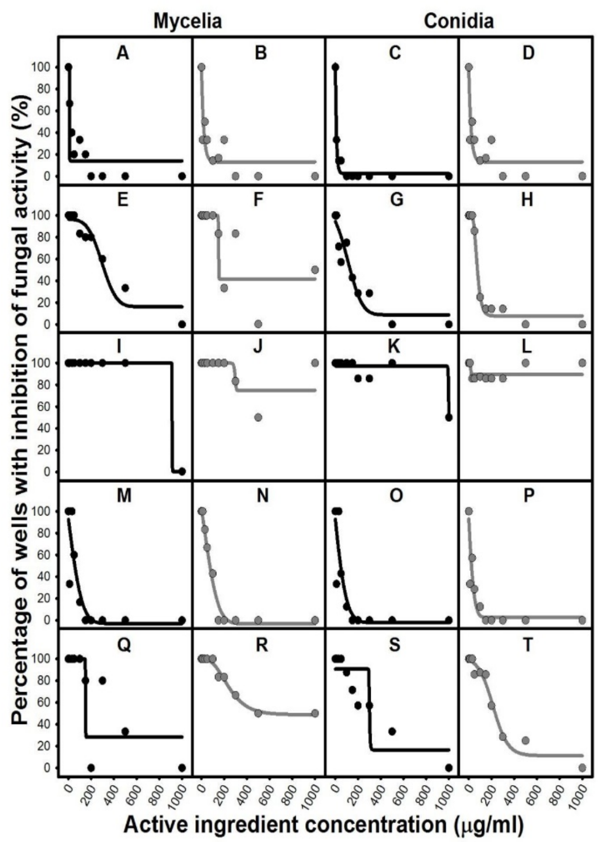



Figure 8 EC50 calculations from the alamarBlue® assay. The five a.i. are shown horizontally [mancozeb (A-D), potassium phosphite (E-H), pyriofenone (I-L), tetraconazole (M-P), and thiophanate methyl (Q-T)]. The black dots and lines represent *C. siamense* and the gray dots and lines represent *C. fioriniae*.

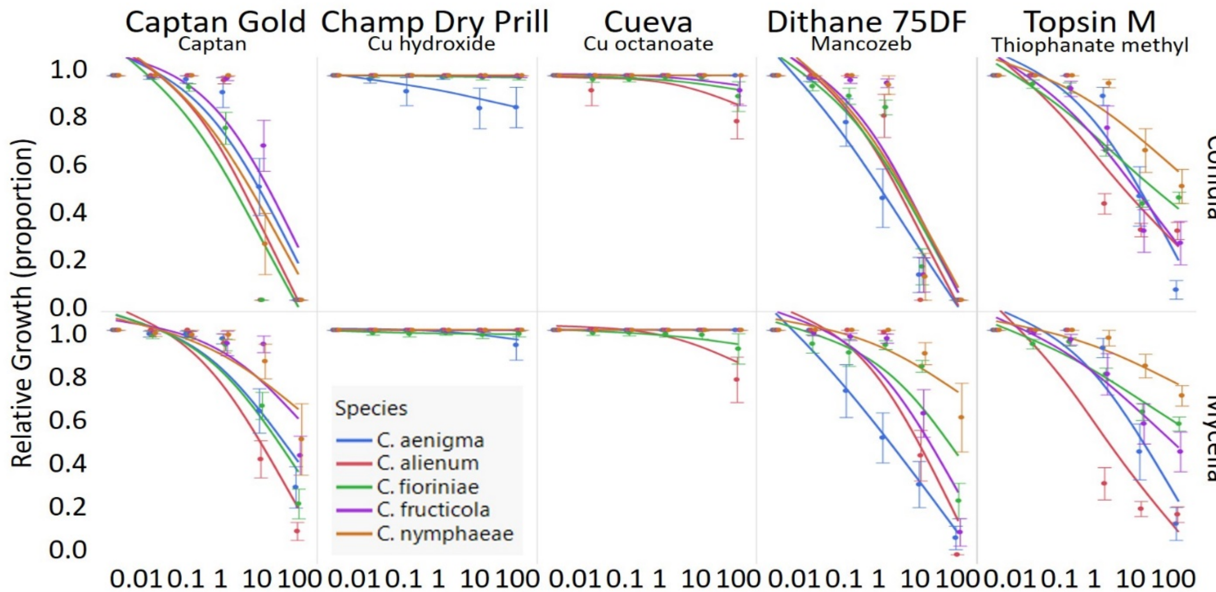



Figure 9 Multisite mode of action a.i with preliminary EC50 curvatures for five *Colletotrichum* species. Each line/dot combination represents the combined data of five isolates (three isolates for *C. nymphaeae*). The error bars represent one standard error from the mean.

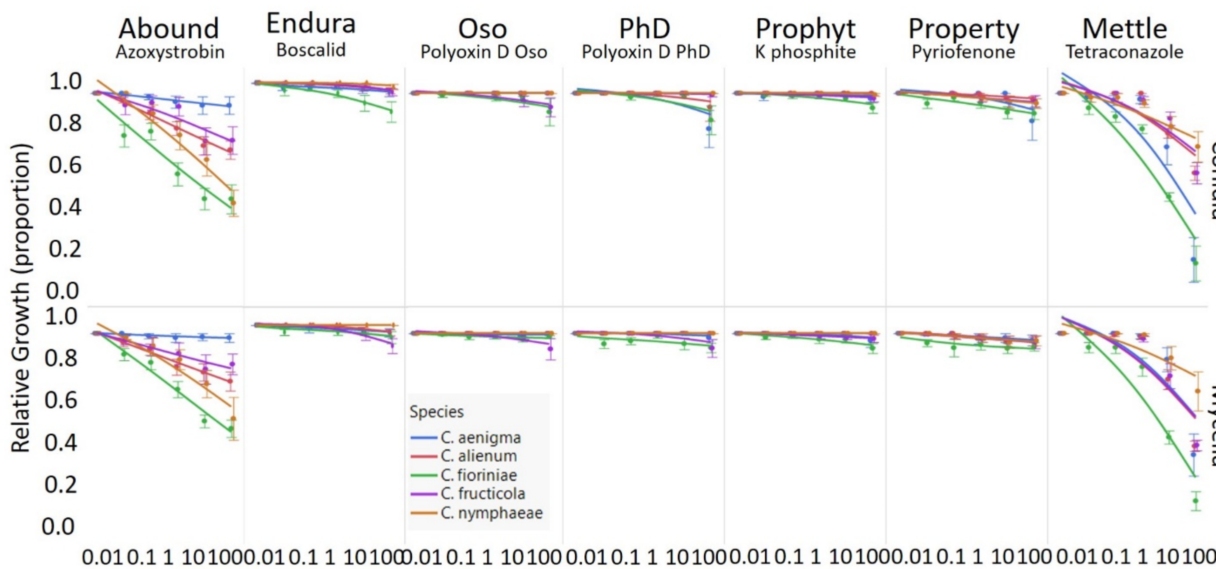



Figure 10 Single site mode of action a.i with preliminary EC50 curvatures for five *Colletotrichum* species. Each line/dot combination represents the combined data of five isolates (three isolates for *C. nymphaeae*). The error bars represent one standard error from the mean.

**Table 1** List of fungicide active ingredients tested in the solid media and alamarBlue® assays, including trade name, company and FRAC group

| Active ingredient (a.i) | Trade Name | a.i.% | Company | FRAC[Z] | Rate per Acre |
|---|---|---|---|---|---|
| Azoxystrobin | Abound® | 22.9 | Syngenta Crop Protection | 11 | 355 ml |
| Boscalid | Endura® | 70.0 | BASF Corporation | 7 | 237 ml |
| Captan | Captan Gold™ 80 WDG | 78.2 | Makhteshim Agan of North America | M4 | 907 g |
| Copper hydroxide | Champ® Dry Prill | 57.6 | NuFarm Americas | M1 | 1361 g |
| Copper octanoate | Cueva® | 10.0 | Certis USA | M1 | 18927 ml |
| Mancozeb | Dithane® 75DF Rainshield | 75.0 | Dow Agro Science | M3 | 1361 g |
| Potassium phosphite | ProPhyt® | 54.5 | Helena Chemical | 33 | 2366 ml |
| Pyriofenone | Property® F | 18.0 | ISK Biosciences | U8 | 148 ml |
| Tetraconazole | Mettle® 125 ME | 11.6 | Gowan Company | 3 | 118 ml |
| Thiophanate-methyl | Topsin® M 70 WDG | 70.0 | United Phosphorus Inc | 1 | 454 g |
| Polyoxin-D | Ph-D | 11.3 | Arysta Lifescience | 19 | 176 g |
| Polyoxin-D | Oso | 5.0 | Certis USA | 19 | 192 ml |

| **Supplemental chemicals used in alamarBlue® assay** | |
|---|---|
| Ethanol | Fisher Scientific |
| Salicylhydroxamic acid (SHAM) | Fisher Scientific |
| Sodium bicarbonate | Fisher Scientific |

**Objective 3:** In 2016, we have constructed a small “moist chamber” that enable us to monitor rate of spore germination while keeping relative humidity in the chamber consistent throughout the duration of the experiment. One of challenges were to find a sensor that can measure high relative humidity. Our initial trials using a common temperature/RH sensor resulted in very poor results at high RH conditions. E.g., the sensor will produce error message or simply stop working. We identified two (HTU21D-F from Adafruit.com, and Honeywell’s HIH-4030 from Sparkfun.com) sensors (as a breakout board to be able to use it with our system) worked very well. HTU21D-F sensor, which has a typical accuracy of ±2% with an operating range that's optimized from 5% to 95% RH, worked better with our system.

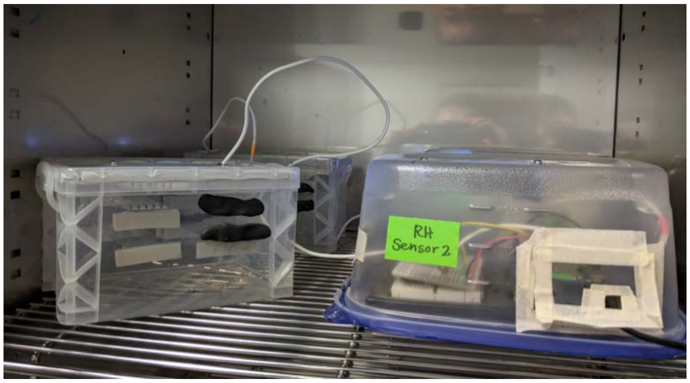



Figure 11 Experimental set up. Clear box on the left contains solution, slides with spores, and temp/RH sensor, and the box on the right contains Arduino microcontroller board and data logger.

The other challenge was to determine how to adjust relative humidity in the moist chamber. There were several literatures from the past, but many used sensors that were not able to accurately measure the range of relative humidity. Thus, we had to conduct a series of experiments to determine the ratio of glycerol and water that can provide the target relative humidity. The chart below shows the results from our trials which were conducted in 2016-2017. Each run took three days to complete, and at each temperature and % glycerol:water combination, there were two runs. To our surprise, the effect of temperature was very small, probably because of the small size of the chamber (approximately 3 x 5 x 4 inches).

