FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

Final Performance Report

2014 Specialty Crop Block Grant Program
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Project (1): T-GAPs optimization for the reduction of Salmonella risk in Florida tomatoes

Project Partners: University of Florida

Project Summary

The over-arching goal of this proposed work is to improve microbiological safety of Florida tomatoes and to define a combination of straightforward practices to that end. The achievement of a significant improvement in the microbiological safety of tomatoes will require a comprehensive approach that combines plant breeding, manipulation of the fertilization regime, and promoting targeted education. Such a comprehensive approach to microbiological safety of tomatoes will cut across biological and social sciences, all while remaining one project with a single over-arching goal. The rationale for this proposal is based on our discoveries of 10-100 differences in the susceptibility of different cultivars of tomatoes to post-harvest contamination with Salmonella and the fact that the physiological changes in tomatoes that are associated with maturity dramatically affect the ability of Salmonella to proliferate in tomatoes. Furthermore, with previous funding from SCRI, we learned that proliferation of Salmonella in tomatoes linearly correlated with the levels of nitrogen in tomato leaf tissues and sap (corresponding to the different fertilization regimes), but these effects were cultivar- and maturity-dependent. While contributions of several other individual factors (fertilization and irrigation regimes, phyto-pathogen management, and cultivar selection) to tomato safety outcomes are known, it is not yet clear how these factors interact to affect produce safety. These observations give us a realistic expectation of finding the combination of practices, which – without dramatically changing production conditions, or reducing the yield or increasing the cost of production – will promote safety of vegetables at all production scales. Furthermore, these analyses will establish which production practices (especially those that are time-consuming and expensive) are inconsequential to the produce safety outcomes. Such optimization of production practices is the goal of this research team and our partners and will have immediate benefits to the industry.

This project is timely because Florida is the nation's leader in the production of fresh tomatoes, especially in Spring and Fall seasons. Based on USDA ERS data, fresh market tomatoes comprise about 40% of Florida's fresh market vegetable cash receipts. Outbreaks of gastrointestinal illness linked to fresh produce are tremendously damaging to the producers.

The issues of food safety represent the greatest threat to sustainability and profitability of Florida tomato industry. Based on USDA ERS data, following the June-August 2008 outbreak of salmonellosis caused by S. enterica sv. St. Paul (which was initially wrongly blamed on tomatoes from Florida) the price of tomatoes at the point of first sale dropped from 56.8 cents/lb in June to 25.6 cents/lb in August.

This nearly obliterated Florida tomato industry. Even though there were no major outbreaks of salmonellosis linked to Florida tomatoes over the last two years, over 19,500 lbs of tomatoes (packed by a Florida packer and distributed to 6 states) were recalled due to Salmonella contamination in February 2014 (http://www.fda.gov/Safety/Recalls/ucm385209.htm). Promoting microbiological safety of Florida produce will help maintain its competitiveness on the domestic and international markets. This will benefit millions of Florida consumers, tens of thousands farmers, packers and retailers.

Project Approach

The work plan to achieve Goal 1 was divided into two overlapping phases:

Phase 1. Meta-analysis of the data obtained by the collaborating research groups

Phase 2. Field validation of the data

Meta-analysis was performed with regression trees to identify the field production conditions that were best able to explain the observed variation in Salmonella proliferation in post-harvest tomatoes. The analysis combined, compared, and contrasted results from three different studies conducted by our groups in order to identify patterns among tomato production practices and their contribution to the microbiological safety of tomatoes. These included data sets on the effect of three levels of irrigation (in three different seasons, in two locations in Florida for two tomato cultivars), 9 fertilization levels (3 levels of potassium x 3 levels of nitrogen, in three seasons in two locations for two cultivars), and the effects of foliar sprays with Fe and Cu. These data were originally obtained in separate experiments, some conducted with previous funding from FDACS and from other industry groups. The main outcome of this meta-analysis is that fertilization and irrigation regimes, as well as Cu and Fe, do not seem to have a significant consistent impact on the microbiological safety outcomes for tomatoes. This is important because it frees up producers from optimizing these parameters to maintain both yields and microbiological safety of the product.

In contrast, we determined that tomato maturity at harvest and weather conditions at (or within a few days prior to) harvest have the most significant impacts on the microbiological safety of tomatoes. Specifically, red ripe tomatoes were significantly and consistently more conducive to the proliferation of Salmonella. In addition, tomatoes harvested in the driest, sunniest season were the most conducive to post-harvest proliferation of the pathogen. To follow up on the field data and validate field observations, we determined the effects of relative humidity pre-harvest on proliferation of Salmonella in tomatoes post-harvest. The lab experiments confirmed that high humidity pre-harvest decreased the potential Salmonella proliferation, likely related to the presence of native microbiota. When tomatoes were surface disinfected prior to the humidity treatment (and thus lost their native microbiota) they supported the same levels of Salmonella proliferation regardless of humidity level.

The work plan to achieve Goal 2 was performed as the third phase of the project:

Phase 3. Outreach to the stakeholders

Ten educational videos (5 in English and 5 in Spanish) were developed, recorded, edited and published. The goal of these videos was to provide guidance on how to investigate outbreaks of food- or water-borne illnesses. The first video deals with the epidemiological survey, the second video focuses on culture-based detection of pathogens, and the following videos focus on molecular approaches (nucleic acid-based, immunological and fingerprinting). These videos are publicly available on Youtube: https://www.youtube.com/channel/UCxwK77gbah_yedin0LfdD_Q

As of October 2017, the videos have been watched a total of 594 times (290 for English language versions, 304 for Spanish language versions).

The following presentations/workshops/training sessions were conducted:

1) Of mice and men… and tomatoes: comparative and functional genomics of Salmonella's alternate lifestyles. USDA-ARS Western Regional Research Center, May 6, 2016. Albany, CA. Attended by 12 USDA employees.

2) Of mice and men… and tomatoes: comparative and functional genomics of Salmonella's alternate lifestyles. UC Davis Post-harvest Physiology Group. May 5, 2016. Davis, CA. Attended by 10 graduate students and technicians.

3) An avirulent Salmonella surrogate strain: construction, validation and potential uses. 2016 Florida Association for Food Protection Annual Education Conference. May 11-13, 2016. Crystal River, FL. Attended by 45 industry scientists and managers.

In addition, two UF IFAS EDIS factsheets (in English and Spanish) regarding the results of the meta-analysis were developed and are freely available on the internet.

"Impact of Tomato Varieties and Maturity State on Susceptibility of Tomatoes to Salmonella"

English: http://edis.ifas.ufl.edu/ss627

Number of times downloaded: 2015 - 613; 2016 - 228; 2017 - 294; total (2015-2017): 1135

Spanish: http://edis.ifas.ufl.edu/ss629

Number of times downloaded: 2015 - 502; 2016 - 270; 2017 - 286; total (2015-2017): 1058

"The Role of Crop Production Practices and Weather Conditions in Microbiological Safety of Tomatoes and Peppers"

English: http://edis.ifas.ufl.edu/ss628

Number of times downloaded: 2015 - 594; 2016 - 424; 2017 - 406; total (2015-2017): 1424

Spanish: http://edis.ifas.ufl.edu/ss630

Number of times downloaded: 2015 - 445; 2016 - 318; 2017 - 221; total (2015-2017): 984

Goals and Outcomes Achieved

Goal 1: Develop scientifically-based recommendations on improving microbiological safety of tomatoes by optimizing pre-harvest production conditions (e.g. macro- and micro-nutrient fertilization, irrigation regime, cultivar selection, maturity at harvest and environmental conditions at harvest).

Performance Measure: In year 1, we will develop a model that links pre-harvest production practices with susceptibility to Salmonella based on the meta-analysis of the data collected by the co-PIs over the last 5 years. In year 2, we will validate the model in the field.

Benchmark: Currently, in market tomatoes, Salmonella numbers can proliferate by 10^5 fold within a week.

Target: Increase resistance of tomatoes to Salmonella by at least 10-fold through the optimization of pre-harvest production practices.

Actual accomplishments for Goal 1: The meta-analysis revealed that high relative humidity in the week before harvest decreased proliferation of Salmonella 10 to 100-fold in tomatoes post-harvest. The target for Goal 1 was met.

Goal 2: Promote microbiological safety of tomatoes through on-site and web-based training.

Performance Measure: Number of tomato growers that intend to adopt workshop recommendations.

Benchmark: None.

Target: Eighty percent (120) of the 150 participants in two on-site training workshops in tomato-growing regions around the state will demonstrate intent to implement recommendations on modifying production practices to improve microbiological safety of tomatoes.

Actual accomplishments for Goal 2: With the unanticipated staffing turnover at the beginning of this project (Dr. Marvasi accepted a faculty position in Europe), the two large training workshops were not conducted as originally planned. Instead, three smaller presentations with a total of 67 attendees were conducted without collecting the metrics needed for the target. In lieu of the original target, the high number of views (approximately 600 total, and growing) for the English and Spanish language training videos on YouTube provides evidence for the extent of the outreach efforts. The continued access of these videos and of the EDIS factsheets (http://edis.ifas.ufl.edu/) demonstrates that stakeholders are seeking and finding these resources online.

Beneficiaries

The meta-analysis performed during this project provides straight-forward, science-directed solutions to reduce the risk of Salmonella in post-harvest tomatoes consumed fresh by consumers across the nation. This information was distributed through peer-reviewed publications, EDIS factsheets, and through YouTube training videos. The beneficiaries of this information include:

1) Consumers in Florida and nationwide, where Florida tomatoes are sold

Based on the USDA ERS data, tomato is the most consumed fresh vegetable: in 2009, Americans purchased > 18 lbs. of fresh tomatoes per capita. Florida ranks first (or second, depending on the metric) nationally in the acreage, production, and value of fresh market tomato. This project provides science-backed solutions to ensure the continued safety of fresh tomatoes for consumers.

2) Producers, farmers, and packers

Over 31,5000 acres are under cultivation for the fresh tomato market in Florida based on USDA ERS data. Even though Florida tomatoes haven't been linked to a major outbreak of human illness in at least several years, these outbreaks, when they occur, could be very costly. For example, the Salmonella St. Paul outbreak in 2008 caused over $100 million in damage to Florida tomato industry. Losses from the California Spinach outbreak in 2006 were estimated at $3,500/acre. Producers and farmers will have an opportunity to optimize production practices, in particular the timing of harvests with respect to rain events, to further reduce the risk of outbreaks.

All told, the 2012 USDA Census of Agriculture counts 565 operations with area harvested for tomatoes grown in the open. Improvements to state TGAP regulations will benefit all of these operations.

Lessons Learned

One of the most important lessons learned from this project is that fertilization and irrigation regimes, as well as Cu and Fe application, do not seem to have a consistent impact on the microbiological safety outcomes for tomatoes. This is important because it frees up producers from optimizing these parameters to maintain both yields and microbiological safety of the product. In addition, we changed

our work plan to focus on simulating environmental conditions (temperature, humidity, etc) under the laboratory and/or greenhouse conditions, rather than field experiments since our meta-analysis revealed that irrigation, fertilization, or spraying regimes do not have an impact on the susceptibility of tomatoes to post-harvest contamination with Salmonella. Rather, the most consistently effective method for reducing Salmonella in post-harvest tomatoes was to harvest less mature fruits and/or harvest tomatoes when relative humidity is high, which was confirmed with laboratory experiments.

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Funding Expended: $58,294.58

Project (2): Sustainable Phosphorus Management for Potato Production in Northeast Florida

Project Partners: University of Florida Board of Trustees

Project Summary

The Hastings area belongs to St. Johns River Watershed and has the largest river in the state. This area is also the potato capital of Florida and has approximately 21,000 acres used for potato production. Phosphorus management is most important to protect water bodies from pollution because P is the key nutrient responsible for algal bloom. Soils used for potato production in the area have low pH that serves to protect potato tubers from infection of common scab diseases. However, at low soil pH, soil aluminum and/or other metals is active and can tie P up, limiting the bioavailability of P in the soil. This limitation results in P application greater than the UF/IFAS recommendation (Vegetable Production Handbook of Florida, 2017-2018, Liu et al. 2017).

The purpose of this project was to enhance the sustainability of potato production and the environment through increasing potato growers' awareness about optimizing P management practices. Our surveys of the 32 potato farms revealed that the extractable P levels of the soils were up to 600 ppm, which is approximately 15 times greater than the UF/IFAS recommendation for potato production. In 2012, the research team's P-rate trial on soil with 170 ppm extractable P showed positive yield response: 136, 239, 270, and 280 cwt/acre for 0, 50, 75, and 100 lb/acre P2O5, respectively. Only the two greatest P-rates were not significantly different in tuber yields (Zotarelli, 2013, research report). Based on the UF/IFAS recommendation, no P-fertilizer should have been applied to the soil for potato production in the area. This yield response to P fertilizer application on P-rich soils indicates that the IFAS recommendation may need to be adjusted in the Hastings area. These positive yield responses to P fertilization may be likely related to high levels of extractable aluminum, calcium or other metals in soils in the area.

Project Approach

This project was performed in field trials with chipping potato, 'Atlantic' (2015 through 2017) on the UF/IFAS Hastings Agricultural Extension Center (HAEC) and with tablestock potato, 'Yellow Star' (2015) and 'Fabula' (2016 and 2017) on a private potato farm in the Hastings area for three growing seasons. There were six P rates and two gypsum rates totaling 12 treatments on the HAEC, and six P rates and three gypsum rates totaling 18 treatments on the private farm in 2015. The data in 2015 showed that soil pH was low at 4.8. A lime treatment of 2 t/acre lime was added to the trials at either location for both 2016 and 2017 growing seasons. During the three growing seasons, 13,200 leaves were measured for leaf greenness, 1,824 plant tissue samples for biomass and P, K, Ca, and Mg contents, 1,482 soil samples for extractable P and Ca, pH, CEC, 152 samples for P fractionation, 608 tuber samples for external, internal and specific gravity, and 632 samples for tuber yield. The farms with the trials had extractable nutrients of 300 to 400 ppm P, 150 to 200 ppm K, 900 to 1,300 ppm Ca, and 100 to 120 ppm Mg in soil. Soil pH ranged from 4.8 to 5.8, occasionally to 6.3. At this low soil pH, two thirds of soil P

were tied up mostly by active aluminum and slightly by active calcium. There was not any significant difference in leaf greenness among the P and gypsum application rates. Statistically, P application didn't make any significant contribution to potato yield and quality including external and internal quality and specific gravity based on the data collected from these trials. Neither did gypsum application. However, zero P application had the lowest tuber yields in most of cases but 40 lbs/acre P2O5 had very similar tuber yields with any of the above P application rates. As fertilization is only 13% (http://fred.ifas.ufl.edu/pdf/iatpc/files/HastingsTablePotato09.pdf) to 18% (http://fred.ifas.ufl.edu/pdf/iatpc/files/HastingsChipPotato09.pdf) of production cost, potato growers want to maximize tuber yield. The results from these farms show that 40 lbs/acre P2O5 should be sufficient for both potato yield and quality in the area. Currently, soil is rich in calcium and no gypsum application seems needed. To enhance potato grower awareness, three field day demonstrations were completed at HAEC and two grower meetings at a private potato farm. Another grower meeting will be held at the private farm on October 4th, 2017. There were 176 participants in the aforementioned Extension events for potato production. Their evaluation on knowledge gain from the events was 4.4 out of 5.0 on average.

Goals and Outcomes Achieved

1. Optimize P fertilization management for potato production on P-rich soils to maximize P-use efficiency and maintain or increase potato tuber yield in Six P rates and two Ca rates will be applied to both chipping and tablestock potatoes before planting and at emergence. Plant growth, tuber yield will be assessed. A replicated Current benchmark for P fertilization rates for potato production range from 0, 60, and 120 lb/acre P2O5 for high, medium and low extractable P. Gypsum (Ca) Reduce approximately 20% of P and 50% of Ca (as gypsum) fertilization rates without decreasing tuber yields, thereby with reducing production costs and mitigating P Northeast Florida. experimental design and appropriate statistical analyses will be used. fertilization is used to remove excess sodium (Na) and build soil Ca levels when a pH change is not desired. Plant tissue analysis for 10 inches tall potato plants ranges from 0.6% to 2.0% Ca. pollution in water bodies.

Currently, most of potato growers annually apply 100 lbs/acre P_2O_5 in the area. The 3-year results from this project show that the right P rate should be 40 lbs/acre P_2O_5. This means that we can reduce 60% of current P application rate.

Because soil pH was as low as 4.8 in growing season, aluminum was active. We need to find a way to minimize aluminum activity and maximize P bioavailability.

The current gypsum application rate ranges from 800 to 1,000 lbs/acre per growing season in the area. Our research data repeatedly showed the soil was rich in calcium. The data also indicated that gypsum application didn’t contribute to tuber external and internal quality and specific gravity. We can eliminate gypsum application in the area.

The results from this project indicate that there is a great potential for us to help growers reduce P application from 100 to 40 lbs/acre P_2O_5 and gypsum application from 800-1,000 lbs/acre to 0 lbs/acre. This reduction of P and gypsum application can potentially reduce potato production cost by more than $1,000,000 per growing season based on 21,000 acres of planted acreage.

2. Evaluate tuber quality of both chipping potato and tablestock potato grown in six P fertilization rates and two Ca fertilization rates to minimize potato growers' concerns about tuber quality after adjusting P and Ca application rates. Two 20-feet long rows will be harvested for yield measurements and graded for marketable: C's, B's, A1, A2, and A3 and non-marketable: too large, A4 and culls. Twenty tubers randomly collected from each plot will be used for determination of specific gravity, hollow heart, brown rot, corky ringspot, internal heat necrosis and brown center. The current benchmarks for tuber quality for commercial potato production include tuber size from 0 to 3.3 inches, specific gravity: 1.065 for tablestock potatoes and 1.078 for chipping potatoes. Maintain the same potato tuber quality by reducing 20% of P and/or 50% of Ca fertilization rates on P-rich soils.

Evaluation results showed that more than 40 lbs/acre P_2O_5 didn't contribute to tuber quality of either chipping potato 'Atlantic' or tablestock potato 'Fabula'.

Similarly, gypsum application didn't make any changes in tuber quality either.

These data proved that growers don't need to have any concern about tuber quality after adjusting P and gypsum application rates.

3. Increase potato growers' awareness about improved nutrient management practices by 20% through trial participation and field day demonstration on this project. Help them adopt the new practices from the trials gradually. Work with potato growers directly on their potato farms. Complete two field day demonstrations. Surveys will be used to evaluate the improvement of growers' awareness about P management practices. There is no current benchmark for growers' awareness on improved nutrient management practices. Increase growers' knowledge gain on optimization of P management practices by 20%. Help potato growers adopt the new techniques from this research.

We completed three field day demonstrations on the UF/IFAS Hastings Agricultural Extension Center on April 10, 2015, April 19, 2016, and April 27, 2017.

The PI and his PhD student talked to the audiences: updating the information on Sustainable P/Ca Management for Potato Production on the trial site for three growing seasons.

There were 176 participants in the demonstrations for potato production.

Their evaluation on knowledge gain from the events was 4.4 out of 5.0 on average.

The growers understood the benefits of reducing P and gypsum application but want to see how good the new field practice in large scale trials is. We have started large scale trials on four commercial potato farms since spring 2018. Each of the four farms has approximately 20 acres of chipping potato or tablestock potato. Three of the farms have three-P rates: 0, 50, and 100 lbs/acre P_2O_5. The other farm

has an additional P rate of 150 lbs/acre P_2O_5 besides the above three P rates. These trials will continue for three growing seasons to help growers adopt the new field practices with lower P application rates.

Beneficiaries

The results from this project indicates that there is a great potential for us to help growers reduce P application from 100 to 40 lbs/acre P2O5 and gypsum application from 800-1,000 lbs/acre to 0 lbs/acre. This new practice can potentially reduce potato production cost by more than $1,000,000 per growing season based on 21,000 acres of planted acreage, by optimizing P and gypsum management. The related environmental impact can't be evaluated in US dollars. One hundred seventy six participants including potato growers and county Extension agents participated in the field demonstrations at HAEC and the grower meetings held at the private potato farm with this project. They all received timely updates. Their current practice has lasted for three generations. It is a long-term task to change their behavior. Another most important task is how to unlock the tied up phosphates from soil. More research and Extension projects are needed.

Lessons Learned

As the data showed, soil pH was as low as 4.8, and soil aluminum is very active. An effort was made to increase soil pH by adding 2 t/acre lime per growing season which didn't work because potato has to be grown in a relatively low pH condition to minimize infection of common scab. Introducing scab-resistant varieties of potato would permit raising soil pH, thereby helping to mobilize those immobilized phosphates in soil in the Hastings area.

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Funding Expended: $68,619.03

Project (3): Weed and Nematode Control for Cut Flower and Vegetable Production

Project Partners: USDA, ARS, USHRL

Project Summary

The use of methyl bromide for soil fumigation in the United States has effectively come to a close. Although the Florida vegetable and cut flower producers have continued to apply for its continued use under the Critical Use Exemption process, their requests have been denied, leaving these industries with few, if any, viable broad-spectrum soilborne pest control materials. The cut flower growers had transitioned to the use of Midas® (iodomethane), which is no longer registered and vegetable growers are relying on combinations of several marginally efficacious materials. PicChlor60 (chloropicrin and 1,3-dichloropropene) can be used in vegetables, but with variable outcomes, particularly with regard to weed control. PicChlor60 has limited application in cut flower production areas due to regulatory contraints.

At this moment, there is no replacement for methyl bromide for cut flowers and the replacement for use in vegetable production is a complex, multi-pesticide application process that includes at least one material that is a "probable" carcinogen. Without additional research on combinations of efficacious and biologically-based soilborne pest control tactics, it is likely that the cut flower industry will continue to decrease until there is no Florida-based industry. Vegetable producers will continue to face stronger regulation of soil fumigants and need to have research on more environmentally acceptable alternatives.

A previously-funded SCBGP project allowed for preliminary testing of the experimental material SPK, for which a jointly held patent application between the USDA and University of Florida is still pending. This material's efficacy is principally as a nematicide, which was determined through the previous funding. Weed control was the weakest efficacy area and it is with this proposal that we wish to identify compatible weed control materials. If the patent is granted, then it is likely that one of the interested commercial entities would seek registration of the non-fumigant material. If there is no patent granted, then the formulation would be publicly available and accessible. The previous project included only a comparison of the experimental material to currently registered fumigants. The current project includes a biofumigant that is commercially available, but does not control the entire pest spectrum needed for production of the specialty crops included here.

Project Approach

Field trials were conducted as specified in the original work plan with two additional cut flower trials to compensate for a lack of weed pressure in the first two cut flower trials.

Crop Production Cycle 1 (January 2015-May 2015)-Activities for cut flower tests to be conducted during the reporting period were conducted as outlined in the proposal. Two field trials were established in

sunflower production and one in celosia. For this trial, IRF-135 was selected to compare to methyl bromide for soil fumigation. Replicated strip applications were made by commercial applicator using paired plots of 100 ft long by 13 feet wide. Soil moisture at the time of application averaged 11.7%. The test was conducted on Oldsmar sand with methyl bromide shank applied at 400 lb/A under Klerk's virtually-impermeable film 1.2 mil. IRF-135 was applied at 40 gal/A and covered with the same film. Both materials were shank-applied to 8" depth. The field was separated into multiple planting areas after plastic removal 30-45 days after fumigation, depending upon the planting schedule for each variety. Sub-plots were established for the application of post-plant, pre-emergent herbicide applications to be applied after crop establishment. Cut flower crops included snapdragons, delphiniums, lupins, dianthus, and sunflowers. Weed, nematode, and fungal plant pathogen assessments were conducted as outlined in the proposed plan of work. In both field trials, weed control by the main plot fumigants negated the necessity for the application of herbicides. Only one plot had significant weed pressure, which was due to a faulty shank orifice. Efficacy of Dominus weed control in cut flowers was found to be equivalent to methyl bromide and significantly better than in untreated areas. Plant pathogenic nematode control was equivalent to methyl bromide in early plantings in resistant crops, but was not equivalent in later plantings on susceptible crops. Targets were met for the first goal for establishing efficacy of Dominus. A second trial was established in cut flowers to determine if the addition of a chitin amendment before fumigation, or following fumigation would enhance the level of nematode control achieved by Dominus application. Significant changes in the actinomycete populations associated with nematode control, mediated by chitin amendment were documented. For this trial, Dominus was applied at 40 gal/A shanked in at 8" and chitin was amended 24-hour before fumigation or 21 days after fumigation at 1200 lb/A. All members of the team conducted the portions of the work that were outlined. Pretreatment soil samples for the fall pepper and tomato field trials were taken on August 27. The pepper and tomato field trials were established using the following treatments: Dominus was drip applied at 30 gal/ A in a acre inch of water for application; combination of organic acids (SPK) at a rate of 1714 gal/A and an untreated check. Soil treatment (main plots) were split with an application of pre-emergence herbicide Reflex (sodium salt of fomesafen) at 1 pt/A prior to tarp application. Tomato and pepper transplants were established three weeks after fumigant application. Weed populations were monitored in both crops on a biweekly basis, soil nematode populations quantified post-treatment, mid-season and at harvest. Plant roots were removed after the fifth harvest in order to assess root galling and quantify root-knot nematode root populations. The second series of cut flower trials were established with the same soil fumigant treatments described above, but the main plots were split with four ways to include an untreated check, and pre-emergent, post-transplant establishment, ornamental herbicides Showcase (trifluralin, isoxaben, and oxyfluorfen 2.3 lb/1000sq ft); Dimension (dithiopyr 2.2 ml/100 sqft), and Snapshot (trifluralin, isoxaben 0.23 lb/100 sq ft). Each herbicide-treatment plot was split to accommodate two cut flower species, snapdragon (Opus pink) and sunflower (Procut Orange). Herbicides were applied after crop establishment using hand applicators.

he first sunflower trial was the repeated trial from cycle one, evaluating the combination of IRF-135 and chitin application. The test was designed to determine if chitin amendment before fumigation, or following fumigation would enhance the level of nematode control achieved by Dominus (IRF-135) application. For this trial, Dominus was applied at 40 gal/A shanked in at 8" and chitin was amended 24-hour before fumigation or 21 days after fumigation at 1200 lb/A. The field was separated into multiple planting areas after plastic removal 30-45 days after fumigation, depending upon the planting schedule

for each variety. From this trial, it was concluded that application of chitin did not enhance nematode control but significant changes in the actinomycete populations associated with nematode control, mediated by chitin amendment, were documented. An additional, small trial was established to determine if the application of chitosan would provide improved nematode control over the chitin amendment. This application also did not reduce nematode impact on the sunflower crop. It is likely that the application of these materials over multiple seasons could impact long-term control but after three cropping cycles, this has not occurred. The second series of cut flower trials were established with Dominus (40 gal/A), SPK (organic acids), and untreated soil fumigant treatments. The main plots were split with four ways to include an untreated check, and pre-emergent, post-transplant establishment, ornamental herbicides Showcase (trifluralin, isoxaben, and oxyfluorfen 2.3 lb/1000sq ft); Dimension (dithiopyr 2.2 ml/100 sqft), and Snapshot (trifluralin, isoxaben 0.23 lb/100 sq ft). Two cut flower species, snapdragon (Opus pink) and sunflower (Procut Orange) were evaluated for phytotoxicity and growth parameters. Herbicides were applied after crop establishment using hand applicators. The repeat of the pepper and tomato field trials were established using the following treatments: Dominus was drip applied at 30 gal/ A in a acre inch of water for application; combination of organic acids (SPK) at a rate of 1714 gal/A and an untreated check. Soil treatment (main plots) were split with an application of pre-emergence herbicide Reflex (sodium salt of fomesafen) at 1 pt/A prior to tarp application. Tomato and pepper transplants were established three weeks after fumigant application. Weed populations were monitored in both crops on a biweekly basis, soil nematode populations quantified post-treatment, mid-season, and at harvest. Plant roots were removed after the fifth harvest in order to assess root galling and quantify root-knot nematode root populations. Tomatoes and peppers were picked twice for each crop and yield quantified for early and late picks and graded by USDA standard sizes.

Results from the first cut flower season that are significant are included below. Early weed populations were only affected by the fumigant treatment and not by the herbicide. Specific weeds that were differentially impacted by the soil treatment included carpetweed (Mollugo verticillata $p=0.0467$), goosegrass (Elusine indica $p=0.0183$), and horseweed (Conyza canidensis $p=0.0008$). Total percentage of weed cover was also influenced by fumigant ($p=0.0008$). No phytotoxicity was observed in the sunflower crop, but there was a significant interaction ($p=0.0102$) between soil fumigant treatment and herbicide effect on snapdragon phytotoxicity with the greatest impact occurring in Dominus and SPK soil treatments combined with the herbicides Showcase and Snapshot. In the untreated soil, Showcase also had a significantly greater negative impact on snapdragon than the other herbicides in that treatment. For late season weed control, there was also a significant interaction between soil treatment and herbicide ($p=0.0238$) on total percentage of weed coverage of the bed and horseweed ($p=0.003$). Carolina geranium (Geranium carolinianum, $p=0.0027$) and carpetweed ($p=0.0001$) coverage were influenced only by herbicide. There were no significant differences between soil treatments or herbicides with regard to sunflower yield but there was a significant interaction between the effects of soil treatment and herbicide on snapdragon yield ($p=0.0019$). Showcase, a combination of trifluralin, isoxaben, and oxyfluorfen had a highly significant negative impact on snapdragons in all three soil treatments. Snapshot, containing trifluralin and isoxaben had the greatest negative impact on snapdragons when combined with Dominus and SPK. Dimension, active ingredient dithiopyr, had a more negative impact on yield when combined with SPK or the untreated soil. The greatest yield of snapdragons resulted from the use of Dominus with no herbicide application. In the repeated trials on snapdragon and sunflower, similar results were obtained in which the greatest number of snapdragon

marketable stems came from plots treated with Dominus (p=0.0002) with 658 stems compared to SPK and untreated with 500 and 434 stems, respectively. There was no soil treatment by herbicide interaction, but highly significant differences between herbicides relative to yield (p=0.0001). As in the previous season, both Snapshot and Showcase caused phytotoxicity to snapdragon and significantly reduced yields compared to Dimension (760 stems) and no herbicide (681 stems), while Showcase application reduced marketable stems to 364 and Snapshot to 316.

Goals and Outcomes Achieved

Goal 1) Establish efficacy of IRF-135 (Dominus) and "SPK" applied via flat shank and raised-bed fumigation for weed, nematode, and fungal plant pathogen control.

Eight field trials were completed establishing the efficacy of IRF-135 for weed, nematode, and disease control. Results with SPK were more variable than the pest control achieved with IRF-135. In vegetable trials, IRF-135 provided the greatest control of bacterial wilt of tomato in both years. IRF-135 resulted in a significant increase in yield over both the untreated and SPK-treated plots in both pepper and tomato over both years, with SPK treatment resulting in significantly greater yield than the untreated check in both pepper crops, where disease was minimal. IRF-135, in direct comparison to methyl bromide, provided comparable weed control, with the exception of control of Carolina geranium, which was poorly controlled by methyl bromide, but less control was provided by IRF-135. Nematode control with IRF-135 was equivalent to methyl bromide under very high pressure and provided control of snapdragon disease that was also equivalent. Root-knot nematodes in pepper and tomato were significantly reduced by application of IRF-135, significantly reducing resulting root galling on both crops in both years. Nutsedge control with IRF-135 applied alone was not adequate and, in fact, nutsedge germination significantly increased under IRF-135 under high nutsedge pressure. The target of identifying the potential of IRF-135 as an alternative to methyl bromide was met and the inadequacies of both IRF-135 and SPK were identified.

Goal 2) Identify multiple broad-spectrum herbicides, currently labeled for use in ornamentals, that are applicable for in-ground cut flower production.

Application of the bioherbicide Opportune resulted in control of monocot weeds that was equivalent to the application of trifluralin and increased the number of harvested snapdragon stems significantly over the untreated control. Experiments with sunflower in which the herbicides Dimension, Snapshot, and Showcase were applied post-planting resulted in no significant impact of any herbicide application on the number of harvestable stems. No phytotoxicity was observed on sunflower with any of the tested herbicides and all three herbicides resulted in a significant reduction in overall weed coverage in this crop. For sunflower production, use of any of the tested herbicides would provide acceptable weed control and crop yields. In the absence of soilborne disease, it is possible that the Procut series of sunflowers could be produced without the aid of a soil fumigant using any of the herbicides tested. In contrast, a high level of phytotoxicity was observed in the snapdragon crop, resulting from application of

both Snapshot and Showcase, regardless of the soil treatment. There was, however, a significant interaction between the soil treatment and Snapshot in which phytotoxicity was greatest when this herbicide was combined with either IRF-135 or SPK. Snapdragon yields were significantly higher in IRF-135-treated plots when no herbicide was applied, although the use of Dimension herbicide with IRF-135 under high weed pressure resulted in better yields than other herbicide-treated plots. The target of identifying herbicides for safe use in the tested cut flower species was met, with the use of Opportune safe for both crop types, all safe for sunflower, and snapdragon having some sensitivity to all of the tested herbicides, with Dimension having the least negative impact.

Goal 3) Identify combinations of herbicides labeled for tomatoes and bell peppers that can be effectively used to improve weed control of "SPK" and IRF-135 (Dominus).

Application of both herbicides Reflex and Sandea resulted in significantly better weed control than no herbicide treatment with either soil treatment. IRF-135 increased nutsedge germination to a significantly greater level than that found in either SPK or the untreated check in the absence of an herbicide. It clearly had a stimulatory effect, occurring in both tomato and pepper and in both years. Results from application of SPK were not as consistent as those obtained with IRF-135 but both treatments provided better disease and nematode control than the untreated. IRF-135 combined with either of the labeled herbicides has the potential to serve as an alternative to methyl bromide for the production of tomato and pepper.

Goal 4) Provide research results on the combination of "SPK" and IRF-135 (Dominus) and labeled herbicides to regulatory groups, and cut flower and vegetable producers in Florida.

Results have been shared with regulatory and grower representatives through presentation at the annual meeting on alternatives to methyl bromide, as well as through a demonstration plot and field day for cut flowers. Information continues to be extended as the complete data sets are tabulated.

Beneficiaries

The combined acreage harvested from bell pepper, tomatoes, strawberries, and cut flowers in Florida in 2012, the most recent year for which data is available, was approximately 55,000. The number of producers is in the hundreds and the number of farm workers impacted by the production of these specialty crops in the state are in the tens of thousands. All of these commodity producers have been impacted by the loss of methyl bromide and have few options for soilborne pest control. Identification of an effective biofumigant for control of soilborne fungal and bacterial pathogens benefits all of the open field pepper, strawberry, tomato, and cut flower producers. The identification of crop-specific herbicide partners for two species of cut flowers, bell pepper, and tomato provides a tool to these growers that allows continued production with potentially less-expensive inputs in the absence of methyl bromide. Presentations of data to growers and extension agents have been made. Peer-reviewed manuscripts are in draft form and will be submitted to horticultural journals. Popular press

articles are in preparation for release of the information. Without sustainable alternatives to methyl bromide soil fumigation, the loss of production in tomatoes and peppers alone is as high as $600 million dollars.

We estimate the total number of beneficiaries of this project to be 1,996. This is the total number of floriculture producers in the state as counted by the 2012 Census of Agriculture.

Lessons Learned

All project goals were achieved. A delay in the establishment of the sunflower trial resulted in a request for extension which was granted and allowed for completion of the stated work plan. Additional time could have been added to the term of the agreement in order to facilitate additional opportunities for extending the information to interested parties, although this effort will continue once the relevant manuscripts have been submitted. Presentations to growers, industry partners, and other interested parties will continue beyond the scope of time described here. Two very interesting outcomes of the research will be pursued in future projects. Two of the herbicides tested in the ornamental crops caused a significant level of phytotoxicity to snapdragon transplants although they were applied in compliance with the label. The application of IRF-135 in a raised bed, plasticulture crop resulted in increased germination of nutsedge in the absence of an herbicide partner. Both labeled herbicides provided excellent control of nutsedge when applied with both IRF-135 and SPK.

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Project (4): Screening Germplasm for Bean Red Node Resistance in Snap Beans

Project Partners: Florida Specialty Crop Foundation
University of Florida, Institute of Food and Agricultural Sciences
Everglades Research and Education Center

Project Summary

Tobacco Streak Virus (referred to as bean red node on beans), which causes yield losses and increases crop grading and sorting expenditures, is a major problem for snap bean growers in the Everglades Agricultural Area. The problem has been increasing in importance over the past 20+ years. Yield losses to this virus have been growing steadily. Growers have been limited to managing the disease by managing the thrips vector with insecticides. A resistant cultivar would eliminate the need for 4-5 insecticide sprays under elevated pressure and would increase marketable yield.

We screened commercially available and USDA germplasm over two years with 3 planting dates each year. Germplasm included fresh market snap bean, bush type dry beans, and pole bean cultivars. The first season showed that there was some variability in the susceptibility with ranges in individual plantings from 0%-80% showing symptoms on the pods. We selected some promising varieties for the following year and added additional commercial varieties. However, the second year provided us with the heaviest thrips pressure we had seen since we started working with the thrips in snap beans in 2009. None of the lines tested proved to be resistant under high pressure. The average percentage of pods with symptoms in the second planting was 64% and the lowest percentage of pods affected in that planting date was 25%.

Project Approach

Forty-five PI-lines from the USDA and 15 commercially available cultivars were planted on February 16, March 5, and March 23 of 2015. Leaf and flower samples were collected for all plantings. Harvests occurred 60 days after planting. Pods were counted and rated for red node damage (Table 1). Five PI-lines and one cultivar were identified as possibly having resistance: PI 136741, PI 165462, PI 200967, PI 207182, PI 207205, and 'Valentino'.

Planting dates for 2016 were Feb 23, March 17, and April 5. Fifty-two cultivars were planted on the first, 64 on the second, and 56 cultivars on the third dates, respectively. Leaf samples and flower samples for thrips were made during growing period. Harvests occurred April 20 for the first planting and May 12 for the second planting (Table 2). Heavy rains destroyed the 3rd planting prior to flowering; therefore, there was nothing to harvest. Pods were counted and rated for red node damage. It is apparent now that none of the tested varieties are resistant to thrips or bean red node, although a case could be made for tolerance. A field day on 5-11-2016 was attended by many growers, scouts, and seed industry representatives interested in seeing our results.

Goals and Outcomes Achieved

1. Identify BRN resistant cultivars of snap beans that growers can plant to manage Bean Red Node without use of insecticides and identify their mode of resistance.

While sixty cultivars were evaluated in 2015 and 64 cultivars were evaluated in 2016, none were ultimately found to be resistant to the Tobacco Streak Virus, or BRN. Pods harvested in from five lines that were replanted in 2016 after they appeared to be resistant in 2015 were frequently >50% infected with the virus. Previous sample counts in snap bean blooms from 2009 through 2014 seasons were normally fewer than 5 per bloom. Counts in 2015 were frequently less than 3 per bloom; however, thrips populations were much greater in 2016 with counts frequently >7 per bloom. BRN infection rates varied among cultivars and planting dates.

2. Increase awareness of Bean Red Node resistant cultivars.

No BRN resistant cultivars were identified, but the trial brought greater awareness of the risk of thrips feeding and egg laying scars, as well as BRN in beans to growers, scouts and pest control agencies, and seed companies.

3. Calculate cultivar specific thresholds for thrips and BRN to give growers a tool to estimate BRN risk.

Thrips counts in 2015 were less than half what they were in 2016; however, BRN incidence still reached 80% in some cultivars. Therefore, we believe the number of virus-carrying thrips is potentially more important than the total number of thrips, particularly for the primary infection of the planting. With the lack of available resistance in commercial cultivars suitable for growth in southern Florida, the important lesson at this point is for the growers to plant as early as possible to take advantage of greater prices and to avoid the great thrips populations that traditionally come into the fields beginning in April and May.

4. Dissemination of research results to growers, breeders, crop consultants, and researchers.

Growers, field scouts and commercial pest management companies, and seed companies were invited to visit the trial toward the end of the second year. They were able to see first hand the devastating nature of BRN and that there were no currently available cultivars or PI lines that demonstrated

resistance to the virus. This knowledge will lead to increased attention to planting dates and timely insecticide treatments to kill thrips before they become established in their fields.

Beneficiaries

The primary beneficiaries of the project were the 15 major snap bean growers in the Everglades Agricultural Area. Unfortunately, their problem was not solved as it was shown that there were no resistant varieties. They did get to see how a wide cross-section of germplasm performs in the region. The seed producers that supply the growers in the Everglades Agricultural Area benefited from the knowledge of how their products handle bean red node. A field day was held for interested parties to examine the plantings on May 11th 2016. Twenty people attended representing growers, crop consultants, researchers and seed company representatives. E-mail reports were sent to interested people who could not attend. The main benefit of the research is that we now have a long list of cultivars that are known to not be resistant and a list of cultivars that do not produce well under normal conditions in the Everglades Agricultural Area in the late Spring. Some of the cultivars may be tolerant of the virus and/or thrips vector, but further investigation would be required. The results also demonstrated that insecticides are an important tool for reducing the numbers of thrips to attempt to combat this virus. While the discovery of a resistant cultivar may have led to increased growing season expanding into the late spring with its corresponding heavy thrips pressure, this research also accentuated the need to continue to plant and harvest early to try to avoid the heavy thrips pressure common in mid April through May.

Lessons Learned

The biggest lesson learned was to budget more time for counting thrips. This activity proved to be more time consuming for this project than it had been in previous years. Weed control proved to be difficult in the first year, and during the second year additional time and resources were devoted to weed control activities. Conditions were generally dry during the 2015 planting season and all plantings were made in a timely manner. The 2016 season was excessively wet and all plantings were made later than preferred. This resulted in the final planting being flooded out by an early start to Summer rainfall. The USDA has limited seed supply and it can be difficult to produce seed in outside conditions in southern Florida. In hindsight, we should have found a partner to increase the seed from the USDA so that we could have an abundant amount of seed available for planting. Some seed was not available during the second year and some was only available for one planting. PI lines with low percentage BRN infected pods in 2015 should be re-evaluated after obtaining much larger quantities of seeds. While no tested bean cultivar proved to be resistant to the virus, this was the first known research on the effects of this virus on a wide bean germplasm. A wider selection of germplasm may be evaluated in the future using the lessons learned in this study, but the intensive thrips pressure in the second year demonstrated the potency of this virus and the lack of readily identifiable resistance in the available germplasm.

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Funding Expended: $51,837.38

Project (5): Revising Chemical Control of Laurel-Wilt Vectors

Project Partners: University of Florida
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Tropical Research and Education Center
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Homestead, FL, 33031

Project Summary

Laurel wilt (LW) is a deadly disease of trees in the Laurel Family. The disease has caused widespread mortality of redbay (Persea borbonia) and other native Lauraceae throughout the southeastern United States and is now affecting avocados in Florida. The key vector of this disease in native lauraceous hammocks is the redbay ambrosia beetle RAB (Xyleborus glabratus). RAB was expected to attack avocado trees in large numbers, as observed in natural areas where native Lauraceae trees have been severely attacked by this beetle. However, while RAB is easily detected infecting native Lauraceae trees, it is very seldom detected in avocado orchards. Other `resident' species of ambrosia beetles appear to have become vectors of the disease in south Florida avocado orchards and two species (i.e, Xyleborus bispinatus and Xyleborus volvulus) have been shown experimentally to be capable of transmitting laurel wilt pathogen to avocado. Avocado growers were using management tactics to control a single disease vector (RAB) in their groves and it was unknown whether these tactics were appropriate for the other ambrosia beetles vectoring LW in avocados. This project was of extreme importance for avocado growers and its results provided them with a wider arsenal of chemical tools to manage ambrosia beetles in avocado groves. Avocado growers started using new insecticides to control resident ambrosia beetles that are capable of vectoring LW in avocados. The LW- ambrosia beetle control recommendations were adjusted to control resident ambrosia beetles capable of vectoring the LW pathogen to avocado. This research increased from three to five the number of insecticides that avocado growers can legally use against vectors of laurel wilt. Two insecticides (Talstar® and Epi-Mek®) were already registered for use on avocado and could be used immediately. In addition, efficacy data was obtained to request a new pesticide emergency exemption (EPA section-18) permit for the insecticide Cobalt® (lambda cyhalothrin + chlorpyrifos), which provided the best protection against ambrosia beetles vectoring LW in avocados.

This project builds on the previous SCBGP funded project "Mitigation and Chemical Control of the Red Bay Ambrosia Beetle". The effectiveness and residual efficacy of over 15 insecticides for control of RAB was assessed and the best insecticides were included in an integrated pest management program for Florida avocados. However, RAB is seldom found in avocados and other resident species of ambrosia beetles are believed to be the most important vectors, carrying and transmitting LW. It was unknown if the insecticides that showed a high efficacy on RAB were efficacious on other resident ambrosia beetles. In addition, little was known regarding key biological characteristics, such as the reproductive potential and flight behavior of ambrosia beetles capable of vectoring LW in avocado orchards, which is essential to combat these pests. The aim of the proposed project was to obtain the baseline information needed to redirect the management strategies to target the resident ambrosia beetles playing an important role in the spread of LW in avocado orchards in south Florida.

Project Approach

Objective 1.

Determine key biological characteristics of ambrosia beetles that vector LW in avocado orchards to optimize management tactics against these species.

1.1. Life cycle and reproductive potential of ambrosia beetles that vector LW in avocado orchards.

This part of the research was conducted at the UF Tropical Fruit Entomology Laboratory and is explained in detail in two attached manuscripts that will be submitted for publication in a peer reviewed journals. In short, three artificial media containing sawdust obtained from either avocado or silkbay (Persea humilis Nash) were evaluated for laboratory rearing of two ambrosia beetles that are known capable of transmitting laurel wilt to avocados, Xyleborus volvulus and Xyleborus bispinatus. The colonies of these beetles have been maintained over several generations and the life cycle and reproductive potential of both beetles have been determined. We also used these colonies to study the association of these beetles with the laurel wilt pathogen, Raffaelea lauricola.

Xyleborus volvulus Eichhoff (Coleoptera: Curculionidae) is a pantropical ambrosia beetle species with a broad host range. Like other ambrosia beetles, X. volvulus lives in a mutualistic symbiotic relationship with Ophiostoma fungi that serve as its food source. Until recently, X. volvulus was not considered a pest, and none of its symbionts were considered pathogens of trees. However, recent reports of an association between X. volvulus and Raffaelea lauricola T.C. Harr. Fraedrich & Aghayeva (Ophiostomatales: Ophiostomataceae) --the cause of laurel wilt disease --and its potential role as a vector of this lethal disease of avocado meritted further investigation. We evaluated three artificial media containing sawdust obtained from either avocado or silkbay for laboratory rearing of X. volvulus. The effect of R. lauricola in the rearing media on the beetle's reproduction was also evaluated. In the best rearing medium one X. volvulus female can establish a colony in either avocado or silkbay media and produce approximately 15 offspring in a 40-day period. Females represent 80 % of the brood and beetle reproduction was not affected by the type of sawdust (avocado or sillbay). In the best rearing medium X. volvulus developed similarly in the presence or absence R. lauricola. On the other two media, there was a significant effect of sawdust type on beetle reproduction, and the presence of R. lauricola had a negative effect on brood production. There was limited colonization of R. lauricola within the mycangia (the internal organ that stores fungal spores) of X. volvulus reared on media inoculated with the pathogen. From galleries formed within the best medium, there was 50% recovery of R. lauricola, but recovery was much less from the other two media. Of the three media, the one with the greatest nutritional content and intermediate water content provided the best conditions for rearing X. volvulus (See APPINDIX 1).

Xyleborus bispinatus Eichhoff was reported in Florida for the first time in 2013. Previously, it was unrecognized and not distinguished from the morphologically similar Xyleborus ferrugineus (F.). Like other members of the tribe Xyleborini, X. ferrugineus (and possibly X. bispinatus) can cause economic damage in lowland areas of the Neotropics. In addition, when breeding in a host with laurel wilt, X. bispinatus has been found to incorporate the laurel wilt pathogen, Raffaelea lauricola, into its mycangia and may potentially function as a vector of the disease in avocado (Persea americana Mill.) orchards. We evaluated three artificial media containing sawdust from avocado or silkbay for rearing X. bispinatus under laboratory conditions. The effect of R. lauricola on the biological parameters of X. bispinatus was also evaluated. Two of the media supported high reproduction of X. bispinatus, but the avocado-based medium was generally better than the silkbay-based medium. Under optimal rearing conditions, a X. bispinatus female can

establish a colony in either avocado or silkbay media and produce approximately 26 offspring in a 40-day period. Females represent 65 % of the brood. The presence of R. lauricola had a neutral or enhancing effect on beetle reproduction. When X. bispinatus was reared on media inoculated with R. lauricola, there was low colonization of the beetle's mycangia with the pathogen. Raffaelea lauricola was recovered from ~64% of the galleries in the best two media. The two media with lower water content were best for rearing X. bispinatus under laboratory conditions.

Eventhough several ambrosia beetles have been found carrying the laurel wilt pathogen, only Xyleborus volvulus and Xyleborus bispinatus have shown capable of transmitting this disease to avocado. Our results show that Xyleborus bispinatus can develop and reproduce in the presence of Raffaelea lauricola in the breeding substrate. Xyleborus bispinatus can also benefit from the association with R. lauricola by increasing its reproduction. By contrast, Xyleborus volvulus is negatively affected by the presence of this fungus. These results suggest that Xyleborus bispinatus plays a more important role as a vector of laurel wilt in avocado.

The rearing methodologies and reproductive parameters of Xyleborus volvulus and Xyleborus bispinatus are described in detail in two attached manuscripts that will be submitted for publication in a peer review journal (APPENDIX 1 & 2).

1.2. Flight height and daily periodicity of ambrosia beetles that vector LW in avocado orchards.

Knowing the flight height of ambrosia beetles could provide insights on the beetle's interaction with different structures of avocado trees, key information for effective protection of trees against beetle attacks. We evaluated the flight height of several ambrosia beetle species in three avocado orchards affected by laurel wilt.

The vertical distribution of ambrosia beetles in three avocado orchards with ambrosia beetle infestations and laurel wilt-diagnosed trees was investigated from August 2016 to December 2016 in Homestead, FL. The first orchard (N 25° 29' 33.53'' W 80° 28' 57.21'') had approximately 10 acres of 20-30 year-old trees form the avocado cultivar Booth 7. Since July 2013 laurel wilt has killed approximately 80% of the trees. During the experiment, this grove had numerous standing laurel-wilt affected trees with large ambrosia beetle infestations. The second orchard (N 25° 29' 23.49'' W 80° 27' 49.05'') had 46.5 acres of the avocado cultivar Simmonds and LW was detected in August 2012. Even though approximately 40% of the trees had been affected by LW and harbor large ambrosia beetle infestations, affected trees were not be removed from this orchard. The first and second orchards were not being actively managed. The third orchard (N 25° 27' 54.16'' W 80° 32' 22.03'') had approximately 200 acres of avocados of the cultivars Miguel, Lula and Monroe. Laurel wilt was first detected in September 2013, and since then, 5% avocado trees had been removed and chipped to avoid spreading of this disease. Management practices in this orchard include irrigation, fertilization, pest management, pruning, and harvesting.

Ten ladder-like traps with unbaited sticky panels arranged at three height levels (i.e., low: 1 - 2 m; middle: 3 - 4 m; high: 5 - 6 m) were placed in each grove in close proximity to laurel wilt affected avocado trees. The number of ambrosia beetles per species captured during a three month period was recorded. A total of 1,306 individuals of 12 species of ambrosia beetles were captured. The primary vector of R. lauricola, Xyleborus glabratus, was not captured in this study. Six species accounted for ~95% of the captures (Xyleborus volvulus (31.5%), Xyleborinus saxesenii (18.2%), Euplatypus parallelus (17.0%), Xyleborus bispinatus (13.4%), Xyleborus affinis (7.9%), and Hypothenemus sp. (6.6%). The number of captured beetles captured at the three heights tested was similar except for X. volvulus that showed a preference for the low-level. Xyleborus bispinatus showed no preference between the low and middle levels. The results suggest that these two ambrosia beetles interact with the main trunk and major scaffold limbs but that the other captured species appeared to have no clear flight preference.

Fig 1. Effect of three height levels on numbers of ambrosia beetles trapped. (Low = 1 - 2 m; Middle = 3 - 4 m; Top = 5 - 6 m). Bars represent the mean ± SE of ambrosia beetles caught per height level. Bars with the same letters in the same column are not significantly different ($P < 0.05$).

The flight daily periodicity studies determined that Xyleborus volvulus engages in flight behavior approximately at 5 pm. Xyleborus bispinatus was found actively flying at dusk (4-7 pm) but the number of captures do not allow an accurate determination of a specific time of flight between 4 pm to 7 pm. Additional studies on the effects of abiotic factors such as wind speed, temperature, light intensity, and biotic factors such as the resource availability and physiologically available energy used for flying, are needed to gain a better understanding of the flight behavior of ambrosia beetles.

Objective 2.

Evaluation of insecticides recommended for control of RAB against other beetles capable of vectoring LW.

This experiment was conducted during the spring and summer of 2015 in a different avocado orchard with known infestations of ambrosia beetles and LW. Forty-eight container-grown healthy trees of the avocado cultivar, Simmonds (clonal scions grafted on seedling rootstocks, 3-4 yr old, 2 m tall, and 4 cm diameter at the trunk base) were placed in one commercial avocado orchard forming a grid so that each tree was separated from other experimental trees by 15 m. The grove was affected by laurel wilt (N 25° 27' 54.16'' W 80° 32' 22.03'') and had approximately 200 acres of avocados of the cultivars Lula, Miguel and Monroe. Ethanol-injections of trees were used to induce attacks by ambrosia beetles to evaluate the effectiveness of insecticides currently recommended for control of RAB. Each plant was injected with 50 ml of 75% ethanol (EtOH) using an Arborjet ® trunk injection system and assigned randomly to one of the following six treatments: 1) no treatment -negative control, 2) ethanol injection + no insecticide -positive control, 3) ethanol injection + Danitol® 2.4 EC (fenpropathrin), 4) ethanol injection + Malathion® 5EC (organophosphate), 5) ethanol injection + Hero® (z-cypermethrin + bifenthrin), and 6) ethanol injection + Endigo® ZC (L-cyhalothrin + thiamethoxam). All insecticides were applied with a backpack sprayer at label recommended rates and mixed with an adjuvant (NuFilm®) to increase the rain-fastness of the insecticides. Each treatment was replicated eight times (8 trees/treatment). The insecticide treatments were applied the plants immediately after injecting the EtOH.

The number of beetle attacks (entry holes) and the appearance of LW symptoms on each tree was recorded weekly during two months. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle attacks for each sampling date, cumulative total attacks, and the number of beetles per species emerging from the experimental trees. Plants treated with Hero®, Malthion® and Danitol® had significantly fewer beetle attacks than plants treated with Endigo® but similar to inject-control (Fig 2). However, there was a high mortality of plants after the ethanol injections, which may be attributed to the effect of the ethanol or the wounds made by the injection ports. This impeded ambrosia beetle reproduction and LW development in the plants. Thus, we decided

Fig 2. Containerized avocado trees were injected with ethanol to induce attacks by ambrosia beetles and evaluate the effectiveness of insecticides. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle attacks ($P<0.05$). Those columns with different letters are significantly different from each other.

to replicate the experiment using fermented logs as the experimental unit. Avocado cv. Booth 7 bolts (30.0 ± 0.4 cm long × 9.0 ± 0.1 cm dia.) were each submerged in water for 7 days and allowed to dry for one day

before applying the insecticides. The insecticides were applied as described above and the treated bolts were deployed (hung from avocado trees) in the same LW affected avocado grove for X days. The number of beetle attacks and emergence of ambrosia beetles from the bolts after X days orchard exposure was analyzed as above. Bolts treated with Hero® had less beetle attacks followed by plants treated with Malathion®, Danitol®, Endigo® and control bolts (Fig 3).

Fig 3. Attacks by ambrosia beetles on soaked (fermented) avocado bolts used to evaluate the effectiveness of insecticides. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle attacks ($P<0.05$). Those columns with different letters are significantly different from each other.

Fewer beetles of the most abundant ambrosia beetle species, X. volvulus emerged from bolts treated with Malathion®, followed by Hero®, Danitol®, the control and Endigo® (Fig 4)

Fig 4. Ambrosia beetles emerging from fermented logs treated with insecticides and deployed in a LW affected avocado orchard. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle numbers ($P<0.05$). Those columns with different letters are significantly different from each other.

Even though none of the tested insecticides completely protected trees or avocado bolts from beetle attack, in both experiments Hero® (z-cypermethrin + bifenthrin) provided the best ambrosia beetles protection for trees and bolts. This material was approved for use in avocado under a pesticide emergency exemption (EPA section-18) permit. This product was included in the LW-ambrosia beetle control recommendations to control resident ambrosia beetles that are capable of vectoring LW in avocados. However, this product is registered only for use in non-bearing trees.

Objective 3.

Identify insecticides that were not effective for control of RAB but might be effective on other LW ambrosia beetle vectors.

During the first two quarters of 2016 the following insecticides were evaluated: 1) fermented logs - positive control, 2) fermented logs + Epimek® 0.15 EC (abamectin; 20 fl. oz/acre), 3) fermented logs + Permethrin® (permethrin; 8 fl. oz/acre), 4) fermented logs + Talstar ® (bifenthrin; 0.2 lb/ acre), 5) Fermented logs + Rimon ® (novaluron; 40 fl. oz./acre) and 7) fermented logs + Hero® (z-cypermethrin + bifenthrin; 10.3 fl. oz./acre). Talstar®, Epimek®0.15EC, and Hero® provided the best protection to avocado bolts from attack by ambrosia beetles (Fig. 5). Epimek® and Talstar® have been included in the LW-ambrosia beetle control recommendations.

Fig 5. Attacks by ambrosia beetles on soaked (fermented) avocado bolts used to evaluate the effectiveness of insecticides. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle attacks ($P<0.05$). Those columns with different letters are significantly different from each other.

During the last two quarters of 2016 the following insecticides were evaluated: 1) fermented logs -positive control, 2) fermented logs + Hero® (z-cypermethrin + bifenthrin; 10.3 fl. oz./acre), 3) fermented logs + Cobalt® (lambda cyhalothrin + chlorpyrifos), 4) fermented logs + Lorsban® (Chlorpyrifos), 5) Fermented logs + Ex-icute/Rapid-O (blend of horticultural oils), 6) fermented logs + Botanigard (Beauveria bassiana), and 7) fermented logs + Bb (?????) .

Fig 6. Attacks by ambrosia beetles on soaked (fermented) avocado bolts used to evaluate the effectiveness of insecticides. Generalized linear mixed model (Glimmix) analysis was used to determine differences in beetle attacks ($P<0.05$). Those columns with different letters are significantly different from each other.

Cobalt® and Lorsban® provided better control than all treatments except Hero®, the best known insecticide to control ambrosia beetles in avocado. The PIs are planning to apply for a pesticide emergency exemption (EPA Section-18) for Cobalt® with the support of avocado growers.

The research findings of this project have been presented to the local growers in a monthly basis (the second Wednesday of each month) during the Florida Avocado Administrative Committee meeting and through separate workshops on management of laurel wilt vectors that are conducted every 3-4 months. In addition, research finding of this projects were presented at the Laurel Wilt Summit on Nov 3-4 to approximately 117 participants.

Goals and Outcomes Achieved

Goal 1

Established: Identify key biological characteristics (i.e., flight behavior and reproduction rates) of two (X. bispinatus and X. volvulus) ambrosia beetles that vector LW in avocado orchards to optimize management tactics against these species.

Accomplished: This goal was accomplished. Two ambrosia beetles (X. bispinatus and X. volvulus) that vector LW in avocado orchards were successfully reared using avocado sawdust and their life history and flight behavior were determined. We exceeded the initially proposed goal by determining the interaction these beetles have with the laurel wilt pathogen. This information resulted in the preparation of three scientific manuscripts (attached).

Performance measure 1

Established: Follow at least two generations of each of the two ambrosia beetle species capable of spreading LW in avocados. Determine the flight behavior of at least 100 individuals of each of these ambrosia beetle species.

Accomplished: This performance measure was fully accomplished. We followed two generations of the two ambrosia beetle species capable of spreading LW in avocados and determine the flight behavior of at least 1300 individuals of ambrosia beetle species.

Benchmark 1

Established: Determine their reproductive rates on avocado and whether they have unimodal, bimodal or multimodal emergence patterns throughout the year. Determine the flight height and flight periodicity of each of the ambrosia beetle species capable of spreading LW.

Accomplished: We determine that the beetles have multimodal emergence patterns and can complete one generation in as short as 40 days. We determined that both beetles fly only at dusk. X. volvulus has a low flight, primarily 2 m above the ground, whereas X. bispinatus flies mostly 4 m above the ground.

Target 1

Established: Based on the key biological characteristics (i.e., flight and reproduction rates) recommend the optimum timing and chemical control tactics to control ambrosia beetle vectors of laurel wilt.

Accomplished: Ambrosia beetles that vector LW interact with the main trunk, scaffold branches and stems and all these should be covered when applying an insecticide. The optimum timing for applications of insecticides and biopesticides is

at dusk or late in the afternoon and should be applied only to suppress populations after sanitation practices.

Goal 2

Established: Verify whether current chemical control strategies designed for control of RAB are also effective against resident ambrosia beetles that are capable of vectoring LW.

Accomplished: This goal was fully accomplished. All insecticides recommended for RAB control were tested on other ambrosia beetles capable of vectoring LW. In all experiments Hero ® (Z-Cypermethrin + Bifenthrin) provided the best protection to avocado trees and bolts from attack by ambrosia beetles. This material was approved for use in avocado under a pesticide emergency exemption (EPA section-18) permit and was included in the LW- ambrosia beetle control recommendations to control resident ambrosia beetles that are capable of vectoring LW in avocados. However, this product is registered for use in non-bearing trees only.

Performance measure 2

Established: Obtain field efficacy data on all insecticides registered for use in avocado, or recommended for management of other wood boring insects, that could be useful to control LW vectors in avocado.

Accomplished: Three field trials were conducted testing fifteen insecticides in commercial avocado orchards affected by LW. This research identified new insecticides that were included in the LW- ambrosia beetle control recommendations to control resident ambrosia beetles capable of vectoring LW to avocado.

Benchmark 2

Established: Avocado growers start using these insecticides targeting other ambrosia beetle species that vector LW in avocados. If these insecticides are not registered for use on avocado provide data from the project as part of a petition to register them for use on avocado and/or seek an emergency use (immediate use) of one or more of the products.

Accomplished: Avocado growers started using new insecticides to control resident ambrosia beetles that are capable of vectoring LW in avocados. Two insecticides (Talstar and EpiMek) were already registered for use on avocado and could be used immediately. We obtained data to request a new pesticide emergency exemption (EPA section-18) permit for the insecticide Cobalt ® (Lambda Cyhalothrin + Chlorpyrifos), which provided the best protection against ambrosia beetles vectoring LW in avocados.

Target 2

Established: Redirect chemical management tactics, originally designed targeting RAB, to target other ambrosia beetle species that vector LW in avocados.

Accomplished: The LW-ambrosia beetle control recommendations were adjusted to control resident ambrosia beetles capable of vectoring LW to avocado. This research increased from three to five the number of insecticides that avocado growers can legally use against vectors of laurel wilt.

Goal 3 (established)

Established: Determine whether insecticides that were not efficacious against RAB control could be useful tools against resident ambrosia beetles that are capable of vectoring LW in avocados.

Accomplished: The insecticides Talstar and EpiMek were not efficacious against RAB but provided some of the best results against resident ambrosia beetles that are capable of vectoring LW in avocado orchards. These insecticides are already registered for use on avocado and could be used immediately.

Performance measure 3

Established: Obtain field efficacy data on the selectivity of all contact insecticides currently recommended for RAB on other ambrosia beetles capable of vectoring LW.

Accomplished: Three field trials were conducted testing fifteen insecticides in commercial avocado orchards affected by LW. This research identified new insecticides that were included in the LW-ambrosia beetle control recommendations to control resident ambrosia beetles capable of vectoring LW to avocado.

Benchmark 3

Established: Avocado growers start using these insecticides targeting other ambrosia beetle species that vector LW in avocados. If these insecticides are not registered for us on avocado provide data from the project as part of a petition to register them for use on avocado and/or seek an emergency use (immediate use) of one or more of the products.

Accomplished: Avocado growers are now using new insecticides to control resident ambrosia beetles that are capable of vectoring LW in avocados. Two insecticides (Talstar and EpiMek) were already registered for use on avocado and could be used immediately. We obtained data to request a new pesticide emergency exemption (EPA section-18) permit for the insecticide Cobalt® (Lambda Cyhalothrin + Chlorpyrifos).

Target 3

Established: Obtain field efficacy data on all insecticides registered for use in avocado, or recommended for management of other wood boring insects, that could be useful to control LW vectors in avocado.

Accomplished: We obtained field efficacy data on all insecticides registered for use in avocado, or recommended for management of other wood boring insects, that could be useful to control LW vectors in avocado. This research identified insecticides that were previously included in the RAB-ambrosia beetle control recommendations to control resident ambrosia beetles capable of vectoring LW to avocado. In addition, we obtained data to request a new pesticide emergency exemption (EPA section-18) permit for the insecticide Cobalt® (Lambda Cyhalothrin + Chlorpyrifos).

Beneficiaries

The beneficiaries of this project involve not only avocado growers and homeowners, but workers employed by growers and ancillary industries such as packinghouses, chemical companies, and irrigation companies. The Florida avocado industry consists of about 7,500 acres, which represents about 60% of the total tropical fruit crop acreage, and is the state's third-largest fruit industry. There are over 400 growers that make part, most, or all of their income from avocado production.

The research findings of this project have been presented to the local growers in a monthly basis (the second Wednesday of each month) during the Florida Avocado Administrative Committee meeting (25-40

participants per meeting), at grower-research advisory committee meetings (called Panel Meetings, 42 participants), and through separate workshops on management of laurel wilt vectors that are conducted every 3-4 months (75 participants). A post-workshop survey found 50% and 53% of grower participants spraying insecticide in areas of the grove affected with laurel wilt and wood chips of destroyed trees, respectively. However, after the workshop 75% of the grower participants indicated they are more likely to spray insecticide in laurel wilt affected areas, a 25% increase. In addition, research findings of this projects were presented at the Laurel Wilt Summit on Nov 3-4, 2016 to approximately 117 participants.

This project benefits the avocado growers and packers through reducing the loss of avocado trees; dead trees make no fruit. Laurel wilt is a lethal disease that kills avocado trees within 4-8 weeks after infection. At this time trees cannot be cured once infected. This project has provided science-based information for the recommendations for effective ambrosia beetle control, potentially saving producers time and money. It is critical to improve the control of ambrosia beetle vectors to stop the spread of this lethal disease.

In terms of lost sales, property damage and increased management costs, left unchecked the potential economic damage from laurel wilt exceeds $350 million with tree replacement costs of over $200 million (Evans and Crane, 2013).

If LW continues its movement toward the Texas avocado growing areas and then continues its dispersion toward the large California avocado industry [74,767 acres (2012 Census of Agri.); >$381 million (2012 Noncitrus Fruits and Nuts], the benefits of this project are not only for just Florida but for all U.S. states where avocado are grown.

Lessons Learned

We found a high mortality of plants after the injections with ethanol which could be attributed to the effect of the ethanol or the wounds made to place the injection ports into the tree stems. This impeded ambrosia beetle reproduction within the plants and LW development in the plants. We decided to replicate the experiments using fermented logs as the experimental unit which provided more consistent results.

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Project (6): Effective, Sustainable Management of Thrips in Fruits and Vegetables

Project Partners:
University of Florida
USDA-ARS
Glades Crop Care, Inc.
Florida Strawberry Growers Association
Florida Fruit and Vegetable Growers Association

Project Summary

Invasive pest thrips species and the plant viruses they vector are serious challenges to agriculture in Florida. Growers responded to the invasion of these pests by applying broad-spectrum insecticides according to calendar schedules. This has resulted in a classic '3R' situation: 1) resistance to insecticides, 2) resurgence of pest thrips due to the killing of natural enemies and native competitors, and 3) replacement of native non-target thrips with new species with elevated pest status. In Florida fruit and vegetable systems western flower thrips (*Frankliniella occidentalis*) have attained this pest status due to high pesticide resistance and pesticide suppression of both the primary predator (the minute pirate bug, *Orius insidiosus*) and primary competitors (benign, native species of flower thrips, namely the Florida flower thrips, *F. bispinosa*). An overreliance on insecticides to control thrips has resulted in the development of resistance to the available insecticides, and an inability to prevent unacceptable damage in many specialty crops. Conversely, integrated pest management tools that define pest status (economic thresholds), increase biotic resistance (natural enemies and competition), integrate preventive and therapeutic tactics (scouting, ultraviolet-reflective technologies, biological control, and compatible insecticides), and vertically integrate the programs with other pests provide effective, economical, and sustainable management. Continued success and growth of integrated pest management of thrips requires: 1) evolving new techniques to incorporate into control strategies, and 2) continued rapid and accurate dissemination of new technologies to producers.
Developing and implementing integrated pest management programs is a complex task. It has taken years of research to develop effective integrated pest management programs for western flower thrips in fruits and vegetables. The implementation of these programs was complicated by the fact that these crops are affected by other pests, and growers must be able to contend with western flower thrips and these other pests effectively. Growers are faced with many decisions that affect their crop management and productivity. Unfortunately, the wrong decision regarding the use of insecticides can result in the elimination of natural biotic resistance factors and in outbreaks of the target and non-target pests. Repeated attempts to control the target and non-target pests in this manner results in insecticide resistance. This is exactly what has happened in the case of the spinosyn insecticides. This group of insecticides was the most effective insecticide for control of western flower thrips, and it was compatible with conservation biological control using natural infestations and artificially released populations of minute pirate bugs. The spinosyns are used for thrips and other pests in conventional and organic production systems.

Integrated pest management programs are knowledge-based systems that are fine-tuned to different crops and different regions of Florida, and they need updating regularly as new research findings become available. Effective, economical, environmentally-friendly, and sustainable integrated pest management programs are the result of large research and education investments. There will be a continued need to invest in research to develop additional tactics and to refine these integrated pest management programs to meet emerging challenges and unforeseen problems (e.g., establishment of additional invasive pests and pathogens). There is still a great need to continually train existing users and continually to recruit additional practitioners for expanded future successful implementation of such knowledge-based systems. We want to further develop and evaluate new technologies suitable for integrated pest management programs and to expand adoption to address needs in strawberries and crops double-cropped with strawberries. Collaboration between the University of Florida and consultants has strengthened and improved outreach to producers. We have continuee to develop our infrastructure for thrips integrated pest management extension including web resources, publications, workshops, demonstrations, and work closely with the Florida IPM program for fruits and vegetables to develop a systems approach that is in concert with concerns for the control of other pests.

Thrips-vectored plant viruses are of increasing concern for fruit and vegetable production warranting an expansion of research on both pest thrips species and a complex of identified and new pathogenic viruses. This Specialty Crop Block Grant proposal addressed the thrips vectors along with another synergistic grant by Adkins et al. for research on the viruses.

We previously conducted research to develop effective integrated pest management solutions for thrips in fruiting vegetables. These programs were implemented, and we have demonstrated that they significantly improved management of thrips and thrips-vectored viruses in fruiting vegetables in Florida. Resistance to the main thrips insecticides, the spinosyns, has spread to additional geographic areas and more specialty crops. In particular, the problem has developed in central Florida in strawberries and fruiting vegetables double-cropped after strawberries. At the same time, production of conventional and organic production is increasing. Our resistance management protocol (which is the basis for a sound, effective, sustainable integrated pest management approach) includes the following: apply insecticides only when required, make accurate and precise insecticide applications, diversify the types of management tactics used, and conserve natural enemies.

We continuously evaluate new tactics that merit inclusion into integrated pest management strategies. These include broad-spectrum insecticides and biorational insecticides from novel chemical classes. Biorational insecticides in this case are those that are efficacious against thrips and other target pests but are less detrimental to natural enemies, including the minute pirate bugs that are the key predators of thrips. These bugs naturally invade many fruit and vegetable crops in Florida in numbers sufficient to suppress thrips populations. Biorational insecticides are relatively innocuous to nontarget organisms by having low or no direct toxicity or having systemic or rapid translaminar activity or short field residual, thereby minimizing exposure of natural enemies to the insecticide. The discovery of new biorational insecticides that conserve natural enemies such as the minute pirate bugs is critically important because many populations

of thrips have developed resistance to the spinosyn insecticides. Thrips also are resistant to the traditional broad-spectrum insecticides, including synthetic pyrethroids, organophosphates, and some carbamates. New broad-spectrum insecticides with activity against thrips and other difficult-to-control pests have utility in integrated pest management programs. Although growers are encouraged to use more selective, biorational insecticides from different chemical classes, the use of certain broad-spectrum insecticides against thrips may be warranted in particular instances when non-target effects are minimal. Namely, their use is reserved for times near the end of the season, if needed, to prevent scarring damage to fruit.

An understanding of the population dynamics of invasive and native thrips in strawberries grown in different regions of Florida was lacking, and the ability of natural populations of minute pirate bugs and other natural enemies in controlling thrips had not been determined. Yet, this is critical knowledge in order to develop effective integrated pest management programs for conventional and organic production in each region. In fruiting vegetables, the invasive thrips species are highly damaging by feeding on fruit and by transmitting plant viruses. Conversely, the native thrips cause much less fruit injury even at high densities and they do not vector viruses, while they effectively out-compete the invasive, damaging thrips species. Economic thresholds were developed for each species in strawberries, the interactions of between species determined, and the ability of minute pirate bugs to suppress each thrips species evaluated.

The overall purpose of this research was to develop and implement effective, sustainable IPM practices for thrips in strawberries, other fruits, and vegetables. We previously determined economic thresholds for thrips in fruiting vegetables and evaluated ultraviolet-reflective technologies, biological control, and conventional and biorational insecticides for use against these thrips. We now conducted research on the population dynamics of invasive and native thrips in strawberry grown in different regions of Florida.

Specific objectives of this research were:

1) Characterizing the injury to strawberry fruit caused by adult and larval thrips of different species, so that species and stage-specific economic thresholds can be determined.

2) Determining the role that minute pirate bugs, other natural enemies, and competing thrips play in suppressing pest thrips populations in order to develop a conservation biological control program for strawberry.

3) Evaluating conventional/biorationale insecticides and ultraviolet-reflective technologies for their efficacy against western flower thrips, common blossom thrips, and other pests of strawberry.

4) Determining if pest and non-pest thrips species are resistant to certain insecticide classes and monitoring thrips populations for development of resistance.

5) Determine population dynamics of thrips and natural enemies in commercial fields and identify non-crop sources of individual thrips species infesting crops.

6) Our Extension objective was to disperse knowledge of these new techniques to growers for expeditious implementation. We have developed the required infrastructure, including websites, publications, demonstration plots, and a network of Extension Specialists and Agents to serve producers. Findings from this study and other research were distributed to growers as the construct for outreach was already available. Dispersal of knowledge has been a priority and this work was in concert with the infrastructure supported by a variety of grants. Dissemination of results from the proposed research was unique to this grant, however. In addition, we conducted field demonstrations, in-service trainings, and grower meetings for fruiting vegetables and strawberries to demonstrate the knowledge.

Project Approach

Objective 1 (Research conducted by graduate student and biological scientist Iris Strzyzewski with technical assistants supervised by PD Funderburk)

Greenhouse plants. 'Festival' strawberry plugs were established during 2014 and 2015 in 3.8-liter pots containing Fafard 4 Potting Mix (Sun Gro Horticulture, Agawam, MA). Plants were fertilized every two weeks using Miracle-Gro Water Soluble All Purpose Plant Food 24-8-16 (Miracle-Gro Lawn Products, Inc., Marysville, OH) and Osmocote Smart-Release Plant Food Plus 15-9-12 (The Scotts Company, Marysville, OH). No chemical pesticides were applied. Spider mites were controlled with the release of the predatory mite, *Neoseiulus californicus* (SPICAL, Koppert Biological Systems, Inc., Howell, MI). Senescent leaves were removed by hand, and plants were watered as needed.

Thrips colonies. Colonies of *F. occidentalis* and *F. bispinosa* were established from field populations throughout 2015 and 2016 as needed. Thrips were kept in 15 x 15 cm plastic containers with a 5 x 5 cm ventilation opening at the top covered with thrips-proof mesh. Commercial green bean pods soaked in 10% bleach, rinsed, and air dried were provided as food and oviposition substrate. Filter paper was placed at the bottom to absorb excess moisture, and pine pollen was added as an additional food. Containers were kept at 25 $\pm$ 2 C. Bean pods were replaced every 3-4 days, and old pods transferred to new containers with a new bean pod until all eggs hatched.

Experiments in Growth Chambers. Experiments were conducted at the North Florida Research and Education Center, University of Florida in growth chambers maintained at 25 $\pm$ 2 C and 14 photophase: 10 scotophase. Experimental units consisted of a strawberry plant with one freshly-opened flower. All fruits and excess flowers were trimmed prior to use in experiments. Experimental design was completely random. Treatments were a factorial arrangement of thrips species (*F. occidentalis* and *F. bispinosa*), thrips density (0, 2, 4, 8, 16, and 32 adult females), and duration of infestation (2, 5, and 10 days). For each thrips density, thrips were released onto the single plant. The plant immediately was enclosed with a plexiglass cylindrical cage (15.5-cm in diameter and 36.5-cm in height). Cages were also placed over the control plants with no thrips at each duration. The top of the cage was covered with thrips-proof screen (Green-Tek, Inc., Janesville, WI), and the bottom was inserted into the soil to prevent escape. Each cage had two holes, each 2-cm in diameter, covered with thrips-proof screen to increase ventilation. The number of replicates for each treatment ranged from seven to nine. Cages were removed after the appropriate duration of infestation, the plants were carefully examined, and the number of adult and larval thrips determined. Fruit were harvested 21 days after first flower and examined for symptoms of thrips-inflicted injury. Fruit set, weight, and diameter were determined. The

exterior of the fruits also were examined for thrips injury, namely fruit distortion ('cat-facing') and bronzing ('russeting'). The amount of distortion was estimated by counting the number of strawberry seeds in the injured area on each individual fruit. Fruits also were graded as USDA number 1, number 2, or cull.

Statistical analyses. The main and interactive effects of thrips species, density, and duration of infestation on fruit weight, diameter, and thrips injury were analyzed using three-way analysis of variance for a completely randomized design. When the main effect of thrips density or duration of infestation was significant ($\alpha = 0.05$), the treatment sum of squares was further partitioned into orthogonal contrasts. The effects of thrips species and density on fruit set were analyzed with logistic regression for a binomial distribution and a logit link.

Results. Fruit set was affected by the presence of thrips in the flowers. Both species resulted in significantly reduced fruit set compared to controls ($X^2 = 5.5$, d. f. = 1, $P = 0.02$). In the controls, 41 of 46 flowers set fruit (89.2%). Fruit set was poorer when *F. occidentalis* were present in the flowers than when *F. bispinosa* were present in the flowers ($X^2 = 11.6$; d. f. = 1; $P = 0.0007$). For data pooled across thrips density, 84 of 102 flowers set fruit in *F. bispinosa* treatments (82.3%) and 47 of 122 flowers set fruit in *F. occidentalis* treatments (38.5%). There were no significant differences in fruit set among thrips densities, with fruit set no different for treatments of 2, 4, 8, and 16 thrips per flower than for the treatments of 32 thrips per flower ($X2 = 0.0$, 0.0, 0.7, and 0.2, respectively; d.f. = 1; $P > 0.05$).

The mean fruit weight (SEM) was 8.5g (0.7) for data pooled across control treatments, while the mean fruit weight (SEM) for *F. bispinosa* and *F. occidentalis* for data pooled across thrips density and duration of infestation was 7.5g (0.5) and 5.0g (0.4), respectively. Fruit weight for the thrips treatments differed significantly from the controls ($F = 8.4$; d. f. = 1, 215; $P = 0.003$) and for the two species from each other ($F = 16.5$; d. f. = 1, 215; $P < 0.0001$). The mean fruit diameter (SEM) for data pooled across control treatments was 22.7mm (1.7) for data pooled across control treatments, while the mean fruit diameter for *F. bispinosa* and *F. occidentalis* for data pooled across thrips density and duration of infestation was 20.4mm (1.2) and 15.5mm (1.2), respectively. Fruit diameter for the thrips treatments differed significantly from the controls ($F = 5.2$; d. f. = 1, 208; $P = 0.03$) and for the two species from each other ($F = 7.7$; d. f. = 1, 208; $P = 0.007$). The mean number of seeds in cat-faced areas (SEM) for data pooled across thrips density and duration of infestation was 58.7 (6.7) and 37.6 (5.5) for *F. occidentalis* and *F. bispinosa*, respectively. The mean number of seeds in cat-faced areas (SEM) for data pooled across control treatments was 15.2 (4.1). Cat-facing for the thrips treatments differed significantly from the controls ($F = 14.6$; d. f. = 1, 118; $P = 0.003$) and for the two species from each other ($F = 6.7$; d. f. = 1, 118; $P = 0.01$).

There were no effects among treatments with thrips at different densities from 2 to 32 per flower for fruit weight ($F = 0.3$; d. f. = 4, 211; $P = 0.84$), fruit diameter ($F = 0.1$; d. f., = 4, 208; $P = 0.97$), or mean cat-facing ($F = 0.6$; d. f. = 4, 118; $P = 0.63$). The thrips species x thrips density interactions were not significant for fruit weight ($F = 0.2$; d. f. = 5, 215; $P = 0.94$), fruit diameter ($F = 0.7$; d. f. = 5, 208; $P = 0.60$), or cat-facing per fruit ($F = 1.0$; d. f. = 5, 118; $P = 0.42$).

The duration of infestation of either 2, 5, or 10 days did not affect fruit weight ($F = 1.6$; d. f. = 2, 215; $P = 0.21$), fruit diameter ($F = 0.3$; d. f. = 2, 208; $P = 0.72$), or cat-facing per fruit ($F = 0.2$; d. f. = 2, 118; $P = 0.83$); therefore, the data are not shown. There were no significant interactions of thrips species x duration of infestation for fruit weight ($F = 0.4$; d. f. = 2, 215; $P = 0.66$), fruit diameter ($F = 0.8$; d. f. = 2, 208; $P = 0.43$), or cat-facing ($F = 1.0$; d. f. = 2, 118; $P = 0.42$).

Conclusions. The experiments showed that *F. occidentalis* was highly injurious to strawberry fruit, even at densities as low as 2 per flower. Injury resulted in very poor fruit set and fruit that developed were reduced in diameter and weight and the amount of cat-facing was increased. *Frankliniella bispinosa* proved slightly injurious over a range of densities as high as 32 per flower. No bronzing on fruit were noted. Strawberry may have the ability to compensate to some degree for poor fruit set by producing more flowers or by increasing the size of existing fruit. Data from the field experiments were used to understand the ability of strawberry to compensate for reductions in fruit set.