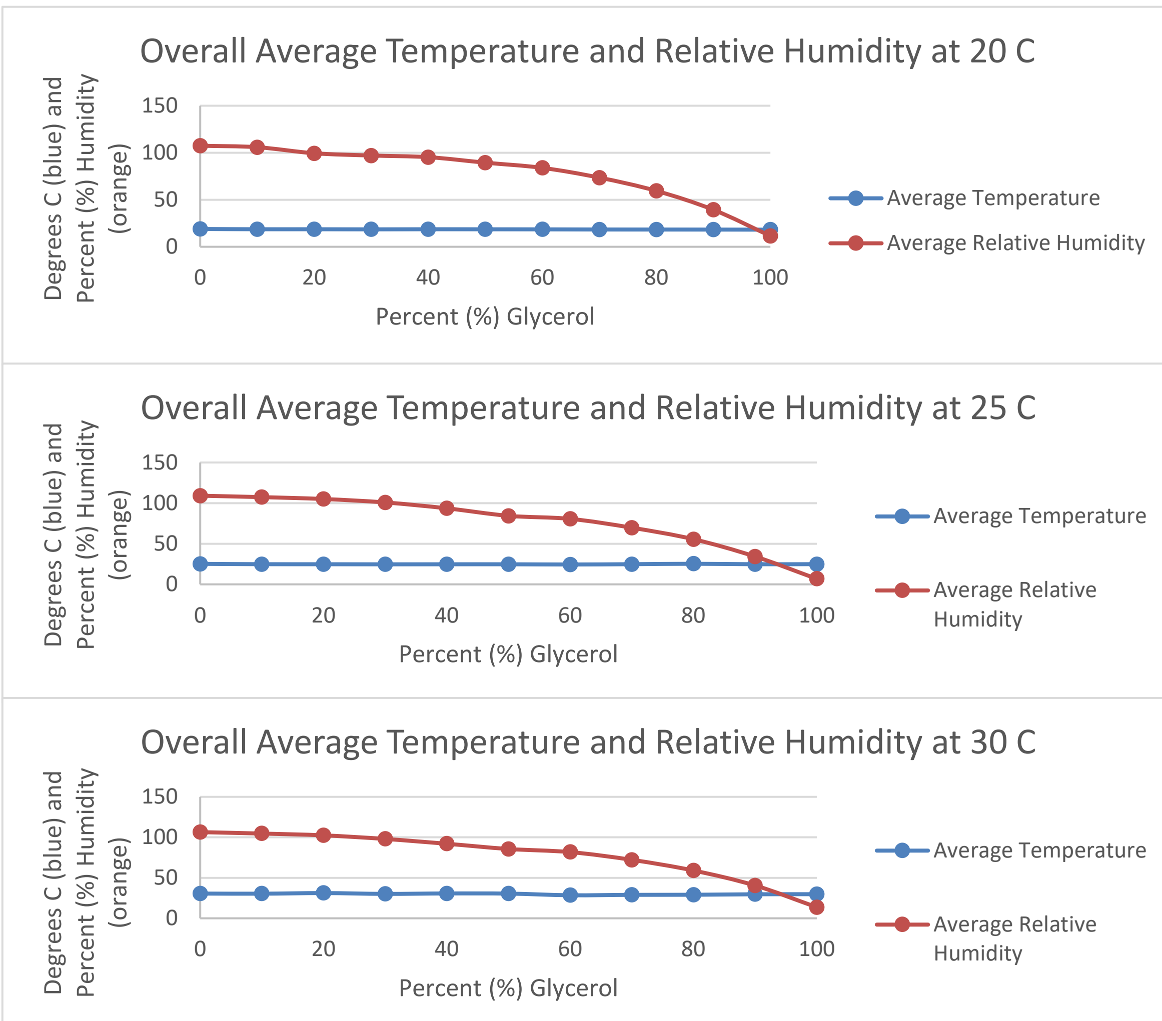



Figure 12 The effect of relative humidity to spore germination

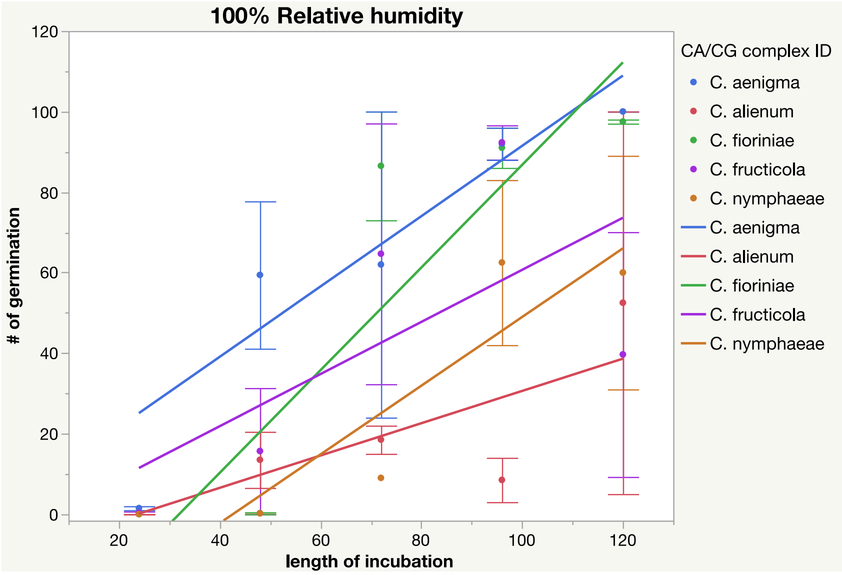
In order to determine the effect of relative humidity on spore germination of *Colletotrichum* species, we selected five *Colletotrichum* species that are commonly found in previously conducted VA statewide survey. These are *C. aenigma*, *C. fioriniae*, *C. alienum*, *C. fructicola*, and *C. nymphaeae*. All are isolated from wine grape berries samples in VA. We initially tested the glass microscope slide as a surface for spore germination, but we found the very erratic results. Thus, we have used cellulose membrane, which will provide more "natural" surface topography than very flat glass surface. A 4mm circles of Cellulose Membrane (CM), also known as dialysis tubing was cut using a single hole punch. The CM circles were boiled in two changes of distilled water with a drop of surfactant (Tween 20). Then these CM circles were autoclaved at 121C for 25min in distilled water. At the same time 30% solution of agar in distilled water was autoclaved. Then a CM circle was adhered using the autoclaved agar to a microscope slide.

Figure 13 A microscope slide with CM circles.

Spores of *Colletotrichum* isolates were prepared as following. An isolate derived from a single spore (to ensure genetic uniformity) was grown on amended-PDA. Nine to fourteen days old culture was then flooded with distilled water. The surface of the amended-PDA was gently rubbed with a sterilized glass rod to promote the release of spores. Suspension was filtered with two layers of Miracloth to remove mycelium. The spore suspension was then adjusted to 1 x $10^5$ spores/mL with a use of hemacytometer. On the CM circle, four drops of the spore suspension (20 $\mu$L) was placed. The plate with the CM circle was dried under a laminar flow hood for one hour, so that there won't be no free water on the surface of the CM circle. Then 100 spores were visually inspected under a microscope (Nikon Eclipse E200) for the rate of germination before the experiment.

The moist chamber is prepared with a predetermined ratio of water and glycerol solution as indicated above. The moist chamber was placed in an incubator (Fisher Scientific Isotemp Incubator) to achieve target temperature. The inside of the chamber was kept dark to minimize the influence of light. It is prepared 24 hours prior to the placement of the microscope with the CM circle to achieve the target relative humidity prior to the start of the experiment. The microscope slides with the CM circle and four drops of the spore suspension were placed in the moist chamber, and then removed at 24, 48, 72, 96, and 120 hours. At each time point, 25 spores per drop were examined for the rate of germination and of appressoria, which is a fungal structure used for penetration of plant tissue, production under the microscope. For each temperature, relative humidity, and time point, there were two to four replications of microscope slides. The number varied due to uneven rate of spore production.

Our plan was to test three different temperatures, 20, 25, and 30 °C. Many *Colletotrichum* species are active on these temperature ranges. We are also testing relative humidity of 100%, 96-98%, 93-95%, and 90%. Our preliminary results showed that with less than 90% relative humidity, there were no spore germination even after 120 hours. As of 23 Oct 2018, we have finished 30 °C and 100% and 96-98% RH. The results are shown below.




The figure above shows the rate of germination over the length of incubation. We observed only a few germinated spores after 24 hours; however, at 48 hours, 60 % on average of *C. aenigma* spore germinated. At 72 hours, *C. fioriniae* and *C. fruticola* germinated. *C. nymphaeae* resulted in high germination rate after 96 hours, while *C. alienum* took until 120 hours to germinate.

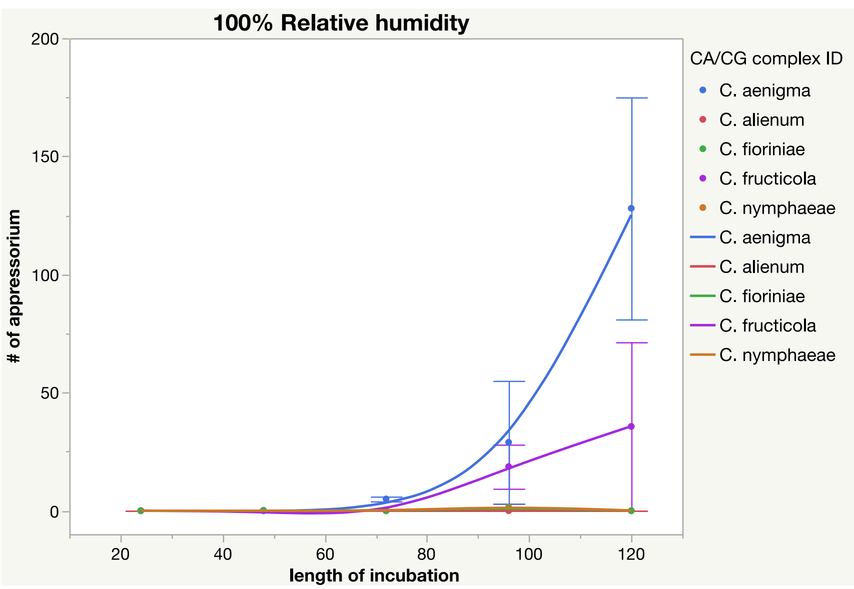
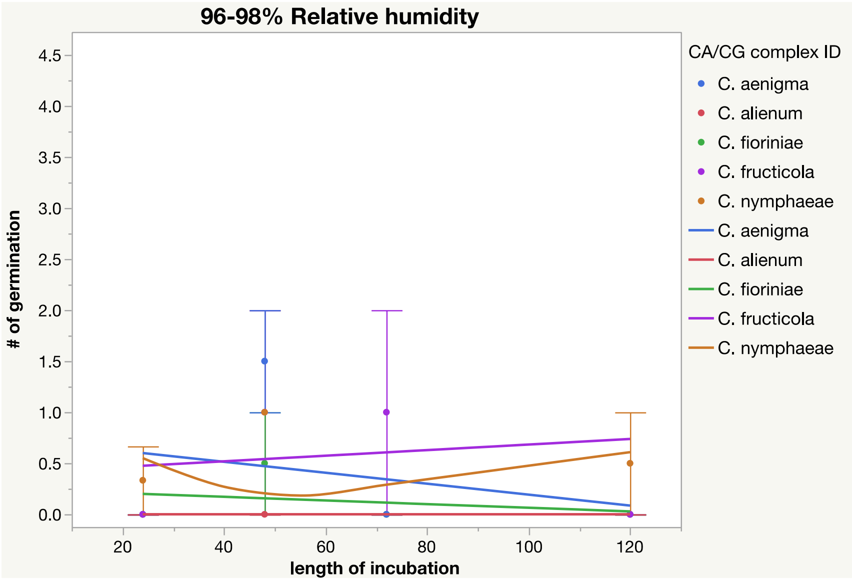
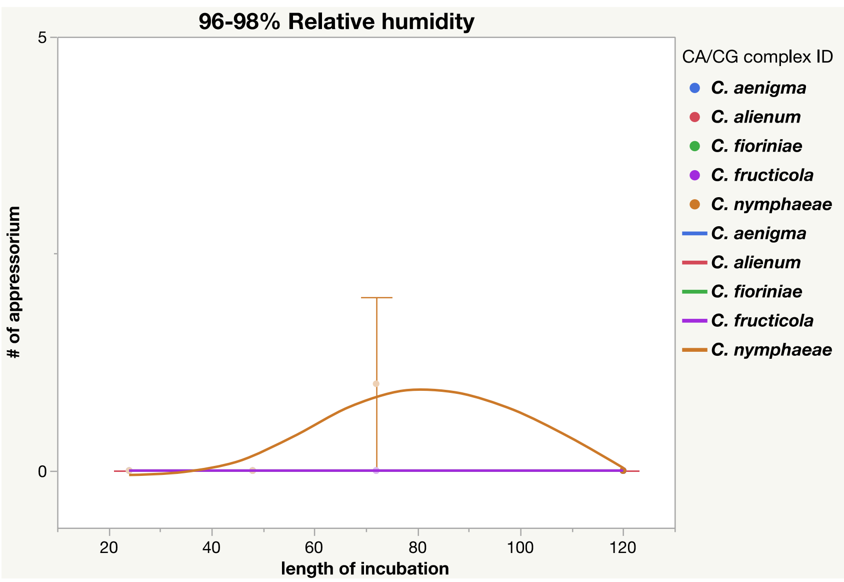



Figure above shows the rate of appressorium formation over the length of incubation. Both *C. aenigma* and *C. fructicola* were able to produce as many appressorium as 125 on average after 120 hours of 100% relative humidity. The number can be more than 100 because one spore can produce more than one appressorium. Appressorium is a structure the fungus produces to aid penetration of plant cuticle tissue, thus, formation of it is a good indication that these isolates were germinating and recognized the cellulose membrane as a host surface.




When relative humidity was dropped to 98-96% range, the rate of germination was greatly reduced for all isolates. There were a few spores germinated with *C. aenigma, C. fiorinae, and C. nymphaeae* at 38 hours and *C. fructicola* at 72 hours, but we conclude that these isolates were most likely not able to germinate when relative humidity is less than 100%.

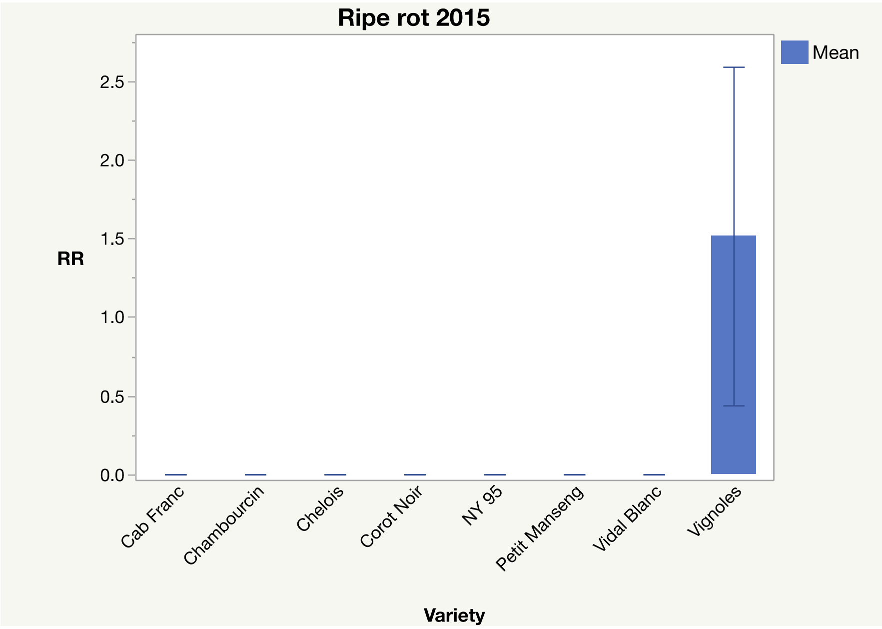



As expected, only a few appressorium was produced at 96-98% relative humidity condition. This further confirms that these isolates were not active if relative humidity is less than 100%. The experiments above were conducted from January 2018 to Oct. 2018. We are currently conducting 25 C experiments. Each experimental run needs five days, and at each time point, it takes 1-2 hours to measure spores, thus, the whole process is very time consuming.

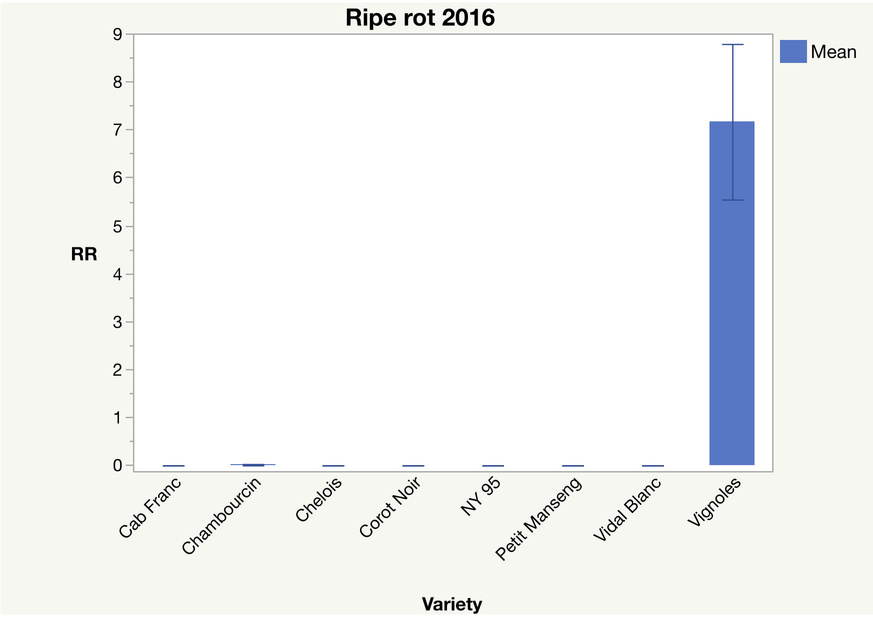
Objective 3: Cultivar susceptibility

In 2015-2017 seasons, we used our field plot that contain eight different cultivars to examine the susceptibility of these cultivars to ripe rot. The list of cultivars are: Cabernet Franc, Chambourcin, Chelois, Corot Noir, NY 95 (Arandell), Petit Manseng, Vidal blanc, and Vignoles. The field was sprayed with copper, which has little or no effect on ripe rot development, every two weeks to prevent development of downy mildew and powdery mildew. The vineyard was planted in 2013, and trained in head trained cane pruning method, with 4 ft between vines within a row, and 9 ft between rows. Each row contained four blocks, and within each block, these cultivars are placed randomly. We assessed disease severity (% of cluster area diseased) on 80 clusters per cultivar. The assessment was made at the time of harvest.

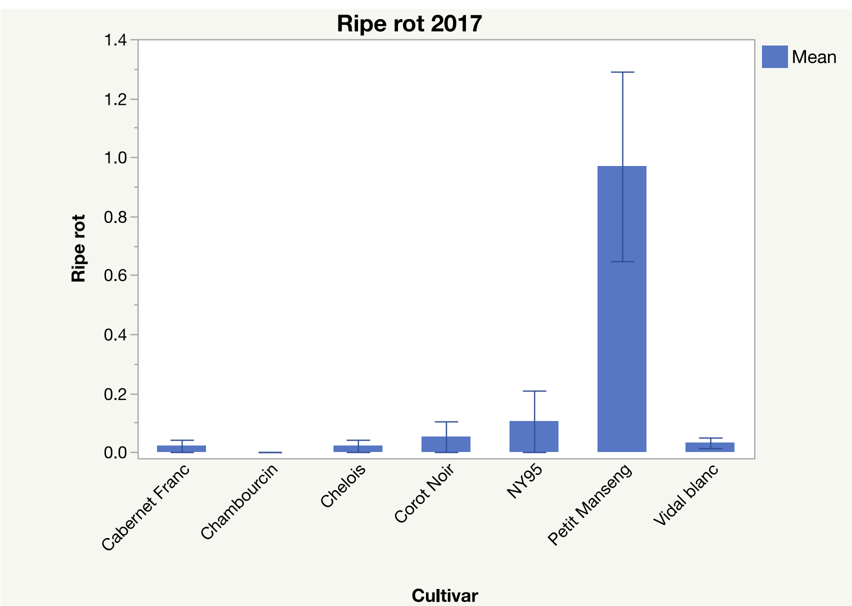
In 2015, we did not observe many ripe rot among cultivars, probably because of the age of vineyard. The only exception was Vignoles, which resulted in the average of 1.5% disease severity. Based on the one-way analysis of variance, the cultivar effect was significant ($F = 6.6$, $P < 0.01$), where the mean ripe rot severity of Petit Manseng was significantly higher than the others.



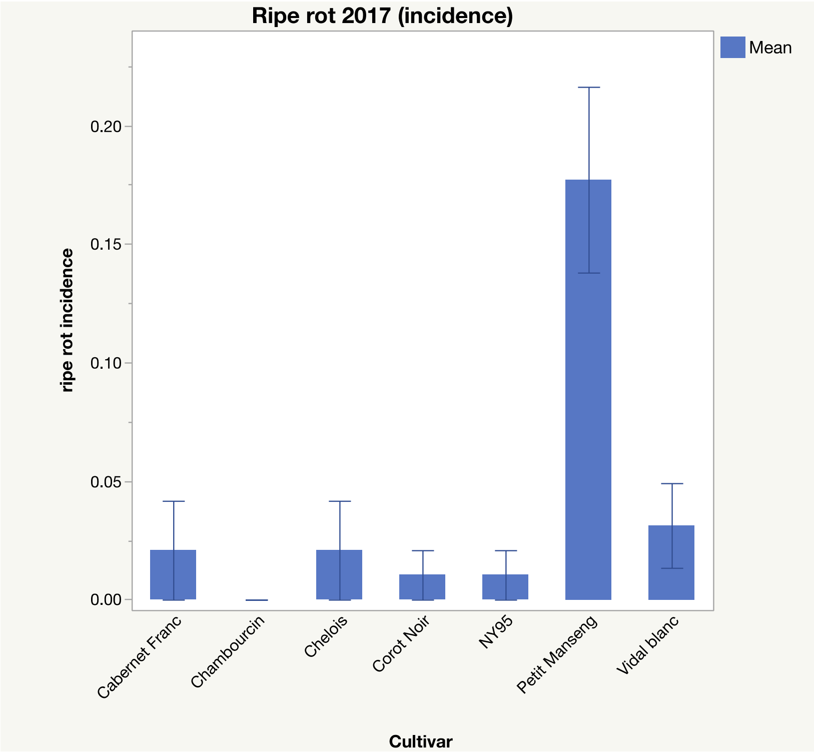

In 2016, the result was very similar to that of 2015. Only Vignoles berries showed ripe rot. However, ripe rot disease severity increased to 7%. Based on the one-way analysis of variance, the cultivar effect was significant ($F = 29.0$, $P < 0.01$), where the mean ripe rot severity of Vignoles was significantly higher ($P \leq 0.05$) than the others. None of other cultivars were significantly different from each other.




In 2017, ripe rot pathogen finally seemed to move in to the vineyard. There was a certain level of disease development with the most of cultivars. In particular, Petit Manseng resulted in much higher disease severity than the other cultivars. Based on the one-way analysis of variance, the cultivar effect was significant ($F$ = 5.5, $P$ < 0.01), where the mean ripe rot severity of Vignoles was significantly higher ($P \leq$ 0.05) than the others. None of other cultivars were significantly different from each other.




Since there were more ripe rot development we conducted an analysis of variance on disease incidence (Yes/No on ripe rot on a cluster). Based on a nominal logistic model, the cultivar effect was significant (Chi-square = 37.2, $P$ < 0.01), and as in the severity Petit Manseng resulted in significantly higher disease incidence ($P \leq$ 0.05) than the others. However, none of other cultivars were significantly different from each other.




In 2017, cultivar Vignoles was not assessed for diseases because the health of the vine was too poor to be considered in the experiment. However, I should note that many surviving vines had ripe rot infected berries.

Therefore, among tested cultivars, it is safe to say that both Vignoles and Petit Manseng were more susceptible than other cultivar against ripe rot. It should also be noted that Chambourcin seems to be more resistant to ripe rot than the other cultivars.

Originally, we proposed to have an inoculation experiment on detached berries; however, with initial few attempts, we quickly realized that it will be very challenging because the rate of successful inoculation varied, probably due to the combination of the age (health) of the spore, condition in the containers, and residual chemical or microorganism on berries. In addition, the field observation will provide more practical information than the lab experiments.

## GOALS AND OUTCOMES ACHIEVED

We completed a state-wide survey of vineyards, created a culture collection of over 1500 isolates of *Colletotrichum* species, and identified two *Colletotrichum acutatum* species within the complex (*C. fioriniae* and *C. nymphaeae*) and six *C. gloeosporioides* species within the complex (*C. aenigma, C. alienum, C. conoides, C. fructicola, C. kahawae* subsp., and *C. gloeosporioides*) and additional cryptic and subspecies.

Using a subset of thirty isolates, comprised of five *Colletotrichum* species, our lab screened a total of twelve commercial products that covered eleven a.i. and ten modes of action. We found that captan, and mancozeb controlled all five *Colletotrichum* species. Tetraconazole and thiophanate methyl could potentially serve as tank-mix partners for control. For the demethylase inhibitor (i.e. tetraconazole) and succinate dehydrogenase inhibitor (i.e. boscalid) classes, additional investigations are required. Previous studies suggest that insensitivity or resistance to one product in the class does not entail inactivity from all members.

We established a method to measure spore germination under high relative humidity. Although we tested only against five *Colletotrichum* species, the same method can be used for other moisture-driven fungus and bacteria pathogens such as *Botrytis cineria* which is a causal agent of Botrytis gray mold on grape and other fruits such as strawberry. We were also able to prove that all five *Colletotrichum* species tested were able to germinate after 48 hours under 100% relative humidity. *C. aenigma*, *C. fioriniae*, and *C. fruticola* were particularly active. This result supports the observations in the field. Late in the season when dew formation happens every morning, we tend to observe rapid increase in ripe rot disease development even without prolonged rain events. These results will help us to determine the most effective timing of protective fungicide applications.

With tested cultivars, we observed Vignoles and Petit Manseng being more susceptible to ripe rot than others. In addition, our previous research showed that Cabernet Sauvignon, Merlot, and Chardonnay are also susceptible. Thus, if you are growing wine grapes in warmer region, these cultivar probably need be managed to reduce the risk of ripe rot outbreak.

BENEFICIARIES

The main beneficiaries are wine grape growers in Virginia who suffer annually from this economically important fungal disease. Wine grape growers will be informed about selection of fungicide materials, and importance of keeping fruiting zone as open as possible via VA Cooperated Extension's meetings, and other media outlets such as industry newsletters.

The benefits will also extend to consumers since ripe rot is known to cause negative impact on wine flavor. This also means that wineries and people who are associated with wineries, such as people in the touring industry will also be benefited from better wine quality that should translate into better economic impact. A previous economic impact report showed the annual impact of Virginia wine industry is $1.2 billion, and more than 4,000 people are involved directly to the industry. As ripe rot has become a much larger issue in the past several years, this is an accurate reflection of beneficiaries from this project.

Since *Colletotrichum* species can also cause diseases on other fruits such as apple, strawberry and mango, our results will also benefit growers of these crops as well. Thus, even though the direct impact will be made in Virginia, the results will have international impact.

LESSONS LEARNED

It was unfortunate, but we learned that many of existing fungicide modes of action have limited efficacy against *Colletotrichum* species. This is a very important finding since many growers may think this mode of action is effective and may waste their time, money, and other resources. We are currently conducting a lab and field experiments with mixtures of two modes of action, which are showing some promising results.

We also learned about environmental conditions (i.e., high relative humidity) that help *Colletotrichum* species germinate. It is critical to educate growers to reduce the risk of ripe rot by creating a better (i.e., more open) canopy by removing excessive vegetation around fruiting zone of vines.

With tested cultivars, we observed Vignoles and Petit Manseng being more susceptible to ripe rot than others. In addition, our previous research showed that Cabernet Sauvignon, Merlot, and Chardonnay are also susceptible. A cultivar Chambourcin seemed to be less susceptible than others.

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ADDITIONAL INFORMATION

**Oral presentations of findings**

Oliver, C. and Nita, M. "Laboratory fungicide testing for control of *Colletotrichum* species isolated from Virginia vineyards", Virginia Vineyards Association, 24 Feb., 2018

Oliver, C. and Nita, M. "*In vitro* fungicide screening for *Colletotrichum* species isolated from Virginia vineyards", Cumberland-Shenandoah Fruit Worker's Conference, 30 Nov., 2017.

Oliver, C. and Nita, M. "Identification, histological investigation, and evaluation of potential fungicide controls of grape ripe rot *Colletotrichum* species" Plant Pathology, Physiology and Weed Science Departmental seminar, 19, Apr. 2017

Oliver, C. and Nita, M. "Survey and identification of wine grape ripe rot (*Colletotrichum gloeosporioides* & *C. acutatum* complexes) in VA vineyards" American Phytopathological Society – Potomac Division Meeting, 23, Mar. 2017.

Oliver, C. and Nita, M. "Investigations on infection Timing of Ripe Rot of grapes caused by *Colletotrichum* species complexes, & their sensitivity to the QoI fungicides" Southeast Regional Fruit and Vegetable Conference, 7, Jan. 2017.