Research Publications and Research Presentations objective 1:

Strzyzewski, I., J. Funderburk, H. Smith, and J. Renkema. 2016. Injury of *Frankliniella* species to strawberry. International Congress of Entomology, Orlando, Florida.
Strzyzewski, I., J. Funderburk, and M. Srivastava. 2015. Defining thrips injury and damage relationships in strawberries to determine economic injury levels and economic thresholds. Entomological Society of America, Minneapolis, Minnesota.

Objective 2 (Research conducted by Biological Scientists C. Nagle, M. Srivastava, I. Strzyzewski with technical assistants and supervised by PD Funderburk and Co-PD Smith)

Field experiments. The data for the role of minute pirate bugs, *O. insidiosus*, in suppressing thrips populations in strawberry were collected in the field experiments conducted as described under objective 3 below.

Data analyses. The predator to prey ratio (total adult and larval thrips/total adult and nymphal *O. insidiosus*) was used to evaluate whether predator numbers were sufficient to suppress thrips populations in the experiments. The predator is capable of suppressing a thrips population at a ratio of 1 per 180 thrips and of causing control at a ratio of 1 per 51 thrips.

Results. In the Hillsborough County experiment, the number of predators relative to the number of thrips was not sufficient in strawberry during February 2015 to suppress thrips populations. Conversely, predator numbers were sufficient in some treatments to suppress thrips during February 2016. Predator numbers increased greatly in March both years in numbers sufficient to suppress thrips populations. Predator numbers were significantly affected by some insecticides, and this altered the predator to prey ratios so that there were insufficient numbers to suppress thrips populations in these treatments. Specifically, predator numbers were reduced in acetamiprid, bifenthrin, azadirachtin, and kaolin treatments. Predator numbers were very low both years in the Gadsden County experiment.

Conclusions. Predators developed naturally in the main strawberry production area of Hillsborough County during the winter production season. Their numbers appear to develop earlier in some years than others, undoubtedly in relation to environmental conditions. It is clear that a conservation biological control program would be effective in this strawberry production area. Insecticides such as cyantraniliprole and spinetoram are registered that control thrips while conserving predator populations. Predator numbers do not develop naturally in the northern Florida production area during the winter/early spring production season. Their populations overwinter as diapausing adults in sheltered locations.

Research Publications and Research Presentations objective2:

Funderburk, J., G. Frantz, C. Mellinger, K. Tyler-Julian, and M. Srivastava. 2016. Biotic resistance limits the invasiveness of the western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae). Insect Science 23: 175-182.
Funderburk, C., Funderburk, J., Tyler-Julian, K., Srivistava, M., Knox, G., Andersen, P. and Adkins, S. 2015. Population dynamics of *Frankliniella bispinosa* (Thysanoptera: Thripidae) and the predator *Orius insidiosus* (Hemiptera: Anthocoridae) as influenced by flower color of *Lagerstroemia* (Lythraceae). Environmental Entomology 44: 668-679.
Tyler-Julian, K., J.E. Funderburk, S.M. Olson, M.L. Paret, C. G. Webster, and S. Adkins. 2015. A stimulo-deterrent method of thrips and *Tomato spotted wilt virus* management in tomatoes. Acta Horticulturae 1069: 251-258.
Funderburk, J. 2015. Biotic resistance limits the invasiveness of western flower thrips in Florida. International Symposium of Thysanoptera and Tospoviruses. Asilomar Conference Grounds, Pacific Grove, California.
Funderburk, J. 2015. Integrated pest management programs for western flower thrips in Florida. International Symposium of Thysanoptera and Tospoviruses. Asilomar Conference Grounds, Pacific Grove, California.
Funderburk, J. 2015. Challenges and opportunities for managing thrips and tospoviruses. International IPM Symposium. Salt Lake City, Utah.

Objective 3 (Research conducted by Biological Scientists C. Nagle, M. Srivastava, and I. Strzyzewski with technical assistants and supervised by PD Funderburk and Co-PD Smith)
Field plots. Split plot randomized complete block design experiments with four replications were established in October of 2014 and again in October of 2015 at the Gulf Coast Research and Education Center (Hillsborough County) and at the North Florida Research and Education Center (Gadsden County) to evaluate the separate and interactive effects of plastic mulch and insecticides on thrips and *O. insidiosus* populations and on strawberry yield and quality. Subplot size was 2 beds by 8.5m with each bed consisting of two linear rows of 'Festival' strawberry with a 38-cm plant spacing within and between rows. Raised beds were 33-cm in height and 68.6-cm in width with 1.2 m spacing between beds at the Gulf Coast Research and Education Center (Hillsborough County). Foliar applications of fungicides were applied as needed for preventive disease control. No insecticides beyond the insecticide treatments under investigation were applied.
Treatments. Whole-plot treatments were UV-reflective mulch and black mulch (Berry Plastics Corporation, Evansville, IN). In the experiments established in 2014, subplot treatments were a control and nine insecticide treatments. The insecticide treatments were spinetoram (Radiant SC at 53 g a.i./ha; Dow Agrosciences, Indianapolis, IN), bifenthrin (Brigade WSB at 224g a.i./ha; FMC Corporation, Philadelphia, PA), cyantraniliprole (Exirel 10 SE at 149 g a.i./ha + Induce at 0.25% vol/vol, DuPont, Wilmington, DE), acetamiprid (Assail 30 SG at 143.5g a.i./ha, United Phosphorous, Inc., King of Prussia, PA), pyrethrin (PyGanic EC 1.4 II at 30.4g a.i./ha, MGK, Minneapolis, MN), sulfoxaflor (Closer SC at 39 g a.i./ha, Dow Agrosciences), azadirachtin (Aza-Direct at 27.7g a.i./ha, Gowan Company, Yuma, AZ), Capsicum oleoresin extract (Captiva 7.6% at 2.34 L/ha; Gowan Company; Yuma, AZ), and kaolin clay (Surround WP at 13.4 kg a.i./ha; Novasource; Phoenix, AZ). Insecticides were the same in the experiments established in 2015

except that the treatments of bifenthrin, pyrethrin, and sulfoxaflor were omitted. Applications in both years and locations were made using a CO_2-powered backpack sprayer at an application volume of 467.7 liters per ha. All insecticide treatments were applied at least once weekly. In Hillsborough County, insecticide treatments were applied on 18, 25 February and 4, 11 March in 2015 and on 9, 15, 22, and 29 February in 2016. Kaolin was applied twice weekly in 2015 only, with additional applications on 23 February and 2, 9 & 17 March. In Gadsden County, applications of all insecticides were made on 7 and 21 April in 2015 and on 29 March and 5 April in 2016. Additional applications of kaolin were made on 10 and 24 April in 2015 and 1 and 27 April in 2016.

Insect Sample Collection and Processing. The densities of adult *F. occidentalis*, adult *F. bispinosa*, adult *F. tritici*, larval *Frankliella* species, and adult and nymphal *O. insidiosus* were estimated 2- and 6-days post-application each week, by randomly collecting on each sample date 10 flowers per plot in 100-ml vials with 70% ethanol. Insects in each sample were extracted from the flowers and identified under a 17 to 150 X magnification. Voucher specimens are kept at the North Florida Research and Education Center University of Florida in Quincy. In the Hillsborough County experiment, flower samples were collected on 19, 24, 27 February and 3, 6, 10, 13, 17, 20 March in 2015. In 2016, samples were collected on 11, 15, 17, 22, 24, 29 February and 2, 8 March 2016. In the Gadsden County experiment, samples were collected on 9, 14, 23, and 27 April in 2015 and on 30 March and 4, 6, and 11 April in 2016.

Estimating Fruit Yield and Quality. In the Hillsborough County experiments, all ripe fruits from 10 strawberry plants from each plot were harvested on 2 March 2015, 16 March 2015, and 10 March 2016. Berries were determined to be ripe if at least 50% of the surface was pink or red. The weights of marketable and unmarketable fruits harvested from each insecticide treatment and mulch type were measured. Marketable fruits were graded as number 1, number 2, or unmarketable (USDA this needs citing appropriately here). Number 1 fruits were at least 75% pink or red in color, at least 19mm in diameter, and did not show symptoms of disease or injury such as malformation ("cat-facing"), bronzing, and lesions from insects or environmental factors. Number 2 fruits were at least 50% pink or red in color, at least 16mm in diameter, and showed symptoms of minor injury. Fruits that were overripe, diseased, less than 16mm in diameter, or severely injured were deemed unmarketable. The number and weight of number 1, number 2, and unmarketable fruits in each plot were recorded.

Statistical Analysis. The effect of mulch and insecticide treatment on the number and weight of number 1, number 2, and unmarketable fruit was determined for each harvest date each year in the experiments conducted in Hillsborough County using analysis of variance for a split-plot randomized complete block (PROC GLM procedure, SAS Institute 2011). Block and mulch main effects were determined using the block * mulch interaction as error. The remaining residual in the model (i.e., the combination of the block * insecticide treatment interaction and the block * insecticide treatment * mulch interaction) was used as the error to test for the insecticide treatment main effect and the insecticide treatment * mulch interaction. The effects of mulch and insecticide treatment on the numbers of adult *F. occidentalis*, adult *F. bispinosa*, adult *F. tritici*, larval *Frankliniella* species, nymphal *O. insididiosus*, and adult *O. insidiosus* were analyzed using an analysis of variance for a split-plot randomized complete block design as described above. Separate analyses were conducted by year, location, and the number of days

after application. Sample date was treated as a repeated measures effect in the model. Individual insecticide treatments were compared using Duncan's Multiple Range Test when the overall effect of treatment was significant ($\alpha = 0.05$). The data were normal, and the analyses were conducted in all cases on the original data.

Population Dynamics of Insect Populations in Hillsborough County. Populations of *F. bispinosa* and *F. occidentalis* developed each year in February, and both species were abundant in March. *F. bispinosa* accounted for 51 and 77% of the total thrips collected in the strawberry samples in 2015 and 2016, respectively; whereas, *F. occidentalis* accounted for 6 and 1% of thrips collected in 2015 and 2016, respectively. *Frankliniella* species larvae accounted for 42 and 22%, respectively. Other species in the samples were *F. fusca* and *Thrips hawaiiensis.* Seasonal trends of *F. bispinosa* and *F. occidentalis* adults, *Frankliniella* larvae, and *O. insidiosus* adult and nymphs mean numbers (± SEM) for individual sample dates in 2015 and 2016 are shown in Figure 3-X and 3-X, respectively. The mean number of *F. bispinosa* adults per 10 flowers (±SEM) for data pooled over 2015 and 2016 sample date were similar at 34.9 ± 1.49 and 35.5 ± 1.07, respectively. Mean numbers (±SEM) of *F. occidentalis* adults per 10 flowers for data pooled over sample date were 4.06 ± 0.18 in 2015 and 0.25 ± 0.05 in 2015 and 2016, respectively. *F. occidentalis* reached the highest numbers during the third week of sampling in 2015, while *F. occidentalis* numbers were low throughout all sampling dates in 2016. Thrips larval populations developed each year in February and became more abundant in March. Mean numbers (±SEM) of larvae per 10 flowers for data pooled over sample date were 29.4 ± 0.98 and 10.3 ± 0.55 in 2015 and 2016, respectively. The mean number (± SEM) of *Orius* adults and nymphs per 10 flowers for data pooled over sample date were 2.07 ± 0.10 and 0.34 ± 0.04 in 2015 and 2016, respectively.

Population Dynamics of Insect Populations in Gadsden County. Populations of adult thrips were both *F. bispinosa* (47%) and *F. occidentalis* (53%). Combined densities of all thrips including adults and larvae of all thrips species rarely exceeded 1 per 10 strawberry flowers. They never reached damaging levels either year at this North Florida location. The number of *O. insidiosus* also remained very low on all sample dates each year.

Effects of Mulch and Insecticides on Insect Populations in Hillsborough County. The UV-reflective mulch reduced the number of *F. bispinosa* adults only on 6 March 2015. Mulch did not affect the numbers of *F. occidentalis* adult or *Frankliniella* larvae populations on any date.

There significant differences among insecticide treatments on *F. occidentalis* adults on the 2-day post application sample date 27 February, while mean numbers of *F. occidentalis* were significantly higher in plots treated with acetamiprid and bifenthrin than in plots treated with the other treatments. *F. occidentalis* numbers were higher in plots treated with capsicum than in the untreated plot and in the plots treated with azadirachtin, spinetoram, pyrethrin, and kaolin. Treatments of spinetoram, pyrethrin, and kaolin resulted in the lowest numbers of *F. occidentalis*, but they did not differ significantly from the untreated plot. Insecticide treatment did not affect *F. bispinosa* or larval populations. The interactive effect of mulch*insecticide treatment was significant for *F. occidentalis* on 2-day post application dates 19 February and 3 March as well as the 6-day post application date 13 March. This interaction indicated differences in the effects of insecticide treatments on *F. occidentalis* populations between the black and the ultraviolet-reflective mulch. There were no effects of the mulch*insecticide interaction on *F.*

bispinosa or larvae populations. The interactive effects of mulch*block were not significant on any sample date for *F. bispinosa* adults, *F. occidentalis* adults, or thrips larvae.

There was a significant effect of mulch type on the number of thrips larvae on 3 February, but there were no significant differences between mulch types on any other sample dates. Mulch type did not affect the numbers of *F. occidentalis* or *F. bispinosa* adult populations.
Unlike 2015 experiments, the mean *F. occidentalis* numbers did not differ among insecticide treatments in 2016. For both *F. bispinosa* and larvae, however, insecticide treatment effect was not significant on the pre-treatment date or the first 2-day post application date 11 February but was significant for all other later dates. *F. bispinosa* populations were significantly lower in plots treated with spinetoram than in untreated plots on all sample dates after 11 February. Conversely, *F. bipinosa* numbers did not differ significantly in azadirachtin and capsicum treatments from the untreated plots for any sample date. Treatments of cyantraniliprole and acetamiprid also resulted in significantly lower *F. bispinosa* numbers than in untreated plots on the later dates except 8 March and 22 February, respectively. The use of kaolin significantly reduced *F. bispinosa* populations except on 2 and 8 March. Similar trends were observed in thrips larvae numbers. Treatments of cyantraniliprole and acetamiprid significantly reduced larvae compared to untreated plots for all sample dates after 11 February. Spinetoram also resulted in decreased numbers compared to the untreated plots on the same dates except 8 March, and kaolin applications resulted in decreased numbers on 24 February and 2 March. On the other hand, treatments of azadirachtin resulted in significantly increased larvae numbers on 24 February and 8 March, and capsicum resulted in an increase in larvae on 8 March. The interactive effect of mulch*insecticide was significant for *F. occidentalis* numbers on 2 March. This interaction indicated differences in the effects of insecticide treatments on *F. occidentalis* numbers between the black and the ultraviolet-reflective mulch. In addition, mulch*insecticide effect was also significant for larvae on 24 February, which reflected that the magnitude of differences in larvae numbers differed in the black mulch versus the ultraviolet-reflective mulch. The interaction of block*mulch had a significant effect on *F. occidentalis* and larvae numbers on 15 February and 2 March, respectively. These interactive effects indicated that significant differences in numbers were observed between mulch treatments among the blocks. There was no significant effect of the interactions of mulch*insecticide or block*mulch for *F. bispinosa* numbers for any date in 2016.
Effects of mulch and insecticide treatment on Orius populations. There were no significant effects of mulch type on *Orius* populations in 2015 or 2016. In 2015, insecticide treatment had a significant effect on *Orius* populations in the third week of sampling on the 2-day post application date 6 March. Treatment with spinetoram resulted in significantly higher numbers of *Orius* compared to treatments with sulfoxaflor, azadirachtin, capsicum, bifenthrin, pyrethrin, and acetamiprid as well as the untreated control. There were no interactive effects of mulch * insecticide on *Orius* numbers. Insecticide treatment had a significant effect on *Orius* on the last three sample dates 29 February, 2 March, and 8 March. Treatment with capsicum resulted in significantly higher numbers of *Orius* compared to the untreated control and all treatments except azadirachtin. Treatments with cyantraniliprole resulted in an increase in *Orius* numbers compared to treatments with spinosad, kaolin, and acetamiprid on 02 March, but there were no significant differences from the control or capsicum and azadirachtin treatments. On 8 March,

Orius numbers were significantly increased with capsicum treatment from the control and all treatments except spinetoram. There were no interactive effects of mulch * insecticide on *Orius* numbers in 2016.

Effects of mulch and insecticide treatment on strawberry yield and quality. There were no significant effects of thrips on yield or quality in 2015. There were significant increases in marketable fruit weight as a result of ultraviolet-reflective mulches compared to black mulch in 2016 ($F = 91.9$; $df = 1, 36$; $P < 0.0024$). Control of *F. bispinosa* with insecticides also increased marketable fruit weight ($F = 3.1$; $df = 6, 36$; $P < 0.05$). There were no interactive effects of mulch*insecticide treatment on marketable or unmarketable fruit weight and numbers.

Conclusions. Populations of *F. bispinosa* thrips reached high numbers in March in Hillsborough County. Control of populations with several broad-spectrum and biorational insecticides sometimes resulted in yield increases. Populations of *F. occidentalis* were less common. Populations of *O. insidiosus* also developed in February or March in Hillsborough County. Populations were suppressed by the broad-spectrum conventional insecticides. Several biorational insecticides were identified that conserved populations of these predators.

Research Publications and Research Presentations objective 3:

Garrick, T. A., O. E. Liburd, and J. Funderburk. 2016. Effect of humidity on fecundity and egg incubation of *Frankliniella bispinosa* and *Frankliniella occidentalis* (Thysanoptera: Thripidae). Florida Entomologist 99: 505-508.

Cluever, J. D., H. A. Smith, J. E. Funderburk, G. Frantz, C. A. Nagle, and J. L. Capinera. 2016. Effects of insecticide rotations on density and species composition of thrips (Thysanoptera) in strawberry. Florida Entomologist 99: 203-209.

Skarlinsky, T., and J. Funderburk. 2016. A key to some *Frankliniella* (Thysanoptera: Thripidae) larvae found in Florida with descriptions of the first instar of select species. Florida Entomologist 99: 463-470.

Tyler-Julian, K., J. Funderburk, G. Frantz, and C. Mellinger. 2014. Evaluation of a push-pull system for the management of *Frankliniella bispinosa* (Thysanoptera: Thripidae) in bell peppers. Environmental Entomology 43: 1364-1378.

Srivistava, M., J. Funderburk, O. Demirozer, S. Olson, and S. Reitz. 2014. Impacts on natural enemies and competitor thrips of insecticides against *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in fruiting vegetables. Florida Entomologist 97: 337-348.

Funderburk, J., S. Adkins, and I. Badillo-Vargas. 2015. Challenges and opportunities in the management of thrips and thrips-vectored viruses in Florida. Florida Entomological Society meeting, Sanibel, Florida.

Badillo-Vargas, I., J. E. Funderburk, and S. Adkins. 2015. Transmission of tospoviruses and ilarviruses by thrips. Florida Entomological Society meeting, Sanibel, Florida.

Skarlinsky, T., and J. Funderburk. 2015. Toward the identification of thrips larvae with cultivated crops and ornamentals in Florida. Florida Entomological Society meeting, Sanibel, Florida.

Objective 4 (research conducted by graduate student Danielle Sprague)

Flower Thrips Populations Sampled. Flower thrips were collected in 2015 and 2016 from different counties in Florida including Palm Beach, Collier, Hillsborough, Marion, Manatee,

Suwanee, Gadsden, Jackson, Alachua, and Santa Rosa. These included samples of thrips populations collected from strawberry, bell pepper, eggplant, cucumber, and ornamentals.
Bioassay Procedures. Adults collected from the field were aspirated into tubes and then emptied into individual plastic 35-ml cups with uncoated paper caps. The cups were provided with 20-mm sections of snap bean pods sealed at either end with a thin layer of paraffin. After sealing, bean pod sections were submerged for 30 seconds in 10 different concentrations of spinetoram in distilled water, and allowed to air dry for one hour. Individual cups were placed in a sealed plastic 5.7-liter rearing container. These containers were held in a controlled environmental chamber at 23°C, 60% relative humidity, and a photoperiod of 14 hours light: 10 hours dark. Over 10 thrips were placed in each container with three containers per dilution.

Statistical analyses. Data were analyzed using logistic regression. In all cases, mortality in the control was minimal and there were no corrections for mortality necessary in any analysis. The lethal concentration of 50 percent mortality (LC50) with 95% confidence interval was determined using the logistic regression for each population of each thrips species. Results were compared with previously determined baselines of a susceptible population. The resistance ratio was determined by dividing the LC50 value by that of the previously determined LC50 value of the susceptible population.

Results. Populations of *F. bispinosa* collected in 2015 and 2016 from eggplant, strawberry, tomato, and bell pepper in Coller, Hillsborough, Manatee, and Palm Beach Counties had LC50 values for spinetoram concentrations of 0.01 to 0.05 ug/mL. These were not significantly different from the susceptible baseline population, and the results indicated that high mortality would occur at a normal field-labeled rate. Populations of *F. occidentalis* collected from strawberry, bell pepper, eggplant, ornamentals, and cucumber in Gadsden, Hillsborough, Palm Beach, Suwannee, and Santa Rosa Counties had LC50 values for spinetoram concentrations of 15 to 2516 ug/mL, with resistance ratios ranging from 1421 to 247,394. These were significantly different from the susceptible baseline population, and the results indicated very little mortality would occur at a normal field-labeled rate.

Conclusions. Populations of *F. bispinosa* in Florida remain susceptible to the spinosyn class of insecticides; whereas, populations of *F. occidentalis* are resistant throughout Florida. This highlights the need to identify and consider the difference in damage between the two species when making decisions about management. Populations of *F. occidentalis* are more damaging, and they present a greater challenge in controlling with available insecticides, especially the spinosyns that are important in conserving populations of *O. insidiosus*.

Research Publications and Research Presentations objective 4:

Hou, W., Q. Liu, Q. Wu, K. san Miguel, J. Funderburk, and J. Scott. 2014. The α6 nicotinic acetylcholine receptor subunit of *Frankliniella occidentalis* is not involved in resistance to spinosad. Pesticide Biochemistry and Physiology 111: 60-67.
Sprague, D., and J. Funderburk. 2016. Resistance in *Frankliniella* thrips to spinosyn and neonicotinoid insecticides. International Congress of Entomology, Orlando, Florida.

Objective 5: Determine population dynamics of thrips and natural enemies in commercial fields and identify non-crop sources of individual thrips species infesting crops (Research supervised

by Co-PD's Liburd, Frantz, Mellinger, and Adkins and conducted by Post Docs Janine Spies and Elena Rhodes)

Thrips populations in strawberries on organic commercial farms in North-Central Florida. Sampling was conducted on two organic farms. Farm 1 is located in Gainesville, FL and farm 2 is located near Hawthorne, FL. Farm 1 had five 200 ft rows of strawberries. The two outer rows were planted with the variety 'Festival'. The three inner rows were planted with a mix of varieties 'Festival', 'Sensation', and 'Winterstar'. Five flowers and five trifoliate leaves were sampled from each row every other week from 8 Dec. 2014 until 13 Apr. 2015. Only 'Sensation' was sampled from the 1st inner row, 'Winterstar' from the 2nd, and 'Festival' from the 3rd. On farm 2, there were six 200 ft rows of strawberries. There were two guard rows between our plots and the grower's plot. These two rows and the outer row on the other side of the plot were planted with variety 'Camino Real'. The three inner rows were planted with a mix of varieties 'Festival', 'Sensation', and 'Winterstar'. Five flowers and five trifoliate leaves were sampled from each row every week from 8 Dec. 2014 until 13 Apr. 2015. Only 'Festival' was sampled from the 1st inner row, 'Sensation' from the 2nd, and 'Winterstar' from the 3rd. Leaves were examined under a dissecting microscope. Flower samples were processed using the shake-and-rinse method. Thrips were identified to species and gender.

Effect of companion plants and non-crop sources on thrips in strawberries. The study was conducted at the University of Florida, Plant Science and Research Unit (PSRU) in Citra, Florida from October 2015 to March 2016 and repeated the following year October 2016 to March 2017 (currently being conducted). The plot size was approximately 16 ft x 16 ft and strawberry plants (var. Festival) were established in double rows per bed on black synthetic mulch. There was a 15 ft buffer zone of bare soil between each plot to limit pest movement across treatment plots. The experiment was arranged as a split plot design with four replicates. The main plot treatments included a 20 m 1) cultivated (tillage of weeds) and 2) non-cultivated area surrounding the strawberry field. The sub-plot treatments evaluated were 1) planting peppers as a trap crop, 2) planting onions as a trap crop, and 3) no trap crop (control). In treatments where a trap crop was planted, peppers and onions were planted on the outer rows of each strawberry plot.

Flower samples were collected weekly once the plants began flowering (December). Three strawberry flowers were randomly collected from each plot and placed in 50 ml centrifuge tubes containing 25 ml of 70% ethanol. Flower samples were also collected randomly from the peppers and any weeds surrounding the strawberry fields. Vials were brought back to the Small Fruits and Vegetable IPM (SFVIPM) laboratory for processing. Flower thrips were sampled using the shake-and-rinse method developed by Arévalo & Liburd (2007) for use in blueberries. Thrips were identified to species and sexed using a compound microscope. The number of males and females of each species were recorded. Natural enemies collected from the flowers and leaves were also recorded and identified. Four trifoliate leaves were collected weekly from each plot. Four leaves from either peppers or onion were also collected weekly from plots where the trap crop was present. The leaves were inspected for thrips and natural enemy populations under a dissecting microscope, and the taxa were identified and counted. Yield was also collected weekly throughout the season.

Statistical analyses. Data were analyzed using repeated measures with two-way analysis of variance (ANOVA; PROC GLM) of the main and interactive effects of the main plot treatment (cultivation) and the sub-plot treatment (trap crop). Sample date was the repeated measure. Treatment means were separated by least significant differences (LSD) test where ANOVA indicated a significant difference between treatments. Differences among treatments were considered significant if $P \leq 0.05$.

Results. Similar trends in thrips species composition were seen on leaves collected from the organic farms. A few thrips were encountered on leaves, mostly the six-spotted thrips, *Scolothrips sexmaculatus*, which were seen in March when twospotted spider mite populations were high. The few larvae that were seen were also sampled during this time. An occasional *Frankliniella bispinosa* was seen on the leaves, too. Thrips were much more abundant and diverse in flower samples. On farm 1, thrips larvae were collected in small numbers throughout the season. Larval populations increased on 30 Mar. 2015 and remained high on 13 Apr. 2015. *Frankliniella bispinosa* females were collected in small numbers from 8 Dec. 2014 until 5 Jan. 2015. Female *F. bispinosa* were collected again on 16 Mar. 2015 and the population exploded after that. Male *F. bispinosa* were not collected until 2 Mar. 2015 and followed the same trend as the females after this date. Other species encountered in small numbers throughout the season included *F. fusca*, *F. occidentalis*, *Microcephalothrips abdominalis*, and *Thrips hawaiiensis*. In flower samples from farm 2, larvae were collected sporadically until 16 Feb. 2015. The population remained low until 23 Mar. 2015 and peaked on 30 Mar. 2015. The *F. bispinosa* population followed a similar trend with females peaking at a much higher number than males. Other species encountered in small numbers throughout the season included *F. fusca, F. occidentalis,* and *T. hawaiiensis*.

The species distribution of thrips in strawberries in Citra, FL in the 2015-2016 season was similar to trends observed in previous years, such that there was an overwhelming abundance of *F. bispinosa* (approximately 35/strawberry bloom counted at the end of the season). There were also low populations of *F. fusca*, *F. occidentalis*, *T. hawaiiensis*, and *M. abdominalis* (< 1/bloom). Adult flower thrips collected from strawberry flowers were different between trap crop treatments ($F = 2.94$; df = 2, 358; $P = 0.0541$), such that there were more adult flower thrips in the control (not trap crop) compared to the pepper trap crop treatment; however, thrips densities were not significantly higher in the control compared to the onion trap crop treatment. Adult flower thrips collected from strawberry flowers were not different between cultivated and uncultivated plots, and there was no interaction effect between trap crop and cultivation. Conversely, immature thrips populations collected from strawberry flowers were higher in the uncultivated treatments compared to the cultivated treatments ($F = 15.96$; df = 1, 357; $P \leq 0.0001$), but were not different between trap crop treatments and there was no interaction effect. *Orius* spp. densities were also higher in the uncultivated plots compared to the cultivated plots ($F = 5.89$; df = 1, 358; $P = 0.0157$), but were not different between trap crop treatments and there was no interaction effect. Marketable strawberry yields were higher in the cultivated plots compared to the uncultivated plots ($F = 9.68$; df = 1, 458; $P = 0.0020$) and lower in the control (no trap crop) treatment compared to the onion trap crop treatment ($F = 3.52$; df = 2, 458; $P = 0.0304$).

Conclusions. There was an overwhelming abundance of *Frankliniella bispinosa* compared to other thrips species found in strawberries. Although *F. bispinosa* is a common flower thrips species, they can attain large numbers quickly and cause significant damage to flowers if not managed. The findings from the PSRU in Citra showed that adult flower thrips collected from strawberry flowers were higher in the control treatment (no trap crop), and therefore could have contributed to the reduced marketable yields that were observed. Higher marketable yields were observed in the onion and pepper trap crop treatments; therefore, onions and peppers could serve as effective trap crops in strawberry fields to suppress high flower thrips populations and ultimately improve marketable yields. Adult thrips populations were not different between cultivated and uncultivated plots; however, immature thrips populations were higher in the uncultivated treatments. Surrounding weedy hosts, such as wild mustard *Sinapis arvensis*, could be serving as a reservoir for pest thrips species and contributing to reduced yields. *Orius* spp. densities were higher in the uncultivated plots compared to the cultivated plots. Therefore, weedy culture surrounding the field could provide a habitat for natural enemies of thrips in strawberries. If managed effectively and combined with IPM tactics such as biological control and reduced-risk pesticides, the provision of non-crop hosts nearby commercial strawberry fields could enhance thrips management and improve marketable yields.

Thrips populations and thrips-vectored tospoviruses in strawberries and other hosts in Central Florida. Populations of thrips infesting commercial strawberry fields were determined by identifying thrips collected in samples of strawberry foliage, blooms and fruits. Samples were collected on two week intervals from November 2014 to April 2015 and from December 2015 to April 2016. Sampling was carried out in commercial conventional and organic strawberry fields located in Manatee and Hardee Counties, and from U-Pick farms located in Lee County, FL. Sampling was carried out by removing two trifoliate leaves, two blooms and two green fruits from strawberry plants on every sixth row following a diagonal path across the field. Samples were flooded with 70% ethyl alcohol to kill and preserve the insects. Tomato and pepper crops were sampled in the U-Pick farms and at the conventional strawberry farm in Manatee County during the 2014-15 season. Sampling in these crops and in associated weeds was carried out by collecting samples of 25-50 blooms into 70% ethyl alcohol. Plants showing virus-like symptoms were sent to Scott Adkins for diagnosis of tospovirus presence. Thrips were identified by first washing them from the sampled plant parts with water, sieving out debris and plant material, and collecting the thrips on a fine mesh filter screen. Thrips were examined under 20-40X magnification under a dissecting microscope. Specimens requiring further study were mounted on microscope slides.

Results and Conclusions. Economically important thrips species infested strawberries, peppers, tomatoes, and weeds at all sampling sites. These species included primarily *Frankliniella bispinosa*, *F. occidentalis*, *F. schultzei* and *Thrips palmi*. Very low numbers of other potentially important species were also encountered, including *F. fusca* and *Scirtothrips dorsalis*. Of the major species, *F. bispinosa*, *F. occidentalis* and *F. schultzei* were active in the strawberry crops, while *T. palmi* was present mostly in the pepper crops and in some weed species. *F. occidentalis* was largely absent from strawberry blooms in the Hardee and Lee County fields while they were a significant part of the thrips fauna in the Manatee County conventional fields. Their near absence from the Lee County U-Pick fields is interesting because this species reached significant

numbers in the pepper crops in both U-Pick farms. Growers managed thrips populations in the commercial strawberry fields using either conventional synthetic or organically approved insecticides. The impact of these management programs was evident in three ways: a) Thrips numbers were maintained below economically damaging levels through most of the season with high numbers developing only during the final weeks of the crop, coinciding with seasonally high populations in local citrus and vegetable crops as well as in uncultivated woodlands and weedy areas; b) the Florida native *F. bispinosa* was the most abundant species in the organic strawberry fields, while in conventional fields, the non-native *F. occidentalis* and *F. schultzei* were present in numbers equal to or greater than *F. bispinosa*; and c) *Orius* spp (which included *Orius insidiosus* and *Orius pumilio*) reached significant numbers only in the organic fields in Manatee County, where their numbers were high enough at the end of the season to apparently cause a reduction in thrips numbers. Thrips population trends in U-Pick strawberries were similar to those found in the conventionally grown commercial fields. All plants at these locations were free of tospoviruses.

Research Publications and Research Presentations objective 5:

Spies, J. and O. E. Liburd. 2016. Evaluating the implementation of trap crops to manage thrips populations in strawberries. XXV International Congress of Entomology. Orlando, FL; September 30.

Adkins, S., C. A. Baker, C. Y. Warfield, C. Estévez de Jensen, I. Badillo-Vargas, C. G. Webster, *G.* Frantz, H. C. Mellinger, J. E. Funderburk, R. Naidu. 2017. Viruses of ornamentals emerging in Florida and the Caribbean region. Acta Horticulturae, in press.

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Objective 6: To disperse knowledge of these new techniques to growers for expeditious implementation (extension)

To recruit producers, workshops were conducted in South, Central and North Florida: Developing Small Farms Teaching Teams, Extension Professionals Association of Florida, Naples, FL, September 3, 2015; Thrips Management in Strawberry, Florida Strawberry Growers Association meeting, Dover, FL, October 20, 2015; Thrips Management Grower Meeting-Peppers, West Palm Beach, FL, January 19, 2016; Thrips Diagnostics: the Good, the Bad and the Ugly, LaBelle, FL, January 20, 2016; 2016 Strawberry IPM Workshop, Starke, FL, February 18th, 2016; and UF/IFAS Certified Crop Adviser CEU Session, Gainesville, FL, April 13, 2016. In an allied project, research was conducted to develop IPM recommendations for delivery to UF/IFAS Extension agents, producers, crop advisors, field scouts, and others. This project provided Extension information on the abundance and dynamics of thrips and their natural enemies in strawberry, pepper and other fruiting vegetables; insecticide efficacy and resistance monitoring; biological and cultural control; and economic thresholds for different thrips species. The Extension IPM programs included presentations by Joe Funderburk, Hugh Smith, Oscar Liburd, and Norm Leppla; cooperator Amanda Hodges; and graduate students Iris Strzyzewski, Danielle Sprague and Nicole Casuso. A novel feature was an interactive puzzle that required participants to pin key taxonomic characters on diagrams of corresponding thrips species. Adoption by growers of IPM for thrips and other pests in specialty crops. Growers have been adopting UV-reflective mulch technologies and using relatively low risk conventional broad-spectrum and natural organic insecticides against thrips. Additionally, strawberry growers are selecting IPM practices that are compatible with conservation biological control programs for minute pirate bugs, use tomato cultivars resistant to tospoviruses with horticultural suitability for production in South Florida, and maintain companion plants in their farmscapes to increase natural enemies and pollinators. Thrips specialists in Florida have been organized to deliver a state-wide management plan for the thrips species complex. They have effectively communicated to growers the ways to mitigate the thrips/tospovirus problem through numerous workshops and meetings, written and online educational materials, and one-on-one discussions. Through this process, many growers have become aware of their options and have adopted the IPM tactics that have been developed. However, to maximize their effectiveness, these tactics must be implemented in a coordinated, synchronized fashion. An in-service training was conducted to train extension specialists and agents about insecticide resistance and thrips and how to manage it (Funderburk J. 2016. Managing thrips and thrips-vectored viruses in Florida crops. Certified Crop Advisor Training. Gainesville, Florida.) Increase grower's knowledge of how to implement new IPM practices and systems. Thrips management requires training in the accurate identification of species. The first comprehensive set of photo-based diagnostic materials was produced for identifying the seven primary thrips species affecting horticultural crops in Florida. The diagnostic set includes a

series of quick guides (fact sheets), two posters, a PowerPoint tutorial for the non-specialist, and an illustrated key for people with taxonomic training. At one of the thrips workshops, attendees' mean pre-training score of 13% increased to 87% post-training for identifying thrips, aphids, white flies, spider mites, big eyed bugs, stink bugs, sap beetles, spotted winged drosophila, and botrytis (gray mold). PowerPoint presentations included: "Thrips, spider mite and beetle update" (O. Liburd), "Managing thrips in Florida strawberry" (H. Smith, J. Cluever and C. Nagle), "Developing small farms teaching teams" (R. Hochmuth, N. Leppla, D. Treadwell, A. Hodges, E. Skvarch, H. Carter, D. Nistler, S. Galindo, and M. Henry), and "Thrips management in strawberry" (J. Renkema, J. Funderburk, I. Strzyzewski, D. Sprague, O. Liburd, J. Razze, E. Rhodes, J. Taylor, A. Whidden, and N. Leppla).

The following fact sheets and trade journal articles were produced:

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Goals and Outcomes Achieved

Goal 1 was to quantify the economic injury level for specialty crops caused by thrips of different species, so that growers have specific recommendations for applying control measures. This knowledge allows specialty crop growers to scout strawberry, melon, pepper, and tomato fields

and assess the injury caused by adult and larval thrips and other pests. Prior to the development of economic injury levels, the pest management practice specialty crops was the calendar application of broad-spectrum insecticides with some scouting but only subjective thresholds. We have developed economic injury levels for different species of thrips in pepper, tomato, and eggplant. Surveys indicated that the number of growers of these specialty crops applying economic injury levels is greater than 50% (our initial target). We also have a better understanding of the economic injury level for different species of thrips in strawberry. Strawberry growers are gaining the knowledge, and most are adopting changes in insecticide-use practices as a result.

Goal 2 was to determine the impact of minute pirate bugs and of competing thrips species, on thrips and other pests of specialty crops to enable growers to develop conservation biological control as a primary management practice. This knowledge allows specialty crop growers to scout fields, assess the need for therapeutic management, and make insecticide decisions based on the thrips species and the number of predatory minute pirate bugs. Our research showed that minute pirate bugs naturally invade pepper, eggplant, and strawberry fields in numbers sufficient to control thrips. Further, populations of *F. bispinosa* naturally outcompete populations of *F. occidentalis* and prevent them from reaching damaging numbers. Therefore, it is important to distinguish between thrips species in scouting programs. Surveys showed that extension agents, scouts, and growers increased their ability to identify thrips from 13 to 87% (our initial target was to increase this knowledge to greater than 50%).

Goal 3 was to provide specialty crop growers with effective and economical management of thrips and other pests of specialty crops by conducting research to evaluate conventional and biorational insecticides and ultraviolet-reflective technologies. This provides specialty crop growers with effective, sustainable management of thrips and thrips-vectored viruses. Our results have shown that UV-reflective technologies of silver/aluminized mulch and kaolin are effective in reducing both thrips and thrips-vectored tospoviruses. We also have identified new conventional and biorational insecticides with efficacy against thrips. This data was key in supporting a newly labeled insecticide, tolfenpyrad. These results were widely conveyed to growers through publications and presentations which has led to wide adoption.

Goal 4 was to determine if pest and competing pest thrips species are resistant, monitor thrips populations for resistance, and provide a protocol for minimizing insecticide resistance. We have determined that resistance to the key insecticide, spinetoram, is widespread in *F. occidentalis* populations. Populations of *F. bispinosa* remain susceptible. These results were widely conveyed to growers through publications and presentations. Changes in management strategies were made in extension recommendations to deal with and manage the problem of resistance. This involved careful monitoring and identification of thrips species, the use of economic thresholds, increased use of biological control and UV-reflective technologies, and careful selection of alternative, effective insecticides.

Beneficiaries

Thrips and thrips-vectored tospoviruses are key pests in peppers, tomatoes, eggplant, tomatoes, and strawberries in Florida. Losses to these commodities in Florida on some farms have at times exceeded 50%. Overall, growers of these commodities in Florida rank solutions for thrips as one of their major needs. Thrips also are a pest in cucurbits and snap beans. The value of the above commodities to farms in Florida exceeds $1 billion. In particular, the growers identify sampling methods for thrips, determination of economic thresholds for thrips, and the development of effective management tactics for thrips and tospoviruses as top priorities. In addition, the development of resistance in thrips populations to the most effective insecticide is a major problem that was addressed. Few insecticides are effective against *F. occidentalis*, the most damaging thrips and the key vector of tospoviruses. And very few are available that provide control of thrips and other pests while at the same time conserving key natural enemies. This proposal addressed the above needs through a combination of research objectives. This proposal also connected effectively with the end users of the developed technologies through a combination of in-service trainings for extension agents, meetings for growers, on-line extension fact sheets, field days, and trade journal articles. Overall, we know that more than 50% of growers gained knowledge about thrips and tospovirus management and adopted developed technologies as a result of our research and extension efforts for thrips and tospoviruses.

The project will benefit about 100 strawberry growers, as well as approximately 1,200 growers of fruiting vegetables.

Lessons Learned

This grant represented a number of research objectives and an extension objective; yet, each was accomplished according to the original timelines as planned and there were no serious problems encountered with the work plan. This undoubtedly was the result of the experience of the PI and Co-PI's. There were problems with change in personnel, but this is to be expected at off-campus research sites. It is difficult to measure accurately the knowledge gained and the level of adoption by growers. However, it is clear that we exceeded the expected goals and outcomes.