Nita, M. and Bly, A. "Screening for QoI resistance among *Colletotrichum* species associated with ripe rot of grape in Virginia vineyards", American Phytopathological Society National Meeting, 1 Aug. 2016.

**Acknowledgements**

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**11.**

Final Report

Title: Evaluating Foliar Nutrients Effects on Fruit Quality and Yield of Two New Blackberry Cultivars

Organization: Virginia Tech

Project Lead: Jayesh Samtani

**PROJECT SUMMARY**

There is insufficient evidence that supplemental foliar nutrient applications improve fruit quality or increase crop yield. Virginia growers had limited information on two new thornless, primocane bearing blackberry cultivars- PrimeArk® Freedom and PrimeArk® Traveler. Both primocane cultivars are considered compatible for USDA hardiness zones 4-8. A study was conducted at the Hampton Roads Agricultural Research and Extension Center (AREC), Virginia Beach, VA (USDA zone 8A) with thirty-six PrimeArk® Freedom and Traveler plants each that were established on raised beds covered white woven polyethylene and supported by T-post trellis. The objective of this study was to determine if supplemental foliar treatments showed increases in total soluble solids (TSS) content, yield and fruit size. Treatments included foliar nutrients AgGrand (4-3-3); Sugar Express (40-10-40); K-Ace (0-0-25) and an untreated control. Six foliar applications treatments were applied from pre-bud to bloom through harvest in 2017, and five foliar applications were made in 2018 at the same plant development stage. There were no significant differences among treatments, on crop yield, TSS content, or overall fruit size. PrimeArk® Traveler yields were higher than Freedom and the PrimeArk® Traveler seems more suitable for cultivation in USDA zone 8A.

**PROJECT PURPOSE**

Primocane fruiting blackberry cultivars are of interest to growers that are seeking crop diversity, season extension and improved blackberry taste at farm stands and farm markets. When it comes to blackberry production, growers new and experienced, lack information on blackberry cultivars that perform well in Virginia. Educators do not have sufficient data from Virginia to back up any recommendations for cultivar consideration. Growers often have to rely on sources from outside of the state, or word of mouth knowledge from other growers, on blackberry cultivar performance. The proposed project evaluated newer cultivars for yield and performance in Virginia soils and climatic conditions, and evaluated if nutrient foliar applications will increase berry sweetness and firmness. These factors have an influence on shelf-life and consumer taste appeal, both important considerations while growing and marketing berries.

**PROJECT ACTIVITIES**

Two-year old, thornless primocane cultivars ‘Prime-Ark® Freedom’ and ‘Prime-Ark® Traveler’ were established at the Hampton Roads Agricultural Research and Extension Center. In total 36 blackberry plants for each of the two cultivars ‘Prime-Ark® Freedom’ and ‘Prime-Ark® Traveler’ (Nourse Farms, MA) were transplanted at 5’ center spacing on 24 April 2016, having three plants per replicate. Soil in the study site was amended with dolomitic limestone at rate of 3.25 tons/A in April 2016 as per the soil test recommendations. Beds of dimensions 2.5 ft. wide by 100 ft. long were made on 14 April, 2016 and were covered with 5 mil T-55 white, woven, polyethylene tarp (Reef

Industries, Inc., Texas). A 10’ wide furrow spacing was maintained between two blackberry rows and furrow area was seeded with perennial ryegrass on 21 April, 2016. Drip irrigation was installed on 25 April 2016, using polytubes with 2.0 gph pressure compensating emitters at planting hole. Blackberry plants were band fertigated with calcium nitrate on 30 June, 2016 to meet 185 lb nitrogen/A. In July 2016, T-trellis system using vertical posts of dimensions 4”x4”x10’ and with 2”x4” cross arms were installed, and the vertical post was secured 2 ft. into ground with concrete. Blackberry plants were treated with 10 oz/acre rate Brigade WSB to keep damage from Japanese beetles in check in July, 2016.

<u>2017.</u> Dormant canes were pruned in mid-February 2017 retaining three to five healthy canes per plant and were sprayed with Captan right after pruning. Plant leaves were collected (in accordance with Oregon State Univ. foliar analysis guidelines) and shipped to an independent lab. for initial analysis on April 10 prior to foliar application sprays, for a base line comparison after completion of foliar applications. Foliar nutrient treatments were applied using recommended label rates of: (i) Aggrand (4-3-3); (ii) Sugar Express (40-10-40); (iii) K-Ace (0-0-25) in total six times between 17 April, 2017 and 16 July, 2017 using a rechargeable cart-tank sprayer at 30 psi (Master Manufacturing, Paynesville, MN) with a ConeJet X20 nozzle (TeeJet, Springfield, IL). No surfactants were utilized. These treatments were compared to (iv) nontreated control. Through the growing season, plants were treated with insecticide to control for stinkbugs, Japanese beetle, raspberry cane borer, and Spotted Wing Drosophila (SWD). Primocanes were tipped two inches when they reached 3 ft. height to promote laterals and when those laterals reached 1.5 ft in length, they were tipped again. Periodically throughout the growing season, canes were supported on trellis. Additional samples of cane, tip die back sections, and root ball, were shipped to Dr. Chuck Johnson-Plant Pathologist at SPAREC for analysis. It was suggested that Ridomil be dispensed through drip irrigation on September 28, 2017. Soil samples were collected and soil was shipped for analysis on October 3, 2017 and indicated a pH level of 6.4 for this site.

<u>2018.</u> Dormant canes were pruned in mid-February 2018 and six healthy canes about 4 ft. high were retained for each plant. Plants were sprayed with Captan right after pruning. Foliar nutrient treatments were applied in total five times between 22 April and 8 July. Primocane bearing canes were pinched four to six inches starting mid-May when the primocane reached about 3 ft to 4 ft. and canes were pinched as needed through most of the summer season. Plots were treated with insecticidal sprays to control for stinkbugs, Japanese beetle, raspberry cane borer, and SWD.

*Data collection.* The plants were maintained as a double crop and yield data was collected on floricanes over summer season, and on primocanes, late summer through fall season. Yield data were collected by harvesting fruits three times a week during summer season, and twice over the fall season and fruits were weighed into U.S. No. 1, U.S. No. 2, and unclassified berries. US No. 1 berries are considered firm, developed, but not overripe, with an entire dark black color, and are free from disease, decay, or damage by insects or other mechanical means. US No. 2 berries are berries that fail to meet the requirements of US No. 1 berries. They do not contain more than 10%, by volume, of berries that are seriously damaged by any cause and not more than 2% of berries that are affected by mold and decay. Unclassified (unmarketable) berries were unable to be used for processing or local or shipping markets (USDA, 1997). Fruit size, fruit firmness and ◦Brix readings were taken on five fruits per plot to determine differences due to foliar treatments on the above mentioned fruit quality parameters (data not shown).

*Results.* When maintained as a double-crop, Prime Ark® Traveler seemed to have a higher yield over Prime Ark® Freedom. Traveler fruit size appeared to be smaller than Freedom but the Traveler fruit was slightly firmer than Freedom (data not shown).

**GOALS AND OUTCOMES ACHIEVED**

More growers in the state are now aware of the two primocane bearing cultivars. The information generated through this study dissuades growers (about 5 to 10% of the blackberry growers in state) from making blind foliar applications of nutrients with the goal to improve crop yield and fruit quality and reduce overall production costs. We are recommending 'Prime Ark® Traveler' as a cultivar suitable for production in coastal Virginia climactic conditions. The blackberry plots now at the Hampton Roads AREC also serve as an educational subject for various grower, consumer and student tours.

**BENEFICIARIES**

Findings from the study were disseminated at the Berry School in Petersburg, VA on March 8, 2018. The meeting was attended by ~90 berry growers. The information was also presented at the 2018 American Society for Horticultural Science meeting in Washington, D.C. where findings were disseminated to horticulture researchers, educators, and graduate students. We intend to present a poster on the study at the 2019 southeast regional fruit and vegetable conference in Savannah, GA. The information generated dissuades growers (about 5 to 10% of the blackberry growers in state) from making blind foliar nutrient applications with the goal to improve crop yield and fruit quality, and reduce overall production costs. We anticipate 'Prime Ark® Traveler' acreage in the state to increase in the coming two years.

**LESSONS LEARNED**

At the conclusion of this project, we now have a better understanding of the pests that attack blackberries in Virginia coastal climactic conditions and how to better control them. We also have a better understanding on how to prune and train blackberry plants when primocane bearing blackberry are maintained as a double-crop.

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**12.**
**Final Report**
**PROJECT TITLE**

- Bringing New Technology to Southwest Virginia Apple Producers: Establishing a High Density Demonstration Orchard
- Virginia Cooperative Extension (Carroll County Unit)
- Danny Peek, District Director, Virginia Cooperative Extension

PROJECT SUMMARY

In three counties in southwestern Virginia, all of the 57 apple growers are currently using traditional style and less efficient orchard planting systems. However, as apple production elsewhere in the United States moves towards high-density orchard systems producers must update their plantings in order to remain an economically viable enterprise in SW Virginia. This project will demonstrate the benefits of high-density apple systems to growers in southwest Virginia. Funds were used to develop a high-density demonstration orchard that will serve as a foundation for extension and research activities. The orchard includes 300-apple trees total, representing 10 cultivars, to allow for productions comparisons between cultivars. The cultivar trial will allow for more in-depth demonstrations in pruning, training, and variety performance within the trellis system. By utilizing a demonstration high-density orchard, producers in the area we have direct access to seeing the performance of highly productive orchard systems in their unique climate. The establishment of the orchard occurred April 18, 2016.

Since the orchard was established, very little fruit has been harvested, thus hard to compare varieties based on yield. The most significant accomplishment has been getting the orchard established. Thus, giving growers in the area the opportunity to learn all that is involved in the process. In addition, it has allowed educational programs to help producers learn correct pruning techniques for this new system, as well as the traditional system.

PROJECT PURPOSE

This project is important and timely because the number of apple producers in southwest Virginia is slowly declining; in Carroll County alone from 2007 to 2012 there was a decrease from 37 to 25 apple producers. Many producers and their children do not see the profitability in growing apples, and farms are going out of production. I hypothesize that these systems could invigorate their operations leading to growth and profitability that would keep the apple industry alive and prosperous in southwest Virginia.

The primary objective of this project is to create a demonstration high-density apple orchard used to educate producers about changes in the apple industry regarding trellis systems. The demonstration orchard would be a high-density planting called tall spindle allowing producers to observe for themselves that these systems work in the climate of southwest Virginia. The planting will also consist of a variety of cultivars and rootstocks so the producers can see what works well in the system and area. The use of this demonstration orchard would be multifaceted; serving as a location for field experiments, field days, and multiple programming events.

Directly, this project does not have the potential to enhance the competitiveness of non-specialty crops.

This project is not a continuation of a project that the Specialty Crop Competitive Grant (SCCG) funded previously.

PROJECT ACTIVITIES

The project site was prepared for planting the high-density orchard. After fruit trees and trellis materials were purchased, the orchard was established in April of 2016. Producers and Extension faculty have participated in educational programs on site. Since the orchard was established, four organized events such as field days and trainings have taken place at the orchard site.

There are a limited number of apple producers in Southwest Virginia; however, several producers exist in this one area of Carroll County. Throughout the duration of this project, many of these producers have visited the high-density orchard to evaluate the production system and variety performance within the system.

- Site was prepared for orchard establishment.
- The high-density apple orchard was established on Bethany Hill's farm in Cana Virginia, April 2016
- 550 apple trees consisting of 10 cultivars were transplanted to demonstrate the production system of a high-density orchard. The trellis system was established, and the trees have been attached to a trellis system and have become productive.
- Suzanne Slack, Extension Agent has conducted one field day on sight to discuss the project and its potential impact for producers. In addition, producers from neighboring counties have visited the site on tree fruit tours.
- Virginia Cooperative Extension conducted a fruit orchard tour in 2017. This orchard was Virginia Cooperative Extension conducted a fruit orchard tour in 2017. This orchard was part of that tour.
- Virginia Cooperative Extension Specialist used the orchard to provide trainings for farmers
- Yield and quality data will be collected once the orchard begins to produce fruit.

GOALS AND OUTCOMES ACHIEVED

- The high-density demonstration orchard consisting of ten cultivars and a total of 550 trees was established in April 2016. has been established. One hundred and twenty two apple producers, industry and Extension personnel have participated in educational programs on how to establish a high-density orchard, pruning, and application of crop protectants since the beginning of the project. Through an annual field day Producer will continue to learn about producing apples in a high density, trellis system. Yield and quality data will be collected, summarized, and distributed to producers throughout Southwest Virginia region.

- Based on observation yield can be drastically increased on a per acre basis. However, the system will require more intensive management.

- Meaningful yield data will be collected and summarized in the 2019 production year. This will enable growers to calculate the benefit or potential return on initial investment.

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BENEFICIARIES

- The primary beneficiaries were apple producers in Carroll, Patrick, and Wythe Counties. However, numerous other producers from other Virginia Counties, as well as North Carolina producers benefited from the project and will continue to benefit from data disseminated from the project.
- Approximately 112 current apple producers benefited from the project
- Producers were able to visual see the production system and have \experienced Extension professionals answer production and production cost questions with no risk to their own operation.
- Producers were able to compare varieties for their production capabilities within this high-density trellis system.
- Berrier Farms Orchard has established seven acres of high-density orchard using the trellised system.

LESSONS LEARNED

- This project should have been designed to continue for a longer time period to ensure the opportunity to collect more meaningful yield data. The establishment of the orchard was timely; however, production of new orchard is slow. Thus, the delay in collecting any yield data that would significantly influence producers' decisions regarding varieties best suited for the area and production system has been much slower.

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ADDITIONAL INFORMATION
N/A

**13.**
**Final Report**
**PROJECT TITLE:** Facilitating Coriander Production in Virginia
Organization: Virginia State University
Project Lead: Harbans Bhardwaj (Additional investigators: Dr. A.A. Hamama and Dr. C. Kim)

PROJECT SUMMARY

This project conducted field trials in Virginia with a goal of developing cilantro (greens stage of the plant) and coriander (seed stage) and identified a new slow-bolting variety, identified several varieties with potential for facilitating fall-planted and spring-planted coriander/cilantro production, established that fall-planted crop can be successful for harvest in late winter and early spring, identified that 15-inch rows are superior than 30-inch rows, and obtained considerable information about health-related properties of cilantro and coriander. It was observed that both cilantro and coriander have considerable concentrations of anti-oxidants. A laboratory study revealed infestation with harmful micro-organisms such as yeast/mold, coliform bacteria, and mesophiles varied based on the store and cilantro produced at university farm had the least population of these micro-organisms.

PROJECT PURPOSE:

Objectives of this project were: characterization of available germplasm of coriander for plant and seed traits, breeding coriander to develop/identify superior coriander cultivars, and identification of optimal production practices for coriander production.

This project aimed to facilitate production of coriander in Virginia to meet the food demands of immigrants from South Asia and Central/South America. Considerable markets exist in metro areas around Washington, D.C. and New York for green leaf stages of coriander (Known as cilantro). An informal survey of four South Asian ("Indian") and three "Mexican" stores in Richmond (Virginia) area indicated that a robust local demand exists for CILANTRO - green leaf stages of coriander. In addition, considerable demand for coriander seeds exists locally and at national/international levels.

This effort's long term goal is to develop/establish coriander as specialty crop for Virginia farmers. This project will help provide a source of coriander for use by extensive local immigrant populations around Washington, D.C., help provide alternatives for Virginia farmers to produce coriander to enhance their farm incomes, and help food-related industries in Virginia by providing them raw materials.

This project was not built on any previously-funded project.

PROJECT ACTIVITIES:

<u>Germplasm evaluations:</u> A total of 185 coriander accessions were obtained from USDA-ARS-Regional Plant Introduction Station, Ames, Iowa. All these accessions were planted during 2016 at Randolph Farm of Virginia State University in spring and summer of 2016. Both these experiments were un-successful. All these accessions were planted again on November 2, 2016 and it was observed that all accessions except for about 14 survived winter and produced seed. This indicates that coriander can be planted in the fall in Virginia for harvest during the next late spring. An additional experiment was planted on July 6, 2017. About half of these accessions produced seed. Twenty-nine accessions were identified to be slow-bolting (Ames 4998, Ames 18562, Ames 18563, Ames 18564, Ames 18568, Ames 18569, Ames 18570, Ames 18574, Ames 18590, Ames 19932, Ames 19089, Ames 20048, Ames 24911, Ames 24915, Ames 24921, Ames 24924, Ames 24925, Ames 24928, Ames 25174, Ames 25175, Ames 27392, PI 171592, PI 172808, PI 268378, PI 483232,

PI 531296, PI 665271, PI 669953, and PI 674286). These results are from only one year's observations and may need to be obtained from repeated experiments.

Development of Superior Coriander/Cilantro Varieties:

Field experiments were conducted with several commercially-available varieties (Calypso, Cruiser, Marino-Organic, Santo, and Santo-Monogerm). These trials also included a coriander/cilantro variety of unknown origin (the seed was purchased from a grocery store) tentatively named "Indian". This variety had dwarf plants and were observed to be heat-tolerant and slow-bolter. It is expected that further studies with this variety might results in development/establishment of a superior coriander/cilantro variety. The plant breeding procedure of mass selection was used to select several plants of this variety to constitute a bulk population for future studies. It is feasible that several accessions from USDA-ARS germplasm could also be good candidates for development of superior varieties in the future.

Production research:

Several experiments were conducted to determine/identify optimal practices for coriander/cilantro production in Virginia with following results:

Table 1: Seed (Coriander) and green plant material (Cilantro) yield as effected by varieties and inter-row spacing.

| Treatment | Sub-treatment | Dry seed (Coriander) Pounds/acre | | Green plant material (Cilantro) pounds/acre | |
|---|---|---|---|---|---|
| | | 2015 | 2016 | 2015 | 2016 |
| Variety | Santo | 1556 a | 1280 a | 5782 a | 9476 a |
| | Santo-Monogerm | 1029 b | 1279 a | 5424 a | 11825 a |
| | Marino-Organic | 819 b | 869 b | 3456 a | 11561 a |
| Row spacing | 15-inch | 1427 a | 1334 a | 6894 a | 15153 a |
| | 30-inch | 877 b | 951 b | 2881 b | 6755 b |

Table 2: Composition of seed (Coriander) as effected by varieties and inter-row spacing during 2015 and 2016.

| Treatment | Sub-Treatment | Protein (%) | Iron (PPM) | Copper (PPM) | Zinc (PPM) |
|---|---|---|---|---|---|
| | | 2016 | 2016 | 2016 | 2016 |
| Variety | Santo | 14.9 a* | 76.5 a* | 12.5 a* | 26.0 a* |
| | Santo-Monogerm | 16.2 a | 92.2 a | 14.0 a | 29.0 a |
| | Marion-organic | 14.6 a | 76.7 a | 12.5 a | 22.0 a |

| | | | | | |
|---|---|---|---|---|---|
| Row Spacing | 15-inch | 14.8 a | 86.2 a | 13.2 a | 26.5 a |
| | 30-inch | 15.6 a | 77.5 a | 12.8 a | 24.8 a |

* Means followed by similar letters within sub-treatments were not significantly different according to Duncan's Multiple Range Test.

Table 3: Composition of green plant material (Cilantro) as effected by varieties and inter-row spacing during 2015 and 2016.

| Treatment | Sub-treatment | Protein (%) | | Iron (PPM) | | Copper (PPM) | | Zinc (PPM) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Variety | Santo | 17.1 a* | 14.9 a* | 89 b* | 76.5 a* | 12.0 b* | 12.5 a* | 27.2 a* | 26.0 a* |
| | Santo-Monogerm | 16.5 a | 16.2 a | 84 b | 92.2 a | 13.5 a | 14.0 a | 29.5 a | 29.0 a |
| | Marion-organic | 17.2 a | 14.6 a | 118 a | 76.7 a | 13.2 a | 12.5 a | 28.7 a | 22.0 a |
| Row Spacing | 15-inch | 17.7 a | 14.8 a | 104 a | 86.2 a | 13.3 a | 13.2 a | 30.8 a | 26.5 a |
| | 30-inch | 16.2 a | 15.6 a | 91 b | 77.5 a | 12.5 a | 12.8 a | 26.2 a | 24.8 a |

* Means followed by similar letters within sub-treatments were not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Table 4. Composition of green plant material (Cilantro) as effected by varieties when planted on October 19, 2017 and harvested on April 26, 2018 (values as percentages on dry weight basis unless otherwise indicated)*

| Trait | Average | Minimum | Maximum |
|---|---|---|---|
| Foliage yield (pounds/acre) | 11,213 | 7,515 | 12,921 |
| Protein | 17.6 | 11.9 | 19.7 |
| Oil | 2.58 | 2.36 | 2.84 |
| Fructose** | 6.13 | 2.85 | 11.33 |
| Glucose** | 6.66 | 4.22 | 14.15 |
| Sucrose** | 0.98 | 0.27 | 1.65 |
| Raffinose** | 0.03 | 0.00 | 0.14 |
| Stachyose** | 0.02 | 0.01 | 0.03 |
| C14:0*** | 2.16 | 1.22 | 2,76 |
| C14:1*** | 0.93 | 0.34 | 1.21 |

| | | | |
|---|---|---|---|
| C16:0*** | 29.93 | 28.04 | 34.32 |
| C16:1*** | 13.53 | 12.19 | 15.52 |
| C18:0*** | 1,73 | 1.36 | 2.95 |
| C18:1*** | 1.96 | 0.89 | 4.03 |
| C18:2*** | 30.41 | 27.73 | 34.04 |
| C18:3*** | 17.9 | 14.86 | 20.28 |
| C20:0*** | 0.44 | 0.36 | 0.57 |
| C22:1*** | 0.52 | 0.38 | 0.79 |

* Means over two replications and five varieties (Calypso, Indian, Santo, Santo Monogerm, and Marino Organic.
** Sugars (Raffinose and Stachyose are anti-nutritional sugars).
*** Fatty acids in oil (C18:3 is Omega-3 fatty acid which is considered healthy for human diets, C22:1 is erucic acid which is considered undesirable for human diet).

Additional studies:

Due to increasing interest in health-related properties of coriander/cilantro, additional experiments were conducted with following results:

Table 5. Anti-oxidants in coriander/cilantro grown during 2016 at Petersburg, Virginia

| Crop | Variety | Trolox | DPPH | TPC |
|---|---|---|---|---|
| Cilantro | Marino-Organic | 10.44 a* | 48.9 a | 5.09 a |
| | Santo | 10.24 a | 47.9 a | 4.99 ab |
| | Santo-Monogerm | 9.67 a | 50.1 a | 4.77 b |
| Coriander | Marino-Organic | 5.44 a | 66.2 a | 1.24 ab |
| | Santo | 5.98 a | 65.7 a | 1.36 a |
| | Santo-Monogerm | 5.25 a | 69.2 a | 0.85 b |
| | | | | |

* Means followed by similar letters were not statistically different according to Duncan's Multiple Range Test at 5% level of significance.

Table 6. Comparison of anti-oxidants in coriander and cilantro grown during 2016 at Petersburg, Virginia

| Crop | Trolox | DPPH | TPC |
|---|---|---|---|
| Cilantro | 10.10 a* | 48.9 b | 4.95 a |

| | | | |
|---|---|---|---|
| Coriander | 5.55 b | 67.0 a | 1.15 b |
| | | | |

* Means followed by similar letters were not statistically different according to Duncan's Multiple Range Test at 5% level of significance.

Table 7. Population of microorganisms recovered from cilantro samples acquired from Randolph Farm and local stores.

| Sample ID | Total mesophiles (log CFU/g) | Yeast and Mold(log CFU/g) | Coliforms (log MPN/g) |
|---|---|---|---|
| Farm[1] | 3.3 | 3.3 | 2.0 |
| Store 1 | 7.1 | 4.7 | 3.2 |
| Store 2 | 7.1 | 5.1 | >4.0 |
| Store 3 | 6.0 | 4.5 | 2.6 |

GOALS AND OUTCOMES ACHIEVED

This project has made considerable progress as per the following details:

1. A germplasm collection consisting of 185 accessions, received from USDA-ARS, was evaluated by planting during fall of 2016 and summer of 2017. Most accessions survived the winter. Several accessions performed well during summer of 2017 and 29 accessions were identified to be slow-bolting.
2. Field evaluations with several coriander/cilantro varieties and a new variety were conducted. The new variety of unknown origin (The seed was purchased from an ethnic grocery store) had plants with shorter height than other varieties (Calypso, Cruiser, Marino-Organic, Santo, and Santo-Monogerm) is tentatively named "INDIAN". Plants of this new variety were considerably later in flowering (slow bolting).
3. Extensive production research indicated that cilantro (Green plant material) yields in Virginia could be expected to range from 3456 to 11825 pounds per acre with an average of 7920 pounds per acre.
4. Extensive research indicated that coriander (Mature seed) yields in Virginia could be expected to range from 819 to 1556 pounds per acre with an average of 1139 pounds per acre.
5. Extensive research indicated that between row spacing resulted in superior seed and green foliage yields.
6. An important observation was that coriander planted in the fall could provide good yield of cilantro in late winter and early spring of the following year, thus, facilitating local production and to reduce dependence on imports from other areas.
7. Concentrations of protein (%), iron (ppm), copper (ppm, and zinc (ppm) in coriander seed were observed, respectively, to be 15.2, 81.8, 13.9, and 27.7. The corresponding values for cilantro were 16.1, 89.4, 12.9, and 27.1, respectively.
8. Cilantro produced in Virginia contained about 2.6 percent oil, considerable concentrations of desirable and un-desirable sugars, approximately 18 percent Omega-3 fatty acid, and negligible concentration of erucic acid.

9. Cilantro was observed to contain considerable concentrations of anti-oxidants which are considered anti-inflammatory and are desirable for human diet. Cilantro was observed to contain significantly higher concentration of Trolox, an important measure of anti-oxidant activity.
10. A study was conducted to determine occurrence of harmful micro-organisms in cilantro. The cilantro produced at university farm had considerable lower populations of total mesophiles, yeast and mold, and coliforms.
    **Recommendations:** This research suggested that Santo is a desirable variety, as of now, for cilantro and coriander production in Virginia. This research also indicated that 15-inch between row spacing should be used.

All proposed activities were completed except for organic production.

BENEFICIARIES:

This was, essentially, an applied research effort to help in introduction/establishment of coriander/cilantro as an alternative crops for Virginia farmers. The results will be disseminated via publications in refereed journal. Most results from this project were presented at a field day held on June 17, 2017. Approximately 100 persons visited the booth that was established near the field plots. Several Asian and Latino persons expressed interest in a "pick-your-own" type of production on a continuous basis after they were invited to harvest cilantro from the field of a farmer where about half-acre each of Calypso, Cruiser, and Santo varieties were produced.

LESSONS LEARNED

Some experiments were conducted in cooperation with a certified organic farmer but these experiments were unsuccessful due to lack of stand establishment and appropriate management of weeds. Organic production research should be conducted at university farm to facilitate better crop production activities.