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Project (7): Blueberry trees? Improving Profitability of Florida's Blueberry Industry

Project Partners: University of Florida

Project Summary

The specific issue, problem, or need addressed:

This project addressed two issues Florida blueberry growers have identified as major factors impacting their profitability: 1) the high cost of hand-harvesting and 2) the requirement for extensive soil inputs. Florida's blueberry industry is based on the fresh market and growers receive high prices for their early crop. However, production efficiency and profitability are constrained by high harvest costs – which comprise a major portion of total production costs - and the uncertainty of labor for hand harvesting. In order to reduce harvest costs, mechanical harvesting systems for fresh market blueberries have been developed, but results have been less than ideal. Fruit losses of 30% or more can occur, resulting in significant profit loss. The multi-caned architecture of highbush blueberry is a primary contributor to fruit loss during mechanical harvesting, because the catcher plates on mechanical harvesters cannot close tightly around multiple canes. Multiple canes also increase the incidence of fruit bruising when berries drop to the catcher plates, therefore reducing fresh market quality.

In addition to harvesting costs, blueberry production efficiency and profitability are limited by the high costs of soil amendments, which are required for successful blueberry production. Blueberry has strict soil requirements for satisfactory growth and this is reflected in establishment and maintenance costs. Blueberry cultivation is limited to acidic soils with high organic matter. Such soils are limited and are often located in or adjacent to wetlands. In fact, blueberry growers have expressed concern over wetland regulatory policies that affect development of potential production sites. Although blueberry can be grown on more typical mineral soils (i.e. higher native pH, lower organic matter), the soil amendments required to maintain productivity – primarily pine bark mulch - are extensive and costly.

We have identified a wild blueberry relative, Vaccinium arboreum (sparkleberry), as a potential rootstock for use in a novel blueberry production system. Sparkleberry is a single-trunk, tree-like species that is adapted to high pH, low organic matter soils. Use of sparkleberry as a rootstock for grafted southern highbush blueberry (SHB) cultivars has the potential to overcome constraints to mechanical harvesting, as the single trunk will increase harvest efficiency by allowing the catcher plates to close more tightly around the trunk, thus decreasing ground losses. Further, the requirement for pine bark mulch soil amendment could potentially be eliminated using sparkleberry as a rootstock because this species grows well on low organic matter, non-amended soils.

Importance and timeliness of the project:

In 2014, the Florida Blueberry Growers' Association identified the high cost and labor problems associated with hand-harvesting and the high cost/low sustainability of soil inputs (pine bark mulch) as two of the top issues facing their industry. Not surprisingly, these are issues facing all major blueberry producing areas in the U.S. The Florida blueberry industry is growing rapidly, with acreage increasing 5-fold in the last 10 years. Since Florida's early blueberry crop is destined for the fresh market - which commands high prices and a high profit for the industry - Florida blueberries are harvested almost exclusively by hand. As the blueberry acreage in Florida continues to increase, the labor demands associated with hand-harvest grow proportionally. Hand-harvesting is expensive and labor intensive, and availability of labor is becoming increasingly threatened. A recent study suggests that U.S. farms will likely face a labor shortage in the near future, regardless of any immigration reform legislation. This is primarily due to increased wealth in Mexico, which has traditionally supplied most of our labor. Workers are shifting away from agriculture into other job sectors. Further, wages on Mexico's own farms are increasing, which means U.S. farmers will have to pay higher wages to attract the decreasing supply of farm workers. The report concludes that "labor shortages [in the U.S.] will keep getting worse", and that U.S. farmers need the capability to mechanically harvest fresh fruits and vegetables.

The high cost and low sustainability of pine bark mulch is an equally important and timely issue facing the Florida blueberry industry. Both establishment and maintenance costs are high in blueberry production. Estimates for field preparation and first-year establishment costs average as much as ~$20,000 per acre in Florida, one-third of which is the cost of pine bark mulch. The high cost of pine bark mulch is unsustainable for the Florida blueberry industry, as continued high profits are already being jeopardized by increased competition from Mexico, which has doubled production every year for the past three years. Blueberry production in Mexico is expected to continue this rate of growth for the foreseeable future; thus, to remain viable, Florida blueberry growers must decrease their production costs immediately.

This project was initiated by funding from a 5 year USDA-SCRI grant, which will expire in September 2014. Three field plantings were established in 2011 and preliminary data have been collected with funding from that grant. Plants will be in full production by 2016, and funding to continue the experiments and collect critical yield data is necessary.

Project Approach

Activities performed and results

The project focused on two goals:

Goal 1: Determine if vegetative and reproductive growth differs between own-rooted SHB vs those grafted onto sparkleberry rootstocks and both grown on amended vs non-amended soils.

This was accomplished by measuring plant canopy volume of own-rooted vs grafted blueberry plants in either amended or non-amended soils at two locations. By the end of the first year (2015), canopy volumes of grafted 'Farthing' plants on either soil type and own-rooted plants on amended soil were similar at the Archer location and were significantly larger than canopy volume of own-rooted 'Farthing' on non-amended soil (Table 1). However, at Citra, canopy volume of own-rooted 'Farthing' on amended soil was larger than own-rooted or grafted 'Farthing' on non-amended soil. Grafted 'Meadowlark' on either soil type and own-rooted 'Meadowlark' on amended soil had greater canopy volumes at both locations compared with own-rooted plants on non-amended soil. By the end of year two (2016),

canopy volumes of grafted and own-rooted 'Farthing' plants on amended soil were similar at the Citra location, and greater than canopy volumes of own-rooted and grafted on non-amended soil (Table 2). At Archer, canopy volumes of grafted and own-rooted 'Farthing' on amended soil were similar, while canopy volume of grafted plants on non-amended soil was greater than that of own-rooted plants on non-amended soil. Grafted 'Meadowlark' on amended soil had greater canopy volume than own-rooted plants on amended soil at both locations (Table 2). At Citra, canopy volumes of grafted 'Meadowlark' on both soil types were similar, while at Archer, canopy volume of grafted 'Meadowlark' on amended soil was greater than that of grafted plants on non-amended soil. At both locations, grafted plants on both soil types had greater canopy volume than own-rooted plants on non-amended soil.

Flower bud number, fruit set, total yield, and individual fruit weight were also determined. In year one (2015), there were no significant differences in bud number or fruit set in any of the treatments. There were no differences in flower bud number in grafted vs own-rooted 'Farthing' or in amended vs non-amended soils at either location in 2016. Own-rooted 'Meadowlark' on non-amended soil had a greater percent flower bud number compared to the other treatments at Archer. At Citra, grafted 'Meadowlark' had greater percent flower bud number compared with own rooted plants, regardless of soil treatment. There were no differences in fruit set in grafted vs own-rooted 'Meadowlark' or in amended vs non-amended soils at either location. However, fruit set on grafted 'Farthing' was significantly greater than own-rooted plants, regardless of soil treatment or location.

In year one (2015), yields of own-rooted 'Farthing' on amended soil and grafted 'Farthing' on both soil types were similar and significantly higher than yields of own-rooted 'Farthing' on non-amended soil at the Archer location. However, at Citra, yields were similar among all treatments (Table 3). For 'Meadowlark', yields of own-rooted plants on amended soil and grafted plants on both soil types were significantly greater than yields of own-rooted 'Meadowlark' on non-amended soil at both locations. There were no treatment effects on berry size for 'Farthing', which averaged 2.1 g/berry; however, grafted 'Meadowlark' plants had significantly larger berries than berries from own-rooted plants (2.2 vs 1.8 g/berry, respectively).

In year two (2016), yields of grafted and own-rooted 'Farthing' on amended soil were similar and significantly higher than yields of own-rooted 'Farthing' on non-amended soil at the Archer location (Table 4). In Citra, yields were greatest in grafted 'Farthing' on amended soil. Own rooted plants on amended soil and grafted plants on non- amended soil had similar yields, while own rooted plants on non-amended soil had a significantly lower yield compared to all the other treatments. For 'Meadowlark', grafted plants on both soil types and own-rooted plants on amended soil had significantly greater yields than own-rooted 'Meadowlark' on non-amended soil in Archer. At Citra, yields of grafted 'Meadowlark' were significantly greater than yields on own rooted plants, regardless of soil treatment. There were no treatment effects on berry size for 'Farthing', which averaged 1.9 g/berry; however, grafted 'Meadowlark' plants had significantly larger berries than berries from own-rooted plants (2.2 vs 1.8 g/berry, respectively). These results suggest that blueberry grafted onto sparkleberry rootstock (V. arboreum) has the potential to out-yield own-rooted plants on both amended and non-amended soils.

The winter of 2015-16 was unseasonably warm, which resulted in low yields across all treatments, particularly at the Citra location. We obtained a no-cost extension so we could collect yield data for the 2017 season. Yields obtained in 2017 confirmed the pattern observed in the previous two years, as reported above.

Leaf and soil samples were collected twice a year for nutrient analysis in order to monitor and maintain optimum fertilization. Results showed that soil and leaf nutrient levels were within the appropriate range for all treatments at both locations and there were no treatment effects on leaf nutrient content or concentration.

Goal 2: Determine differences in yield efficiency of mechanically harvested vs hand-harvested grafted and own-rooted SHB and compare post-harvest storage characteristics of fruit.

Plants at the Archer location were mechanically harvested three times in 2015. Additional plants were hand-harvested at the same time for comparison of yield and postharvest attributes. Before and after each harvest time, ground loss fruit were collected. All fruit was transported back to the laboratory, sorted into ripe, unripe, and damaged berries, and weighed by class. Mechanical harvesting significantly reduced marketable yield compared with hand harvesting for all treatments, with reductions ranging from 42-59%. Yields of mechanically harvested plants were similar between grafted plants on both soil types and own-rooted plants on amended soil. However, the percent of ground loss fruit in grafted plants was significantly less compared with ground losses of own-rooted plants during mechanical harvesting (Table 5).

Fruit firmness at harvest was similar between mechanical and hand-harvested fruit of both cultivars. Fruit firmness did not decline after 7 days of cold storage for either harvesting method in either cultivar (Table 6). By 14 days of storage, fruit firmness of mechanically harvested fruit was significantly lower that of hand-harvested fruit. Similarly, fruit appearance ratings decreased, and softness, shriveling, and decay increased in mechanical- compared with hand-harvested fruit by 14 days of storage. There was no effect of harvest method on fruit soluble solids during 14 days of cold storage; however, acidity decreased in mechanical- compared with hand-harvested fruit by 14 days of storage, resulting in an increased maturation index in mechanically harvested fruit. There were no consistent effects of grafted vs own-rooted plants on fruit quality parameters or storage life in either cultivar.

The comparison of mechanical vs hand-harvest was continued in 2016. Mechanical harvesting significantly reduced marketable yield compared with hand harvesting for all treatments, with reductions ranging from 52-65%. Yields of mechanically harvested plants were similar between grafted plants on both soil types and own-rooted plants on amended soil. However, as seen in 2015, the percent of ground loss fruit in grafted plants was significantly less compared with ground losses of own-rooted plants during mechanical harvesting (Table 7).

Fruit firmness at harvest was less in mechanical vs hand-harvested fruit for both cultivars (Table 8). Fruit firmness did not decline after 7 days of cold storage for hand harvested fruit of either cultivar, but decreased in mechanical-harvested fruit. This decline continued in mechanically harvested 'Farthing' fruit through 14 days of storage. Fruit appearance ratings decreased by 14 days of storage, and softness, shriveling, and decay increased in mechanical- compared with hand-harvested fruit by 14 days of storage. There was no consistent effect of harvest method on fruit soluble solids or acidity during 14 days of cold storage, nor were there consistent effects of grafted vs own-rooted plants on fruit quality parameters or storage life in either cultivar.

These preliminary field observations indicate that growth and yields of grafted plants are similar to or greater than those of own-rooted blueberry and suggest that it may be possible to reduce soil amendment application in blueberry production. The use of a rootstock decreased ground losses during mechanical harvesting compared with own-rooted (non-grafted) SHB. An unexpected development in these plantings occurred when bacterial leaf spot (causal agent Xylella) was observed on own-rooted blueberry, while grafted plants exhibited little or no symptoms of Xylella infection. We are currently examining this more closely to determine the level of tolerance exhibited by grafted plants.

The primary project partners for this research were Caroline Hamilton, Eric Ostmark, and Moshe Doron (Biological Scientists) who were most directly involved with day-to-day field and lab work. Dr. Jeff Williamson provided suggestions and research guidance, and Dr. Rebecca Darnell provided suggestions, research guidance, and laboratory space. Alto Straughn, owner of Straughn Farms, LLC, supported this project by providing land, irrigation, fertilization, weed control, and supervision for the research plot in Archer, FL.

Goals and Outcomes Achieved

Goal 1: Assess vegetative and reproductive growth in grafted compared with own-rooted SHB grown on amended vs non-amended soils.

Measurements of vegetative canopy volume, flower bud number, fruit set, and fruit yield were done as per the goal and allowed quantification and characterization of vegetative and reproductive growth in grafted vs own-rooted blueberry on the different soil types.

Preliminary data indicated a one-year lag in vegetative growth of grafted plants that appeared to be overcome the second year after planting. This recovery was particularly evident in the non-amended soil treatment. Following that lag year, grafted blueberry generally exhibited increased vegetative growth, reproductive development and yield compared with own-rooted SHB , particularly in plants grown on non-amended soils.

Goal 2: Determine differences in yield efficiency of mechanically harvested vs hand-harvested grafted and own-rooted southern highbush blueberry and compare post-harvest storage characteristics of fruit.

Yield data were collected as per the goal and used to determine ground loss, unripe berry yield, damaged berry yield, and marketable yield to allow comparison of machine harvest efficiency between grafted and own-rooted plants. Post-harvest storage experiments determined how harvesting method affected fruit quality during cold storage.

Mechanical harvest data indicated that grafted plants experienced less ground loss of fruit during harvesting than did own-rooted plants. Mechanically harvested fruit did not store as well as hand harvested fruit - which we anticipated – and exhibited decreased fruit firmness and appearance following 14 days of storage. However, part of this may have been due to the longer time the fruit stayed on the plant between mechanical harvests compared with hand harvests, which resulted in more overripe fruit in the mechanical harvest treatment at the time of harvest. Decreasing the length of time between mechanical harvests would alleviate this problem.

Beneficiaries

Commercial blueberry growers throughout Florida and allied industry experts who work with the Florida blueberry industry will benefit from this research. The ability to decrease soil amendments and increase the efficiency of mechanical harvesting will reduced the cost to the grower, as well as the consumer. Pine bark soil amendment accounts for 30% of the cost of planting one acre of blueberries, thus a reduction in pine bark use can dramatically decrease establishment and maintenance costs for growers.

Allied industry may benefit as blueberry nurseries will be able to offer their clients the option of purchasing grafted blueberry plants; the agricultural machinery industry will benefit through increased use of mechanical harvesters and harvesting aids. Additionally, the public will benefit since the reduced soil inputs and improved harvest efficiency will decrease costs and support a more environmentally and socially sustainable production system. Finally, the decreased cost will potentially motivate more consumers to substitute fresh blueberries for high-fat, highly processed snack foods, with consequent reductions in diet-related health problems. The beneficiaries have been made aware of these results through field days, grower presentations, and a dedicated website.

We estimate that this proejct will impact up to 825 growers, the total number of Florida blueberyr operations with area harvested as recorded in the 2012 Census of Agriculture.

Lessons Learned

The project goals and work plan were carried out as described in the proposal. The 2015-16 winter was unseasonably warm and plants did not fulfill their chilling requirement. This resulted in sporadic budbreak and a reduction in the number of buds that broke, which ultimately impacted yield. We collected yield data from the 2017 harvest, which supported the treatment effects observed in 2015 and 2016.

Although grafted plants exhibited reduced ground loss of fruit during mechanical harvest compared with own-rooted plants, we speculate that an even greater reduction could be obtained by grafting the fruiting cultivar higher on the rootstock. Thus, future grafted plants will have the fruiting cultivar grafted at least 30-40 cm above the soil line. This will enable the catch frame to more fully close around the single trunk of the rootstock.

Surprisingly, we observed that grafted plants exhibited increased tolerance to blueberry leaf scorch (Xylella) than did own-rooted plants. This was an unexpected benefit and we are currently examining the source and extent of this tolerance.

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Project (8): Critical Bud Temperature Determination in Low-Chill Peach and Blueberries

Project Partners: University of Florida

Project Summary

Low-chill peach and blueberry growers in the southeastern U.S., particularly in Florida and Georgia, face significant risk from frost/freeze damage because their bloom periods coincide with multiple frost/freeze events in December – February. Commercial peach and blueberry growers have typically used frost/freeze mitigation strategies such as irrigation with overhead sprinklers and wind machines to keep flower and vegetative bud tissues above critical lethal temperatures. Irrigation is used to take advantage of the latent heat of freezing, in which water, releases a significant amount of heat (1200 BTUs/gallon or 80 calories/gram) when liquid water freezes to ice during the transition from liquid to solid ice. A consistent flow and amount of water is required (0.25 inch/hour) to adequately protect flower buds and young fruit. However, the volume of water for frost protection can be restricted, depending upon agricultural water management districts' policies, changes in aquifer levels, and sinkhole incidence, particularly in Central Florida. In addition, the costs associated with pumping water for frost protection can be significant given rising fuel prices.

Critical bud temperatures are those temperatures at which a significant percentage of the flower buds are killed, leading to minor or occasionally severe crop loss. In both peaches (Ballard et al., 1994) and blueberries (Patten et al., 1991; Spiers, 1978), these temperatures have been established; however in the case of peaches, the variety used was a high-chill accumulating variety grown in northern latitudes. It is not known how these critical bud temperatures are affected by different germplasm (e.g., low-chill peaches vs. high-chill peaches) or a subtropical climate as is observed in the southeastern United States. In blueberries, a comparison of cold injury on southern highbush vs. rabbiteye blueberries found that rabbiteye blueberries were more cold sensitive (Patten et al., 1991). It is important for growers to have the most accurate information to make frost/freeze mitigation decisions. The definition of the critical bud temperature will also provide the growers with the assessment of the economic tradeoffs between revenue & yield reductions and the reductions in water pumping costs.

This was a timely project, as the winter (December – February) months of 2015-2016, and the following years, 2016-2017 were the warmest winters on record, with low chill accumulation, typically leading to decreased bud cold hardiness. The warm day and nighttime temperatures led to uneven flowering and fruit set in many of the Florida germplasm. This warm weather also contributed to variability in the results for each phenological stage, particularly in low-chill peach varieties in Florida. It is predicted that winter months may be similar in future years, and thus, it is imperative that this data be used to strengthen future observations.

The objectives of this project are to track the critical bud temperatures and progression of bud cold hardiness for low- and mid-chill peach varieties and southern highbush and rabbiteye blueberry varieties in Florida and Georgia at key phenological stages. These stages have been established for peach (http://lake.ifas.ufl.edu/agriculture/citrus/

documents/PeachBudChartEB0914.pdf) and blueberry (http://msue.anr.msu.edu/topic/

blueberries/growing_blueberries/spring_critical_temperatures); however, these estimates may not be applicable to the varieties and growing conditions in Florida and Georgia. Collection of branch samples and monitoring of bud damage will be conducted using differential thermal analysis or other methods to determine critical bud temperatures. Finally, as a part of the economic analysis component, the potential water and energy cost savings will be estimated based on producer surveys and use of the temperature information provided by this project.

Project Approach

Goal 1: Critical Bud Temperature Determination for Low- and Mid-Chill Peach Varieties.

Two peach cultivars from Florida, 'UFOne' and 'TropicBeauty', and two from Georgia, 'Flavorich' and 'Elberta', were used to determine the critical bud temperature for low- and mid-chill peach varieties using freeze tolerance test and differential thermal analysis (DTA). Freeze testing began in Florida in November 2016 and in October 2016 in Georgia.

Georgia:

Two peach cultivars from Georgia, 'Flavorich' and 'Elberta', were used to determine the critical bud temperature for low- and mid-chill peach varieties using freeze tolerance test and differential thermal analysis (DTA). Weekly freeze tolerance tests were conducted for three weeks in February 2015 in Florida. Similarly, weekly freeze tolerance tests and DTA were conducted from January to March 2015 in Georgia.

2014-2015 Georgia Season: Approximately 30 twigs per variety were collected from commercial plots to determine the critical bud temperature of 'Flavorich' and 'Elberta'. Peach orchards were maintained using commercial practices as recommended in the southeastern peach management guide. Twigs were transported in a bag and maintained in a cooler with ice until arrival to the Griffin campus, Griffin, GA. After arrival, twigs were kept overnight at 4°C in a refrigerator until further processing. Four types of tissue samples were processed from twigs: 1) 2'' twigs with buds, 2) 8'' twigs with buds, 3) excised flower buds, and 4) excised vegetative buds (Appendix 1).

Hereafter, these different tissue samples will be referred as "tissue types". Bud flower stages were used to sort samples within each tissue type. Sampling protocols established during the 2014-2015 season were carried out during 2016. From October to December, approximately 70 twigs per variety were collected from commercial plots to determine the critical bud temperature of 'Elberta' and 'Flavorich' peach varieties.

Freeze tolerance tests: Replicates per tissue type were wrapped using moist filter paper and kept in a Ziploc bag. Each bag contained representatives of each tissue type: four

2'' twigs with buds, four 8'' twigs with buds, eight excised flower buds, and four excised vegetative buds. One control bag was kept at 4°C in the refrigerator. The programmable freezer was used with a cooling rate of 4°C/hour from –2°C to –27°C once started, with freezing treatments corresponding to one bag for every -3°C interval from -3°C to -27°C (a total of 9 bags). Bags were kept overnight at -2°C before the freezing program was started. Bags

were removed every -3°C and transferred to 4°C for a week. Excised buds, stems, and buds in a stem were dissected and evaluated to determine whether the tissue was dead or alive (Fig 1).

DTA: Four excised flower buds were placed in two interconnected thermo-electric modules (TEMs), with two buds per TEM. The TEMs were installed in a metal frame. The frame was installed inside of the programmable freezer. A cooling rate of 4°C/hour from RT to –27°C was used for DTA. Two different settings were used before freezing: 1) -2°C before the DTA program was started, and 2) DTA program without overnight treatment. TEMs were covered with aluminum rectangle covers that go on top of the plate. Data was stored using a Campbell Scientific data logger. Data points were filtered and analyzed using Sigmaplot software. Temperature exotherms were analyzed to evaluate the critical bud temperature.

Results:

Overall, all factors, including collection date, cultivar, sampling type (5 cm stems, 20 cm stems, and excised buds), and tissue (floral, vegetative, and stems), were found to be significantly different for LT50 as determined by the artificial freezing test ($P<0.001$). Our study demonstrated the effect of excision and stem length on artificial freezing test of peach (Table 1). Artificial freezing test conducted with excised floral bud tended to yield more conservative estimates of cold hardiness of peach floral buds (Table 1), in agreement with previous studies (Ashworth, 1982). Stem length did not affect determination of bud cold hardiness of attached buds nor did affect stem cold hardiness determination (Table 1). It is also possible that the minimum stem size in this study (5 cm) reached the critical size of 20 g that did affect freezing behavior of the sample as compared to nature as determined by Ashworth and Davis (1984). Stems of 5 cm were already big enough to fulfill the role of water sink, and therefore increasing stem size did not change the water behavior anymore as shown with 20 cm stem samples. In conclusion, buds attached to stems no shorter than 5 cm were found to be the optimal size for artificial tests and they are recommended for future studies.

In our artificial freezing tests, differences between ‘Elberta’ and ‘Flavorich’, were identified (Fig 2). These differences can be attributed to the inherited differences present in their chill requirement. Chilling requirement of ‘Elberta’ peach cultivar is reported at 850 chill hours, and ‘Flavorich’ chill requirement is reported at 700 chill hours.

Differences in deacclimation patterns of ‘Elberta’ and ‘Flavorich’ were observed (Fig. 2). For ‘Flavorich’ floral buds, deacclimation started earlier than floral buds of ‘Elberta’ for all three seasons. In the first season, deacclimation process of ‘Flavorich’ already started after the first collection date (January 20, 2015), while ‘Elberta’ maintained acclimated until February 9, 2016 (Fig. 2A). LT50s of ‘Elberta’ floral buds were always lower than that of ‘Flavorich’ floral buds. In the second season, floral buds of both cultivars started deacclimation around February 23, 2016. However, floral buds of ‘Flavorich’ did not achieve a critical bud temperature as low as ‘Elberta’. During mid-winter, the lowest LT50 of ‘Elberta’ was -18.2 °C, and the lowest LT50 of ‘Flavorich’ was -15.5 °C. For the 2016-2017 season, the Southeastern U.S. experienced an exceptional warm winter. By the end of this study on March 27, 2017, floral buds of ‘Elberta’ did not develop normally. The majority of floral buds were still tight or slightly swelling, with few open flowers on some trees. Vegetative buds did not sprout either. In the meantime, floral buds of ‘Flavorich’ were able to come out of dormancy, but bud development was slow and not uniform. As shown in the deacclimation pattern, for one week and were dissected to determine whether the tissue was alive or dead.

Florida:

Twigs of ‘UFOne’ and ‘TropicBeauty’ were collected from the University of Florida Plant Science Research & Education Unit (Citra, FL) from October 2015 – March 2016 and November 2016-March 2017. Bud were excised from twigs and sorted by bud stage.

Freeze tolerance tests: Preparation protocol was similar to that established in Georgia. Ten excised buds per bud stage per temperature treatment were placed in moist tissue paper and kept in labeled Ziploc bags. One control bag/bud stage was kept at 4°C in the refrigerator. Buds were placed in a TPS Tenney Temperature Chamber (Thermal Products Solutions, New Columbia, PA) and kept overnight at -2°C. The programmable chamber was then cooled at a rate of 4°C/hr between -3°C and -27C°; buds were removed at different temperature intervals depending on bud stage. Once removed from the programmable freezer, bags were kept in the 4°C refrigerator for one week and were dissected to determine whether the tissue was alive or dead.

DTA: DTA was not used during the 2016-2017 season as it was not found to effective method of evaluating bud hardiness during testing in the 2015-2016 season.

The data were analyzed using the 'drm' Package, a supplement designed for calculating lethal dose response, in R Software.

Results:

The dissection data was used to create logistic models for each bud stage. For most of the bud stages, date, in addition to temperature, was found to be a significant variable in the model. The weekly LT50 values for ‘UFOne’ was found to positively and significantly correlate with the average temperature during the week prior to collection. The sensitivity of the low-chill cultivars, ‘TropicBeauty’ and ‘UFOne’, were compared to high-chill cultivars, ‘Elberta’ and ‘Flavorich’, and found to significantly differ on several dates. Critical temperatures for ‘UFOne’ and ‘TropicBeauty’ were also compared to published results from older research on ‘Elberta’ in Washington state (Table 2). Critical bud temperatures were found to diverge from previous published findings for the later bud stages. This could be due to the tissue preparation method as the results from Georgia indicate that testing excised buds results in more conservative lethal temperature estimates.

In both years, the standard errors for the estimated LT50 (lethal temperature at which 50% of the buds are dead), were large, contributing to the difficulty of separating the temperatures between the varieties. The warm winter seasons in both years led to uneven development of the phenological stages for sampling, resulting in small replications of certain bud stages. Additionally, there was insufficient plant tissue collected in order to estimate LT50 values for Green Calyx and Full Bloom stage for ‘UFOne’ and for First Bloom stage for both ‘UFOne’ and ‘TropicBeauty’ (Table 3).

Warm temperatures during the week influenced the LT50 values for dormant buds in ‘UFOne’ in the week preceding sample collection. Differences in deacclimation were found between the two varieties (Figure 3);

correlating with the chill unit requirement for each variety. ‘TropicBeauty’ requires less chill than ‘UFOne’, which was reflected in the advanced deacclimation when compared to ‘UFOne’.

Goal 2: Critical Bud Temperature Determination for Low- and Mid-Chill Blueberries

Three blueberry cultivars from Florida, ‘Emerald’, ‘Jewel’, and ‘Savory’ and two from Georgia, ‘Emerald’ and ‘Farthing’, were used to determine the critical bud temperature for low-chill blueberries using freeze tolerance test. Freeze tolerance tests were conducted over two seasons from November to February 2015-16 and from November to January 2016-17 in Georgia and from November to February both seasons in Florida.

Georgia:

Approximately 50 twigs per variety were collected from commercial plots to determine the critical bud temperature of ‘Emerald’ and ‘Farthing’. Twigs were transported in a bag and maintained in a cooler with ice. Samples were shipped overnight from Tifton, GA to the Griffin campus, Griffin, GA. After arrival, twigs were processed. Two tissue types were processed from twigs: 1) 2’’ twigs with buds and 2) excised flower buds. The floral buds were sampled until bud swell occurred during two seasons (2015-2016 and 2016-2017) from a commercial farm in Lakeland, GA. Samples were pretreated then subjected to either DTA (-2.0 to -27.0 °C) gradient program, decreasing at 4.0 °C.h-1) or to freeze tolerance in a programmable freezer (removing bud tissue at -3.0 °C increments). The samples were stored for a week at 4.0 °C and evaluated for floral bud tissue damage. To evaluate floral bud damage, a lethal temperature threshold of 50% floral bud damage (LT50) was used as a critical loss threshold.

Results: In 2015-2016, ‘Emerald’s lowest LT50 was on 25 Jan at -18.0 °C for attached flower buds and ‘Farthing’s lowest LT50 was on 8 Feb at -19.0 °C for attached flower buds (Table 4). In 2016-2017, ‘Emerald’ and ‘Farthing’ had the lowest LT50 on 5 Jan for attached flower buds at -19.0 °C and -20.2 °C, respectively (Table 4). ‘Emerald’ and ‘Farthing’ excised flower bud LT50's were 46-53% higher in temperature with a difference of 10.2 °C and 9.5 °C, respectively, compared to attached flower buds on 5 Jan. Neither cultivar’s excised flower buds showed hardiness below -13.0 °C throughout the season in either year. DTA exotherms were not consistently detected and detected exotherms did not reflect freeze test analysis, suggesting DTA is not an appropriate method to estimate blueberry floral bud cold hardiness. In conclusion, attached flower buds were hardier than excised flower buds. SHB lethal temperatures decreased from late fall reaching a maximum hardiness level and subsequently increased until budbreak. Exotherms established by DTA profile were significantly warmer than freeze tests values. SHB evaluated in this study had greater sensitivity to cold than previously described for NHB and SHB ‘Legacy’.

The primary project partners for Goal 2 at UGA is Drs. Erick Smith, Dario Chavez and Orville Lindstrom. Developing and testing of methods are also part of this goal. Data analyses and evaluation for blueberries were conducted by Lauren Redpath, MS student, and for peaches by Jun Liu, MS student. .

Florida:

Approximately 40 twigs per variety were collected from the UF Plant Science Research & Education Unit between October 2015 to March 2016 and November 2016 to March 2017 to determine the critical bud temperature of 'Emerald', 'Jewel', and 'Savory' blueberry cultivars. Buds were excised and sorted by bud stage, wrapped in moist tissue, and stored in bags overnight at -2°C before the freezing program was initiated. During the freezing program, bags were removed at predetermined temperatures and transferred to 4°C for a week. Excised buds of different developmental stages were dissected and assessed as a proportion of living florets.

Results: Exotherm results from differential thermal analysis were not found to be correlated with dissection results from freeze tolerance testing and, as a result, was not continued in Georgia or Florida beyond the 2015-2016 season.

Logistic models were tested for all three cultivars at each of the seven bud stages. At the dormant stage, date was not found to be a significant model factor for 'Jewel' (Table 4). This suggests that 'Emerald' and 'Savory' could be more susceptible to temperature fluctuations than 'Jewel'. Additionally, 'Jewel' was more sensitive to freezing temperature than 'Emerald' and 'Savory' on several dates. Critical bud temperatures for other stages were compared with current temperatures published for Northern Highbush cultivars (Table 4). Similar to the peach results, the latter bud stages were found to be much hardier than published temperatures.

In the 2016-2017 season, 'Jewel' was again found to be more sensitive than 'Emerald' for most bud stages, whereas it was found to be statistically similar to 'Savory' for most bud stages (Table 3). Similar to the peach results, the latter bud stages were found to be much hardier than published temperatures; perhaps in part due to sample size. For example, the calculated LT50 for 'Jewel' at Petal Fall is -18.3°F because no tested temperature treatment produced 100% bud mortality and so the model estimated what it would be if trends continued based on the limited data available. Different techniques for sample preparation and injury assessment should be explored.

The primary project partners for Goal 2 at UF are J. Williamson, Moshe Doron, and former graduate student Elizabeth Conlan.

Goal 3: Economic Analysis of Using Critical Bud Temperatures in Frost/Freeze System Engagement Decisions.

Production data has been collected for Florida and Georgia peach and blueberry producers. During 2015-2016, grower meetings, farm visits, and producer surveys were conducted in Florida and Georgia in order to collect information related to on-farm water use, freeze protection irrigation strategies, pumping volume, etc., for peach and blueberry growers. Based on these data, two publications were developed:

(1) UF/IFAS Outreach Publication: Bradley, T., Borisova, T., Olmstead, M. and J. Williamson. 2016. Improving the Precision of Blueberry Frost Protection Irrigation" (University of Florida EDIS publication # FE979)

(2) UF/IFAS Outreach Publication: Bradley, T., Borisova, T., and M. Olmstead. 2015. Frost Protection Irrigation for Florida Peaches: Economic Considerations (University of Florida EDIS publication # FE980)

The economic analysis was led by Dr. Tatiana Borisova with supplemental peach and blueberry farm production data provided by M. Olmstead and J. Williamson. Interviews were conducted with selected producers in Alachua and Marion counties, along with surveys conducted in regional and local meetings in Georgia and Florida. Conservative (low bound) estimate is that the survey respondents manage about 1,696 acres and 2,850 acres in Florida and Georgia, respectively, or at least 37.7% and 19.0% of the total blueberry acreage in the states.

Economic analysis primarily focused on examining potential economic gains (in terms of potential diesel cost savings) and water use reduction from research and educational program allowing producers better tailor their frost/freeze protection irrigation decisions to the plants' frost/freeze tolerance level at each blooming stage.

For peach production in Pasco, Polk, and DeSoto Counties (Florida), the number and duration of frost events were determined for the past few seasons following the tailored frost protection approach based on temperature as it relates to petal and bloom stages, along with wind speed, as recommended in Extension publications by the University of Florida (based on research at the Washington State University). The number and duration of frost events were then determined again for the same seasons using 32°F as the relevant critical temperature and by observing the wind speed without consideration for the petal and bloom stages. This is assumed to reflect the uniform frost protection irrigation approach frequently followed by peach producers in Florida. For both precision and uniform approaches, for the nights with temperatures below the critical levels, the duration of frost events was assessed as the number of hours from the hour when the average temperature dropped below 33°F (start of the event) and the hour when the average wet bulb temperature raised above 33°F (end of the event). On average for the production season, farmers following the uniform approach run frost protection irrigation for approximately 9 hours longer in comparison with the farmers following the precision approach. Assuming a 0.3-inch-per-hour water application rate, the area of 20 acres served by one pump at 8.5 gallons per hour of diesel use, and the cost of $2.50 per diesel gallon, producers can save $200 per pump per production season following the precision approach (or $10 per acre per season). The savings in particularly cold production seasons (such as 2009/10) can be more than $1,000 per pump (or $50 per acre). In addition to the money savings, changes in frost protection irrigation can translate into reductions in water withdrawals, with the estimated average difference between the two approaches being 76 thousand gallons per acre per season.

In turn, for blueberry production in Florida, it was observed that tailored freeze/frost protection irrigation strategy can result in significant reduction in the number of frost protection irrigation events per production season, especially for northern counties (the difference was smaller but still nonzero for the southern counties as well). For six production seasons (2009–2015), the average estimated difference in water pumping costs for the tailored and common (uniform) frost/freeze protection irrigation strategies was $515 per pump for growers in Alachua, and $170 per pump for the growers in Hillsborough and Polk Counties, respectively (or $15.8 and $8.5 per acre). There was also a significant difference between the volumes of water pumped for freeze/frost protection given the tailored and common (uniform) practices. The estimated average water savings are 120 and 65 thousand gallons per acre per season for the growers in Northern Florida (Alachua and Marion) and Central Florida (Hillsborough and Polk Counties), respectively. If the water is valued at $4 per thousand gallons (average residential water rate for customers using 8 thousand gallons per month), the value of the water use reduction is $481/acre and $259/acre, respectively.

An important limitation is the use of the precision approach developed by the researchers from the state of Washington. While these recommendations are used in Extension publications by the University of Georgia and

the University of Florida, additional Florida-based research is being conducted to tailor these recommendations to Florida's peach varieties and production conditions.

Goal 4 – Use of Critical Bud Temperatures for Low- and Mid-Chill Peach and Blueberry Varieties.

A nineteen-question survey was distributed to Florida peach and blueberry growers between October and December 2015. Nineteen responses were received from peach growers and fifty-five responses were received from blueberry growers. E. Smith distributed the same nineteen question survey to Georgia blueberry growers at local meetings; sixty-three responses were received. The survey for Florida was written by T. Borisova and E. Conlan with additional input provided by M. Olmstead and J. Williamson. The survey was reviewed by the University of Florida Institutional Review Board. In addition, a semi-structured interview for peach growers in Georgia regarding their frost/freeze protection systems and/or decision-making factors were created by T. Borisova, S. Simnitt, and D. Chavez. For peach, interviews were conducted on-farm with 4 out of the 5 major peach growers in Georgia, representing approximately 80% of the peach acreage in Georgia.

Results: Frost protection was used by a vast majority of the growers surveyed with irrigation being the dominant method of frost protection used. Information on water use and frost protection will be used to further refine economic recommendations. Due to the variability in the data collected in both states, a website with weekly information was not established, as there was little confidence in the data for use in frost mitigation decisions. At least two – three additional years would enhance the confidence of these measurements and allow the team to begin to model response of these low-chill peach and blueberry varieties in the southeastern U.S.

Skyler Simnitt, PhD student, has prepared a manuscript based on survey and interview data collected and analyzed during 2015 and 2016. The manuscript was submitted and accepted for publication in HortTechnology, a peer-reviewed horticulture journal. This manuscript will be used as a need assessment tool for future research and grant applications.

As reported in the manuscript, we found that producers' choice among active frost protection methods is based on factors such as the planning horizon, initial investment needs, frequency of frost events, and the effectiveness of the frost protection method. Problem areas that producers identified as priorities for the future research in frost/freeze protection included improving the effectiveness of frost protection methods; reducing initial investments required to install frost protection systems; and employing better spatial targeting and configuration of frost protection strategies (to reduce investment costs while maintaining or improving the effectiveness of frost protection). We also found that Georgia peach producers rely on information about critical temperatures for different bud stages to make frost protection decisions, and hence, improving the quality of information regarding frost susceptibility for Georgia-specific cultivars and climate conditions can help producers make better frost protection decisions (and potentially reduce electricity costs and water use for frost protection).

In turn, for blueberry producers, T. Borisova and E. Conlan analyzed results from frost protection surveys distributed to Georgia and Florida blueberry growers. The results were submitted for review and publication as an outreach document through UF / EDIS system. We found that there is a large variation among producers regarding the temperatures to turn the irrigation systems on and off, and the number of frost protection irrigation events per season. Even for producers operating in the same geographical region, the number of frost protection

irrigation events can be up to ten-fold (based on survey responses). This difference can be due to the differences in producers' risk aversion, as well as lack of information regarding the frost susceptibility and potentially lack of accurate local weather forecasts available for producers. Overall, this implies that there is a need to develop tools to assist producers in their frost-protection decisions.

Goals and Outcomes Achieved

1. Critical bud temperature determination for low-chill and mid-chill peach varieties.

Freezing damage causes major economic losses in peach production in the Southeast U.S. The study of the cold hardiness of 'Elberta' and 'Flavorich' peach varieties commonly grown in middle Georgia allowed us to analyze and optimize two methods, the freeze tolerance test and the differential thermal analyses (DTA), to measure cold hardiness of peach and to provide a better understanding of the freezing process in peach floral buds. For artificial freezing test, floral buds attached to 5 cm stems were the most efficient sampling type to accurately measure cold hardiness. When using DTA, cooling scheme that consisted of an overnight -2 °C incubation before start cooling at 4 °C·h-1 improved correlations between LTE (low temperature exotherms) temperatures and LT50 from standard artificial freezing test.

Although the results for the 'TropicBeauty' and 'UFOne' in Florida were variable due to the unusually warm winters in 2015-2016 and 2016-2017, critical peach bud temperatures for later bud stages were not found to be consistently different than what was previously reported for 'Elberta', a high-chill peach variety, but were found to be more cold sensitive at the dormant and bud swell stages (Table 2). In addition, the temperature at which 50% of the buds were dead was significantly correlated with the average temperature for the week prior to bud collection, indicating that warm temperatures decreased bud hardiness. Patterns of deacclimation were different between 'TropicBeauty' and 'UFOne', with 'TropicBeauty' deacclimating faster than 'UFOne'. 'TropicBeauty' does require fewer chill units, while 'UFOne' has a higher chill unit requirement and deacclimated more slowly.

2. Critical bud temperature determination for southern highbush and rabbiteye blueberry varieties.

In Georgia, critical temperatures were evaluated experimentally in freeze chambers and via differential thermal analysis (DTA). Tight floral bud stage was selected because prior knowledge of critical freezing temperatures was unknown in sub-tropical climates. Other stages were not evaluated because there is extreme variability of stages expressed in the field (visible swelling to petal fall), which causes growers to turn on frost protection (predominantly overhead irrigation) at 34 °F (1.1 °C) wet-bulb when a freeze is in the forecast. This is to ensure that sprinkler heads are operable and not frozen. Rabbiteye were not followed because they are generally not frost protected for two reasons: 1) they usually bloom outside of potential for freeze and 2) the value of the crop is not sufficient to warrant frost protection. These data were gathered from surveys and conversations with growers. For DTA, the exotherms or peaks identifying water freezing were not reliable and did not correlate with freezing methods. Freezing tight floral buds showed attached buds were hardier than excised buds. Generally, attached tight floral bud hardiness ranged from -10 °C (14 °F) to 20.2 C (-4 °C) cultivar and sample timing dependent. At an

accumulation of ~ 250 chill hours, the attached floral buds were hardiest; entering dormancy and bud swell showed lower critical temperatures. Excised floral buds had an average critical freezing temperature of -10 °C (14 °F), regardless of sample timing or chill hour accumulation. For areas of commercial blueberry cultivation in both Florida and Georgia, field observations to determine the validity of these data may be difficult because historic low temperatures range from -9.4 °C (15.1 °F) to -6.7 °C (19.2 °F) and even warmer for Florida. Over the two seasons tested in Georgia, maximum low temperature observed in the commercial planting was -4.4 °C (24.1 °F). Considering the assessment for critical temperatures for southern highbush, growers should be aware that at -10 °C (14 °F) there is potential for damage in tight floral buds.