CONTACT PERSON

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ADDITIONAL INFORMATION

NONE

Project Income: NONE

**14.**
**Final Report**
**Establishment of Green Tea Production in Northern VA**
**Virginia Tech**
**Mizuho Nita**

## PROJECT SUMMARY

The main objective of this project was to determine if green tea production is suitable for northern VA area. Tea is the world's most popular drink. In 2010, the world tea production increased annually by 2.6%. Tea tree cultivation does not require heavy equipment or specialized cropping systems; it is disease resistant and yields 300 to 1,740 lb/acre, and it can be sold for $15 or more per oz. Having a major metropolitan area nearby, Virginia has a great opportunity to develop local tea production. The diverse population, an increase in specialized beverage consumption and the area's increasing affluence and educated public are now coupled with a desire to eat healthier and locally-grown products. Virginia is poised for its entry into this new area of agricultural affluence; however, a cogent plan and study was needed. Our three-year two-location study regrettably discovered that green tea production was very challenging, most likely due to the soil type and cold tenderness of the transplant materials. Our study also indicated that the interest level is very high in the area, and by planting seeds (rather than purchasing plant material), tea trees may have a better chance of survival under Northern VA environmental conditions.

## PROJECT PURPOSE

The level of interest for green tea production in Northern VA was high prior to the beginning of the project. We did not have any issues obtaining letters of support from local growers, tea distributers, and tea houses at the time of grant application. However, there were no history of growing green tea in the area. Thus, our objectives focused on whether we can grow them, and if the use of high tunnel structure can help winter survival or not.

The original objectives: 1) Examine three cold hardy tea cultivars for their cropping potential under Northern VA; 2) Determine the effect of two pesticide regimens (organic and conventional) on fungal and insect pathogens of tea; 3) Examine the effect of a high tunnel on tea trees.

## GOALS AND OUTCOMES ACHIEVED

## PROJECT ACTIVITIES

2015-16: First planting

We planted four cultivars (‘Sochi’, ‘large leaf’ (generic long leaf cultivar without a cultivar name), ‘Christine’s choice’, and ‘Korean’) in 2016, and set up high tunnels at AHS Jr. AREC at Winchester, VA and Green Hill Garden at Lovettsville, VA. Tea plants were purchased from a collaborator, Camelia forest in Chapel Hill, NC who also heled us select cultivars. At both locations, there were two blocks, a block with a high tunnel and the second block exposed to the air. Within each block, there were two rows that further divided into two subplots. Within each subplots, cultivars were planted as a group of three trees. The location of each triplet within the subplot was random. Since soil pH at both locations were not ideal (i.e., above 6.0), we constructed raised beds which were filled with a combination of peat moss and top soil. Then we applied pine needle mulch on the surface to promote lower pH, which tea plants prefer. We monitored pH level throughout the course of the season and added sulfur soil amendment as needed.


Tea trees shortly after planting at AHS AREC


In October 2016 at Green Hill Garden, near the end of the season.

Issues observed in 2016: We noticed feeding damages from Japanese beetle, mites, and leaf spot (probably caused by a fungal pathogen *Colletotrichum* sp.), but none are severe enough to warrant an action against them.

2017: Winter damage

Although we reinforced the base of the high tunnels with cement and construction of doors and supports at the end of the structure to make it more stable, both high tunnel structures collapsed after only 2 inches of snow. Trees were kept under the cover for the entire winter.

In May 2017, assessment of plant survival was conducted to find out that nearly 97% of trees were dead, regardless of plastic cover, and only a few produced leaves.

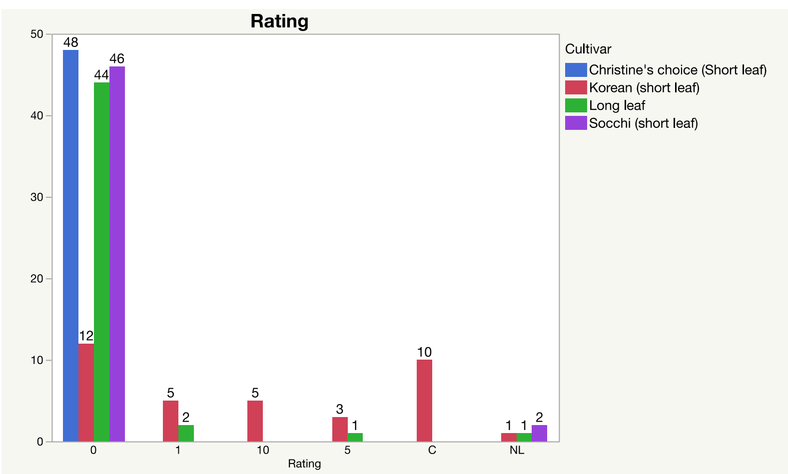



Figure above shows an example from Winchester AREC. We rated trees as follows (0 = dead, 1-3 leaves on the tree, 5 = 3-5 leaves on the tree, 10 = 5-10 leaves on the tree, C = more than 10 leaves on the tree, and NL = no leaf, but vascular systems are still somewhat green). Different colors represent different cultivars.

The results from at the second location (Green Hill Garden) were very similar. They recorded 98% plant loss).

2017: Modification of objectives and replanting.

The modified objectives: 1) Examine two additional cold hardy tea cultivars for their cropping potential under Northern VA; 2) Communicate with potential growers to understand the local interest level for tea production.

We replanted our plots with three cultivars: 'Black sea', 'Korean' and 'small leaf' (generic cultivar with no name). All are small leaf cultivars, and known for better winter survival. We tested Korean in 2016, and decided to repeat in 2017 because relatively speaking, it survived better (please see the figure above). In addition, we used sulfur soil amendments to aggressively lower pH. At both locations, pH were in lower 6 or upper 5. Each row of planting was divided into two subplots and within two subplots, ten of the same cultivars were planted. The location of each cultivar was randomly selected. The only exception was cv 'Black sea' which was planted in a boarder row.

At the end of the season (Oct 2017), trees looked much healthier than what we observed in Oct 2016 (please see the image above).

Issues observed in 2017: We noticed feeding damages from Japanese beetle, aphids, mites, and leaf spot (probably caused by a fungal pathogen *Colletotrichum* sp.), but none are severe enough to warrant an action against them.

2018: Winter damage

The winter of 2018 was relatively warm; however, temperature dropped sharply in the beginning of January and there were a few days in March when we experienced very cold nights (< -10 C).

We waited until June 2018 to rate survival of the tea plants. We did not see any leaves on any of trees. (Please note that in a typical tea production, the first harvest should happen in May.) Root development seemed to be better than that of 2016, which was very weak. We believe that lowered soil pH helped the trees. We cut into every tree to see if we can see any sign of life. We recorded 0 = dead, 1= have partially green vascular system, 2 = have more than 80% green vascular system. At AHS AREC location, we used a plastic horticulture cover (ground cover) on the ground to protect roots from freezing. It was applied two rows while the other two rows were not covered.

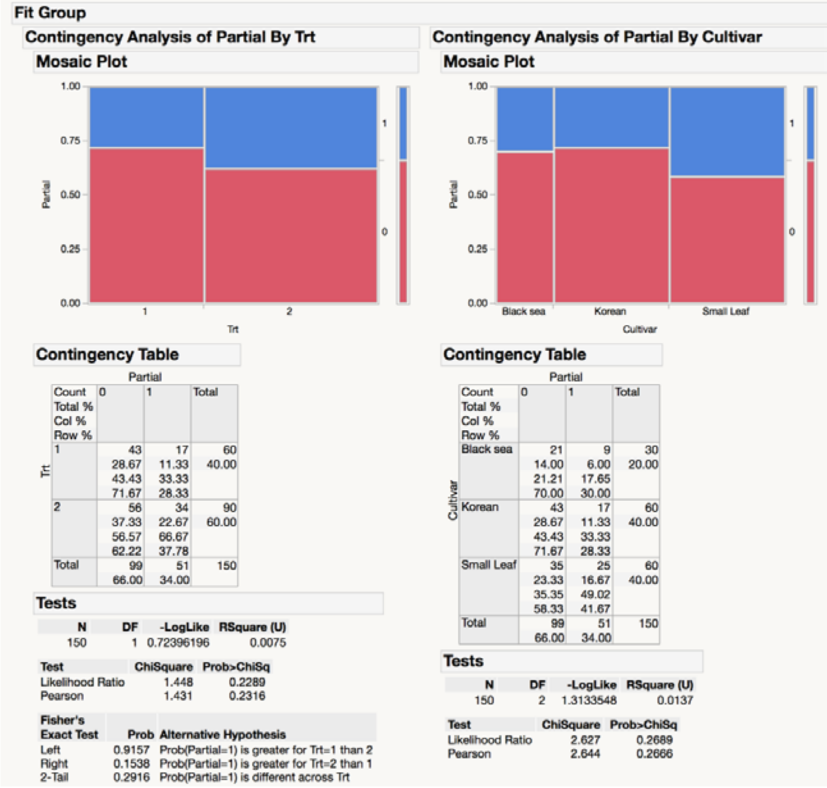

Example of the category 1, have partially alive vascular tissue.


Example of the category 2, have more than 80% alive vascular tissue (note the brown discoloration on the central part of the tree).

On partially alive (have some level of green vascular tissue)

Completely dead = 66%, some level of green vascular tissues = 34%

The effect of treatment (ground cover) and cultivar was both not significant.




**Contingency Analysis of Partial By Trt**

Contingency Table

| Trt (Count / Total % / Col % / Row %) | Partial 0 | Partial 1 | Total |
|---|---|---|---|
| 1 | 43 | 17 | 60 |
| | 28.67 | 11.33 | 40.00 |
| | 43.43 | 33.33 | |
| | 71.67 | 28.33 | |
| 2 | 56 | 34 | 90 |
| | 37.33 | 22.67 | 60.00 |
| | 56.57 | 66.67 | |
| | 62.22 | 37.78 | |
| Total | 99 | 51 | 150 |
| | 66.00 | 34.00 | |

Tests

| N | DF | -LogLike | RSquare (U) |
|---|---|---|---|
| 150 | 1 | 0.72396196 | 0.0075 |

| Test | ChiSquare | Prob>ChiSq |
|---|---|---|
| Likelihood Ratio | 1.448 | 0.2289 |
| Pearson | 1.431 | 0.2316 |

| Fisher's Exact Test | Prob | Alternative Hypothesis |
|---|---|---|
| Left | 0.9157 | Prob(Partial=1) is greater for Trt=1 than 2 |
| Right | 0.1538 | Prob(Partial=1) is greater for Trt=2 than 1 |
| 2-Tail | 0.2916 | Prob(Partial=1) is different across Trt |

**Contingency Analysis of Partial By Cultivar**

Contingency Table

| Cultivar (Count / Total % / Col % / Row %) | Partial 0 | Partial 1 | Total |
|---|---|---|---|
| Black sea | 21 | 9 | 30 |
| | 14.00 | 6.00 | 20.00 |
| | 21.21 | 17.65 | |
| | 70.00 | 30.00 | |
| Korean | 43 | 17 | 60 |
| | 28.67 | 11.33 | 40.00 |
| | 43.43 | 33.33 | |
| | 71.67 | 28.33 | |
| Small Leaf | 35 | 25 | 60 |
| | 23.33 | 16.67 | 40.00 |
| | 35.35 | 49.02 | |
| | 58.33 | 41.67 | |
| Total | 99 | 51 | 150 |
| | 66.00 | 34.00 | |

Tests

| N | DF | -LogLike | RSquare (U) |
|---|---|---|---|
| 150 | 2 | 1.3133548 | 0.0137 |

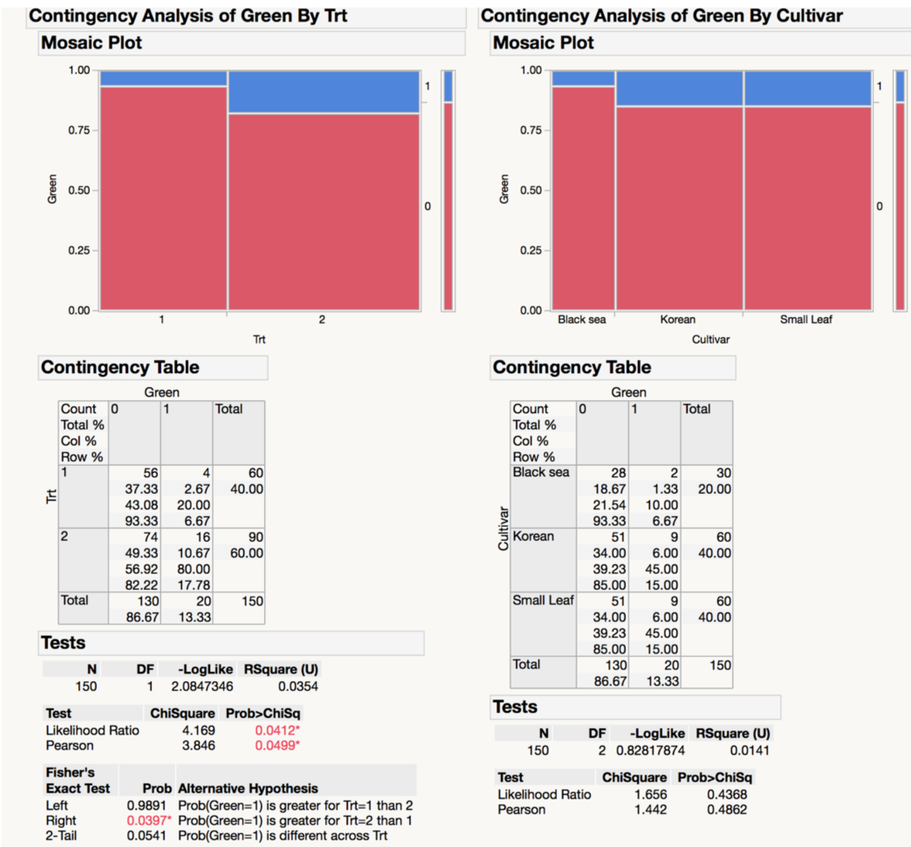
| Test | ChiSquare | Prob>ChiSq |
|---|---|---|
| Likelihood Ratio | 2.627 | 0.2689 |
| Pearson | 2.644 | 0.2666 |

In the figure above, red part of the figure represents dead trees and blue part represent “live” trees (trees with at least some green vascular tissues). The statistical test examined the effect of treatment (1 = no cover and 2 = ground cover), and cultivar (Black sea, Korean, and small leaf) using chi-square test.

On partially alive (have more than 80% of green vascular tissue)

Completely dead = 87%, > 80% of green vascular tissue = 13%

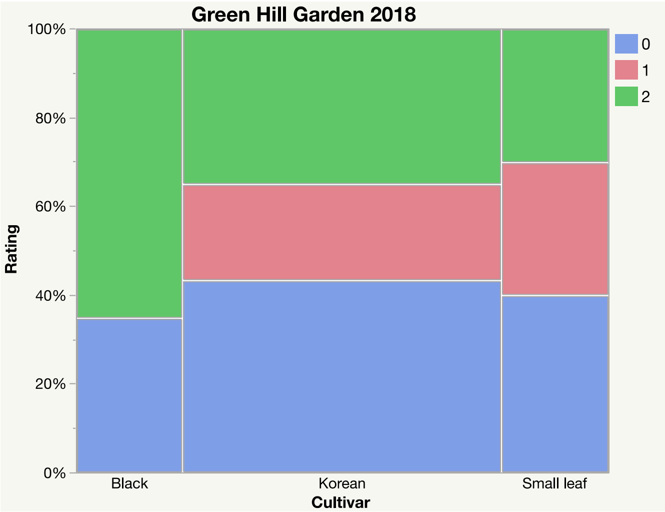
The effect of treatment (ground cover) was statistically significant based on chi-square test to determine the probability of survival between two treatments (*P* = 0.04), but that of cultivar was not significant (*P* = 0.44). With the winter cover, there was significantly more trees survived; however, we are comparing 3% survival to 10% survival.




In the figure above, red part of the figure represents dead trees and blue part represent “live” trees (trees with at least 80% green vascular tissues). The statistical test examined the effect of treatment (1 = no cover and 2 = ground cover), and cultivar (Black sea, Korean, and small leaf) using chi-square test.

Thus, we showed that the positive effect of the winter ground cover, but we still consider it is not commercially acceptable to have nearly 90% dead tree and no leaves in June. Moreover, as we noted above, we did not see any foliage emerging in June.

The second plot at Green Hill Garden did not have any ground cover; however, better percentages of trees with green vascular tissues. A total of 41% of trees appeared as dead, while 59% showed some level of green vascular tissues. A total of 40% trees showed more than 80% of vascular tissues being green at the time of assessment (June 2018). As with the AREC location, there were no leaves on the trees, and no sign of active buds.




In the figure above, blue, red, and green portion represents, dead, tree with some level of green vascular tissue, and tree with more than 80% green vascular tissues, respectively.

**Ordinal Logistic Fit for Rating**

**Whole Model Test**

| Model | -LogLikelihood | DF | ChiSquare | Prob>ChiSq |
|---|---|---|---|---|
| Difference | 1.69908 | 2 | 3.398165 | 0.1829 |
| Full | 103.06196 | | | |
| Reduced | 104.76105 | | | |

| | |
|---|---|
| RSquare (U) | 0.0162 |
| AICc | 214.545 |
| BIC | 224.545 |
| Observations (or Sum Wgts) | 100 |

**Lack Of Fit**

| Source | DF | -LogLikelihood | ChiSquare |
|---|---|---|---|
| Lack Of Fit | 2 | 4.66418 | 9.328359 |
| Saturated | 4 | 98.39778 | Prob>ChiSq |
| Fitted | 2 | 103.06196 | 0.0094* |

**Parameter Estimates**

| Term | Estimate | Std Error | ChiSquare | Prob>ChiSq |
|---|---|---|---|---|
| Intercept[0] | -0.5291295 | 0.2355915 | 5.04 | 0.0247* |
| Intercept[1] | 0.26291973 | 0.2313944 | 1.29 | 0.2559 |
| Cultivar[Black] | -0.6281149 | 0.335807 | 3.50 | 0.0614 |
| Cultivar[Korean] | 0.30354327 | 0.2589517 | 1.37 | 0.2411 |

**Effect Wald Tests**

| Source | Nparm | DF | Wald ChiSquare | Prob>ChiSq |
|---|---|---|---|---|
| Cultivar | 2 | 2 | 3.67338581 | 0.1593 |

**Effect Likelihood Ratio Tests**

| Source | Nparm | DF | L-R ChiSquare | Prob>ChiSq |
|---|---|---|---|---|
| Cultivar | 2 | 2 | 3.39816481 | 0.1829 |

Since there were slight difference among cultivars, we conducted ordinal logistic analysis. However, cultivar effect was not statistically significant ($P$ = 0.16), indicating that cultivar effect did not significantly affect the rate of trees with green vascular tissues.

The trees with better vascular system may survive (i.e., sprout out from root), but unfortunately, we concluded that even with different cultivar selection and the use of ground cover, green tea did not survive the winter of Northern VA.

We noticed considerably better root development in 2017 than 2016. Better cultivar selection and aggressive pH management probably resulted in the difference.

***Additional observation:*** Independent of our project, there was a new planting at Green Hill Garden that was started from seeds sown on the ground and covered with a plastic mulch in 2015. The rate of germination was about 85%, about 95% of these trees survived until 2018. It was also observed, that transplanted trees from pots, which were prepared by Green Hill Garden in their green house, had a low survival rate. These observations indicate that if we grow from seeds to make trees accommodate to the soil and winter environment, we may have a better chance to establish tea trees in our area. In addition, Green Hill Garden planted another cultivar in 2017, which came from a high elevation growing area in Korea. This planting has been as successful as the planting in 2015 (pictures are attached in the "additional information" section). Thus, with right combinations of cultivar and planting methods, it is probably possible to grow green tea under our (Northern VA) environmental conditions. However, compared with propagated plants, it will take more years before it matures, thus, this method may not be appealing to potential commercial growers. More research is necessary to determine this will hold truth for coming years.

 Tea plants at Green Hill Garden, grown from seeds and protected with a ground cover (planted in spring 2015 and pictured in Nov. 2017).

One of objectives of this study was to disseminate information about green tea production to potential growers. This project captured the interest of the Green Tea Group (in the near future “Virginia Tea Association”) formed of two potential growers, two owners of tea shops, one person with experience on harvesting and processing, and the Loudoun County Commercial Horticulturist. Its main focus right now is to establish Best Management Practices for green tea production, which include correct site and aspect, appropriate varieties, adequate sun and shade exposure and weed control techniques. The group has met on March, April and May 2018.

BENEFICIARIES

Beneficiaries are potential green tea growers and other stakeholders in Northern VA area. We hosted monthly informal meetings, with the producer, from the time the project started until February 2018, they were aware of the challenges and issues that the cultivation of this alternative crop could face.

LESSONS LEARNED

Due to destruction of high tunnels and an additional planting, we were not able to achieve two of our objectives: use of high tunnel and measurements of disease and heavy metals. Stronger construction materials could help, but it will be more expensive and may not be practical. There was an evidence of benefits (= better rate of tree survival) with winter ground cover.

We observed minor damages from mites, aphids, Japanese beetle, and leaf scorching, but none were significant enough to warrant an action (e.g., insecticide application). This could indicate that tea plants may not require many inputs for pest management. Since no trees survived the winter, we did not find a need for chemical analysis for heavy metals. More research is required in this topic.

On the blight side, we identified still strong local interests for locally grown green teas among potential growers and suppliers, which resulted in a total of three meetings in 2017-18. In addition, although it was not the scope of this project, we found that tea plants that were grown from seeds may survive better in winter even in our environment.

In addition, the area with milder winter conditions and potentially lower soil pH (e.g., no limestone bed rocks), such as eastern shore VA or southern piedmont area, might be a better location for green tea production in VA. More research is required to confirm our hypothesis.

Regrettably what we found out was the difficulty of green tea production in Northern VA area. We found more than 60% of trees with significant (< 80%) damages on the vascular system even with supposedly winter hardy cultivars. Please note that there are several commercial tea plantings in the north of VA (e.g., NY), thus, this level of mortality, which were repeated twice in two different locations, was quite surprising for us. We also noticed that keeping pH low enough for tea production is another challenge. At both locations, even though we started with a mixture of peat moss and top soil that were topped with pine needle mulch, we consistently needed to add sulfur to lower the soil pH level. Also, as noted above, plants grown from seeds may able to overcome the initial difficulty of establishment; however, it will take more time to develop into mature trees for harvest. Therefore, although the level of interest is very high, we need to proceed with caution.

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15.
Final Report
The Vine to Wine Co-op
Virginia Wineries Association Cooperative
Stephen Rose

## Project Summary

On behalf of Virginia's over 250 farm wineries and 300 vineyards, the objective of the Vine to Wine Co-op was to reduce overall grape and wine production costs and enhance the competitiveness of the Virginia Wine Industry by providing two cooperative endeavors - group purchasing and service provisions.

Early in 2016, due to increasing debt and the overall viability of the Co-op to secure more members, the Co-op's Board decided to utilize a new business model in order to continue the Co-op. A partnership with a procurement company was utilized. The new business model proved to be very successful. Membership grew from 24 wineries to 140 wineries as of September 28, 20189, with substantial savings for our members.

However, due to the change in our business model, resource issues within the Co-op and the inability to resolve key contractual agreements, we were not able to address other issues dealing with fulfillment or to be able to utilize the funding provided by the Grant.

## Project Purpose

The purpose of The Vine to Wine Co-op and this grant was to help reduce overall grape and wine production costs and enhance the competitiveness of the Virginia Wine Industry by providing two cooperative endeavors - group purchasing and service provisions (e.g. fulfillment). The funding was to: 1) Further our progress of education to farm winery and vineyard owners about the benefits of cooperative membership, collective purchasing and services, and how involvement will decrease the cost of production; 2) Reduce production costs and improve profitability by further development of group purchasing by increased participation, expanded offerings, vendor development and coordinated logistics. The goal was to reach sustainable operations by September 2018.

## Project Activities

Due to increasing debt and the overall viability of the Co-op to secure more members and have existing members utilize the procurement process, most of the activities associated with the Co-op were put on hold during the initial period of the Grant. In November and December, 2015 the Vine-to-Wine Co-op Board of Directors and membership decided to utilize a new business model in order to continue the Co-op. First, we reduced our membership dues and simplified our membership application process. To reduce costs and improve the overall procurement and fulfillment processes, we developed a new business model for our operations, which involved working with East Coast Wine Fulfillment and Wine and Beer Supply. All are subsidiaries of Niche Logistics, LLC and their warehouses are centrally located in Richmond, VA. East Coast

Wine Fulfillment provided fulfillment and storage of wine for member wineries. Wine and Beer Supply bought large quantities of materials that our wineries needed (e.g. wine bottles and glasses, corks, capsules) and stored, sold and delivered them to our members. In addition, they were able to put your winery's art on wine glasses for our members.

Wine and Beer Supply also agreed to perform many of the activities associated with our grant. (For instance doing the marketing associated with obtaining new members.) In fact, the person who did the marketing and sales for the Co-op went to work for Wine and Beer Supply doing the same things he was doing in the Co-op. In addition, the Board of Directors agreed to keep expenses down by doing the administrative functions ourselves so that our members could realize even greater savings, while moving forward to grow the cooperative and make it a meaningful part of the Virginia Wine Industry.

**Due to these factors and internal resource issues, no Grant monies were utilized over the initial period of the grant.**

In February, 2018, the work plan was revised and a reduced amount of funding was approved through September, 2018. However, due the inability to resolve contractual issues with our business partner and the lack of in-kind support, we were unable to utilize the extended funding.

Accomplishments/Progress against goals.

- Although we did not utilize the grant funding, the new business model has proven to be very successful. Membership grew from 24 wineries in 2016, to 92 wineries by the end of 2017, to 140 as of September 28, 2018. (Our goal for 2018 was exceeded by 30 members or 25 %.)
- All 140 members purchased products through Wine and Beer Supply, acting on behalf of the Co-op, in 2018. This exceeded our stated goal by 40%.
- Membership is very happy about the savings they are realizing via the Co-op due to the ability to do large group purchases. They are also very pleased with the service provided.

**<u>Beneficiaries</u>**

The new business model has proven to be very successful. Membership has grown from 24 wineries to 140 wineries as of September 28, 2018. An increase of over 600%.

Membership is very happy about the savings they are realizing via the Co-op due to the ability to do large group purchases. They are also very pleased with the service provided.

**<u>Lessons Learned</u>**

We had many problems and delays in utilizing the funds of the Grant even though we have made progress towards our goals. Many of these were outlined in our Annual Report in December 2016. These continued into 2017 and 2018. Finding and utilizing in-kind support has been very hard. This compounded our efforts in resolving key issues and contractual agreements.

In addition, unless you have a service/product that is seen as easy to use and beneficial, it is very hard to recruit members. However, if you can simplify the process and demonstrate value (reduced product costs), they will come.