In Florida, differences in critical bud temperatures were found between southern highbush varieties, 'Emerald' and 'Jewel', and the rabbiteye variety 'Savory'. Similar to the data for peach buds, warm temperatures and insufficient chilling during both the 2015-2016 and 2016-2017 seasons could negatively impacted the reliability of the results. Overall, 'Savory' and 'Jewel' were found to be more sensitive to freezing temperatures and have higher LT50 values for most bud stages than 'Emerald'. As 'Emerald' has the lowest chill unit requirement of the three varieties tested, this suggests that bud hardiness is not closely related to or connected to chilling requirement.

3. Conduct economic analysis of using critical bud temperatures in frost/freeze system engagement decisions.

It was estimated that with irrigation rate of 0.3 inches per hour, the total water application rate per hour for 20 acres served by one pump is 162,872 gallons water per pump per hour. Adjusting the temperature for turning irrigation system on/off (to better match critical temperature recommendations) can reduce the duration of irrigation events by several hours each production season. Based on the blueberry survey results, the mean number of irrigation events reported for 2014-2015 production season was 5. If each irrigation event is shortened by one hour, water use reduction would be 814,360 gallons per pump per season. Conservatively, we estimated that blueberry survey respondents managed at least 4,546 acres. With one pump per 25 acres, this area is irrigated by 182 pumps. Hence, reduction of frost protection irrigation events by 5 hours each season can be translated into 148.1 million gallon per season water use reduction. With estimated cost of $0.13 per thousand gallon, such water use / energy use reduction would translate into $19,252 per season for the survey respondents (or approximately $4 per acre per season). While the monetary savings seem low, savings in water (which protect natural resources and can be used in a public relations campaign) imply importance of selecting proper frost protection irrigation practices.

Similar analysis was conducted for peach production. Generally, the cost of water pumping (for a diesel pump) was estimated at $0.13 per thousand gallon, or $1.06 per acre per hour. Reduction of irrigation event duration by one hour reduces water use by 8,143.6 gallons per acre per hour, potentially resulting in significant reduction in the pressure on local water resources.

4. Use of critical bud temperatures for low and mid-chill peach and blueberry varieties.

In general, it was established that both the standard test – the artificial freezing tolerance test – and the DTA test were able to be used to measure cold hardiness of peach. In the case of the artificial freezing test, it could capture different cold hardiness levels and deacclimation patterns between 'Elberta' and 'Flavorich'. In the case of the DTA, our results showed that the pre-treated DTA (overnight -2 °C incubation) was able to overcome the inefficiency of detecting LTEs after peach deacclimation offering high correlations when compared to the standard artificial freezing test.

The information gathered through the surveys conducted in Georgia and Florida allowed the team to define what conditions and information growers used to make frost mitigation decisions. These decisions were based on weather information from both commercial outlets like The Weather Channel, on-farm temperature measuring systems, and state supported programs, Florida Automated Weather Network (FAWN) and Georgia Automated Environmental Monitoring Network (GAEMN). Additionally, air temperature, dew point, wind speed, bud stage, and expected freeze duration were rated as important or very important factors by Florida and Georgia blueberry growers in deciding to activate their irrigation system for frost protection. Commonly used information sources that growers used when deciding to activate an irrigation system for frost protection include advice from other growers (67% utilizing) and Extensions sources including both agents and websites (40% utilizing).

As many growers did report using Extension-support resources in frost protection decision-making, this infrastructure will be useful in continuing to engage growers on best management practices in frost protection.

Beneficiaries

Peach production in Florida has now expanded to more than 1,500 acres, with 50-60 growers of varying farm size. The gross value of current bearing acreage is estimated at $4 million dollars with previous year's domestic production amounting to 1,500,000 pounds. In 2014, Georgia (10,900 acres, 35,500 metric tons) ranked third top in the U.S.

In 2016, blueberry production from the reporting southeastern states (FL, GA, MS, and NC) accounted for 24% of the total national production at 70,150 tons, and for 33% of the total U.S. blueberry acreage. The farm gate value for the region was $220M, totaling 29% of the total national blueberry market (USDA, 2017). Georgia has reported over the last decade a 240% increase in blueberry acreage: from 7,000 to 16,900 acres. The farm gate value has expanded in the same time period from $60M to $88M, a 147% increase. Over the same period in Florida, harvested blueberry acreage has increased from 2600 to 4700 acres (181 % increase} and the farm gate value has increased from $3.3 M in 2006 to $54 M (163% increase} in 2016 (USDA ERS, 2016). In total production, Florida ranks 7th and Georgia is 3th in the nation.

In Georgia, southern highbush production has been increasing steadily, taking advantage of fresh market fruit sales. Over the last ten years southern highbush production has grown to exceed 50% of the total production acres. The identification of critical temperatures or hardiness of floral buds to freezing temperatures will give growers and marketers another data point help establish production trends after a freezing event. In addition, this work identifies a point where damage may began occur (-10 °C/14 °F), which is below recommended temperatures to use overhead irrigation as freeze protection. If temperatures fall to this point, doing nothing to mitigate the freeze is potentially the greatest cost savings to the grower.

This work has been presented at the 2016 Southeast Regional Fruit and Vegetable Conference (SRFVC) in Savannah, GA. Surveys were also conducted at the 2015 SRFVC and growers meetings in Alma and Homerville, Georgia. Graduate student, Lauren Redpath, presented data at American Society for Horticultural Science (ASHS) Atlanta, GA and Southern Region ASHS, Mobile AL and at both was awarded recognition in her poster displays. Further, Ms. Redpath has successfully completed program and has been accepted in a PhD program at North Carolina State University's Department of Horticulture. The critical temperature research is being summarized for peer review publication.

In Florida, the information from this project was distributed at the UF Stone Fruit Field Days in 2015 and 2016 (E. Conlan) to approximately 100 attendees each year. In addition, a presentation was made and a paper published in the Proceedings of the Florida State Horticultural Society (E. Conlan). Feedback from both events acknowledged that this topic is timely; however, the variable results due to the warmer winters is challenging for this type of research.

Lessons Learned

In Georgia, the blueberry critical temperature analyses were shown to be best focused on research with tight floral buds of southern highbush blueberry because:

1) Both are widely grown commercially in Florida and Georgia

2) Rabbiteye blueberry is generally not frost/freeze protected

3) Bloom is erratic at best and many stages are prevalent throughout the dormant period. Because of this, growers who use overhead irrigation will start freeze protection at temperatures above freezing to insure the system can deliver water and protect the most sensitive floral stage present.

4) Previous work with both northern highbush and rabbiteye blueberry has shown to have similar in sensitivity to freeze in bud stages above swell; however, tight bud stage in subtropical climate has not been thoroughly researched to identify sensitivity.

The greatest benefit of this research is the establishment of a base line to identify when field temperatures could potentially effect production in dormant buds. If the temperature drops to -10 °C (14 °F), within a week of the event growers should assess the potential of floral bud damage. During our observations, we noted that daily maximum temperatures can easily be within the range for active plant growth. In addition, we noted that buds continually grow throughout the tight stage and as water begins to be taken up by the buds the sensitivity to freeze is increased.

In Florida, the conditions needed to detect low temperature exotherms were difficult to achieve for differential thermal analysis. Although it could not have been predicted, the warm winters of 2015-2016 and 2016-2017 led to multiple physiological anomalies in both low-chill peach and blueberry varieties, leading to variable results. Drought in both winter seasons may have affected the water content in the bud, which reduces the sensitivity of DTA to detect freezing in the xylem tissue. Additionally, large standard errors in LT50 determination is a result of small sample size, 5-10 buds/temperature treatment. Additionally, while the freeze tolerance testing methodology in Florida seems to be effective for early bud stages, in particular dormant and bud swell for both crops, the methodology does not produce lethal temperature estimates in later bud stages, particularly full bloom and petal fall in both crops, that reflect either in-field observation or previously published research on bud hardiness. Lethal

damage to reproductive tissue could occur without being visible at low magnification. Alternative methods for assessing lethal cellular damage, such as staining, is recommended for later bud stages.

When using the artificial freezing test in Georgia for peach, we found that bud excision tends to yield more conservation results for LT50 values in comparisons with samples using 5cm and 20cm stems with buds still attached. The use of stems with attached buds as samples for artificial freezing test proved the most effective to measure cold hardiness of peach.

DTA in the other hand, would allow growers to obtain cold hardiness information from samples collected in the field one day prior to the forecasted natural frost. This method would allow UGA Peach Research and Extension program to predict possible damages produced by upcoming frost events based on the cold hardiness information of different varieties. This will help growers to better allocate resources and decide their frost protection strategies, for example, turning on irrigation or wind machines for the night to protect cold susceptible cultivars. In the future, better precision and further refinement of our prediction models is needed for DTA to accurately predict cold hardiness of plants under natural conditions.

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Project (9): Florida Tomatoes: Healthy Boost for Families and Farmers

Project Partners:
Florida Tomato Committee and SenaReider Corporation implemented the project.

Project Summary:

Florida tomato growers have experienced a dramatically decreasing market share over the years due to weather and crop pest conditions, as well as fierce competition from foreign competitors including the increasing volume of low cost imported greenhouse product from Mexico and Canada. The recent 2012 season found Florida's tomato growers experiencing the lowest average price in over twenty years, for the third lowest harvest in the same time period.

More and more consumers and trade partners are gathering information, communicating and transacting in the digital medium. Finding efficient ways to reach these consumers and sellers with pertinent information regarding Florida tomatoes' benefits is vital in gaining back market share for Florida tomato crops. Digital media has been a highly cost effective channel for consumer media for years, putting messages in front of people for a fraction of cost. Florida Tomato Committee's digital campaign was focused on the eastern seaboard of the United States and included a digital media buy, creative marketing executions and a social media campaign. This is a vital area of need because the digital marketing space is quickly becoming one of the most important channels through which to reach consumer audiences.

Project Approach:

We narrowed our strategy approach in order to be as organized and efficient with the digital campaign as possible. The driving factor in making this decision was the cost effectiveness of digital communication. Even more important was the fact our research showed moms, our primary target audience, looks to digital media for healthy meal solutions. Finally digital media is shareable. Our content grew and is still growing organically.

Here are the specific tactics used.
We used digital media, social media and public relations to reach target consumers, increase brand engagement and retail sales of Florida tomatoes. Results:

-A 10-week digital marketing plan was developed to educate the public on the benefits of eating Florida tomatoes. Our communications included highlighting the flavor and nutrition of Florida tomatoes, as well as the responsible and sustainable growing practices of Florida tomato growers and their commitment to producing the highest quality, wholesome tomatoes possible. Highlighting the fact that Florida tomatoes are safely produced is an important one as Florida tomatoes were incorrectly fingered as the culprit in a nation-wide salmonella outbreak several years ago and are still recovering in the minds of shoppers. In addition, the messaging

also assured that Florida tomato growers care for their employees, providing a safe and positive working environment.

-Content center-piece was a 6-part animated digital video series that aired on YouTube, Facebook and the Florida tomato website, floridatomatoes.org. The videos have received more than 1.1 million views, 10.5 million impressions on YouTube to date - which is more than double the expected performance on YouTube. The engaging videos tell the story of Florida tomatoes and what makes the so good and good for consumers- moms and families. With a bit of tongue in cheek, the films lovingly pair a Florida tomato grower with a herd of helpful alligators to tell the larger story of how growers are committed to working "hand-in-claw" with nature and wildlife as stewards of the land. The campaign targeted "Moms" who do the shopping and cooking for the family. The films highlighted what makes Florida tomatoes so special: Florida weather and sunshine, sustainable and responsible farming practices, and, of course the fact that Florida growers do truly care for their employees as well as the tomatoes they produce.

-The video campaign was supported by Public Relations and Blogger outreach resulting in 15 blog posts during the campaign period that garnered 4.5 million unique visitors of our campaign and content on blogger sites. 14 million additional engagements were received as a result of blogger reposts on Facebook, Instagram, Google+ and Instagram.

-Education and teacher outreach included sector bloggers. Communication focused on sharing videos and encouraging use of Florida tomato themed teaching aids supplied at floridatomatoes.org. We saw an 80% increase in "Kids Corner" site traffic during campaign period.

- Retail e-blasts through Progressive Grocer out to supermarket tomato buyers and category managers to encourage them to stock up for campaign and to let them know the availability and benefits of Florida tomatoes and the push our campaign was making with shoppers. The blasts were sent twice to key retail buying and merchandising personnel (3,670) with a delivery rate of 99%, and a click open rate of 19%.

-The quantitative results of our campaign prove that the Florida tomatoes story was told with significant frequency and reach to our target audiences resulting in large increases in brand engagement. The campaign also successfully told and communicated the difference between Florida tomatoes and foreign competitors.

Goals Achieved

Goals and Outcomes Achieved:

Goal 1: 2.5% increase volume sales at retail over last year, same time period, March through June 2015 (compared to March through June 2014) of Florida tomatoes at retail. According to IRI scanner data for round, field-grown tomatoes (PLU 4064, 4063 and 3151), comparing March 2015 through June 2015 to the same time period a year ago, there was an overall 4.51% increase in Florida tomato volume sold at retail (14,564,830 pounds during March

through June 2015 vs. 13,936,811 pounds in 2014.

Goal 2: 10,000% increase in Facebook “likes” and brand engagement through social media. Results:
-Garnered more than 1.1 million YouTube views and 10.5 million impressions
-300 % increase in Facebook “Likes” during campaign period
-60% increase in Twitter traffic
The films remain live online and are still gaining track. It is important to note here that in order to count as a “view,” an individual would need to watch the entire video which is an indication of “liking” the film, in a sense.

Goal 3: 100% increase educator engagement. Results:
-80% increase in activity on “Kids Corner” section of website
-3.7 million engagements on education and teacher blogging sites

Goal 4: 50 million total media impressions in the digital community. Results:
-Produced a unique 6-part animated digital video series
-10-week paid video placement plan on YouTube
-1.1 million digital views on YouTube 10.5 million impressions
-3 million paid video impressions on YouTube
-18.5 million engagements reposts on blogger social media outlets like Facebook, Instagram, Google+ and Pinterest

Summary: From a brand engagement standpoint, the campaign was a great success. We achieved more than 1.1 million video views and 10.5 million impressions in a very cluttered and competitive digital landscape. We were successful in reaching the educator segment with blogger outreach and teaching/kids content on our site with proven by our blogger outreach results and increase in “Kids Corner” site traffic during the campaign period.

Beneficiaries

There are close to eighty Florida tomato growers, however these growers collectively affect thirty-thousand employees and one billion pounds of fresh Florida tomatoes annually, with an estimated value of $300-400 million. Florida tomato growers were made aware of the efforts of the Florida Tomato Committee on this project during annual board meetings of the Florida Tomato Committee and on front of its website and through its social media channels. Moreover, activity and results were reported at annual board meeting the annual report published online at Florida Tomato Committee website. In addition, there was some trade media activity on the campaign. The films still live on the Florida Tomato Website, floridatomatoes.org.

Lessons Learned

For the most part, activities in this campaign went very smoothly.

The shift to a digital campaign proved to be successful on all fronts. The campaign has taken a life of its own and is still growing organically with no paid media. As the campaign is still growing on its own online, we will want to consider developing marketing tools for the upcoming season that help Florida’s tomato growers and their sales force personnel to

communicate Florida tomatoes' benefits with buyers during sales meetings. These tools would also be helpful when meeting with potential customers during trade shows and conferences.

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Project (10): Impact of Nitrogen Rates on Postharvest Peach Fruit Quality

Project Partners: University of Florida/IFAS, Horticultural Sciences Department

Project Summary

This project built upon a previous FDACS-SCBG funded project (#18009) that defined optimal nitrogen (N) fertilization rates for ideal tree health and fruit yield while minimizing nitrate leaching. Results from that project indicated that a N fertilization rate higher than what is recommended (100 lbs N/ac annually) optimizes tree and fruit yield. However, there was concern about overall postharvest quality if higher N rates were used. Very limited research has suggested that higher N fertilization may actually impair peach fruit aroma development, something that must be avoided if Florida peaches are to continue making market gains. In addition, the orchard used in our N fertilization study was established when the treatments were initiated in 2011. Thus, in 2014 it had just started consistently producing marketable yields. In this project, we proposed to define the impact of N on postharvest attributes of peach fruit.

The purpose of this project was to identify the impact that N fertilization has on postharvest fruit characteristics such as color, firmness, sugar and acid content, phytonutrients, and aroma and other flavor compounds in melting and non-melting flesh low-chill peaches. While much effort has been devoted to optimizing postharvest conditions for melting flesh peaches, the Florida industry has been moving towards production of non-melting peaches, typically used for processing in the past. The

University of Florida stonefruit breeding program has been focusing for many years on developing fresh market non-melting peaches and excellent varieties are now available for Florida growers. These peaches with non-melting texture do not typically incur chilling injury that leads to wooly or mealy fruit like melting flesh peaches; yet cooling the fruit immediately after harvest has been shown to have great benefits to extend shelf life.

Several cultural practices can affect postharvest stone fruit quality, among them being mineral nutrition, irrigation, crop load and tree health (Bryla et al., 2005; Crisosto et al., 1997). Previous studies in strawberry have shown that the fruit firmness decreases with increasing N rates (Miner et al., 1997). In addition, harvest maturity can have a large impact on aroma and flavor development and the longer a fruit is allowed to ripen on the tree, both quantity and quality of aroma/flavor compounds are

increased (Do et al., 1969). Nitrogen application has been repeatedly shown to influence fruit maturity and color development. Flesh firmness of the peaches is optimal during the mid-harvest period, while soluble solids and titratable acidity are optimized late in the harvest window (Remorini et al. 2008). In addition, N rates also affect fruit cuticle thickness, which influences fruit gas exchange (i.e.,volatile and

aroma emissions) and thus is a factor in maximizing postharvest attributes (Crisosto et al. 1997). Previous research has shown that increased N can have a detrimental effect on stone fruit quality (Daane et al., 2005; Olienyk et al., 1997); however current research in Florida indicates that tree health and fruit yield are improved when 50% more N than currently recommended is applied (M. Olmstead, FDACS project #18009). In addition, N fertilization can improve the tree response to bacterial canker (Pseudomonas syringae pv. syringae), suspected to be involved in the peach tree short life complex that is responsible for unexplained tree death in the southeastern U.S. (Cao et al., 2012).

This project was important and timely as demand is high from marketers and produce buyers for high quality, tree-ripe Florida peaches. As the previouse FDACS-funded research on optimizing N rates indicated that a higher rate may benefit both tree growth and fruit yield, it was important to know how these higher rates might affect postharvest fruit quality. The Florida industry has been promoting "tree-ripe" peaches, which research has shown to possess increased amounts and more diverse aroma and flavor compounds than those harvested before physiologically mature. However, if an effort to maintain tree health and fruit yield is at the expense of postharvest shelf-life, growers will need this information to adjust their in-season N rates and timing to optimize postharvest fruit quality.

Project Approach

Goal 1: Determine the effect of nitrogen fertilization on postharvest attributes of melting and non-melting flesh peaches.

The hypothesis being tested in this part of our study was that excessive N fertilization of peaches, above that necessary for producing maximum yield, could have negative effects on fruit quality and phytonutrient content, at harvest and during storage and ripening. The N levels we tested ranged from zero (N0) to 240 lbs/acre (N), with the highest rate being more than twice the IFAS-recommended N rate for Florida peaches (Olmstead et al., 2007).

In 2015 and 2016, data collected from three harvests each season of the two peach varieties ('TropicBeauty' (TB) and 'UFSharp' (UFS) were analyzed separately by harvest for each of the postharvest quality attributes measured [color, texture, total soluble solids (TSS), titratable acidity (TA), and pH] and for phytochemicals (carotenoids, anthocyanins and vitamin C). Each of the peach postharvest attributes were measured at harvest, after 7 days at 0°C and when ripe (transferred to 20°C). These results were previously reported, however a summary of harvest 2 for each of the years follows in the next paragraph.

In 2015, TB fruit from N1 (40 lbs/acre) had lower hue than N0 fruit at harvest. Both at harvest and after storage, UFS N0 fruit had significantly lower hue than N2 (80 lbs/acre). In 2016, ripe TB fruit from N1 had the lowest hue angle (more advanced color development) and were significantly different from N0. Ripe UFS fruit from N4 had lower hue angle, and were significantly different from N3 (160 lbs/acre). 'TropicBeauty' firmness in 2015 was higher in N3 after 0°C storage and was significantly different from N0. 'UFSharp' from N4 in 2015 was significantly firmer than N0 after storage. In 2016, ripe N4 TB fruit were significantly firmer than N2. 'UFSharp' firmness in 2016 was higher in N3 and was significantly

different from N0. ‘TropicBeauty’ in 2015 had higher TSS (higher soluble sugars content) in N0 than N4 after storage. In 2016, TSS content was higher at harvest in N3 than N2 TB fruit. In 2016, UFS fruit from N1 and N3 had higher TSS than N4, both at harvest and when ripe.

Based on the previous two seasons’ results, we decided that, in order to have more consistency in the results, postharvest analysis in the 2017 season would be performed only for Harvest 2, which occurred at the same time for both varieties and represented the vast majority of the season's yield. This was expected to help us arrive at a better understanding of the effect of N fertilization on postharvest peach attributes.

In 2017, differences in color were observed in TB after storage and in UFS after storage and when ripe. ‘TropicBeauty’ fruit from N0 had the highest a*value but was only significantly different from N3. In the case of UFS, N2 had the lowest a* value after storage compared to the other treatments. However, this changed when the fruit were ripe, where N3 had higher a*value (more red). Hue angle values showed the same trend as a* values in the two varieties. Fruit texture results were also variable in the two varieties. At harvest, no firmness differences were found in either TB of UFS. However, after storage, firmness differences were found among treatments for both of the varieties. ‘TropicBeauty’ fruit from lower N treatments (N0, N1) were softer than those from the higher N treatments (N2, N3, N4). Different results were obtained when fruit were ripe. Ripe TB fruit from N3 were softer than the other treatments but significant differences were only found between N1 and N4. ‘UFSharp’ ripe fruit did not show any treatment differences for firmness.

In 2017, N treatment affected fruit composition in both varieties. ‘TropicBeauty’ fruit from N0 had higher pH (less acid) and were significantly different from N2. This was observed for all three postharvest sampling times. Total soluble solids were higher in N2 at harvest and after storage. However, ripe N2 had lower TSS and were significantly different from N3. Titratable acidity was higher in fruit from N0, and significant differences were observed for N0 versus N2 and N4 at harvest, but for out of storage and ripe fruit, significant differences were observed between N0 and N2 only.

Fruit composition of UFS had a different response to N treatments. ‘UFSharp’ showed an inconsistent response to N, at harvest and after ripening. Fruit from N0 had lower pH (more acid) at harvest, while N3 had lower pH after storage. The treatment with the highest pH varied during the three sampling times: N4 at harvest, N0 after storage, and N2 at ripe. Total soluble solids were higher in UFS fruit from N0 for all three sampling periods, and were significantly different from N3 at harvest, and were significantly different from N4 after storage and when ripe. The N treatment with the lowest TA varied for at harvest, after storage, and when ripe, while the N treatment with the highest TA was N2 at harvest and N4 after storage and when ripe.

Phytonutrients were not remarkably affected by N fertilization treatments. In 2016 and 2017, carotenoids and anthocyanins showed significant differences between treatments for the two peach varieties. In 2016, ripe TB fruit from N4 had lower carotenoid content, but were higher in 2017. 'UFSharp' fruit did not show significant differences for carotenoids in 2016, but in 2017, N2 had significantly higher carotenoid content than N0. Anthocyanins were higher in 2017 for N2, only for TB fruit.

Although significant differences among the treatments were observed in the 3 years of this study, there was no consistency or trends in the results. Thus, N fertilization effects on peach quality and phytonutrient content are not striking for the range of applied N tested.

Goal 2. Determining effect of N rate on aroma and other flavor components in melting and non-melting flesh peaches.

The hypothesis being tested in this part of our study was that excessive N fertilization of peaches, above that necessary for producing maximum yield, could have negative effects on fruit sensory quality at the ripe stage, when peaches are normally consumed. Specifically, it was thought that high N fertilization could interfere with normal ripening and could lead to higher levels of aroma compounds associated with "green" or "unripe" peach flavor.

Volatile analysis of fruit from the three seasons was performed after ripening using samples from each of the three harvests and two varieties (TB and UFS). Volatiles were collected and analyzed using Gas Chromatography-Mass Spectrometry (GCMS). The analysis of the chromatograms from 2015 and 2016 didn't show consistently significant differences among the N treatments. The differences in the volatiles were mainly found to be due to season and variety. The quantity of lactones, which impart the characteristic peach aroma, were higher in 2015. 'UFSharp' in particular had a higher amount of gamma-decalactone. This compound was present in lower amounts in 2016, but still UFS' had a higher quantity of gamma-decalactone than TB. Aldehydes such as trans-2-hexenal and cis-3-hexanal, which are associated with green and unripe peach flavor, were lower in UFS and higher in TB in 2015. However, in 2016, trans-2 hexanal and cis-3-hexanal were higher in UFS and lower in TB. These results appear to be related to the results obtained in the sensory evaluations, for which the UFS and TB treatments with higher overall liking also had higher amounts of lactones. In the same manner, the less liked treatments were those with higher amount of hexanals. The relationship between attributes evaluated in the sensory evaluation and volatile compounds were seen in both varieties. However, significant differences among the treatments were not consistent over the two seasons.

Two sensory (taste) panels were conducted in 2017. For the first panel, ripe TB fruit from N1 had lower overall liking, poor flavor, and the texture was less liked compared with the other N treatments. The poor flavor appears to have been related to the low scores for sweetness and sourness. In the second taste panel, ripe UFS fruit from N treatments with 0, 40, 80, 160, or 240 lbs/acre and TB from N

treatments 0 and 160 lbs/acre were evaluated by the panelists. 'UFSharp' from N2 was less liked and had poor flavor. In addition, fruit from this treatment were firmer and had a less intense peach flavor.

The volatiles data from 2017 has not yet been analyzed. However, based on the sensory evaluation, it could be inferred that no significant differences among the N treatments are likely to be found. Sugar analyses from the three season are still pending since the laboratory with the Liquid Chromatography/Mass Spectrometry (LCMS) equipment was running other samples. However, samples from 2015 ,2016 and 2017 are already extracted. Sugar extractions were finished in the first week of November, 2017 and LC/MS sugar analysis will be conducted in December 2017 or January 2018.

The results from this part of our study showed that certain aroma compounds do, in fact, have a strong influence, either positive (lactones) or negative (aldehydes), on consumer liking of peaches. Levels of those compounds varied with season and variety more than in response to N fertilization. It appears that the N treatment effects on peach fruit sensory quality were more closely associated with those treatments effects on sugar and acid content (i.e., sweetness) than with the aroma.

Goal 3. Conduct surveys and consumer studies to identify important peach attributes.

The objective in Goal 3 was to identify attributes important to peach consumers that have a role in enhancing purchases. Research may focus on developing a vigorous, healthy and productive tree, however these trees may not yield better fruit in terms of flavor and aroma. The question that was being addressed was "Are growers putting fruit in the markets that consumers desire?"

The IdeaMap survey was launched in August, 2017. A total of 302 participants took the survey. An almost equal number of female (49%) and male (50%) subjects were acquired. Most of them ranged between 25-44 years old (44%), with 16% over 65 years old. The participants were mainly Caucasian (67%) with no children in their household (65%). Thirty-eight per cent of the subjects have some college education and 28% have a bachelor's degree. The majority of the respondents earn less than $30,000 per year (29%) and 23% earn between $30,000 and $50,999, while only 15% earn over 100,000 per year. The participants included 43% who were married and 41% who were single.

The participants were mainly located in urban areas (42%), while 36% live in suburban areas. Participants reside primarily in the Northeast (23%), Midwest (24%), and Southeast (28%), with the remaining 25% residing in the western USA. Almost all (99%) of participants have purchased peaches before. The main form of purchased peaches was fresh (86%), followed by canned (10%) and frozen (3%). Participants purchase peaches generally at a local grocery store (48%). Consumers were mostly either "satisfied" (37%) or "extremely satisfied" (22%) with the quality of peach fruit. There were 33% of the respondents who were "satisfied" with the flavor of peaches and 27% who were "more than satisfied." There were 73% of the participants willing to pay more for a locally grown peach.

The IdeaMap software provided the consumers with a permutation of 35 peach attributes for them to rate using two questions: 1) How likely are you to purchase peaches with attributes like these? And, 2) What price would you be willing to pay for a pound of peaches with these characteristics?

The results provided information on the attributes that are most and least preferred by peach consumers. “Dry and mealy” was the least liked attribute with a -14 interest value (InV)*, while the attribute with the highest interest value was “juicy and fully ripe” (13) followed by “strong peach aroma and sweet peach taste” (10). This leads us to conclude that peach texture and flavor are attributes that definitely drive consumers to purchase peaches. An important outcome from this survey is the fact that consumers also care about where the fruit are from. Consumers rated highly certain attributes such as “grown in Georgia” (11) and “locally grown” (10). In addition participants that were “more than satisfied” with the quality of peaches, prefer peaches “grown in Florida” (14). This could be due to having had a pleasant experience when Florida peaches were purchased.

The data analysis showed that participants over 65 years old were less likely to buy imported peaches (16). In addition, these participants were more willing to buy peaches with “rich flavor of a tree ripened peach.” Participants with children in the household were less influenced by the healthy attributes of peaches, there were low InV s for attributes such as “full of minerals and vitamins” (-3) “rich in Vitamin C” (-6), and “good source of vitamin A” (-4). Texture is more important for this group, since “juicy and fully ripe” had a higher InV (8). In addition, participants with children were less likely to buy peaches with a firm and crispy texture with pit attached to the pulp (-5) – in other words, clingstone varieties, which includes many of those varieties grown in Florida. Participants from rural areas were most willing to buy “locally grown peaches” (17), along with people from suburban areas (17).

The results from the IdeaMap survey showed that Florida peaches have good market potential because consumers desire tree-ripe fruit. However, consumers need to become more familiar with non-melting flesh peaches.

*Higher interest value indicates greater likelihood of purchase generated by a particular attribute. Interest value in parenthesis.

Goals and Outcomes Achieved

Measureable Outcomes

Goal 1. Determine the effect of nitrogen fertilization on postharvest attributes of melting and non-melting flesh peaches.

Measure: Melting and non-melting flesh peaches will be harvested from an existing experiment at color break in which 0, 40,80,160,or 2401bs N/ac annually is applied. Fruit evaluated at harvest and when ripe for respiration rate, ethylene production, skin and flesh color, firmness, Brix, titratable acidity, and phytonutrient content.

Benchmark: Existing information on ripening of melting and non-melting flesh peaches as awell as the effect of refrigerated storage, 1-MCP and hot water treatments is available (Kao et al., 2012a, b).

Target: Knowledge of how N application rates effect postharvest attributes of melting and non-melting flesh peaches will allow growers to adjust their in-season N applications to best optimize tree growth, yield and postharvest fruit quality.

- Nitrogen fertilization rate had no consistent effect on the postharvest quality in general.

Goal 2. Determine differences in peach aroma (volatiles) and flavor compounds as a result of different nitrogen fertilization strategies.

Measure: Melting and non-melting flesh peach fruit from an existing FDACS-funded project (#18009) will be harvested at various ripeness stages [1st harvested when ground color "breaks" (i.e., changes from green to yellowish-green), then weekly for 3-4 weeks] and analyzed for sugars, acids, aroma profiles, and other flavor compounds using published methods.

Benchmark: Previous data on soluble sugars and titratable acidity in peaches and initial aroma/flavor profiling on 'UFSharp' in response to variable N rate has been collected (2013). However, we do not know how genetic alterations in texture or N fertilizer rate affect the balance of sufgars adn acids, and volatiles.

Target: We will nderstand how N rates affect sugar, acid, and aroma development in melting and non-melting peaches. Combined with surveys and taste panels important attribute(s) that contribute to or diminish the "ideal" fresh peach eating experience will be identified and shifts in cultural practices will optimize fruit quality.

- There was a marked seasonal difference in volatiles quantity between 2015 and 2016.

- ‘UFSharp’ overall had higher volatile production than ‘TropicBeauty’

- Nitrogen fertilization rates overall had little effect on synthesis of aroma volatiles or on peach postharvest sensory quality in general, and results were not consistent for the three seasons of data collection

Goal 3. Identify what consumers define as their "ideal" peach, taking into consideration color, size, texture, flavor, and firmness.

Measure: Conduct a nationwide survey using Idea Map® (http://www.ideamap.net/) to identify the most important attributes concerning peach appearance, texture, aroma, flavor and use (fresh vs. processed). This information will be used to conduct consumer taste panels to verify attributes.

Benchmark: Previous research conducted at UF indicates that consumers prefer non-melting flesh peaches over melting flesh peaches; however, cultural practices were not taken into consideration. Previous consumer taste panels for melting and non-melting flesh peaches have developed descriptors of fruit attributes.

Target: We will identify a set of attributes that enhance or detract from the "ideal" peach eating experience specific for various categories (gender, race, household, income, etc.). Data from the surveys and consumer studies will be reported through popular press articles and at field days to reach growers and marketing entities.

- The IdeaMap allowed us to identify the attributes that are most likely to influence consumer decisions to buy peaches.

- Consumers older than 65 years old are most willing to buy locally grown, tree-ripened peaches, which would favor Florida-grown peaches. Florida peach growers could take advantage of this. Since retired people (mostly over 65 years old) are a big part of the Florida population, advertisement of tree-ripe Florida peaches could increase profits for Florida growers.

- Participants are more willing to buy locally grown peaches than peaches from distant growing regions.

- Texture and flavor are the attributes that drive consumers to purchase peaches, more so than their health-promoting attributes.

- Peach field days were held annually at the UF/IFAS Plant Science Research & Education Unit in Citra and the Indian River Research & Education Center in Fort Pierce.

- Several popular press articles mentioned the Florida peach research covered in this project.

Goal 4. Distribute information from both the survey and the impacts of postharvest treatments on fruit quality, flavor and consumer acceptance on the UF Stone Fruit website (http://hos.ufl.edu/extension/stonefruit).

Measure: The performance measure for this would be to record the number of downloads or views the new research reporting page had at each reporting period (6 months, 1 year, 1.5 years, and 2 years).

Benchmark: There is no information currently available in regards to how N rates or the effect of these on postharvest quality of low-chill peaches, thus the measure is 0.

Target: We would target all those that are interested in low-chill peach production in Florida and throughout the Southeast, thus we would target approximately 300 hits or downloads of this information by the end of the funding period.

During the last year of this project, the original P.I. for this project, Dr. Mercy Olmstead, extension specialist left the University, and the position was not refilled until October 2017. Thus, the information developed from this project will continue to be distributed with the new extension specialist moving forward.

- The number of hits and downloads at the UF Stone Fruit website exceeded the target over the course of the project, with over 1,000 hits in regards to nutrient management and postharvest best management practices for the Florida Stone Fruit Industry.

Beneficiaries

The specialty crop beneficiaries of this project are growers in Florida, and throughout the southeastern U.S. that grow low- and mid-chill peaches. Peach production in Florida has now expanded to more than 1,500 acres. The gross value of current bearing acreage is estimated at $4 million dollars with previous year's domestic production amounting to 1.5 million pounds. Current estimates of yield are in excess of 2 million pounds. This project benefits growers throughout the southeastern U.S. in states that are growing low- and mid-chill peach varieties with melting and non-melting flesh textures. In the Florida, Georgia, and South Carolina peach industries, there are over 100 growers. This project comprises a multi-state (FL, GA, SC) impact for peach production areas with higher N fertilization demand because of sandy soil conditions. Growers can use this information to alter fertilization practices as to optimize N rates for fruit quality before harvest and then make in-season adjustments to optimize tree growth and fruit bud development for the following year.

This project benefits the peach specialty crop industry by providing information altering fertilization practices can affect postharvest management and alter fruit quality, fruit aroma, and other flavor compounds. Growers and marketing personnel will receive information on what drives consumers to make initial peach purchases. Although previous research has identified fruit quality characteristics detrimental for return purchases, little information is available on what attributes contribute to an

"ideal" peach eating experience, theoretically driving return purchases. This project will provide information to those in the production, marketing, and shipping chain on postharvest management that will optimize fruit quality at the point of purchase, which is important as demand increases for Florida peaches. As fruit are shipped further from the point of harvest, postharvest fruit quality must be maintained while still providing the customer with a tree-ripe, high-quality product. We know that when compared with imported peach fruit, Florida peaches are superior in texture, flavor, and overall quality. The data generated from fruit sugar, acid and aroma profiles, coupled with taste panel results, will drive further research on the impact of cultural practices in a production system focusing on best management practices.

- Project results can be found at the UF Stone Fruit website (http://hos.ufl.edu/extension/stonefruit)
- Peach field days were held annually at the UF/IFAS Plant Science Research & Education Unit in Citra and the Indian River Research & Education Center in Fort Pierce.
- Several popular press articles mentioned the Florida peach research covered in this project.

Presentations:

Zilfina Rubio Ames, J.K. Brecht, and M. Olmstead. 2017. Impact of Different Nitrogen Rates on Peach Postharvest Attributes. Annual Meeting, Florida State Horticultural Society.

Zilfina Rubio Ames, J.K. Brecht, M.A. Olmstead, D.M. Tieman, H.J. Klee, and C.A. Sims. 2017. Varietal and Seasonal Differences in Volatile Composition and Sensory Quality of Two Florida Peach Varieties. Annual Meeting, American Society for Horticultural Sciences.

Publications:

Vashisth, T., M.A. Olmstead, J. Olmstead, and T.A. Colquhoun. 2017. Effects of Nitrogen Fertilization on Subtropical Peach Fruit Quality: Organic Acids, Phytochemical Content, and Total Antioxidant Capacity. J. Amer. Soc. Hort. Sci. 142:393-404.

Lessons Learned

Problems and Delays:

The postdoctoral associate who began work on this project (T. Vashisth) was began a UF faculty position after the first season; her role in the project was replaced by a Ph.D. student (Z. Rubio), which slowed progress somewhat, necessitating a no-cost extension and the addition of a third season of research. In addition, the original P.I., Dr. M. Olmstead, who was the primary extension and outreach person

responsible for information distribution, left the University of Florida in August 2016. A replacement has recently been hired for her position, and distribution of this information will continue into 2017-2018.

The way in which the test peach trees were pruned each year may have contributed to the overall small or lack of N fertilization rate differences that were found. Specifically, the trees were pruned to a similar size in all treatments, which may have reduced the effects of the higher N rates on vegetative growth and thus on fruit quality.

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Project (11): Increasing marketing effectiveness and awareness of Florida specialty crops: A blueberry case study

Project Partners: The University of Florida Center for Public Issues Education and the Florida Specialty Crop Foundation were the primary organizations conducting this project. Additionally, the Florida Blueberry Growers Association was a project partner.

Project Summary

The purpose of this project was to address barriers and increase the marketability of Florida-grown blueberries among consumers. The Florida blueberry industry is continually facing the pressures of global competition and a short 3-month window to harvest and market their crops. Additionally, consumers struggle to differentiate Florida-grown blueberries from berries grown elsewhere and the industry lacks a unified message. Therefore, the marketing plan developed as a part of this project provides suggestions to help increase recognition of and preference for Florida-grown blueberries among consumers, increase knowledge of the nutritional benefits of blueberries among consumers, increase sales of Florida-grown blueberries, form a unified voice from the industry, and form a collaborative environment among producers, distributors, and organizations.

This project was important and timely as both previous research, as well as the increasingly competitive global food market, indicates a need to create effective messaging and marketing strategies to promote local specialty crops within the state of Florida. Through effective promotion of blueberries, consumers are likely to differentiate and prefer Florida-grown blueberries as compared to those grown in other countries, thus decreasing the pressures of the global food market on Florida specialty crop producers.

This project was not a continuation, but was informed by two previously funded Specialty Crop Block Grants including the “Positioning of Florida-grown specialty crops as local” (2012) and “Florida small farms: Capacity-building, training, and outreach” (2011). These grants identified consumers’ barriers to identifying and accessing local food as well as marketing challenges and barriers to collaboration among producers. These grants laid the foundation and identified the need for current grant project. The current blueberry grant project was informed by these previous grants when considering the development of the consumer and producer survey as well as the marketing plan. However, the blueberry project was unique in that it examined the marketing of a specific specialty crop and identified strategies to improve that marketing through the development of a marketing plan.

Project Approach

Objective 1: To identify barriers to marketing and promoting a cohesive image of Florida-grown blueberries through a survey of producers and distributors.

Activities

- PhD student was hired to support the grant project.

- Through industry benchmarking, many conversations with industry collaborators, and an examination of the industry structure, it was discovered that many blueberry producers are not marketing their own product. Instead, they are using a marketer. As a result, the producer survey was structured so that data could be collected from producers whether they were using a marketer, direct marketing, or using both approaches to marketing.