In-kind support or what I call "sweat equity." For small to medium size wineries, resources are limited. With lots of work to be done, tight budgets and increasing regulatory compliance, finding time to get involved in industry-wide issues via industry associations, or in our case, the Board for a Co-op, is very hard. This is compounded when key Board members have family or health issues. Also when tough issues arise that carry a lot of past history, Board members leave and it takes time to get new members up to speed (if you can find people who want to volunteer). Progress is made but then it is hard to maintain momentum to finalize agreements/actions. All of this made it hard to ever finalize contractual agreements with our fulfillment partner.

In addition, unless you have a service/product that is seen as easy to use and beneficial, it is very hard to recruit members. However, if you can simplify the process and demonstrate value (reduced product costs), they will come.

The original Co-op model involved setting up an organization and associated work processes to buy bulk quantities of supplies for wineries at a reduced cost. The problems were:

- The initial fees to join the Co-op and annual fees were too high, especially for large wineries. Getting the large wineries to join was critical in lowering cost of supplies.
- To make large, group purchases for things like bottles required upfront commitment of the members to get the reduce prices. Most members would not make these commitments (i.e. forecast their needs), and therefore, the best prices were not available.
- The Co-op had no place to store the material once they purchased it and coordinating direct shipments from the supplier to our members was very hard.

In the end, not many members joined and the Co-op was in debt.

When we found a new procurement partner who had the resources, warehouse space, expertise and needed capital, we switched models. We were able, though our partner's efforts and significantly reducing Co-op fees, to grow the Co-op and reduce supply costs for our members.

**<u>Future Plans</u>**

Although the Grant funding period has ended, the Co-op will continue to address in-kind resource issues, administrative support issues, payment of debts, and implementing the fulfillment process utilizing Co-op membership dues. We are certain that the Co-op will continue and become a viable organization that our membership will rely on to reduce their cost of business.

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16.
Final Report
Urban Horticultural Training Project
Another Chance to Excel (ACE)
Billie Brown

**Project Summary:**
The goal of the Urban Horticultural Training Project was to complete the construction of Another Chance to EXCEL's high-end tunnel; as well as, purchase and install heating, ventilation and irrigation systems internally. Once completed, ACE would conduct a ***Sustainable Gardening Practices in High Tunnels Field Day*** at St. Paul's Baptist Church; whereby, small family farmers would learn the benefits derived from installing a high-end tunnel in their operations. Another Chance to EXCEL (ACE) was to grow specialty crops and distribute them to the elderly and needy within the surrounding Richmond communities and to SNAP residents of known "food deserts" within the East End of the City of Richmond. ACE was also to hold nutrition workshops and provide recipes and demonstrations on how to prepare specialty crops to residents within "food deserts".

**Project Purpose:**
The purpose of the project is to enable Another Chance to Excel (ACE) to install and equip the high-end tunnel with heating, ventilation and irrigation systems; which are needed to enhance the tunnel's efficiency, thereby, resulting in higher crop yields – which will in turn be sold within "food desert" communities in the East End of Richmond, Virginia.

In addition, the project will also provide valuable farming information to small farmers, statewide, about the benefits that a high-end tunnel can offer to their operation and afford ACE to schedule and deliver nutrition workshops on-site; demonstrating cooking techniques for retaining plant nutrients and explaining the health benefits of eating specialty crops.

**Project Activities:**

A. **High End Tunnel (May-June 2018)**
   Construct heating, ventilation and irrigation systems within the High End Tunnel
   **Work Plan Outcome**
   Unusual environmental factors; excessive rainfall during the summer months of 2018 and Hurricanes Florence and Michael interfered with volunteer efforts. These factors aided in promoting increased weed growth and slowing down the installment of the high-end tunnel fans, heating, AC and ventilation system. Although not completed within the grant time period (September 30, 2018), the installation of the fans, heating, AC and ventilation system will be completed on or before November 30.

B. **Specialty Crop Nutrition Workshop (June, July & August 2018)**
   Offer specialty crop nutrition workshops on-site at St. Paul's Baptist Church; as well as, within and outside of the High End Tunnel
   **Work Plan Outcome**
   Financial constraints and scheduling setbacks hindered the delivery of the specialty nutrition workshops planned at St. Paul's Baptist Church during the months of June, July

and August. ACE is currently planning a nutrition workshop and volunteer appreciation event – ***"A Date with A Plate"*** – during the month of November; prior to the Thanksgiving holiday. This event will entail a volunteer appreciation reception for the 65 Virginia State University and St. Paul's Baptist Church farm volunteers; along with, a combined nutrition workshop; which will focus on healthy eating, cooking demonstrations, food preparation for nutrient retention, health benefits of eating specialty crops, and recipes for all age groups. The nutrition workshop will be presented by ***"Healthy Heart Plus,"*** Alice M. Freeman, Certified Naturopath & Nutritional Consultant with extensive experience in diabetic education and lactation. During the summer, Ms. Freeman's consulting fee was paid in advance.

C. **Sustainable Gardening Practices in High Tunnels with ACE (August 14, 2018) Work Plan Outcome**
ACE held a Sustainable Gardening Practices in High Tunnels workshop at St. Paul's Baptist Church on August 14, 2018; which included an on-site presentation of the USDA high tunnel. Virginia State University College of Agriculture; in conjunction with the Virginia Cooperative Extension delivered the three (3) hour segmented workshop on Principles of Sustainable Gardening (Dr. Leonard Githinji, Assistant Professor & Extension Specialist), High Tunnel Production (Dr. Reza Rafie, Professor & Extension Specialist), and Environmental Control in High Tunnels (Mr. Chris Mullins, Extension Specialist). Immediately following the workshop, all presenters and attendees received a tour of the ACE farm and high tunnel; led by Ms. Billie Brown (ACE Founder) and Mr. Tyrus Bingham (Farm Manager).

**Goals and Outcomes Achieved:**

**Objective 1** - Create healthier communities by providing specialty crops (specifically peppers, tomatoes, lettuce, eggplant, watermelon, squash, zucchini, onions, sweet potatoes, okra, cabbage, cucumbers, carrots and green beans) to known "food deserts" within the East End of Richmond.

1. During the months of July and August, ACE was able to harvest and distribute a 40lb basket of specialty crop (tomatoes, peppers, squash, eggplants, and string beans) to needy residents within two local food deserts (Gilpin Court and Creighton Court). This represents 80lbs/mth x 2mths totaling 160lbs.

2. ACE distributed approximately four (4) 40lb baskets of specialty crops to St. Paul's Baptist Church seniors two (2) Sundays in the month of July 2018, and two (2) Sundays in the month of August 2018. 160lbs x 4 Sundays totaling 640lbs

3. ACE distributed (6) 40lb baskets of specialty crops to Feed More and individuals living in nursing and assisted living establishments within the St. Paul's surround community during July and August…totaling 240lbs

**Objective 2** - Increase the yield of specialty crops through use of the High-End Tunnel to "food deserts" within the East End of Richmond.

Unusual environmental factors; excessive rainfall during the summer months of 2018 and Hurricanes Florence and Michael interfered with volunteer efforts. These factors slowed down the installment of the high-end tunnel fans, heating, AC and ventilation system. Although not completed within the grant time period (September 30, 2018), the installation of the fans, heating, AC and ventilation system was completed on or before November 30.

***Recommendations/Conclusions:***
Beginning January 2019, a weather projection schedule needs to be compiled for the ACE farm location to coincide with:

1) the volunteer work schedules,
2) potential drought and excess rainfall,
3) heating and cooling schedules, and
4) transplant and germination schedules.

**Objective 3** - Provide on the job horticultural training skills to the volunteers and participants within our program.

Sixty-five (65) St. Paul's Baptist Church members signed up as volunteers to work on the ACE Farm during the 2018 farming season. Tuesdays, Thursdays and Saturdays were designated as times when ACE's Farm Manager would be onsite to provide the horticultural training necessary to maintain the farm. Saturday mornings proved to be the day when larger numbers of volunteers participated and were most active.

In addition, approximately thirty-two (32) small family farmers attended ACE's Sustainable Gardening Practices in High Tunnels workshop at St. Paul's Baptist Church on August 14, 2018 where they received information and guidance on the uses and benefits derived from installing a high-end tunnel in their operations.

**Objective 4** - Provide a workshop for SNAP recipients on specialty crop nutrition as well as incorporate a field day where ACE can demonstrate the benefits of high-end tunnels to small family farmers.

ACE held a Sustainable Gardening Practices in High Tunnels workshop at St. Paul's Baptist Church on August 14, 2018; which included an on-site presentation of the USDA high tunnel. Virginia State University College of Agriculture; in conjunction with the Virginia Cooperative Extension delivered the three (3) hour segmented workshop on Principles of Sustainable Gardening (Dr. Leonard Githinji, Assistant Professor & Extension Specialist), High Tunnel Production (Dr. Reza Rafie, Professor & Extension Specialist), and Environmental Control in High Tunnels (Mr. Chris Mullins, Extension Specialist). Immediately following the workshop, all presenters and attendees received a tour of the ACE farm and high tunnel; led by Ms. Billie Brown (ACE Founder) and Mr. Tyrus Bingham (Farm Manager).

Unfortunately, ACE was unable to sell our produce to SNAP recipients this season. While ACE is a recently approved SNAP vendor, the EBT equipment was not received until September 2018. However, SNAP recipients will be able to use their SNAP vouchers to purchase specialty crops during the upcoming planting and harvesting season in 2019.

Scheduling setbacks coupled with hazardous weather conditions hindered the delivery of the specialty nutrition workshops planned at St. Paul's Baptist Church during the months of June, July and August. ACE did recently hold a nutrition workshop "A Date with A Plate" during the month of November. This event was attended by over 25 farm volunteers, many whom are SNAP recipients. The nutrition workshop was presented by ***"Healthy Heart Plus,"*** Alice M. Freeman, Certified Naturopath & Nutritional Consultant with extensive experience in diabetic education and lactation.

**Beneficiaries**:
The beneficiaries of this Urban Horticultural Training Project are listed as follows:

1. *Residents living within "Food Deserts" in the East End of Richmond.* During the months of July and August, ACE was able to harvest and distribute a 40lb basket of specialty crop (tomatoes, peppers, squash, eggplants, and string beans) to needy residents within two local food deserts (Gilpin Court and Creighton Court). This represents 80lbs/mth x 2months totaling 160lbs.

2. *Feed More - a* Central Virginia Core Hunger-Relief Non-Profit Organization, located in Richmond, Virginia. Within the Feed More organization, produce was received by Feed More's Baynard Community Kitchen and Food Bank Distribution Center. The indirect beneficiaries (recipients) of Feed More are children (ages 5 – 7) enrolled in the weekday after-school program's Kids Café; courtesy of the Baynard Community Kitchen. Three (3) 40lb baskets of specialty crops were distributed to Feedmore in July and August.

3. *Paul's Baptist Church's seniors and nursing and assisted living establishments within the St. Paul's surround community.* ACE distributed approximately four (4) 40lb baskets of specialty crops to St. Paul's Baptist Church seniors two (2) Sundays in the month of July 2018, and two (2) Sundays in the month of August 2018. 160lbs x 4 Sundays totaling 640lbs. ACE distributed (3) 40lb baskets of specialty crops to individuals living in nursing and assisted living establishments within the St. Paul's surround community during July and August….totaling 120lbs

4. *Small family farmers* who learned the benefits derived from installing a high-end tunnel in their operations.
Approximately 32 (thirty-two) small family farmers attended ACE's Sustainable Gardening Practices in High Tunnels workshop at St. Paul's Baptist Church on August 14, 2018 where they received information and guidance on the uses and benefits derived from installing a high-end tunnel in their operations.

**Projected Income:**
Income was projected to be derived from the pop-up markets held every Sunday after service at St. Paul's Baptist Church. In addition to the pop-up markets, produce was scheduled to be sold at Richmond area farmer's markets. Both income projection sources did not generate any

revenue due to the excessive rainfall during the summer months of 2018 and Hurricanes Florence and Michael; which interfered with plant growth and crop harvest.

**Lessons Learned**:
The lessons learned for the specialty crop grant program projects are:

A. Time management
B. Training and workshops
C. Specialty crop planting and harvest schedules. Developing planting and harvesting schedules
D. Beneficiaries. Knowing who your beneficiaries are and remaining on direct communication with them is essential to ensuring produce is available.

For the upcoming planting and harvest seasons, an alternative plan will be implemented to consider growing back-up crops of another variety that could be drought or rain resistant to ensure enough produce will be available to service the designated beneficiaries. In addition, specialty crops (and/or by products of the specialty crops) could be made available for sale to small farmers during the next high-end tunnel workshop and field day in 2019 to supplement income.

**Recommendations**

- Beginning fall 2018, an operational schedule needs to be compiled for the high-end tunnel. This schedule should entail the daily work schedule of volunteers and farm manager.
- Beginning fall 2018, a crop planting and harvesting schedule needs to be compiled for the high-end tunnel for the next 12 months.
- Beginning fall 2018, a high-end tunnel maintenance schedule needs to be complied.
- Since SNAP targets very poor households at and below the poverty line, a weekly nutrition workshop should be created to service those who need more help affording an adequate diet. Healthy cooking guides and recipes should be made available to SNAP participates in accordance with the crops being distributed and sold.
- Compile spreadsheets of the types of specialty crops planted and harvested from the high-end tunnel.
- Compile spreadsheets of the high-end tunnel recipients, produce distributed, and sold in each growing season.
- Compile spreadsheets of the growing schedule of each specialty crop, pest identification and eradication methods.
- Compile a schedule a farm visit schedule for SNAP recipients; which should coincide with the nutrition workshops.

**Additional information**:
Photographs, workshop flyers, agendas and copies of electronic invitations for each project activity are available upon request.

**Contact information:**
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