- The survey was sent to 190 blueberry producers with email addresses. The list of producers was provided by the Florida Blueberry Growers Association. 16 of the emails either bounced back or the recipient indicated that they had sold their blueberry farm and asked to be removed from the list. Out of the 174 usable email addresses, 62 responses were received (35.6% response rate).

- A report of the survey findings was completed and posted to the project webpage. Reference to the project webpage was made in the marketing plan and in presentations to members of the blueberry industry.

- To assist in the current understanding of the breadth, reach, and promotion of Florida blueberries, researchers tracked various grocery store ads from stores representing major chains up the East Coast throughout Florida's blueberry season. The data has been analyzed and informed the development of the marketing plan. A report of these findings is posted on the project webpage.

- Seven in-depth interviews were conducted with marketers/distributors. This data was compiled, analyzed, and incorporated into the marketing plan.

Significant results/accomplishments/conclusions/recommendations

- Of the 64 respondents from the producer survey, 38 were currently engaged in or considering direct marketing. Additionally, 49 respondents were currently using or considering using a marketer. Thus, it can be concluded that many of the respondents market their blueberries through both a marketer and direct marketing outlets.

- The tracking of the grocery store ads revealed that of 31 retail chains (94 stores, 18 cities, 14 states) examined, just 11 retail chains (31 stores) featured Florida blueberries in their online weekly advertisements.

Objective 2: To identify consumers' perceptions of and barriers to purchasing Florida-grown blueberries.

Activities

- A benchmark of the marketing of Florida blueberries present in the Atlanta market was conducted in May of 2015. Researchers visited a variety of groceries stores to examine, the presence of Florida blueberries, advertising of Florida blueberries, and any point of purchase marketing or labeling. These results were analyzed and captured in an undergraduate thesis titled "Identifying Current Marketing Strategies to Promote Florida-grown Blueberries in Georgia Grocery Stores." The results were used to inform the marketing plan.

- The consumer survey was distributed in August of 2015 to 2100 respondents residing in states where Florida blueberries were distributed in the last year. Industry collaborators gave feedback on the survey prior to data collection. The survey captured responses from 1569 consumers who had purchased fresh blueberries in the last year and 531 consumers who had not purchased fresh blueberries in the last year.

- Some of the key findings from the consumer survey were formatted into an, infographic-type handout. This handout was shared broadly with blueberry growers and extension. The handout is also posted on the project webpage. Reference to the project webpage was made in the marketing plan and in presentations to members of the blueberry industry. A presentation of the consumer findings was given to producers attending the Spring 2016 Florida Blueberry Growers Association Meeting and Tradeshow.

- The 1-page handout and presentation of the findings was also shared with the Class V of the Florida Fruit and Vegetable Association's Emerging Leader Development Program. The participants of the class included 11 individuals involved in the Florida fruit and vegetable industry, 4 were directly involved in the blueberry industry.

- A report of the survey findings has been finalized and can be found on the project webpage.

Significant results/accomplishments/conclusions/recommendations

- Only 16% of the consumers surveyed said they knew when Florida blueberries were in season.

- The consumers surveyed preferred 1 pint packages of blueberries, followed by 2 pound packages, and 6 ounce packages.

- More key survey results can be seen in the attached infographic handout or the survey report.

- A presentation of the consumer findings was given to producers attending the Spring 2016 Florida Blueberry Growers Association Meeting and Tradeshow. The presentation received news coverage from The Packer.

o Ohlemeier, D. (2016, February). Florida blueberry growers hear about retail marketing challenges. The Packer. Retrieved from http://www.thepacker.com/news/florida-blueberry-growers-hear-about-retail-marketing-challenges

Objective 3: To develop a marketing plan for Florida blueberry producers.

Activities

- A MS student was hired to work with Dr. Wysocki on the marketing plan.

- Data from objectives 1 and 2 were compiled and a marketing plan was finalized and can be found on the project website.

- A presentation of the marketing plan was given to producers attending the Fall 2016 Florida Blueberry Growers Association Meeting and Trade Show. Each grower present received a media kit (detailed in objective 4).

- An online in-service training featuring the marketing plan and incorporated research was delivered in October of 2016. The webinar was attended by 8 participants. Additionally, the webinar was recorded and available at http://www.piecenter.com/2016/10/04/october-4-strategic-marketing-plan-for-the-florida-blueberry-industry/ for industry and extension to access at their convenience.

Significant results/accomplishments/conclusions/recommendations

Recommended Marketing Tactics

1. Digital Campaign – Implement a digital marketing campaign through the internet including social media, websites, and marking through mobile phones

2. Kids in the Kitchen promotion - Revamp this existing project to include more health benefits and a stronger emphasis on the growing season, along with blueberry recipes

3. Chef Justin - Work with Fresh from Florida to produce clips of Chef Justin speaking about several different ways to use Florida blueberries with direct emphasis on the fruit being in season

4. In-store promotions – Consider blueberry sampling opportunities and shopping cart promotional cards for increased consumer education at the point-of-purchase

5. Billboards - Place billboards on major roadways in Florida with the simple call-to-action that Florida blueberries are currently in season.

6. Labeling – Encourage the industry to utilize Fresh from Florida labeling whether through incorporation of existing labels, complimentary labeling, or closure stickers to drive consumer awareness and demand for Florida blueberries

7. Marketing arm for FBGA – Develop a marketing and communication arm within FBGA to coordinate marketing tactics, Fresh from Florida collaborations, media requests, email pushes to consumer and retailers, grower's questions, etc…

8. Communication platform - Develop a platform for growers to communicate volume information to increase communications and ensure higher prices for longer

9. Retail incentive program - Buy ads in grocery store and other retail publications (print and online through apps and email) to encourage retailers to feature in-season Florida blueberries in their weekly ads, accompanied by the Fresh from Florida logo

10. Retail communications - Purchase advertising space in retail publications (i.e. The Packer, Produce News, Progressive Grocer) to inform retailers about the timing of the Florida crop through informative articles

11. End-Consumer communications - Purchase advertisements or pitch story ideas to popular consumer magazines such as Florida Food and Wine, Southern Living, Garden and Gun, Better Homes and Gardens, etc.

12. Industry Social Media Pages - FBGA should utilize social media (Facebook, Twitter, Instagram) to communicate with consumers and the industry about blueberry recipes, health benefits, individual grower spotlights, contests, U-Pick announcements, countdowns to the Florida season, industry updates, and Florida Blueberry Festival announcements

13. Individual grower Social Media pages – Engage with customers year-round on social media, especially close to and during the Florida season, to further promote the Florida blueberry industry as well as individual businesses

14. Spokesperson – Consider engaging a personality to be the "face" of Florida blueberries to connect consumers to the industry

15. Email pushes - Establish a database of loyal consumers and email these consumers when the first big volume of Florida blueberries come into retail stores

16. Earned Media Opportunities - Create news-worthy promotional pieces to be picked up by large media channels and newspapers in Florida and up the East Coast

17. Agritourism – Consider getting involved in and promoting blueberry related agritourism activities such as U-pick operations that allow consumer to gain personal experiences with the blueberry industry

18. Restaurant partnerships - Develop blueberry recipes and drinks to be served on special menus in Florida restaurants or bakeries while featuring the Fresh from Florida logo

19. Presence at health events in Florida and on the East Coast - Utilize existing health events to target consumers and increase awareness of Florida blueberry season and the health benefits of blueberries

20. Add recipes featured by Fresh from Florida to the FBGA website and individual grower social media pages - When FFF posts recipes, FBGA is encouraged to share these recipes further on their own website and social media sites. Individual growers can also share these recipes with their followers to increase the number of people seeing the recipes

- The marketing plan informed two articles published in the Fall 2016 issue of Blueberry News.

o Johnson, B. (2016, Fall). Grower 411: Study shows opportunities for growers. Blueberry News. Retrieved from http://floridablueberrygrowers.com/2016/09/29/grower-411-study-shows-opportunities-for-growers/#more-2551

o Blueberry News. (2016, Fall) 'Fresh from Florida' shines spotlight on blueberries. Retrieved from http://floridablueberrygrowers.com/2016/10/10/the-fresh-from-florida-campaign-was-created-increase-consumer-awareness/

Objective 4: To develop and disseminate outreach materials, such as a trade publication, insert, or website to jump-start the marketing campaign for the industry.

Activities

- A project webpage was developed and can be found at http://www.piecenter.com/issues/food/local-food/

o All grant materials are under the "Increasing marketing effectiveness & awareness of Florida blueberries" tab

- The 1-page, info-graphic type, handout was developed as an outreach component for industry presentations. In addition, the 1-page handout and project description can be found on the project webpage. The direct link to the one-page handout is http://www.piecenter.com/wpcontent/uploads/2015/12/blueberries3.pdf

- A half page educational flyer featuring the health benefits of blueberries has been developed and can be found on the project webpage. This flyer was one of the two materials developed as outlined in the marketing plan.

- An educational video aimed at increasing the awareness of the Florida blueberry season was developed and can be found on the project webpage and on YouTube at https://youtu.be/K3bCwb8Nrmk This video was one of the two materials developed as outlined in the marketing plan.

- The educational materials (flyer and video) were distributed to blueberry growers along with the marketing plan at the Fall 2016 Florida Blueberry Growers Association Fall Meeting and Trade show. We identified these collective materials as media kits for the blueberry growers. Extra materials were distributed to Extension faculty throughout the state to share with their blueberry clientele.

- An insert featuring highlights from the consumer survey and the marketing plan were published in the Fall 2016 edition of the Blueberry News. Reprints of the insert were distributed to all 67 county Extension offices for distribution to blueberry clientele. Blueberry News is the only endorsed publication of the Florida Blueberry Growers Association (FBGA) and is delivered to every member of the FBGA. The Blueberry News is also available for free at bulk distribution locations and agriculture related facilities throughout the state including agricultural locations at the University of Florida campus, ag extension, Research & Education Centers (REC) located throughout the state, and Florida Farm Bureau offices.

- An evaluation of the marketing plan and educational materials was conducted in the Fall of 2016. The evaluation of the marketing plan was conducted at the Fall 2016 Florida Blueberry Growers Association meeting and trade show. Evaluation data were collected following the presentation of the Strategic Marketing Plan for the Florida Blueberry Industry. A convenience sample of producers that attended the

presentation was utilized. The survey was disseminated to 105 growers that attended the presentation. 40 surveys were returned for a 38% response rate. The evaluation of the educational materials was conducted with a convenience sample of Millennial consumers. The survey was taken by 379 out of 402 respondents, resulting in a 94% response rate. Both evaluation reports can be found on the project webpage.

- A presentation of the project highlights was presented to the Class 6 of the Florida Fruit and Vegetable Association's Emerging Leader Development Program.

- A paper titled "Who knows more about blueberries? Identifying a knowledge gap of blueberry health benefits" was presented at the annual meeting of the Association for Communication Excellence in Agriculture, Natural Resources, and Life and Human Sciences. Following the presentation, the paper received news coverage in more than 20 news sources including local, state, national, and international coverage. The coverage is detailed below. This paper has been submitted for academic publication to the Journal of Human Sciences and Extension.

o Boldsky. (2016, July). Do you know that blueberries can improve vision and memory? Retrieved from www.boldsky.com/health/wellness/2016/do-you-know-blueberries-can-improve-vision-and-memory-102662.html

o Serpico, R. (2016, July). UF study finds people don't know about benefits of blueberries. Retrieved from http://www.alligator.org/news/campus/article_101a8acc-47db-11e6-a65b-3f501f950a0f.html

o The Kashmir Monitor. (2016, July). Do you know blueberries can improve vision and memory? Retrieved from http://www.kashmirmonitor.in/Details/106414/do-you-know-blueberries-can-improve-vision-and-memory

o Buck, B. (2016, July). Blueberries' health benefits better than many perceive. Farmer & Rancher. Retrieved from http://farmerandranchernow.com/2016/07/06/blueberries-health-benefits-better-than-many-perceive/

o Buck, B. (2016, July). Blueberries' health benefits better than many perceive. Before it's news. Retrieved from http://beforeitsnews.com/science-and-technology/2016/07/blueberries-health-benefits-better-than-many-perceive-2834599.html

o Buck, B. (2016, June). What you may not know about blueberries' health benefits. Lab Manager. Retrieved from http://www.labmanager.com/news/2016/06/what-you-may-not-know-about-blueberries-health-benefits?fw1pk=2#.V3EyYY5eKiF

o Stepin2. (2016, June). Blueberries' benefits are better than you think. Retrieved from http://www.stepin2mygreenworld.com/healthyliving/blueberries-benefits-better-think/

o New York Ag Connections. (2016, June). Blueberries health benefits better than many perceive. Retrieved from http://www.newyorkagconnection.com/story-national.php?Id=1327&yr=2016

o Buck, B. (2016, June). Blueberries' health benefits better than many perceive. Fruit Growers News. Retrieved from http://fruitgrowersnews.com/news/blueberries-health-benefits-better-many-perceive/

o All4Women. (2016, June). Blueberries may be even better than we thought. Retrieved from http://www.all4women.co.za/773397/health/nutrition/blueberries-may-even-better-thought

o NDTV Food. (2016, June). Eating blueberries can improve your visions and memory. Retrieved from http://food.ndtv.com/health/eating-blueberries-can-improve-your-vision-and-memory-1422572

o Dna. (2016, June). Eating blueberries can help you retain youth, improve memory and vision. Retrieved from http://www.dnaindia.com/health/report-eating-blueberries-can-help-you-retain-youth-improve-memory-and-vision-2226570

o Heslip, N. (2016, June). The power of blueberries. Brownfield Ag News for America. Retrieved from http://brownfieldagnews.com/2016/06/22/the-power-of-blueberries/

o AhmedabadMirror. (2016, June). Berry berry memorable. Retrieved from http://www.ahmedabadmirror.com/others/you/Berry-berry-memorable/articleshow/52872763.cms

o News 18. (2016, June). Do you know blueberries can improve vision and memory? Retrieved from http://www.news18.com/news/lifestyle-2/do-you-know-blueberries-can-improve-vision-and-memory-1260388.html

o Fresh Plaza. (2016, June). Blueberries' health benefits better than many perceive. Retrieved from http://www.freshplaza.com/article/159641/Blueberries-health-benefits-better-than-many-perceive

o Zee News Health. (2016, June). Blueberries can improve memory, vision. Retrieved from http://zeenews.india.com/news/health/health-news/blueberries-can-improve-memory-vision_1898661.html

o Bollywood Country. (2016, June). Do you know blueberries can improve vision and memory? Retrieved from http://www.bollywoodcountry.com/?q=detail/special/do-you-know-blueberries-can-improve-vision-and-memory?/68897

o NDTV. (2016, June). Do you know blueberries can improve vision and memory? Retrieved from http://www.ndtv.com/health/do-you-know-blueberries-can-improve-vision-and-memory-1421973

o Buck, B. (2016, June). Blueberries' health benefits better than many perceive. IFAS News. Retrieved from http://news.ifas.ufl.edu/2016/06/blueberries-health-benefits-better-than-many-perceive/

o Buck, B. (2016, June). Blueberries health benefits better than many perceive. Growing Florida. Retrieved from http://growingfl.com/news/2016/06/blueberries-health-benefits-better-than-many-perceive-2016-06-20/

o ScienceDaily. (2016, June). Blueberries' health benefits better than many perceive. Retrieved from https://www.sciencedaily.com/releases/2016/06/160617120711.htm

o Buck, B. (2016, June). Blueberries healthier than many perceive. Morning Ag Clips. Retrieved from https://www.morningagclips.com/blueberries-healthier-than-many-perceive/?utm_content=articles&utm_campaign=NLCampaign&utm_source=Newsletter&utm_term=newsletteredition&utm_medium=email

o Stone Hearth News. (2016, June). Blueberries' health benefits better than many perceive: University of Florida Institute of Food and Agricultural Science. Retrieved from

http://www.stonehearthnewsletters.com/en/blueberries-health-benefits-better-than-many-perceive-university-of-florida-institute-of-food-and-agricultural-sciences/updates/

- A poster titled “Exploring online weekly advertisements of Florida blueberries in East Coast grocery stores” was presented at the 2016 annual meeting of the Southern Association of Agricultural Scientists Conference, Agricultural Communication Section. This poster covered the results of the blueberry ad tracking, which is detailed in Objective 1.

- A paper titled “Marketing power berries: An importance-performance analysis of blueberry attributes” was presented at the 2017 annual meeting of the Southern Association of Agricultural Scientists Conference, Agricultural Communication Section. This paper focuses on part of the results of the consumer survey, detailed in Objective 2. Publication in an academic journal will be pursued following the conference.

- A poster titled “Testing if knowledge of the Florida blueberry season increases as a result of video intervention” was presented at the 2017 annual meeting of the Southern Association of Agricultural Scientists Conference, Agricultural Communication Section. This paper focuses on the results of the evaluation of the educational materials.

- A paper titled “Increasing knowledge of blueberry health benefits through an information flyer” was submitted for presentation to the 2017 annual meeting of the Association for Communication Excellence in Agriculture, Natural Resources, and Life and Human Sciences. This paper focuses on the results of the evaluation of the educational materials.

Significant results/accomplishments/conclusions/recommendations

- The evaluation of the educational materials showed increases in knowledge when shown to respondents. There for the industry should work to increase awareness of blueberry season and blueberry health benefits by using educational materials similar to the ones evaluated in this project.

- The evaluation of the marketing plan showed that the majority of blueberry growers were aware of the marketing plan and planning to implement at least one marketing tactic presented in the plan. Follow up should be conducted with growers to see which tactic they implemented and how it has impacted their marketing.

Significant contributions and role of project partners

- The PI and research staff worked to speak with industry representatives and do research to understand how the industry and markets operate in Florida. In addition, the researchers collected data from producers, consumers, and marketers/distributors, have benchmarked the Atlanta market, and tracked ads for Florida blueberries.

- The Florida Specialty Crop Foundation was instrumental in helping manage the grant, providing feedback on grant components, and building relationships with key stakeholders in the blueberry industry.

Goals and Outcomes Achieved

Goal 1: Increase consumer knowledge of the availability of Florida blueberries.

- Performance Measure: Percentage of knowledge gain regarding Florida blueberry availability.

- Target: A 10% increase in knowledge.

o To measure this goal two groups were asked to identify when Florida blueberries were in season. One group received the educational video about the timing of Florida blueberry season. The other group did not receive the video. 95% of those in the video group correctly identified Florida's blueberry season, while only 50% of those in the non-video group correctly identified Florida's blueberry season. Thus, the educational video resulting in a 45% increase in knowledge.

Goal 2: Increase consumer knowledge of the nutritional benefits of Florida blueberries.

- Performance Measure: Percentage of knowledge gain regarding the nutritional benefits of Florida blueberries.

- Target: A 10% increase in knowledge.

o Before viewing the educational flyer on blueberry health benefits, 4.5% of respondents indicated they were extremely or very knowledgeable about the health benefits of blueberries. After viewing the flyer, 50% of respondents indicated they were extremely or very knowledgeable about the health benefits of blueberries. Thus, the health benefits flyer resulted in a knowledge increase of 45.5%.

Goal 3: Achieve awareness of the marketing plan among 75% of Florida blueberry producers.

- Performance Measure: Percentage of producers who demonstrate awareness of the developed marketing plan.

- Target: Increase awareness by 75% (Benchmark is 0%).

o Following the presentation of the marketing plan, 78.9% of blueberry growers attending the Fall 2016 Florida Blueberry Growers Association Meeting and Trade Show reported that they were aware of the marketing plan.

Goal 4: Encourage adoption of the developed marketing plan among Florida blueberry producers.

- Performance Measure: Percentage of producers who adopt a component of the marketing plan.

- Target: Increase adoption by 25%.

o Following the presentation of the marketing plan, 85% of blueberry growers attending the Fall 2016 Florida Blueberry Growers Association Meeting and Trade Show reported that they would implement or increase use of at least one new marketing tactic presented in the marketing plan.

Beneficiaries

The primary beneficiaries of this project included Florida's blueberry growers (~566 farms) and the Florida Blueberry Grower's Association and its members. At the time of the project proposal it was estimated that more than 400 people would benefit from the project. This primary audience was reached by the project results through a variety of channels. Results were distributed via the project website, presentation at the Florida Blueberry Growers Association, in the Blueberry News magazine, industry news coverage, via webinar, and through academic publication. All of these distribution channels are detailed in the project approach section of this report. This audience benefited by understanding consumer perceptions of blueberries to utilize when communicating about and marketing their product. Additionally, they benefited from the marketing plan and media kits that were provided to them. The marketing plan provides specific tactics to improve blueberry marketing in the state. Additionally, the media kit equips them with educational materials that they can use when communicating with potential customers.

The secondary beneficiaries of this project included consumers who purchase blueberries. The consumers will benefit once the blueberry industry/producers have time to implement the strategies and tactics outlined in the marketing plan. Utilization of the educational materials developed as a result of this project have been proven to increase knowledge of the Florida blueberry season as well as blueberry health benefits (as seen in the evaluation data in Objective 4). If the industry and producer utilize these materials and information it is likely that consumer knowledge will continue to increase.

Lessons Learned

The discovery that many blueberry producers were using a marketer, rather than marketing their own product altered the original plan for the producer survey. Thus, the producer survey was delayed to ensure that adequate data were collected. This realization also led us to talk to marketers to inform the development of the marketing plan. We added the component of conducting in-depth interviews with key marketers in the state, which were not originally planned for. In addition, the original timing of the producer survey was scheduled for the height of blueberry season. To ensure good response rates the survey was delayed by a few months.

Additionally, throughout the course of the project invoicing was delayed. The problem was identified and the remainder of the invoicing was conducted in a timelier fashion.

The researchers learned that the length of the project did not allow them to see the implementation of the marketing plan and its potential success. The implementation and potential impact of the marketing plan are long term measurable that exceed the timeline allotted for this grant. We have measured projected use of the marketing plan in our evaluation, but it would have been nice to see the actual use and the impact of that use. However, the impact of the marketing plan would take several years to evaluate.

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Additional information can be found at http://www.piecenter.com/issues/food/local-food/ under the “Increasing marketing effectiveness & awareness of Florida blueberry" tab.

Funding Expended: $146,743.28

Project (12): Optimizing Nitrogen Fertilization for Florida's Blueberry Industry

Project Partners: University of Florida

Project Summary

Commercial blueberry production is a relatively new industry in Florida that is increasing rapidly in acreage and economic importance. Currently there are no research-based recommendations for N fertilization practices for blueberry production in Florida. Florida growers rely on N fertilizer recommendations from other blueberry production regions where cultivars (and blueberry types; northern highbush and rabbiteye vs. southern highbush in Florida) and production practices differ dramatically from Florida. Our research will provide recommendations for N fertilization of new and established southern highbush blueberry plantings under Florida conditions.

Commercial blueberry production occurs across a broad geographical area of Florida from De Soto County north to Alachua County in close proximity to many protected wetlands and population centers. This new industry is developing rapidly in Florida. During the past decade, acreage has increased from 1600 acres to approximately 5000 acres and the value of the industry has increased from $3.1 million in 2002 to a current value of over $70 million. Continued expansion is anticipated since Florida produces blueberries during a lucrative April/May production window when grower returns are two to three times higher than for other U.S. production regions that harvest later in the season. Rapid and sustained growth of the industry, both geographically and financially, underscores the immediate need for proper N fertilization practices, both for the economic health of Florida's blueberry industry, and for the environmental health of Florida.

The objectives of this project are: 1) to determine optimum N fertilization rates during blueberry plant establishment in newly planted fields; and 2) to determine optimum N fertilization rates for mature blueberry plantings that optimize yield, berry quality and profitability while minimizing risks of negative environmental impacts from nitrate leaching.

Project Approach

Goal 1. Determine N fertilization rates for young southern highbush blueberry plants that optimize plant establishment and early production without excessive N fertilization applications that lead to increased nitrate leaching and potential ground water contamination.

Results

Goal 1. Soil moisture, electrical conductivity (EC), pH and temperature were measured continuously at three depths (15cm, 30 cm, and 70 cm) from April 1 through November 28 for the 0, 84 and 336 kg N/ha treatments in the young blueberry planting. At the first and second depth, the 336 N treatment had the highest EC level and the 84 N treatment had the lowest. In contrast, the 84 N treatment EC levels were higher than other treatments at the third depth. Soil moisture of the 0 N treatment was generally higher than the other treatments at the first and second depth however moisture content of soil from the 336 N treatment was greater than the other treatments at the third depth. Soil temperatures did not differ for any of the treatments regardless of depth. Soil pH tended to increase with soil depth for all treatments. Soil pH of the 336 N treatment was lower than the other N treatments.

Soil samples were collected in April, May, July and October and analyzed for nitrate content at three depths (6, 12 and 30 inches). For 'Emerald', the 336N treatment had higher nitrate levels than any of the other N treatments at the 6 and 12-inch depths on the May and July sampling dates (Table 1). For the October sampling date, the 336 N treatment had higher nitrate levels than any of the other N treatments at the 12-inch depth and higher nitrate levels than the two lowest N treatments at the 6-inch depth. At the 30-inch depth, the 336 N treatment had high nitrate levels than the three lowest N treatments at the May sampling date with no other differences for at the other three sampling dates. For 'Farthing', soil nitrate levels for the 336 N treatment were higher than the other N treatments at the 6-inch depth in May and greater than the three lowest N treatments in April and July (Table 2). At the 12-inch depth, the 336 N treatment had higher nitrate levels than any of the other N treatments in October and higher nitrate levels than the three lowest N treatments in July. At the 30-inch depth, nitrate levels for the 336 N treatment were greater than nitrate levels for any of the other treatments in October, and greater than the 0 and 84 N treatments in July, and greater than the 84 N treatment in April.

Leaf greenness (an indication of leaf N concentration) was measured in April, June, July and October. Leaf samples were collected for nutrient analysis in October after the plants had attained enough size that leaf sampling would not adversely affect their growth. There were no significant differences in leaf greenness (SPAD readings) or leaf N concentration across the five N treatments for either cultivar (data not shown).

Plant height was measured on October 8 after the current season's shoot extension growth had stopped. 'Emerald' plants receiving the 0 N treatment were shorter than plants receiving the 84 N treatment but N fertilization rate did not affect height of Farthing' plants (Tables 3 and 4).

In 2016, leaf samples were collected in 1 June and analyzed for foliar P,K, Mg, Ca, S, B, Zn, Mn, Fe and Cu content and for N content on 21 April and 1 June 22 August. Nitrogen treatments had no effect on leaf

nutrient content of young 'Emerald' or 'Farthing' plants (Tables 5, 6 and 7). Leaf N content for 'Emerald' tended to be above the excess level of 2.50% reported for northern highbush blueberry (Eck et al. 1988. Blueberry Science, Rutgers University Press, New Brunswick, NJ). There were no differences among the N treatments and even the lowest N treatment had levels of 2.63 % to 2.66 %, depending on the sampling date. However, nitrogen concentrations tended to be lower across all N treatments for samples collected in August than for samples collected in April or June (data not shown). Leaf N content of 'Farthing' plants was consistently lower than leaf N content of 'Emerald' and within the northern highbush blueberry (NHB) sufficiency range for all N treatments. Leaf nutrient contents for other essential elements were not affected by N treatment but often deviated from published standard ranges based on northern highbush blueberry (NHB). Leaf P content tended to be at the lower end of the standard range for all N treatments and both cultivars (Tables 5 and 6). Conversely, leaf K levels were above the published excess level of 0.95 % for NHB, generally being slightly over 1.00%. Magnesium and Ca tended to be in the upper NHB standard range. Sulfur was consistently at the upper end, or slightly above the NHB standard range. Foliar Fe tended to be at the lower end, or slightly below, the NHB standard range of 60 ppm. Manganese was consistently above the NHB excess value of 450 ppm. Boron tended to be above the NHB standard range but below the excess value of 200 ppm. Copper tended to be below the deficiency level of 5 ppm. It is possible that leaf nutrient content for southern highbush blueberry (SHB) differs from NHB since SHB is a complex hybrid with parentage from several Vaccinium species in addition NHB. Leaf nutrient standards are believed to be different for rabbiteye blueberry (Vaccinium ashei) which is contained in SHB parentage. N treatment had no significant effect on leaf nutrient content for any of the essential elements measured. When considering the entire 2016 growing season, leaf nitrogen levels were highest in April, and steadily declined in June and August for both cultivars, regardless of N treatment.

In 2016, all ripe fruit were harvested at 3 to 4-day intervals beginning when the first 10% of fruit were ripe and ending after all fruit were harvested. Two data plants per plot were harvested for each N treatment/cultivar combination. Plant height, measured in March and June, were not affected by N fertilizer treatment (Table 8). Fruit yield and average berry weight were determined for all N treatments of both cultivars. For 'Emerald' the 336N treatment had higher total berry yield than either the 0N or 42N treatments (Table 9, Fig. 1). For 'Farthing', total berry yield was higher for the 168N and 336N treatments than for the other three treatments (Table 9, Fig. 2). Linear plateau regression analyses found inflection points for the relationship between N rate and berry yield to be222.6 kg N/ha/yr for young 'Emerald' plants and 206.4 kg N/ha/yr for young 'Farthing' plants. Yield and percent ground cover, which is an indication of canopy size were highly correlated for both cultivars (Fig. 3 and4). Seasonal average berry weight of 'Emerald' was less for the 336N treatment than for the 42N treatment (Table 9). For 'Farthing', average berry weight was less for the 336N treatment than for any of the other treatments. Berry firmness and diameter were determined at three times during the harvest season for each cultivar; early, mid, and late season. For 'Emerald' berry firmness was not affected by N treatment for the first two sampling periods but was greater for 336N than for the other treatments at the final sampling period (Tables 10, 11 and 12). For 'Farthing, berry firmness was greater for the 336N treatment than for the 0N, 84N, and 168N treatments at the early and late sampling periods (Tables 10 and 12), and greater than any of the other treatments at the mid-season sampling period (Table 10).

In 2017, the effect of N fertilizer rate on season berry yield in 2017 was similar to 2016. For 'Emerald' plants, the 336N treatment was greater than the 0N or 42N treatments, but not different from the 84N or 168N treatments (Table 13). For 'Farthing', the 168N treatment was greater than the 0N or 42N treatments but not different from the 84N or 336N treatments. For 'Emerald', average berry weight was greatest for the low-yielding 0N and 42N treatments and for 'Farthing' the 336N treatment had the lowest mean berry weight. For 'Emerald', fruit acidity was not affected by N fertilizer rate at any of the early, mid, and late season sampling dates (Table 14). Soluble solids content was also largely unaffected by N fertilizer rate. Fruit firmness was not affected by fertilizer rate during the early harvest period, but tended to be greater for the higher N fertilizer rates at the mid and late season sampling period.

Goal 2. Determine N fertilization rates for mature southern highbush blueberry plants.

Leaf samples were collected for leaf N analyses in April, June, July and October. There were no significant differences in leaf N concentrate among the N fertilization treatments for either cultivar at any measuring date. Generally, leaf N levels declined as the growing season progressed.

Soil samples were collected in April, June, July and October for all N treatments of both cultivars. There were few differences in soil N concentration for 'Jewel'. The 84 N rate had lower soil nitrate concentrations than the 308 N rate at the 12 inch depth, but only at the July sampling date (Table 15). Other soil samples for 'Jewel' did not differ for soil N concentration. For 'Windsor', the 308 N rate had higher nitrate concentrations than the 252 N treatment for two of the four sampling dates (June and July), at the 12 soil depth and higher nitrate concentrations than all other N treatments at the 6-inch depth in June (Table 16).

Total berry yield of 'Jewel' was greater for the 140 N treatment than for the highest N treatment (308 N) (Table 17). For 'Windsor', the 84 N treatment had greater yield than the 252 N treatment. Average berry weight of 'Jewel' was greater for the 140 N treatment than for the 84N, 252 N and 308 N treatments. The highest N treatment (308 N) had lower average berry weight than the three lowest N treatments. No treatment differences in mean berry weight were found for 'Windsor' except that the 252N treatment had lower mean berry weight than any of the other treatments.

Berry samples were analyzed for fruit firmness on April 17, April 23 and April 29 for 'Windsor' and April 20,

Fruit samples were evaluated for titratable acidity (TA), soluble solids (SS) and the corresponding SS/TA ratios were calculated. For 'Windsor', no differences were found for TA, SS or SS/TA ratios at any of the sampling dates (data not shown). Late season samples had lower TA and higher SS values than early and mid-season samples. As a result, the SS/TA ratios for late season berries were higher than for early or mid-season berries.

In 2016, leaf samples were collected in 1 June and analyzed for foliar P,K, Mg, Ca, S, B, Zn, Mn, Fe and Cu content and for N content on 21 April and 1 June. No differences in leaf N content were found among N treatments for 'Jewel' or 'Windsor' or among other nutrients (Tables 18 and 19). Leaf N content tended

to be higher in June than in April for both cultivars and higher for 'Jewel' than for 'Windsor' at both sample dates. Leaf N content for 'Jewel' was within the standard range for northern highbush blueberry at the first sampling date for all treatments and above the standard range for all treatments at the second sampling date. 'Windsor' leaf N content was consistently below the NHB standard range for all N treatments at the first sampling date and at the lower end of the NHB standard range for the second sampling date. Phosphorus was below the NHB standard range but above the deficiency level for 'Windsor' and at, or slightly below, the deficiency level for 'Jewel'. Calcium levels were consistently at, or slightly above, the NHB excess level and iron was consistently below the deficiency level for NHB although no visual symptoms of iron deficiency were observed (Tables 18 and 19). Other elements were generally within the standard range for NHB. As stated previously, it is possible that SHB and NHB have different leaf nutrient levels due to different parentage.

Soil samples were collected in March and May, July and September at 6, 12 and 30-inch depths for all N treatments of both cultivars. There were no differences in soil nitrate concentrations among any of the N treatments at any of the sample dates for any of the soil depths (data not shown). Soil nitrate concentrations tended to be higher at the 6-inch depth than at the 12 or 30-inch depths for both cultivars, and at both sampling dates.

Plant height and width were measured in March and June, 2016. Neither plant width nor plant height of either 'Jewel' or 'Windsor' was affected by N treatment (data not shown).

All ripe fruit were harvested at 3 to 4-day intervals beginning when the first 10% of fruit were ripe and ending after all fruit were harvested. Fruit were harvested from two data plants per plot ('Jewel') and one data plant per plot ('Windsor') to determine total yield for each N treatment/cultivar combination. Average berry weight was determined by weighing 20-fruit subsamples from each larger sample. During representative early, mid, and late-season harvests, fruit sub-samples of each treatment/cultivar were collected and stored at -80C for later determinations of titratable acidity (TA), soluble solids (SS) and the corresponding SS/TA ratios. Total berry yield was not affected by N fertilizer treatment and ranged from 2729 g/plant to 3222 g/plant for 'Jewel' and from 1177 g/plant to 1895 g/plant for 'Windsor' (Table 20). Mean berry weight tended to be greatest for the 140N treatment and that treatment had consistently greater mean berry weight than the 252N treatment (Tables 21 and 22). The highest N treatment, 308N, tended to have smaller mean berry weight than the 140N treatment but differences were significant only at the earliest sample date. Berry firmness tended to be inversely proportional to berry weight with the berries of smaller mean berry weight having greater firmness (Tables 21 and 22).

Project partners for Goal 2. Eric Ostmark (biological scientist) oversees daily field activities and supervises labor during fruit harvest and applies fertilizer treatments. Carole Hamilton oversees and supervises laboratory analyses including determinations of fruit yield and quality. Jeff Williamson and Rebecca Darnell provide research planning and oversight, and interpretation of results. David Liu provides oversight on installation of soil moisture and EC sensors, and data loggers, and provides interpretation of these data.

Goals and Outcomes Achieved

Goal 1. Determine N fertilization rates for young southern highbush blueberry plants that optimize plant establishment and early production without excessive N fertilization applications that can lead to increased nitrate leaching and potential ground water contamination.

There were no differences in leaf N concentration, plant height, or fruit yield between the 168N and 336N treatments for either of 'Emerald' or 'Farthing' in this study. Moreover, the concentration of soil nitrate in the 168N treatment generally did not differ from the concentrations with lower N rates, especially at the 0.76 m depth, which is below the root zone. This suggests that the 336N fertilizer rate offered no additional benefits over the 168N treatment and, in fact, would increase the risk of N leaching compared with lower N rates. However, at the end of second year, 'Emerald' fertilized with 336N had a larger canopy than the other treatments. Although canopy volume was greater for the 336N treatment at the end of the 2016 growing season, the effects of N treatment on berry yield in 2017 were similar to 2016 with no apparent advantage of the 336N rate over the 168N rate with respect to yield or berry size. As in 2016, the 2017 mean berry weight tended to be smaller for the 336N treatment than for lower N rates for both cultivars. This suggests that the optimum N fertilization rate for young blueberry plants during the first 2.5 years following planting using daily fertigation is between 84N and 168Kg/ha/year which agrees with work on northern highbush blueberry (Bryla and Strik, 2015).

Goal 2. Determine N fertilization rates for mature southern highbush blueberry plants that maintain or increase berry yield and quality without excessive fertilization that can lead to nitrate contamination of ground water.

Mature southern highbush blueberry plants receiving annual N rates of 84kg/ha and 140kg/ha produced yields that were similar to higher N rates during the 2015 and 2016 seasons. In 2015, yields were considered high for all treatments ranging from 6948 g/plant to 5217 g/plant for 'Jewel' and 5811 g/plant to 3748 g/plant for 'Windsor'. In 2015 'Jewel' plants receiving the 140N treatment produced higher berry yield than the 308N treatment but not different from the 84N treatment. Mean berry weight of 'Jewel' was greater for the 140N treatment than for the 84N or 308N treatments. For 'Windsor', the 84N treatment produced higher berry yield than the 252N treatment. In 2016, yields were less than in 2015 for both cultivars and for all treatments. This was likely related to the extreme warm winter and the lack of winter chilling during the 2015/2016 winter. Additionally, 'Windsor' was showing symptoms of blueberry leaf scorch during the 2016 season. In 2016, higher N rates tended to have smaller berries for both 'Jewel' and 'Windsor'. The data suggests that an effective annual N fertilizer rate for mature southern highbush blueberry plants that will promote high yield and minimize nitrogen leaching in the soil is between 84 and 140 kg/ha. This information provides a useful baseline for further development of southern highbush nitrogen fertilizer requirements in Florida.

Goal 3. Increase knowledge of blueberry growers on improved nitrogen fertilization practices needed to maximize fruit yield while minimizing negative environmental impacts.

The results of this study were presented, along with other production information, to commercial blueberry growers at the 2016 Fall Blueberry Growers' Association meeting. Ninety percent of the 82 growers surveyed indicated that information presented at the program was likely to influence their decisions on commercial blueberry practices.

In 2017, a county agent in-service training program was held at the UF Plant Science Research and Education Unit where the research is located. The training was attended by 25 county agents, state specialists, and growers. The project was discussed in the classroom, and a tour of the research plots was conducted. The agents, specialists, and growers that were in attendance are critical for distributing the project information to the commercial blueberry industry.

Although the research was designed with commercial growers in mind, it also has application for home gardeners and hobbyists who are growing blueberries. The research project site was part of field tours for two Master Gardener classes (2015 and 2016). Master Gardeners interact with, and make recommendations to, home gardeners.

Beneficiaries

Commercial blueberry growers, Extension educators, consultants, sales representatives, and other blueberry industry professionals will benefit from the results of this research. Currently commercial blueberry acreage is at an all-time high in Florida with between 5000 and 7000 acres. In 2015, the Florida blueberry crop value was estimated at over $80 million. The number of commercial blueberry farms in Florida is not known but attendance at the statewide blueberry meetings typically exceeds 400. There are both large and small growers with blueberry farm size ranging from several hundred acres to less than 10 acres, all of which could potentially benefit from this research. Currently, no research-based recommendations are available for nitrogen fertilization of commercial blueberry plantings in Florida. This work establishes baseline data from which nitrogen fertilization recommendations for young and mature blueberry plantings in Florida can be developed. Proper nitrogen fertilization is critical to improving plant establishment, overall plant health, high yield of quality fruit, and minimizing environmental impacts such as water pollution from fertilizer leaching and run-off. Growers will benefit economically from healthy plants that produce optimum yield both early and later during the life of the orchard, and through the savings associated with the avoidance of excessive nitrogen fertilizer applications.

The beneficiaries were made aware of the project by various methods including –

(1) On-site visits and field days –

County agent and specialist in-service training (2016)

Master Gardener Trainings (2015, 2016)

Farm City Week Open House at the Plant Science and Research and Education Unit (2016)

Individual grower visits to the research site (2015, 2016)

(2) Meetings –

The Florida Blueberry Growers Association Meeting (2016, attendance approximately 400)

The American Society for Horticultural Sciences (2016, Atlanta)

(3) Publications –

In 2017, a paper summarizing the results was submitted for publication in HortScience, a peer-reviewed journal of the American Society for Horticultural Sciences.

In the future, this information will be useful for developing blueberry fertilizer BMP's and UF Extension EDIS documents on blueberry fertilization.

Lessons Learned

A serious disease, blueberry leaf scorch, began to impact the blueberry planting in 2016. Different blueberry cultivars have varying levels of tolerance to this disease. 'Windsor' appears to be more affected by this disease than 'Jewel' which was not noticeably affected during the study.

Studies longer than 2 years would be beneficial for fully understanding the impacts of N fertilization rate on large, mature blueberry plants.

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Funding Expended: $119,991.00

Project (13): Thrips-transmitted ilarviruses in tomatoes and green beans

Project Partners: Florida Specialty Crop Foundation

Project Summary

In March 2014 a novel tomato virus (NTV) causing significant losses in tomato in south Florida since October 2013 (1000 tomato plants were rogued on a single farm in Homestead) was determined to be an unknown member of the ilarvirus genus. The not-yet-named NTV was related to Tobacco streak virus (TSV), cause of red node disease of green beans. Although TSV was first identified in Florida green bean production in 1994, significant losses have only recently been realized. Virtually nothing was known about NTV and significant knowledge gaps in the biology of TSV existed, which limited our abilities to develop effective management for these related viruses.

The purpose of this project was to characterize the basic biological and epidemiological properties of the related tomato and bean ilarviruses, identify which thrips species can serve as vectors, and facilitate development and evaluation of management practices to reduce grower losses. These viruses represented a serious threat to the state's tomato and green bean crops with severe foliar and fruit symptoms observed on infected tomato plants and pod symptoms on infected bean plants, which ultimately reduced marketable fruits or pods.

Thrips-vectored plant viruses remain of increasing concern for Florida fruit and vegetable production warranting an expansion of research on both pest thrips species and a complex of known and newly detected plant pathogenic viruses. This Florida Specialty Crop Block Grant project addressed the plant viruses in synergy with a second Florida Specialty Crop Block Grant project entitled "Effective, Sustainable Management of Thrips in Fruits and Vegetables" that was directed by Funderburk for research on the thrips vectors of these viruses. Some of the investigators lent their expertise to both of these complementary projects.

Since the first detection of NTV infecting tomato plants near Homestead (Miami-Dade County) and Boynton Beach (Palm Beach County) in mid-October 2013, key project personnel observed increasing incidences of the symptoms within affected fields and areas through 2015. Similarly, bean red node was consistently detected in Homestead, and Belle Glade and Pahokee (Palm Beach County) in green beans during the 2013, 2014 and 2015 growing seasons.

Project Approach

Work on the experiments in our original Work Plan for ilarviruses began quickly because all the project partners were already in communication with each other and all the required materials and staff were available to begin the work. As part of this project, NTV was indeed determined to be a novel ilarvirus species, and the name of Tomato necrotic streak virus (TomNSV) was proposed for it – and is used subsequently in this report. Following the first detection each season of TomNSV and TSV during the course of the project, specific work plans for each component of the project were implemented as outlined below.

1) Determine the biology of NTV and fill gaps in basic TSV knowledge:

A) Develop and validate diagnostic assays for NTV and TSV

Complete genome sequence was determined for NTV, now known as Tomato necrotic streak virus (TomNSV), by Adkins laboratory personnel. Analysis by Badillo-Vargas and Adkins confirmed that TomNSV was a new subgroup 2 ilarvirus species. Four of the five TomNSV genes were most closely related to Tulare apple mosaic virus, and the fifth TomNSV gene was most closely related to Citrus leaf rugose virus. Although both of these viruses are also subgroup 2 ilarvirus species, neither has been reported to infect tomato. This genome sequence analysis was included in a report on the characterization of TomNSV that was published in a peer reviewed scientific journal as noted below. Using the complete TomNSV sequence information, molecular diagnostic reagents were refined by Badillo-Vargas, Adkins and Adkins laboratory personnel to provide further options for routine TomNSV testing. Partial sequencing of TSV allowed similar development of additional TSV diagnostics. Inclusion body morphology was explored by Baker as a rapid identification method for TomNSV and TSV while molecular diagnostics were being developed.

B) Experimental host range experiments with NTV and TSV

Graft inoculation techniques for TomNSV were developed by Badillo-Vargas, Adkins and Adkins laboratory personnel and used to test an experimental plant host range. Only tomato and five virology indicator hosts (four tobacco and one lambsquarters species) were found susceptible to TomNSV infection. Other important crops including pepper, green bean and sunflower, and locally important weeds like American black nightshade and Jimsonweed, were not infected with TomNSV in our experiments. These host range results were included in a report on the characterization of TomNSV that was published in a peer reviewed scientific journal as noted below.

These same graft inoculation techniques were also used for TomNSV and TSV to produce virus-infected source plants for thrips transmission experiments as noted in objective 2 below.

C) Survey of Florida vegetable production areas for NTV and TSV

Personnel from Glades Crop Care, under guidance of Frantz and Mellinger, identified areas to sample for incidence of both TomNSV (tomato) and TSV (beans), potential weed hosts, and thrips vectors.

Personnel from both the Turechek and Adkins laboratories in cooperation with Glades Crop Care personnel intensively sampled several bean fields in Belle Glade and Loxahatchee for symptoms of TSV infection, collected samples of thrips for identification, and collected weed samples for virus testing. No TomNSV-infected tomatoes were found after late 2015. TSV-infected green beans were found in high abundance during 2015, and in much lower abundance in 2016 and 2017. However, the weed species identified in this project as a potential TSV reservoir were detected with TSV infection in Palm Beach County and in St. Lucie County. Identification of thrips in samples collected during 2015 and 2016 was completed by Kakkar, Frantz, and Funderburk. The predominant thrips species identified in surveyed bean fields and weeds during both seasons was the Florida flower thrips, Frankliniella bispinosa.

2) Determine the insect vector type and mode of virus transmission:

An experimental TomNSV seed transmission rate of 0.33% was detected by Badillo-Varga, Adkins and Adkins laboratory personnel. Therefore, when a single tomato infected with TomNSV was detected in Palm Beach County in September 2015, all remaining seeds (53) from this particular lot were obtained from the grower and tested individually for TomNSV. No TomNSV was detected in the 53 seeds tested although we acknowledge that this was too few seeds to detect the previously determined 0.33% transmission rate. However, current data suggest that seeds may not be the most important source of TomNSV.

Plants that produced copious amounts of pollen were graft inoculated with TomNSV or TSV (objective 1B above). Pollen collected from these plants was used for mechanical and subsequently thrips inoculation for both viruses. This was only successful for TSV. A host range of TSV was determined using Florida flower thrips (Frankliniella bispinosa) and western flower thrips (F. occidentalis). Controlled transmission studies were conducted under greenhouse conditions using five plant species: tomato, pepper, eggplant, green bean, and cucumber. Among these plants, only bean plants developed the typical red-node symptom and were found to be infected when tested for TSV. F. bispinosa was used as a vector based on its abundance in bean plots from surveys during 2015 and 2016 (objective 1C above).

3) Determine temporal and spatial distribution of each virus and its vectors:

Analysis by Turechek and Turechek laboratory personnel of intensive field sampling data of bean red node disease (caused by TSV) in commercial plantings from 2015 and 2016 seasons was completed. Red node was widely prevalent in 2015, but was not found in commercial plantings in 2016. The reason for this remains unknown. For the 2015 epidemic, analyses showed characteristic clustering of disease that is indicative of short-distance transmission by insects. In many instances, the incidence of red node was higher in certain areas of a field, often near borders which indicates that the vector, the virus or both was likely introduced into the bean crop from a neighboring source. In these cases, we sampled weeds in surrounding area in search of known and possible unknown reservoir hosts for the virus. Parthenium, a known host, was found infected and in abundance adjacent to a red node hot spot; this we suspected was the source of the virus in the commercial bean planting. In 2016, we established an experimental green bean planting at the USDA Farm in Fort Pierce, and then transplanted naturally infected

Parthenium (collected from weed banks around the USDA Farm) in an attempt to initiate an epidemic at the farm for further study. Unfortunately, we were not successful and assumed this was due to the absence of a suitable thrips vector. We continue to monitor commercial plantings for red node, where we will sample and develop a more robust data set for future epidemiological analyses.

4) Evaluate management strategies for NTV and TSV:

A) NTV, TSV and thrips vector management trials in virus affected areas

Hotspots identified in 2015 for TSV infection of green bean in Palm Beach and Miami-Dade Counties by Frantz, Mellinger and Glades Crop Care personnel and confirmed by Turechek and Adkins generally did not become infected in 2016. Thus, management trials were conducted in concert with the synergistic Florida Specialty Crop Block Grant project entitled "Effective, Sustainable Management of Thrips in Fruits and Vegetables" that was directed by Funderburk, and included Frantz, Mellinger and Adkins from this project. Work by Stryzewski and Funderburk laboratory personnel under direction of Funderburk in Hillsborough County was directly relevant to the current project. Florida flower thrips (F. bispinosa) populations reached high levels in strawberry flowers in March in each of two years. Populations were reduced with several broad-spectrum and biorational insecticides, sometimes resulting in increased yield. Western flower thrips (F. occidentalis) populations were common in one of the two years. Populations of the thrips predator minute pirate bug (Orius insidiosus) also developed in February or March but were suppressed by broad-spectrum insecticides. Several biorational insecticides were identified that conserved predator populations. Minute pirate bugs are important predators of thrips in green bean, and the insecticides under study in the strawberry trials are labeled for tomato and green bean. Therefore, these tools will be recommended for management of thrips transmitted TomNSV and TSV in tomato and green bean, respectively.

B) Communication of findings

Adkins presented results to date of NTV [now known as Tomato necrotic streak virus (TomNSV)] at Society of American Florists Pest Management conference in Orlando on February 20, 2015.

Adkins, Baker, Badillo-Vargas, Frantz, Mellinger, Roe and Funderburk co-authored first description of TomNSV entitled "Necrotic streak disease of tomato in Florida caused by a new ilarvirus species related to Tulare apple mosaic virus" for peer-reviewed journal New Disease Reports published April 11, 2015.

All key project personnel prepared an update on TomNSV for growers entitled "New ilarvirus species identified in south Florida tomatoes" that was published by McAvoy and Miller in April 21, 2015 issues of South Florida Vegetable Pest and Disease Hotline Hendry County and Palm Beach County editions, respectively. Subsequent email announcement by McAvoy resulted in coverage by multiple trade publications and invitation to write update for "The Berry/Vegetable Times" newsletter (by Hugh Smith, UF/IFAS GCREC and Alicia Whidden, UF/IFAS Hillsborough County Extension).

Miller, McAvoy and Adkins prepared an update on TomNSV for growers entitled "New ilarvirus species identified in south Florida tomatoes" that was published in the May 2015 issue of the The Vegetarian Newsletter, UF/IFAS Horticultural Sciences Department, Issue No. 601.

Turechek presented TomNSV and TSV sampling progress in tomato and bean, respectively, entitled "Overview of Decision Tools and Methods for Risk Assessment in Managing Insect Vectors and Pathogens in Crops: Accomplishments, Challenges and Gaps" at USDA-AFRI-NIFA-sponsored workshop "Enhancing Risk Index-Driven Decision Tools for Managing Insect Transmitted Plant Pathogens" in Asilomar, CA on May 14, 2015.

Badillo-Vargas presented current results of TomNSV entitled "Tomato necrotic streak virus, a novel subgroup 2 ilarvirus" at 10th International Symposium on Thysanoptera and Tospoviruses in Asilomar, CA on May 17, 2015.

Adkins presented overview of TomNSV at 10th International Symposium on Thysanoptera and Tospoviruses in Asilomar, CA on May 19, 2015.

Funderburk presented on "Challenges and Opportunities for Managing Thrips" at 10th International Symposium on Thysanoptera and Tospoviruses in Asilomar, CA on May 19, 2015.

McAvoy organized meeting and Adkins presented current results of TomNSV in tomato and TSV in green bean at 31st Annual Florida Seed Association/UF-IFAS Seedsmen Seminar in Immokalee on June 17, 2015.

Badillo-Vargas presented an update on ilarvirus and tospovirus transmission at thrips management symposium during Florida Entomological Society annual meeting in Fort Myers, FL on August 4, 2015.

Frantz presented an update on recent development in thrips management in Florida at thrips management symposium during Florida Entomological Society annual meeting in Fort Myers, FL on August 4, 2015.

Funderburk presented an update on thrips and thrips-vectored virus management in Florida at thrips management symposium during Florida Entomological Society annual meeting in Fort Myers, FL on August 4, 2015.

Adkins presented results to date of NTV [now known as Tomato necrotic streak virus (TomNSV)] at American Phytopathological Society annual meeting in Pasadena, CA on August 5, 2015.

Adkins presented an update on emerging vegetable viruses in Florida and the Caribbean region at the 5th Conference of the International Working Group on Legume and Vegetable Viruses in Haarlem, The Netherlands on August 31, 2015.

Funderburk and Adkins presented an update on thrips and thrips-vectored viruses in central and southern Florida at the Florida Tomato Institute in Naples, FL on September 9, 2015.

Funderburk and Adkins presented an update on management of thrips and viruses at the Thrips Management Workshop for growers in West Palm Beach, FL on January 19, 2016.

Funderburk and Adkins presented an update on management of thrips and viruses at the Thrips Management Workshop for growers in LaBelle, FL on January 20, 2016.

Badillo-Vargas, Baker, Turechek, Frantz, Mellinger, Funderburk and Adkins co-authored characterization of TomNSV entitled "Genomic and biological characterization of Tomato necrotic streak virus, a novel

subgroup 2 ilarvirus infecting tomato in Florida" which has been published in the peer-reviewed journal Plant Disease 100:1046-1053.

Kakkar, Funderburk and Adkins co-authored "Thrips-transmitted viruses infect a number of Florida crops" in University of Florida Extension, Panhandle Ag e-News, September 9, 2016 Issue.

Adkins presented update on Florida vegetable viruses observed in 2016 and expected in 2017 (including TSV) at AgExpo at UF-GCREC on November 2, 2016.

Adkins co-authored invited book chapter including thrips and ilarviruses emergence as crop pests entitled "Role of insect supervectors Bemisia tabaci and Frankliniella occidentalis in the emergence and global spread of plant viruses" for Annual Review of Virology 2:67-93.

Funderburk presented 'Thrips Management' at a workshop of specialty crop growers in Hillsborough County Florida on 6 June 2017.

McAvoy organized meeting and Adkins presented update on emerging viruses of Florida vegetables including TSV at 33rd Annual Florida Seed Association/UF-IFAS Seedsmen Seminar in Immokalee on June 8, 2017.

Throughout the project, Miller, McAvoy, Frantz, Mellinger, Turechek, Funderburk, Baker and Adkins responded to requests from growers and Extension personnel for TomNSV and TSV information and diagnosis.

Goals and Outcomes Achieved

Goal 1 was to develop specialty crop growers and industry who were more knowledgeable about NTV, TSV and thrips vectors. This knowledge, disseminated by project personnel, allows better management decisions to be made for these diseases and pests. Surveys of growers were conducted in 2015 at the beginning of the research project into the biology and management of bean red node disease in snap beans caused by TSV (referred to as Bean Red Node Virus, BRNV). Similar surveys were conducted in 2017 at the end of the project. The objective of the surveys was to determine the magnitude and scope of BRNV in south Florida and grower responses to the disease. The project was initiated following an unexpectedly severe outbreak of BRNV during the 2013-14 season which led to many acres of snap beans being destroyed before harvest.

Responses were obtained from three growers in 2015 and from two growers in 2017. These growers represented 500-2000 acres each of snap bean production in the vicinities of Boynton Beach and of Belle Glade, Pahokee and Loxahatchee in Palm Beach County (PBC) and in the Homestead area of Miami-Dade County (MDC).

Survey responses

• All respondents grew snap beans, with no dry bean production in any fields.

• During the 2015 survey all respondents indicated that BRNV had occurred in 2014-15, 2013-14, 2012-13 (3/3 respondents) and prior to 2012 (1/3 respondents) in their respective fields. In the 2017 survey the Palm Beach County respondent reported BRNV incidence during both 2015-16 and 2016-17 seasons, while the Miami Dade respondent reported no BRNV disease in either season.

• Growers indicated that BRNV disease occurred in the spring season in all surveyed production areas.

• Respondents in 2015 indicated their initial responses to detection of BRNV included:

o Submitting samples for disease diagnosis by UF or USDA (3/3 respondents)

o Applying insecticides to manage thrips disease vectors (3/3 respondents)

o Instructing harvesters to pass heavily infected blocks (1/3 respondents)

o Disking infected fields (3/3 respondents)

• One of the two respondents in 2017 reported using all these responses to finding BRNV in his fields in PBC. As the MDC respondent did not encounter BRNV in the two seasons covered by the survey, this question was not applicable.

• Economic losses to BRNV were estimated by respondents in 2015 ranging from zero to minor losses before 2012.

o In PBC, losses for one respondent were steady at $150,000-$200,000 annually in the 2012-13, 2013-14 and 2014-15 seasons, while the second PBC respondent suffered losses increasing from a low of $50,000 in 2012-13 to $75,000 and over $100,000 in the following two seasons. The MDC respondent in 2015 reported a loss of $40,000 in each of the growing seasons.

o The PBC respondent in 2017 reported 5-10% loss, without offering a dollar amount for that level of loss, while the MDC respondent reported no losses.

• Respondents indicated their current IPM practices included In-house scouting (2/3 in 2015; 2/2 in 2017); Scouting by crop consultant (3/3 in 2015; 2/2 in 2017); Periodic thrips sampling and species identification (3/3 in 2015; 0/2 in 2017); Calendar based insecticide applications for thrips vector management (3/3 in 2015; 2/2 in 2017); Insecticide applications based on scouting results (2/3 in 2015; 1/2 in 2017); Pesticide rotation to manage resistance development (3/3 in 2015; 2/2 in 2017).

• When asked if they have changed their IPM practices to deal with BRNV the following responses were obtained:

o 2015: Yes (3/3)

o 2017: Yes (1/2)

• Respondents were asked if they have implemented a range of new IPM practices to manage BRNV. They responded as follows: Reflective mulch (0/3 in 2015; 0/2 in 2017);Kaolin clay applications (0/3 in 2015; 0/2 in 2017); Companion plantings/nursery crops (0/3 in 2015; 0/2 in 2017); Resistant varieties (0/3 in 2015; 0/2 in 2017); Conservation of natural enemies (1/3 in 2015; 0/2 in 2017); Weed

management to eliminate disease reservoirs (2/3 in 2015; 1/2 in 2017); Other: 2/3 (Adjusting planting schedule and field selection to avoid areas with history of disease incidence in 2015) 1/ 2 (Adjusting field selection to avoid previous historical hotspots; insecticide applications to field margins and ditch banks to manage disease vectors in 2017)

• In both surveys, none of the snap bean grower respondents indicated that they have heard of a second ilarvirus recently detected in south Florida tomatoes, Tomato Necrotic Streak Virus.

• In 2015, 3/3 respondents indicated that the research group made up of USDA, UF and Glades Crop Care had expanded their knowledge of BRNV disease. The same response was given by 2/2 respondents in 2017.

• In 2015 2/3 respondents indicated that information from the research group was very important (5 on a 0-5 scale) for the maximum health of their crop production, while in 2017 one respondent graded the information 4/5 and the second respondent gave a grade of 5/5.

• In 2015 2/3 respondents indicated that they received timely updates about identifying and managing BRNV from the research group (5 on a 0-5 scale) for the maximum health of their crop production, while in 2017 one respondent graded the information 5/5 and the second respondent gave a grade of 1/5.

Beneficiaries

The beneficiaries of this research were primarily the Florida specialty crop producers and related industries, but especially producers of tomatoes (30,000 acres with value of $268 million in the 2012 crop year) and green beans (46,000 acres with value of $167 million in the 2012 crop year). Beneficiaries used the knowledge learned about TomNSV and TSV (especially host range and vector thrips species) to help plan and implement effective management strategies for these viruses as indicated in the final project surveys. Consumers of Florida specialty crops also benefited from improved management of TomNSV and TSV that ensures continued availability of high quality fresh fruits and vegetables.

Florida ranks first in value of production of both fresh-market tomatoes and snap beans, producing 31% of the total U.S. value for fresh-market tomatoes and 52% of the total U.S. value for snap beans. All Florida tomato and green bean growers benefited from this project. For tomatoes, 30,000 acres were grown in the 2012 crop year, which was comprised of 339 farms when surveyed in the 2007 crop year. For beans, 46,000 acres were grown in the 2012 crop year, which was comprised of 373 farms when surveyed in the 2007 crop year.

Information was relayed to beneficiaries by a variety of means as noted under objective 4B above.

Lessons Learned

This project contained multiple research and outreach objectives. The majority of all were accomplished due to the expertise of the project team. The lack of significant infection by TomNSV in commercial tomato fields and TSV in commercial bean fields in 2016 and 2017 provided information on conditions that do not promote disease development. Personnel changed several times during the course of the project but this is to be expected in research of this scope and duration.

Frantz, McAvoy and Miller contacted growers representing 75% of Florida tomato and bean acreage to query their awareness of TomNSV and TSV issues. This initially occurred in 2015, with a follow-up survey in summer 2017 to document grower knowledge following a year's worth of outreach on TomNSV, TSV and thrips vectors biology, and management recommendations from the project. Growers valued information from the project team and indicated it had expanded their knowledge of TSV and bean red node disease. In contrast, TomNSV remained relatively unknown to growers, likely because it disappeared from Florida tomato production areas about midway through the project. This identifies a potential opportunity for additional outreach activities. It may also reflect Florida specialty crop industry "fatigue" with new pathogens and pests, which are seemingly introduced to Florida on a regular basis.

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Funding Expended: $184,591.44

Project (14): Expanding Promotion & Consumption of Specialty Crops and Increasing Healthy Food Access to Underserved Communities

FDACS Contract #021722

Specialty Crop Block Grant Funding Year 2015

Reporting Period: January 2015 – December 2016

Project Partners: Florida Certified Organic Growers and Consumers, Inc. (FOG) and program partners,
Wholesome Wave (WW) and their Consultant, Sharon Yeago completed work under the grant contract #021722.

Project Summary

Although Florida's vegetable production is the second largest in the United States, few Florida residents purchase and consume Florida-grown specialty crops. The small farms (less than $250,000 in annual sales) that are the best candidates for conducting in-state direct sales make up 90% of all farms in Florida, but are responsible for only about 15% of total farm sales. These businesses could significantly benefit from new direct marketing opportunities in underserved communities, particularly for beneficiaries of federal nutrition assistance, such as the Supplemental Nutrition Assistance Program (SNAP). Less than 1% of the approximately $5 billion in federal nutrition assistance (for more than 3 million people) that flows into Florida is used to purchase food from the state's specialty crop growers. This program doubles the amount of income Florida specialty crop farmers will receive for these SNAP purchases.

Fresh Access Bucks (FAB) directly impacts farmer revenue and food insecurity issues in our state by increasing sales of Florida-grown specialty crops directly to Florida consumers. FAB provides an incentive for direct markets for Florida's small farmers, while increasing access to and consumption of locally produced specialty crops for low-income residents. According to Feeding America, Florida is ranked 12th in the country for food insecurity with 17% of its residents, or 3.1 million people, considered to be food insecure. People in the state's underserved communities could substantially benefit from enhanced access to affordable, Florida-grown fresh fruits and vegetables, providing a real immediate benefit to the specialty crop industry and the public.

This project has built a highly visible network of Florida farmers markets implementing innovative programs to incentivize the use of federal nutrition assistance benefits to purchase specialty crops. National level data on these programs shows that farmers markets participating in incentive programs for multiple years have achieved annual increases over 100% per year of federal nutrition assistance benefits redemption. With small farms making up 90% of all farms in Florida, but struggling in sales, programs that can double their sales to low-income community members shopping with federal nutrition benefits could have a significant impact on their viability. During the lifetime of this grant, revenues of over $4300,000 were seen for 441 specialty crop farmers.

With poor access to healthy foods, Florida's obesity rates have continued to climb, increasing by 10 percentage points over the last 15 years. According to the Florida Department of Health, only 35% of Floridians are currently at a healthy weight. One quarter are obese, and the rest are overweight. On our current trend by 2030, almost 60% will be obese. The costs of care for chronic diseases from obesity alone – diabetes, heart disease, high blood pressure, and arthritis – are unsustainable and estimated to be $34 billion over the next 17 years. FAB aligns with the Florida Department of Health's new Healthiest Weight initiative to increase access to high quality, affordable fruits and vegetables in underserved communities.

The SCBGP previously funded FAB from 2013-2015 (FDACS Contract # 019715). FOG surpassed its goal of 13 markets for year 1, with a total of 14 markets, and by the end of 2015 FAB was operating in 29 markets, surpassing the stated goal of 20 markets.

With the initial grant, FOG developed and implemented the FAB program, created all necessary materials and tools for FAB (tokens, data collection and program implementation templates, contracts, instructions for implementation and data collection), and successfully vetted, trained and provided technical assistance for 15 markets. With over 100 participating farmers, FOG achieved its goal to provide increased revenue for specialty crop farmers in the targeted counties in order to enhance the competitiveness solely of specialty crops. From May – December in 2013 alone, FAB witnessed 3,842 Federal Benefit Transactions, 1,247 new market shoppers, over $68,529 in revenue generated by FAB and federal benefits on Florida grown produce. As such, FOG surpassed its goal of 200 transactions per market, thus enhancing the market for specialty crops by increasing access and affordability in underserved communities. Due to overwhelming interest from farmers markets, health departments and community organizations across the state, with the assistance of this grant FOG was able to expand FAB to a total of 32 participating markets by the end of 2016.

It is FOG's hope that FAB becomes a permanent feature of our state to increase farmers' revenue and improved people's access to Florida grown fresh fruits and vegetables. As such, FOG has developed a fundraising plan to ensure FAB's longevity, which includes diversified funding sources from the government, private foundations and market matching.

To promote long-term sustainability, FOG works closely with local farmers markets and organizations to expand local funding and capacity building opportunities. Local farmers markets and partner organizations are expected to provide staffing for the EBT and incentive program, assist in outreach, provide supplies for the EBT and incentive booth, including a tent, tables, chairs, etc., (matching funds may be available to assist with these supply costs), collect and enter data, and have the capacity to administer the additional accounting required for this program.

The federal Farm Bill passed in 2014 with significant support for healthy food incentive programs like Fresh Access Bucks. The USDA's new Food Insecurity and Nutrition Incentive Program (FINIP) amounts to $100 million over five years and represents the first time the federal government has supported programs of this type of program through legislation. Organizations, such as FOG, have built the expertise in designing and implementing incentive programs and represent the best strategy to effectively deploy this funding. Due to the support of this grant, FOG was in a competitive position to receive FINIP funds, as we provide the infrastructure for consistent, streamlined, replicable programming.

Project Approach

This project increased the economic competitiveness of Florida specialty crops by enhancing market opportunities in underserved communities. The 2 year project helped to provide increased revenues for 441 specialty crop farmers through direct marketing opportunities at farmers markets throughout the state. During this project we: 1) Provided incentives and technical assistance to 33 market partners; 2) expanded the availability of financial incentives for federal nutrition assistance beneficiaries to purchase Florida specialty crops at farmers markets at more than 5 new markets each year for a total of 26 in 2015 and 33 in 2016. In the two year project period there were over 7,000 unique market shoppers with 15,211 EBT transactions at FAB partner markets equalling over $430,000 in sales. Implementing EBT at markets allows individual specialty crop farmers to diversify their customer base and revenue streams.

The farmers markets and Community Supported Agriculture (CSAs) programs that participated are (Total – 33):

Alachua County: Alachua County Farmers Market, High Springs Farmers Market;

Brevard County: Brevard County Farmers Market;

Broward County: Dania Beach PATCH Market, Las Olas Farmers Market;

Charlotte County: Punta Gorda Farmers Market;

Duval County: Beaches Green Market, Mid-Week Market; White Harvest Farms and Market; Berry Good Farms On the Go Mobile Market, Riverside Arts Market;

Escambia County: Palafox Farmers Market;

Hillsborough County: Sweetwater Organic Farm and Market, Sweetwater Organic Farm CSA;

Lee County: Cape Coral Farmers Market

Leon County: Frenchtown Heritage Farmers Market;

Miami-Dade County: Urban Oasis – Upper East Side Farmers Market, Urban Oasis – SW Community Farmers Market, Verde Farm and Market, UOP - Adrienne Arsht Center Market; Bee Heaven Farm at the Pinecrest Gardens Farmers Market, Bee Heaven Farm CSA;

Manatee County: Bradenton Farmers Market

Orange County: Audubon Park Community Market;

Palm Beach County: Urban Growers - Henrietta Urban Farm and Market;

Pasco County: Tasty Tuesdays Community Market;

Pinellas County: St. Petersburg Saturday Morning Market;

Polk County: Lakeland Downtown Farmers Curb Market;

Sarasota County: Englewood Farmers Market, Venice Farmers Market, North Port Farmers Market;

Sumter County: Sumter County Farmers Market;

Osceola County: Farm Market.

Ongoing activities completed with partner markets to support and maintain program integrity and implementation for Fresh Access Bucks:

Program monitoring: Ensuring that incentives and program operations enhance the purchase of Florida specialty crops through a variety of means, including but not limited to assisting with new partner identification and vetting, trainings, site visits, monthly regional check in calls, and general technical support.

Continued vetting, identifying, scheduling training sessions and organizing new partners: Identified and contacted new, targeted farmers markets regarding interest in participating in the program. WW and their consultant Sharon Yeago assisted FOG in vetting partner markets for program implementation; ensuring participating markets are equipped with the knowledge, skills, tools and capacity to implement the program for the benefit of specialty crop farmers.

Developed a plan for the season: timeline of trainings, partner vetting, incentive program launch, and identified foreseeable challenges.

Developed, refined and updated materials including but not limited to: program descriptions to communicate to potential partner markets; partner market promotional materials; mid and season-end

report forms; data collection tools; Fresh Access Bucks toolkit (Market manager guide, vendor guide, flier templates, recommended signage); vendor agreements; contracts for FOG, WW, and partner markets.

Provided necessary materials and tools for program implementation (tokens, EBT booth management materials, data collection and program implementation templates, and instructions for implementation and data collection). All participating markets signed agreements to implement the program as approved by the USDA. FOG also provided ongoing technical assistance and monitoring of program implementation.

Site visits to present about Fresh Access Bucks and instruct partner markets on implementation. These sites included 23 counties with 98 unique visits.

WW, their consultant Sharon Yeago and FOG participated in regular calls to keep track of progress, next steps and challenges.

Facilitated monthly regional check in calls, providing partner markets with an important outlet to exchange best practices, ideas, and support.

WW and consultant Sharon Yeago provided support to FOG in network management and program development, and advising on technical assistance to participating markets and to markets transitioning to accept SNAP via Electronic Benefits Transfer (EBT).

National Nutrition Incentive Network - WW provides FOG and their partner Fresh Access Bucks (FAB) markets with membership to the National Nutrition Incentive Network, which currently includes nutrition incentive program operators in 38 states and D.C. As members, FOG and FAB markets have access to a national community of practice, which includes a program operator listserv, a monthly newsletter, frequent topical webinars, and an online resource library that houses toolkits, tools and resources developed by WW and network members. The community of practice is intended to support network members in developing, growing and sustaining their nutrition incentive programs though tools and technical assistance designed to build program operator capacity.

Data Collection - WW also provides FAB markets with access to FM Tracks, an (iOS-based) data collection, tracking, and reporting tool co-developed by Wholesome Wave and Case Western Reserve University. Data collected through FM Tracks is stored and accessible from a web-based data portal. Through an integrated mobile app and website, FM Tracks collects and reports customer-, market- and network-level transactions in a streamlined and straightforward way. FAB program staff, WW and market partners collaborate to keep data updated and in a format that can be utilized to further program impact.

Statewide Network-building Support - WW and consultant Sharon Yeago have been providing support to FOG to build their capacity as statewide network administrator as they grow and strengthen the Fresh Access Bucks network. Network-building support included:

Discussion and prioritization of key topics to be addressed as a statewide network;

Sharing of best practices in identifying and vetting new network market sites;

Discussion of strategy for statewide branding; and

Strategy around alternative currency management at the network level

Developing relationships with community partners, and advising on new relationships with community partners, that can be supportive of the program through outreach or other capacities.

Advising on and assisting with the creation of program materials that celebrate the success of the program to date.

Webinars to assist in technical support and training for data collection and reporting with FM Tracks.

Annual FAB partner training - In September 2015 and 2016, the FAB program staff, WW and consultant Sharon Yeago and Kellie O'Dare Wilson helped plan FOG's annual FAB partner meeting. WW presented to FAB partners on the resources available through the WW community of practice, the national nutrition incentive landscape, and conducted an in-depth training on the FM Tracks data collection system. WW staff also met individually with FAB market managers to provide one-on-one technical assistance related to data collection and reporting. While visiting, WW visited the Alachua County Farmers Market, Riverside Arts Market and Beaches Green Market to connect with market managers and observe FAB program administration in-person. Consultant Sharon Yeago presented on farmers market metrics, data collection and national policy issues. Consultant Kellie O'Dare Wilson presented on her research findings on food deserts and diet related diseases. FAB staff presented updates on program impacts, social media best practices, and program research and maintenance. Additionally, market partners that have run successful programs presented as a panel on best practices of: fundraising, community building, outreach, marketing and other topics of general interest. Additionally, time was reserved for in person technical support and regional face to face meetings.

Community engagement and outreach on behalf of Fresh Access Bucks and Specialty Crop Farmers:

Presented about Fresh Access Bucks at the SE Regional Farmers Market Nutrition Program Conference.

Met with the Department of Health and the following County Health Departments to increase the outreach and awareness of the Fresh Access Bucks Program and to incorporate nutrition/taste education initiatives at the markets in collaboration with the County Health Departments: State Department of Health, Miami-Dade County Health Department, Pinellas County Health Department, Alachua County Health Department, Brevard County Health Department, Polk County Health Department, Broward County Health Department, Duval County Health Department, Leon County Health Department, Escambia County Health Department, Sumter County Health Department, Volusia County Health Department, Orange County Health Department.

Met with the Division of Food, Nutrition and Wellness of the Florida Department of Agriculture and Consumer Services monthly to increase outreach and awareness of the Fresh Access Bucks Program.

Met with the University of Florida's SNAP Education Program coordinators monthly to discuss collaborative promotional and nutrition education efforts.

Met with the Department of Children and Families at the state level to increase outreach and awareness of the Fresh Access Bucks Program.

With separate, non-governmental funds, submitted a proposal to raise additional money for staff time spent on SNAP activities to the Farmers Market SNAP Support Grant (FMSSG) and for promotional materials through Wholesome Wave's Nutrition Incentive Support and Innovation Grant (NIPSIG). FOG was awarded the FMSSG in October and NIPSIG in November.

In collaboration with the University of Florida's SNAP Education Program, FOG and the Family Nutrition Program team piloted the first Eat with the Seasons cooking demo at the Brevard County Farmers Market, showcasing in season, locally grown specialty crops in simple and quick recipes.

Presented at the University of Florida's Farmers Market training on Fresh Access Bucks and farmers market EBT.

Worked with a graphic designer to develop promotional materials, including but not limited to a new logo, banner, brochure, postcard, flyer, social media graphics and tent.

Presented on Nutrition Incentive programs and local foods at SSAWG in Lexington, KY.

Presented on FAB at Transforming Food Access Summit in Atlanta, GA.

Presented on FAB and EBT for farms and farmers markets at UF's Small Farm Academy to farmers and farmers market managers.

Convened the first and second FAB advisory board meeting, including representatives from: UF Family Nutrition Program, DOH, FDACS, DCF, Florida Association of Food Banks, Consultant Sharon Yeago, Consultant Kellie O'Dare Wilson, FAB program partners Lee Peron and Gail Eggeman, WW Georgia, WW national, with quarterly meetings to inform programmatic direction and sustainability.

FAB and EBT at market presentation at the 3rd annual Florida Local Food Summit.

Goals and Outcomes Achieved

Goal 1:

Provide increased revenue for specialty crop farmers at participating farmers markets in order to enhance the competitiveness solely of specialty crops through the acceptance of federal nutrition assistance benefits.

Performance Measure:

Through the WW Data Portal, track the amount of money in FAB incentives and federal nutrition assistance benefits received by specialty crop vendors and the number of transactions at participating farmers markets.

Previous Benchmark:

Over 100 participating specialty crop farms from May to December 2013 at 14 participating markets.

Target:

240 Florida specialty crop farmers at up to 25 sites in Year 1 and 30 sites in Year 2 (total 30 in 2 years). Markets process an estimated 300 federal benefits transactions in Year 1 and over 500 in Year 2.

Outcomes Achieved:

Between January 1, 2015 - Dec 31, 2016, 441 specialty crop farms benefited, with more than 7,000 new market shoppers at 33 market outlets. Revenue increased by over $430,000 for specialty crop vendors. There were 5,958 EBT transactions in 2015 and 9,253 EBT transaction in 2016 for a total of 15,211 EBT transactions recorded.

Goal 2:

Enhance the market for specialty crops by increasing access and affordability in underserved communities, while increasing awareness of the importance of including specialty crops (particularly fruits and vegetables) in the diet.

Performance Measure:

Through WW Data Portal, track the amount of money in FAB incentives and federal nutrition assistance benefits received by specialty crop growers at participating farmers markets. Markets record the number of transactions, new SNAP recipients that shop at the markets and specialty crop tokens distributed and redeemed.

Benchmark:

3,842 transactions processed from May to December 2013 at 14 participating markets

Target:

Markets process 300 federal benefits transactions in Year 1 (25 markets) and over 500 in Year 2 (30 markets).

Outcomes Achieved:

28 Markets processed 5,958 EBT transactions in 2015 and 33 markets processed 9,253 EBT transaction in 2016 for a total of 15,211 EBT transactions recorded. More than 7,000 new, unique SNAP shoppers were recorded increasing product reach for Florida specialty crop farmers.

Beneficiaries

The beneficiaries of this project are specialty crop farmers at participating farmers markets accepting federal nutrition assistance benefits in the Fresh Access Bucks network as well as low-income Florida residents who receive federal benefits and will have access to healthy, Florida-grown produce.

Specialty crop beneficiaries included 441 specialty crop farmers, who benefited from increased farmers market sales to federal nutrition assistance recipients. Florida residents, and more than 7,000 unique low-income residents benefited from more access and affordability of fresh fruits and vegetables.

Revenues for specialty crop farmers increased by $430,023.16 from federal benefit recipients and the FAB program. According to Wholesome Wave's nationwide data on farmers market incentive programs, an estimated 34% of federal nutrition assistance benefits recipients that are shopping at the market are new customers. In Florida, we saw an increase of no less than 7,377 new SNAP shoppers at farmers markets.

There is also significant economic benefit in encouraging federal nutrition assistance recipients to spend these dollars in their own neighborhoods. The USDA estimates that every $1 in SNAP spending creates $1.80 in economic impact, but the program's economic impact is magnified when food dollars are being spent to purchase locally and regionally grown food.

While this project is specific to Florida, the data collected will be shared with Wholesome Wave and USDA NIFA partners. The data collected from the FAB program will help inform the impact of incentive programs nationally. Statewide, program data and impact is shared directly with program partners, state and federal agencies, as well as community partners via presentations, social media, and FOG outreach newsletters.

Lessons Learned

Working with organizations that have high capacity or greater internal resources helped FAB spread the network quicker. As a statewide initiative, having connections with strong leaders in regional locations often led to more markets opening in that region. For example, we work with 5 partners that operate more than one market. This type of expansion requires less administrative oversight and more success in maintaining and growing a locally executed farmers market incentive program.

Wooden tokens used for SNAP or incentive currency at farmers markets do not work. Due to Florida's humid climate, FAB staff purchased plastic tokens so that currency would not deteriorate. This is especially important as the tokens do not expire.

Regional support staff increases community connections and impact. Having FAB staff located throughout the state makes travel for site visits and trainings less burdensome, saves time and budget, and increases the oversight that the program staff has on implementation. Additionally, staff located throughout the state allows for a better understanding of power structures, demographic and institutional knowledge of regions.

Problems and Delays

Although FOG was able to meet the goals of increasing market partners, there were many delays in expanding the network, which included:

The FAB team strives to expand the network intelligently and efficiently while maintaining a high level of support for our current partners. We had to think creatively about bringing in new markets and underestimated the amount of time it would take to do background data collection and due diligence on all applications. Florida does not have a state association of farmers markets or definition of a true farmers market. This indirectly requires FAB staff to spend more time researching and ensuring direct marketing, Florida farmers are present at potential FAB markets and provide support to Market Managers for recruiting additional farmer vendors. We received a great deal of applications that did not meet our network requirements, most notably, ones that were not accessible to low income populations, did not have Florida farmers or a transparent, state/farm of origin labeling system.

Many farmers markets in Florida do not have the capacity or revenue to retain competent EBT managers in order to succinctly convey the FAB program to consumers.

The free EBT equipment program with FMC was stalled in late 2016, then resurrected with an end date of May 2017, leaving a gap in the amount of markets that would be able to accept EBT.

Hurricane Matthew impacted not only the opening of many farmers markets throughout the state, but also destroyed and delayed the harvest for many specialty crop farmers throughout Florida during normal peak fall seeding and transplant times.

Market closures - during the course of this grant, FAB staff vetted, trained, and conducted site visits for 6 markets that are no longer in operation.

The distribution of SNAP benefits by FDCF changed from a 15 day cycle to a 28 day cycle, and there have been glitches. More than one of our patrons visited only to find that they had no access to their benefits until the 29th of the month.

Moreover, the number of people on SNAP and its funding in Florida declined.

FDCF policy to not advertise one manner of utilizing SNAP over others greatly decreased our ability to spread the word about this program directly to SNAP recipients.

FAB Markets continue to express that EBT equipment expenses are a financial burden. Moreover, inadequate number of paid market staff hinders their ability to do sufficient outreach to SNAP recipients to inform them of the program, fundraise independently for their SNAP efforts and conduct nutrition education efforts. Transportation to and from FAB markets continues to be a barrier to participation across the state.

Transitioning between two data collection tools (Wholesome Wave's Data Portal to FM Tracks) created some complications and confusion for data entry.

Certain FAB markets lack infrastructure, such as bathrooms, electricity, large dishwashing sinks and smooth, durable and easily cleanable floors, that contribute to logistical complications for nutrition education efforts. In most circumstances, they lack funding to make necessary upgrades.

FOG staff turnover in the FAB program:

FOG's Director of Education & Outreach, Laura Lavid, left FOG to pursue a position in Denver as a means of continuing to serve as an advocate for equitable access to healthy foods. Fortunately, qualified, existing FOG staff already familiar with the program had the availability and interest to fill her role. Mary Hathaway, an existing FOG staff person, was hired as a part-time FAB Coordinator.

FOG's full-time Fresh Access Bucks Coordinator, Cori Keene, left FOG to pursue a position abroad. Katie Delaney was hired as a full time FAB Coordinator.

FAB's Program Manager, Carmen Franz, left FOG to pursue a new position as a means of continuing to serve as an advocate for equitable access to healthy foods. Fortunately, qualified, existing FOG staff already familiar with the program had the availability and interest to fill her role. Mary Hathaway and Katie Delaney, existing FAB coordinators, were hired as FAB Co-managers

FOG's SNAP Tech Support Coordinator resigned, leaving FAB staff to take over responsibilities until a new coordinator was hired. Xanna Prentice, and existing FOG staff and farmers market manager was able to take on this role.

FOG's accounting staff was replaced with a new in house accountant. This transfer occurred at the end of the calendar year, making many of the grant financial reporting requirements more difficult and labor intensive for FAB programmatic staff.

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Funding Expended: $234,490.84

Florida Specialty Crop Block Grant Program Project
Final Performance Report

Project Title

Refining Strategies to Reach Florida Small Farms Specialty Crop Producers with Statewide and Regional Programming

Project Partners

List the primary organization implementing the project, as well as any partner organizations.

The University of Florida – Institute of Food and Agricultural Sciences (UF/IFAS) was the primary organization implementing the project. Specifically, the UF/IFAS Small Farms and Alternative Enterprises Program, a collaboration of State and County Extension Faculty, was the team responsible for project activities. Project leaders were:

- PI Danielle Treadwell, Ph.D., *Assoc. Prof., Department of Horticultural Sciences and co-Leader Statewide Small Farms and Alternative Enterprises Program, UF/IFAS, Gainesville*
- Co-PI Robert Hochmuth, M.S., *Center Director and Regional Specialized Agent, Suwannee Valley Agricultural and Extension Center, UF/IFAS, Live Oak*
- Co-PI Soo Ahn, Ph.D., *Asst. Prof. Food Science and Human Nutrition UF/IFAS, Gainesville*
- Co-PI Sebastian Galindo, Ph.D., *Research Asst. Prof., Agricultural Extension Communication UF/IFAS*
- Co-PI Mary Beth Henry, M.S., *Extension Agent II, and co-Leader Statewide Small Farms and Alternative Enterprises Program, UF/IFAS Extension Polk County, Bartow*

Other collaborators included:

- SF&AE Conference exhibitors representing a wide range of the small farm sector in Florida, including governmental and non-governmental organizations, lending institutions, agricultural input representatives, and more. See below for complete list of partners.
- Florida A&M University Extension administration (Vonda Richardson) and faculty (Alex Bolquez).
- Florida Small Farms and Alternative Enterprises Advisory Committee.
- Many experienced growers and food entrepreneurs who helped shape the conferences and who served as moderators and/or speakers.

Regional Specialty Crop Conference Exhibitors (many exhibited in multiple events)

1. AgriStarts
2. AgroResearch International
3. Atlas
4. BCS America
5. Bionatural Blooming Blossoms
6. BioWorks
7. Capital City Bank
8. Clifton Seeds

9. Creel Tractor
10. DoubleThumb
11. Dow AgroSciences
12. Environmental Turnkey Solutions
13. Enza Zaden Research USA Inc.
14. Farm Bureau Lee County
15. Farm Bureau Sarasota County
16. Farm Credit of NW Florida
17. Farm Credit of Southcentral Florida
18. Florida A&M University
19. Florida Organic Growers and Consumers, Inc,
20. Freshpoint
21. Gulf Coast Small Farms Program
22. Haygrove
23. Imperial Builders and Supply
24. Irrigation-Mart, Inc.
25. Jackson County Soil and Water Conservation District
26. Johnny's Selected Seeds
27. Magna Bon II
28. Market Link
29. MightGrow Organics
30. MW Horticulture Recycling
31. National Center for Appropriate Technology (ATTRA)
32. Nichino
33. OSM-Oggun
34. Perdue Fertilizers
35. Publix
36. Quality Certification Services
37. Regions Bank
38. Robert is Here
39. Sakata Seeds
40. Small Business Development Center at the University of North Florida
41. Southern SARE
42. UF/IFAS Extension Soil Testing Laboratory
43. UF/IFAS Farm to School, Farm to Community Team, Family Nutrition Program , FL Snap-ED
44. UF/IFAS Florida Automated Weather Network
45. UF/IFAS Small Farms Academy
46. UF/IFAS Suwannee Valley Agricultural Extension Center
47. USA-Food and Nutrition Service
48. Valent
49. VertiGro

Project Summary

Florida's small farm operators primarily produce fresh market specialty crops that are sold in direct to consumer outlets. Local food purchases from farmers markets, farm stands, community support agriculture models, and restaurants continue to trend upward and media coverage of the local foods movement is significant. Economic data from the Florida Agricultural Statistics Service indicate the small farm sector of Florida's agricultural industry contributes to nearly 15% of the state's agricultural economy which is a greater contribution than many other traditionally well-known single commodities including tomato. Given the economic importance of this sector and its wider visibility, this project addressed the following needs: 1) specialty crop farmers and farmers market managers need to understand and comply with food safety regulations to ensure consumer safety and trust; 2) specialty crop famers, their service providers and allied industry representatives are faced with increasingly complex environmental, economic and social issues, and one size programming does not fit all; rather, educational programming at local and regional levels are more likely to meet the unique needs of that area compared to the state level programming this team has focused on in past block grants; and 3) Specialty crop farmers whose operation is located at the urban-rural interface are an important group facing unique challenges, and programming will need to be tailored to this audience.

The UF and FAMU Small Farms and Alternative Enterprises Extension Program has received support from Florida's Specialty Crop Block Grant Program since 2010. Active dialog with specialty crop producers and insightful evaluation tools provided this team the guidance it needed to address challenges that left unresolved would negatively impact Florida's specialty crop industry. The small farm sector, with its significant emphasis on specialty crop production, is currently threatened by the changing food safety regulatory environment, limited access to affordable, arable land due to increased population and urbanization, concerns over water quality and quantity, and insecure long-term economic viability. This project implemented the following activities to support this sector: the team redesigned the Florida Small Farms and Alternative Enterprises Conference to more efficiently and effectively extend university research at the local and regional levels, offered farmer and farmers' market manager food safety tools to evaluate risk and ensure compliance to the newly implemented Food Safety Modernization Act, and conducted an evaluation of farmers' adoption and opinions of the Fresh From Florida brand. *This project was important and timely* because the UF and FAMU Small Farms and Alternative Enterprises Extension Team must continue to meet the emerging needs of the highly visible small specialty crop farmer sector while protecting the public interest in their purchases of local food.

This project did not duplicate previous work supported by this grant program. At the time of grant proposal submission, the Food Safety Modernization Act had not been fully implemented and the FDA approved training curriculum was not released until the fall of 2016. Previously the team had been offering farm food safety trainings based on Good Agricultural Practices principles. The project team has now been re-trained by Lead Trainers of the Produce Safety Alliance's Train the Trainer course and beginning 2017, is offering updated farm trainings that now reflect specific FSMA language and regulations. The regional conferences focused on regionally-focused best practice recommendations in a variety of educational formats to specialty crop producers in Florida. The team opted for these smaller regional events based on previous recommendations from farmers, and that approach was firmly validated by attendees.

Project Approach

Goal 1. THE SMALL FARMS SPECIALTY CROP CONFERENCE "AT".

Three regional conferences were promised in the grant, and the team conducted four in four Florida regions: NE, NW, Central, and South Central. The regional conferences offered a lower registration fee than past statewide conferences and provided an opportunity to further develop the networks in place. In each case, event registration and thus the amount of space dedicated to exhibitors was capped by the facility. In all, the team educated 864 attendees. Regional conference teams were formed up to 2 years in advance of the event, and teams meet monthly with the state team for administrative and program support and leadership from Treadwell and Henry assisted by Perez. Each event was a success by all measures; farmers reported knowledge gain and intent to change behavior, the attendees were happy and enthusiastic about the instructors, educational material and hands-on learning experiences, and our 49 exhibitors were appreciative of the opportunity to exhibit. A full list of our partners and collaborators was submitted as an attachment to this report.

ACTIVITY 1.1: Small Farms Specialty Crop Conference in Jacksonville, August 13-15, 2015

- The team conducted three on-farm workshops on August 13-14 at area farms. Each workshop was attended by 40 participants (120 participants total). The conference main event took place on August 15 at the University of North Florida, Student Union Building, in Jacksonville. At the conclusion of this event we had welcomed 177 total attendees, conducted 3 educational labs, 12 educational sessions with 32 speakers, a trade show with 12 exhibitors, and hosted our keynote speaker, Patty Cantrell. Dr. Saqib Mukhtar, UF/IFAS Associate Dean of Extension and Program Leader for Agriculture and Horticulture Programs provided the Welcome. Over 83% of conference attendees were current or prospective farmers.

ACTIVITY 1.2: Mid-Florida Specialty Crops Conference in Apopka, November 6, 2015.

- The Mid-Florida Specialty Crops Conference was held on Friday November 6, 2015 at the Mid-Florida Research and Education Center, in Apopka, Florida. At the conclusion of this conference, we had welcomed 155 total attendees, conducted 1 educational lab, 17 educational sessions, had a trade show with 9 exhibitors, and hosted our keynote speaker, John Rife and our closing remarks speaker was Commissioner Bryan Nelson.

ACTIVITY 1.3: Regional Small Farms and Alternative Enterprises Conference in Fort Myers, April 1-2, 2016.

- On April 1, 2016 we had 27 people attended the bus tour featuring three area farms. The conference kick-off event hosted at Buckingham Farms was attended by 75 people. We also had three farmer keynote speakers who focused on their Farm to Table Programming and Agritourism (not livestock): Paradise Farms owner/operator Gabriele Marewski, Dakin Dairy Farms owner/operator Karen Dakin and 31 Produce owner/operator Michael Greenwell. On Saturday, April 2, the main conference event was hosted at the Holiday Inn Fort Myers Airport at Town center. The conference was attended by 155 people. We conducted 16 educational sessions and a trade show with 13 exhibitors, including Dr. Wilkie (UF/IFAS Professor, Ag and Bio Engineering Dept) and her biogas generator.

ACTIVITY 1.4: Panhandle Fruit and Vegetable Conference in Marianna, October 11, 2016.

- On Tuesday October 11th, 2016, the Panhandle Fruit and Vegetable Conference was held at the Jackson County Agricultural Complex in Marianna, FL. The Conference had over 155 attendants. From these we had 23 speakers, 11 volunteers, 17 staff, 22 exhibitor's representatives, and 86 registered participants. At the conclusion of the event, we had conducted 9 educational sessions,

one keynote speaker session, two in-depth workshops and two farm tours. We also had a trade show with 17 exhibitors.

Goal 2. SMALL FARMS FOOD SAFETY IMPLEMENTATION TEAM ENHANCEMENT.

According to UF faculty leading the Southern Center for Food Safety, Florida has nearly 10,000 agribusinesses (farms and processors) that need have an FDA inspection per FSMA in the next 18-24 months. Clearly this is an all-hands-on-deck training need, and the Small Farms and Alternative Enterprises Team is doing their best to support the food safety training effort. Most of the farm clientele we work directly with are classified as Exempt from FDA inspection for one of several reasons, but primarily it is due to their low gross annual sales. Because Florida reports over 44,000 farms, and most small Exempt farms have the most contact with the general public, we have made this group a priority of our food safety training efforts. Early in our program we were quite successful at recruiting farmers to attend the training, but that interest is waning despite the high quality of educational delivery, educational materials provided to attendees to take home, and frequent sponsored lunch (paid for by a partner such as Farm Bureau or Farm Credit or IFAS). We are aggressively marketing these trainings, but interest is declining. We must change our approach with this program moving forward, and those changes will be reflected in our 2017 Specialty Crop Block Grant that includes food safety training as a major objective. During this grant period, we hosted 12 day-long (or longer) training events and trained 177 farmers and farm staff. In addition, the team presented food safety updates and/or "readers digest" versions of what is required at nine other educational events to at least 321 program attendees (primarily farmers). Our original goal was to train 150 farmers in the two year period. With the no-cost extension, we aimed to train an additional 50. We trained 177 in the full 8-hour training courses, and an additional 321 in sessions that were typically 60 minutes in length, but some were longer. We were successful in training at least 18 county Extension agents (10 were promised) and 70 farmers' market managers and vendors (60 market managers were promised) in food safety educational programs designed specifically for farmers' markets.

ACTIVITY 2.1: Build Your Own Food Safety Manual Trainings

- Twelve Build Your Own Food Safety Manual Trainings were conducted in 2015 and 2016 to 177 attendees.
- The Florida Small Farms Food Safety Implementation Team taught at several other meetings, including the regional conferences listed above and the following:
    - Local Foods Summit, September 20, 2015 in Gainesville, FL (60 minutes)
    - Florida Farmers Market Managers Food Safety Training, November 9, 2015 in Gainesville, FL with 48 attendees for the session on Farm Food Safety GAPs and how UF/IFAs can help train farmers (6 hours)
    - Watermelon Farmers Food Safety Update including HACCP and FSMA, December 1, 2015 in Gainesville, FL with 28 attendees. (60 minutes)
    - Two food safety update trainings were held in Gainesville and Branford in 2016. These meetings were attended by 95 farmers.
    - R. Hochmuth spoke at the SE Regional Fruit and Vegetable Conference in January 2017 in Savannah, GA. The team also presented an educational poster at this event.
    - Robert Hochmuth presented an update on food safety topics to Florida Watermelon Association attendees (100) on January 16, 2016 in Tampa, FL. (30 minutes)
    - A half-day food safety update was organized and implemented on April 5th, 2016 by the food safety team to update 50 vegetable growers in NE Florida on how new FSMA requirements will impact their operations as well as other important food safety updates. (4 hours)

- Mary Beth Henry, co-leader of the Small Farms team and extension agent for UF/IFAS Polk County presented on a session titled "Understanding Food Safety and GAP Certification for Organic Production at the Florida Food Summit in September 9th, 2016 in Orlando, FL. (60 minutes)

ACTIVITY 2.2: Food Safety Curriculum Development for Farmers Market Managers and Vendors

- Educational curriculum was developed for farmers' market managers and vendors with significant emphasis on specialty crop vendors and market economic growth. Topics included:
  - Overview of Florida farmers markets – current status and future
  - Food safety issues associated with farmers' markets
  - Food safety practices: guidelines for growers, vendors, managers and consumers
  - Changes in farmers market shopper trends
  - Payment options for farmers markets
  - Farmers market regulation
- Education packet (180-page) was created covering topics from the developed educational curriculum, and distributed to educational training participants. The packets were also distributed to market managers and vendors as well as extension agents upon request.

ACTIVITY 2.3: County Extension Agent IST- Food Safety at Farmers Markets

- A Food Safety at Farmers Markets Internal Service Training (IST) was held at the Straughn Extension Center in Gainesville FL, on May 18, 2015. Twenty two people participated on this event.
- Ahn participated in an in-service training led by Dr. Karla Shelnutt on Feb 22, 2016 in Bushnell, FL, and gave a presentation to 33 County Agents on food safety practices at farmers' markets.
- Ahn provided an In-Service Training to 26 county extension agents on Cottage Food Operation focused on specialty crops (fruit jams/jellies) on Mar 11, 2016 in Gainesville, FL. Eighteen people participated on this workshop.

ACTIVITY 2.4: Educational Training for Farmers Market Managers and Vendors

- An educational workshop on best practices at farmers' markets was given on Nov 9, 2015 in Gainesville, FL. In total, 45 people attended the workshop. Most people in the audience were either market managers or vendors but there were also educators, extension agents, government liaison, and food policy advocates.
- An educational workshop on best practices at farmers' markets was given on Aug 16, 2016 in Orlando, FL. In total, 25 people attended the workshop, most of whom were either specialty crop growers/vendors or managers of farmers' market but also included extension agents or educators.
- Ahn, Treadwell, Perez, Hochmuth, FDACS staff, farmers' market managers and other professionals served as speakers.

<u>Goal 3. MONITORING AND EVALUATION FRAMEWORK</u>

ACTIVITY 3.1: Small Farm Specialty Crop Conference and Food Safety Program Evaluation

During this period, Co-PI Galindo conducted the following activities supporting the overall evaluation of the project and Goal 3 of the project (i.e. Engage key stakeholders in an assessment of the challenges and opportunities of marketing buy local initiatives for specialty crop production in Florida):

- Prepared and disseminated evaluation materials for eleven Farm Food Safety trainings.
- Reviewed and updated the evaluation instruments for all the regional Specialty Crop Conferences

held in 2015 and 2016 in collaboration with other team members.

- Led the data collection activities at four regional conferences
- Analyzed the collected data and prepared reports for the aforementioned activities.
- Disseminated the results from the evaluation of the aforementioned activities with the whole project team.

ACTIVITY 3.2: Small Farms and Alternative Enterprises Extension Team Strategic Planning Meeting

LEAD PROJECT PARTICIPANT/SUBRECIPIENTS Leaders will be Galindo/Project Staff, Treadwell, Hochmuth, Project Staff, and State and County Team Members. This meeting was held in conjunction with the annual meeting of the Extension Professionals Association of Florida (EPAF) held at the end of summer each year. EPAF is attended by all county agents (inclusive of all assignments) Extension administration and many state faculty to the tune of 500 attendees annually. It is the most important opportunity for evaluating past work, proposing improvements and planning activities for the following year. Communication via email, conference calls, and one-on-one discussion occur among team members and project leads of this grant year-round.

- The Small Farms and Alternative Enterprises Team meets annually at this event. An agenda and any handouts were distributed in advance. Speakers included a welcome by Extension Administration, updates and requests for feedback from Regional Conference Team leaders, presentation of evaluation data collected and interpreted so far, and a discussion of grant activities for the upcoming year.
- These meetings are scheduled for 90 minutes, and are attended by 30-40 agents (some have conflicting meetings due to other professional obligations), but the discussion among this team are prevalent throughout the week of EPAF.
- Meeting minutes were distributed to all team members after the meeting. This meeting is critical to agents who typically begin their Reports of Accomplishments and Plans of Work after EPAF for submission due in November.

ACTIVITY 3.3: Small Farm Case Studies

LEAD PROJECT PARTICIPANT/SUBRECIPIENTS Leaders will be Galindo/Project Staff, with support from Treadwell, Hochmuth, Project Staff, and State and County Team Members.

Case Study: Barriers and Opportunities for Florida's Beginning Specialty Crop Producers

Florida is 5th in the nation in beginning farmers and ranchers, and many of these farmers rely on extension's support to reduce their risks. Florida's population continues to increase, and we are now the 3rd most populous state in the nation. Growth, new industry participants, and ongoing consumer preference for local food create a significant demand for this team's resources. To this end, the team was successful in receiving an award for a sponsored Extension intern (value of $3,900) for the summer of 2016 to conduct interviews of beginning specialty crop farmers in Florida to identify barriers and opportunities. This case study described farmers who have successfully navigated common barriers previously identified from former SCBGP efforts in their own terms.

The intern (a senior undergraduate in the Dept. of Agricultural and Extension Communications) developed a script and series of interview questions under the guidance of Treadwell and project evaluator Galindo. Face to face interviews were conducted during June-July 2016 in north central Florida, and summative notes were taken during the interviews. All participants agreed to be recorded, and recordings were used to clarify summative notes. Each participant was asked the same questions, and allowed the opportunity to elaborate. Data collection activities for this project were conducted under IRB

approval 13U0233 Florida Small Farms Program: Expanding our reach to specialty crop producers.

Six farmers representing five farms were interviewed (one farm was a partnership). Farmers were owners/operators of diversified farm, and had between one and nine years of experience working on their own farm. One farmer was a female, two additional farmers self-identified as minority (non-white). One out of the six farmers interviewed had previously worked on a farm before working on their own. As well as only one of the farmers interviewed came from a farming background.

- The average cultivated area among the five farms visited was eleven acres. (Range: 3 to 30 acres). Total farm size ranged from seven to 520 acres. Four of the farms visited had an average of twenty two acres of total farm area, while one farm had 520 acres. All but one farm hoped to increase their land area in production. All of these farm operations can be considered diversified vegetable and fruit farms, as each farm produced one or more vegetables, herbs, annual and perennial fruits. Only one of the farms produced cut flowers; two farms had some livestock production. Four of the five farms interviewed generated at least 50% of total household income from the farm. One farmer stated 100% of household income was from the farm. All farmers sold direct to consumer (Farmers' markets (5), farm stands (1), CSA (3) and some sold to restaurants (3), institutions (schools) (1), and one farm utilized online sales.

- The most significant barriers for beginning farmers were finding operating budgets for supplies, locating custom services such as liming, crop consulting, etc., securing financing, hiring labor, and purchasing land. All of the farmers interviewed agreed that inexperience was one of the biggest challenges they faced. Learning usually came through failure. Following are the farmers' own words: *"To get all the information that you need together…as a farmer you have a lot of different jobs especially when you start from scratch."* ; "*Figuring out fertility was a big challenge, and figuring out appropriate technology*." ; and "*Lack of experience and there is no support for beginning farmers, training, access to shared equipment, knowledge on the things you need to start farming*."

- All farmers agreed that producing a consistent, high-quality product was the most important skill necessary for a successful farm experience. Also important were fertilizer and pest management skills, as well as understanding market opportunities and appropriate marketing strategies. Computer skills were deemed least important (perhaps because they all had them and took them for granted?).

- Farmers offered the following when asked for the most useful advice in farming they ever received: "*Don't be afraid to change your plans*"; "*Learn the basic things you need such as a tractor and a manure spreader, you will save so much in labor*"; "*Use farmers in the community to learn from their experience*"; and "*Plan, realize the scale you want to produce in order to make you happy. Farmers that produced too little seemed to fight to make ends meet, while farms that are really big seem to be under a lot of pressure*".

These beginning specialty crop producers are considered our area's most skilled and promising farmers, but they each agreed that additional education, particularly hands-on intensive education, delivered on a regular basis (weekly or at least once a month) with input and instruction from experienced farmers primarily as well as research, extension and agency instructors. Years of conducting conferences and pouring over evaluation data have informed us that most of the specialty crop producers minimize off farm external inputs due to costs or philosophical reasons; many use cover crops and other plant- and animal-based fertility inputs and rely on cultural controls and biological strategies to control pests. To this end, a high school student was hired to capture the pest and fertility management strategies of

experienced farmers in video. Clips will be further edited and will be used on the Small Farms website to provide visual instruction to enhance farmer case studies following our successful migration to a T4 platform.

Case Study: Awareness and Perceptions of Fresh from Florida Program

To explore the level of awareness of the Fresh from Florida (FfF) program, as well as perceptions of its value, effectiveness, and need for change, data were collected from 217 people that participated in four specialty crops conferences in Florida during 2015 and 2016. These conferences were: 2015 First Coast (63 respondents), 2015 Mid Florida (40 respondents), 2016 South Central (63 respondents), and 2016 Panhandle (51 respondents). Questions were developed in advance of Regional conferences in collaboration from team members, and were presented in the last section of the event evaluation for each conference. Respondents were attendees and they completed the hard-copy evaluation at the conclusion of the last educational session in the event.

Almost 56% of the respondents were farmers (45% have been farming for less than 10 years and 11% have been farming for more than 10 years). The rest of the respondents included prospective farmers (18%), educators/researchers/students (12%), allied industry representatives (4%), consumers (2%), and 8% "other." (Table 1. attached)

When asked about their familiarity with the FfF program, 29% (n=60) reported not being aware of the program, 57% (n=120) said they were aware of the program but had not participated, and 14% of respondents (n=30) were aware of the program and participating in it. It is important to mention that none of the respondents selected the fourth option available in the survey: "I am aware of the program, have participated in it, but I am not participating in it anymore." Table 1 (attached) presents the distribution of familiarity responses across the different categories of participants.

Looking at the tree categories of farmers (i.e. farming less than 10 years, farming more than 10 years, and prospective farmers), it is clear that a large proportion of prospective and "young" farmers are not aware of the program (i.e. 43% and 30% for prospective and for those farming for less than 10 years, respectively). Almost 80% of those who have been farming for more than 10 years are aware of the program, and close to half of them are current participants of the program. The data suggests that more targeted efforts should be made to raise awareness of the program among "young" farmers, prospective farmers, and consumers (half of the consumers were not aware of the program even though they were participating in a conference focused on agriculture).

Respondents also provided additional feedback regarding their perceptions of the FfF, its value, effectiveness, and how to improve it. Generally speaking, respondents consider the program positive and beneficial for Florida farmers and that the branding helps identify the produce as "local," however, many agreed that additional information is needed so farmers can understand the benefits and the steps to participate. Many respondents have the perception that the Fff program is only valuable for large farmers (big Ag) and not for small farmers. Some of the suggestions for improvement include: reaching out to small farmers, increasing advertising to the general public, including sub-categories for natural and organic, making the participation process easier and user-friendly, and having FfF by regions.

Goals and Outcomes Achieved

GOAL 1: THE SMALL FARMS SPECIALTY CROP CONFERENCE "AT"

The team conducted four regional conferences throughout the project period, instead of the three proposed. We had a total of 864 conference attendants. We worked with regional teams of extension faculty and created locally relevant educational programs. The regional conferences reached a majority of growers who had not previously participated in the state-wide conference. Depending on the topic, the regional conferences were successful at providing knowledge gains and creating intent to change from 60 to 95% of survey respondents. Overall, we were consistently close to our target of knowledge gain (80%) and intent to change behavior (80%). We approached our goal of educating 1,000 participants, but were to some degree limited by the capacity of the venues we selected. Larger venues would have necessitated an economy of scale and increase in registration fee that our team was not willing to commit to, as it would have taken away of our primary goal of creating meaningful and impactful educational events.

- NORTHEAST: Small Farms Specialty Crop Conference in Jacksonville, August 13-15, 2015. Respondents (n=64) reported learning information in all of the ten evaluated indicators by a range of 33-88% and intended to implement practices in eleven skill areas by a range of 23-75%. Data from individual sessions included: An average of eighty four (84%) percent reported learning about new crops and cultivars and crop diversification options suitable for their farm and seventy eight (78%) percent learned new technology and techniques for hydroponic vegetables.
- CENTRAL: Mid-Florida Specialty Crops Conference, in Apopka, November 6, 2015. Respondents (n=40) reported learning information in all of the ten evaluated indicators by a range of 35-90% and intended to apply practices in ten subject areas by a range of 57-70%. Data from individual sessions included: Eighty percent (80%) were planning to evaluate their operation and identify one or more food safety practices to improve and seventy (70%) percent were planning to diversify their operation by adding a new crop, crop variety or production system.
- SOUTH CENTRAL: Regional Small Farms Conference in Fort Myers, April 1-2, 2016. Overall, respondents (n=63) gained knowledge in ten subject areas by a range of 63-85%. Participants intended to implement skills and behaviors in ten subject areas by a range of 60-96%. Data from individual sessions included: eighty seven percent (87%) of respondents said they had learned about the guidelines, program development and marketing tools used in agritourism operations; and seventy nine percent (79%) of respondents stated that as a result of the conference they acquired the skills to diversify their operation with a new crop or service.
- NORTHWEST: Panhandle Fruit and Vegetable Conference, October 11, 2016. Evaluations (n=51) show participants reported knowledge gain in all of the 23 indicators by a range of 26-94% and 82% will be able to apply what they learned. Data from individual sessions included: Eighty three percent (83%) said they had learned at least three crops that can be grown successfully under protected structures on native soil. Sixty eight percent (68%) said they had learned at least two new IPM strategies for insect control.

GOAL 2: SMALL FARMS FOOD SAFETY IMPLEMENTATION TEAM

- Twelve Build Your Own Food Safety Manual Trainings were conducted in 2015 and 2016 to 177 attendees. Knowledge gain was 86%, averaged over all participants, 73% were very likely to implement a plan, 25% indicated they were likely to implement. Additionally, team members taught farm food safety at other 10 separate events reaching more than 320 farmers.
- Sixty nine (69) Extension Faculty were trained on farmers' market specific food safety issues in three separate Internal Service Trainings.
- Seventy (70) people, mainly farmers' markets managers and vendors were trained on food safety in

two separate training events. According to the pre- and post-quiz performed knowledge scores on the topic improved from 64% to 79%.

GOAL 3: MONITORING AND EVALUATION FRAMEWORK

- Reviewed and updated evaluation instruments for four regional Specialty Crop Conferences in collaboration with other team members.
- Provided data collection instruments and led the data collection activities for 12 Build Your Own Food Safety Manual Trainings and four Specialty Crops Conferences.
- Analyzed the collected data and prepared reports for the 12 trainings and the four conferences.
- Conducted two case studies on farmers' use of a state marketing program for their specialty crop products and beginning specialty crop farmer educational needs.
- Shared the evaluation results with the whole project team.
- Tracked the progress on assigned evaluation tasks and intended products, and planned future activities.

Beneficiaries

The primary beneficiaries of this project are small to mid-size farm operators throughout the state. These producers grow a wide variety of specialty crops and market the majority of their produce to their local market. The majority of beneficiaries of this project were considered beginning farmers and ranchers by the USDA.

- The team conducted four regional conferences throughout the project period, instead of the three proposed. We had a total of 789 conference attendants. In order to reach the most underserved clientele, the team made a concerted effort to organize educational programs in as many areas of Florida as possible. We received great verbal and written feedback by farmers who had never attended the statewide conference. These farmers greatly appreciated to have a high quality educational, regionally-focused and networking event closer to home. As a result of these events, our evaluation results show that growers had a high rate of "intent to change" in a variety of farm related practices, such as implementing a new IPM technique and adding a new crop or variety.
- Twelve Build Your Own Food Safety Manual Trainings were conducted between January 2015 and June 2017 serving 177 participants. The team estimates that the value of developing their own food safety program is estimated at $5,000 - $10,000, depending on farm size. Additionally, team members taught farm food safety at other 10 separate events reaching more than 320 farmers.
- Sixty nine (69) Extension Faculty were trained on farmers' market specific food safety issues in three separate Internal Service Trainings.
- Seventy (70) people, mainly farmers' markets managers and vendors were trained on food safety in two separate training events. A follow-up survey for one event found that (n=7) all respondents had changed either their behavior or practices at the market based on the knowledge they gained from the workshop.

In addition to specialty crop growers, many of our extension events benefitted service providers, extension agents, allied industry, food entrepreneurs, and more.

Lessons Learned

- A fifth regional conference in Southeast FL had been scheduled for fall 2016. Due to scheduling problems, the event registration was very low. The organizing committee had to cancel this event. In a follow-up call, the committee discussed the reasons behind the low registration, and how to move forward. Even farmers who had registered for the event offered their support and advice; and encouraged the committee to try again in the near future.
- The regional conferences format was intended to help local agents gain experience in organizing a regional event. All of the four teams worked hard to establish good relations with vendors and speakers, and manage the day to day logistics of an event of this nature. With the tools and guidance provided by the project leaders, the regional teams of agents are now eager to continue these regional events without grant funding support. There is currently one team organizing a follow-up regional conference for March 2018. Funds were requested to cover speaker travel, and many of those funds are left unspent at the project's end, primarily because the team was very frugal with spending! While we would have preferred that our budget request would have accurately reflected our actual spending, we are also proud of the fact that we only spent what was necessary and pertinent to completing the goals and objectives promised.
- Convincing growers to attend and follow food safety trainings and best practices continues to be a vexing challenge. We have been successful in recruiting our highly visible farmers to participate and adopt food safety practices, but there are many more in the state that still need

training. Disappointingly, attempts to engage farmers to attend farm food safety training through farmers' market networks has been met with a degree of contempt. Farmers and market managers do not agree with our team's encouragement and concern for possible libel should something happen down the road. We were successful at meeting our goals in this grant, but recognize that training these farmers is still our responsibility at the moment, in the absence of other venues or partners. We will continue our efforts to strategize about effective communication strategies and will try new approaches to reach the segments of our clientele that for now seem unwilling to participate in farm food safety training.

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Additional Information

List of New Attachments

2017 Final Report

1. Table 1
2. Photo Highlights of Regional Specialty Crop Conferences and Team Award
3. Abstracts, Posters and Collaborations 2015-2017
4. List of Attachments

List of Attachments Previously Submitted in Project Reports

2016 Semi-annual and Annual Report

1. Regional Conferences registration page, Blog and Facebook page screen shots.
2. Publicity materials used for conference (flyer, press release) and conference program book.
3. South Central Conference Program Book
4. South Central Conference Evaluation Summaries (3) Participant, Farm Tour, and Exhibitor
5. South Central Conference Flyer
6. Panhandle Conference Program Book
7. Panhandle Conference Evaluation Summaries (3) Participant, Farm Tour, and Exhibitor
8. Social Media Snapshots
9. Food Safety Poster Abstract

2015 Semi-annual and Annual Report

1. First Coast Specialty Crop Conference Flyer
2. First Coast Specialty Crop Conference Program Book
3. First Coast Specialty Crop Conference Exhibitor Evaluation Results
4. First Coast Specialty Crop Conference Participant Evaluation Results
5. Mid-Florida Specialty Crop Conference Flyer
6. Mid-Florida Specialty Crop Conference Program Book
7. Mid-Florida Specialty Crop Conference Exhibitor Evaluation Results
8. Mid-Florida Specialty Crop Conference Participant Evaluation Results
9. Social Media Snapshots
10. Farmers Market Food Safety Agenda May
11. Farmers Market Food Safety Agenda November

ADAM H. PUTNAM
COMMISSIONER

Florida Department of Agriculture and Consumer Services
Division of Administration

CERTIFICATION REGARDING LOBBYING; DEBARMENT, SUSPENSION AND OTHER RESPONSIBILITY MATTERS FOR EXPENDITURE OF FEDERAL FUNDS

LOBBYING

As required by 7 CFR Part 3018, for persons entering into a contract, grant or cooperative agreement over **$100,000** involving the expenditure of Federal funds, the undersigned certifies for itself and its principals that:

(a) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the making of any Federal grant, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress or an employee of a Member of Congress, in connection with this Federal grant or cooperative agreement, the undersigned shall complete and submit Standard Form - LLL, "Disclosure Form to Report Lobbying,' in accordance with its instructions; and

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

PRINTED NAME!TITLE OF REPRESENTATIVE

CONTRACT *I* PURCHASE ORDER NUMBER

SIGNATURE OF REPRESENTATIVE *I* DATE

DEBARMENT, SUSPENSION AND OTHER RESPONSIBILITY MATTERS

As required by 7 CFR Part 3017, for persons entering into a contract, grant or cooperative agreement over **$25,000** involving the expenditure of Federal funds, the undersigned certifies for itself and its principals that:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;

(b) Have not within a three-year period preceding this application been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a Government entity (Federal, State, or local) with commission of any offenses enumerated in paragraph (b) of this certification; and

(d) Have not within a three-year period preceding this application had one or more public transaction (Federal, State, or local) terminated for cause or default; and

Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

PRINTED NAME!TITLE OF REPRESENTATIVE

CONTRACT *I* PURCHASE ORDER NUMBER

SIGNATURE OF REPRESENTATIVE *I* DATE

FDACS-01522 09/12

Project (16): Expanding and Promoting Florida Specialty Crop Exports to Taiwan

Project Partners: Florida Department of Agriculture and Consumer Services (FDACS) Division of Marketing and Development

Project Summary

Florida is internationally renowned for is fresh produce with shipments reaching every region of the world. Florida's worldwide fresh vegetable exports totaled $293.9 million in 2015. However, Florida Fresh vegetable exports to Taiwan declined 72% from $27,518 in 2014 to $7,763 in 2015. Clearly, this represents an under-served market. Florida fruit and nut exports to the world declined 10.4% from $413.9 million in 2013 to $370.8 million in 2015. Over the same period, fruit and nut exports to Taiwan declined 12.5%, again leaving room for improvement.

In the 1950s agriculture constituted a significant portion of Taiwan's GDP. By the turn of the century that number had dwindled to 2%. In short, agriculture has fallen far from the preeminent position it long held in the Taiwan economy. High production costs and low return have driven much of the agricultural work force away to industry. The growing scarcity of land on Taiwan is causing serious disagreements over land resources between agricultural, industrial and housing interests.

In 2015 Florida's total agricultural exports to Taiwan increased 21.5% from $21.5 million in 2014 to $25.5 million in 2015. The channel is wide open for an increase in fruits and vegetables.

Consumers in Taiwan have a number of options for purchasing fresh fruits and vegetables, including wet market stalls, convenience stores, supermarkets and hypermarkets. In recent years, convenience stores have been the most popular purchasing location with 7-Eleven being the leader, despite a marginal loss in share. Supermarkets performed especially well in 2015. Internet retailing is growing in popularity, spurring sales in hypermarkets. Traditional grocers are popular outlets for meats, fruits, and vegetables because consumers consider the products to be affordable, fresher, and of high quality.

This project is important and timely because boosting Florida's exports to Taiwan spreads the Fresh From Florida brand to new avenues of export, benefiting the state's overall economy as well as the farmers who grow these products. An increase in shipments will bring a corresponding increase in revenue into Florida. Conducting an in-depth market research project provided valuable information and insights into potential market segments that can be targeted for Florida agricultural commodities.

The objective of this research project was to gain insight into the buying habits and consumer preferences of the Taiwanese in order to determine the feasibility of marketing more Florida products. It is critical to understand the success of grocery retailers in Taiwan to learn which locations are optimal for Florida agricultural products. By understanding the buying patterns and grocery industry in Taiwan, a successful plan can be formulated to expand exports to Taiwan. This project also provides important

insights on how to boost Taiwanese consumer confidence in Florida products, which in turn will boost demand.

To ensure that this project solely enhances the competitiveness of specialty crops, it focused on establishing retail deals with Taiwan involving only specialty crops grown in Florida, including citrus, berries and vegetables. The survey focused on consumers' purchases of fruits and vegetables.

This proposal has not been submitted to or funded by any other state or federal program.

Project Approach

The project along with all accompanying tasks was done in a concentrated effort to better understand Taiwanese produce buying habits and consumer preferences. The main focus of the project was for researchers to determine the feasibility of marketing more Florida specialty crop products to Taiwan. An additional understanding and analysis of the grocery industry in Taiwan was undertaken so that a successful plan could be developed to increase Florida agricultural exports to this area. Activities performed on this project to-date include multiple operational components. These components are as follows:

1. Initial research:

Florida Department of Agriculture representatives conducted research to create a better understanding of the market before arrival.

2. Survey design and distribution:

Mid-Florida Marketing and Research, Inc. designed and helped along with FDACS representatives to complete a total of 425 surveys.

3. Market research within Taiwan:

Individuals from FDACS met with grocery retailers to discuss opportunities involving the import of Florida products. Favorable developments from this involved the negotiation of a Fresh From Florida marketing program in Taiwan that resulted in the import of Florida blueberries.

4. Analysis of the data and writing the final report:

Mid-Florida Marketing and Research, Inc. did a complete analysis of all data resulting from the surveys, and members from FDACS compiled this data to complete the final report. Recommendations for the future involve beginning to write parts of the report prior to departure for conducting on the ground research. This would expedite any writing and analysis that depended solely on research preformed prior to on the ground research.

Goals and Outcomes Achieved

Goals for this project included:

1. Increase the exports of fresh Florida fruits and vegetables to Taiwan with a target of $1.76 million in 2015.

Using the baseline of $1.63 million established in the project proposal, exports of Florida fruits and vegetables to Taiwan have increased to $2.65 million. Between 2013 and 2014 this is an increase of 63% or $889,312 above the goal.

2. Establish connections with grocery retail chains in Taiwan to further promote sales of Florida products with the target of a 10% increase in the number of stores promoting "Fresh From Florida" products by use of marketing channels. Before the project took place, no retailers were engaged in actively promoting Fresh From Florida products. After negotiations with retailers, both Wellcome and Jason's supermarkets (225 stores total) were actively engaged with "Fresh From Florida" marketing promotions.

Significant findings include:

--Export growth, as well as advances in electronics, tourism and services, helped income grow 3.4% from 2008 to 2013 (pg. 7).

-- Florida agricultural exports to Taiwan during 2014 included edible fruits and nuts as the third highest value of $2.65 million (pg. 26).

--The majority of respondents or someone from their household shop 2-3 times per week and purchase imported fruits and vegetables 1-4 times per month (pg.28).

Beneficiaries

This project benefited specialty crop agricultural growers across the state of Florida that produce on a scale large enough for export. With accurate market research, previous values could be reached again. Vegetable growers have an untapped market to reach into, and this project could give growers data that could be used to determine the viability of sending their products into Taiwan. Fresh fruit and vegetable farmers also will be able to see any benefits associated in sending their products to Taiwan. After learning the buying patterns and needs of Taiwanese consumers, Florida farmers could pinpoint opportunities to increase their agricultural exports to Taiwan.

Conducting a market research project in Taiwan assists in the development of what commodities Taiwanese consumers are searching for and are likely to purchase. Understanding the buying patterns of consumers and the preferred market places for fresh produce purchases reduce the risk for our producers. Marketers can then determine the best products to export and the best places to sell these products. Establishing insights and connections with grocery retailers helps further promote and execute successful sales of Florida products.

The final copy of the report will be given to the trade development section of marketing and development for distribution at trade events for exporters of Florida specialty crop products (see attached).

Initially, six (6) producers of Florida fresh blueberries and citrus as well as wine were assisted with establishing business contacts with area retailers. However, Taiwanese retailers were also interested in other commodities and contacts and 3 associations were provided 12 copies each of the report to distribute to their respective members involved in or exploring international export opportunities.

Lessons Learned

The only unexpected delay that occurred during the project was that the analysis and writing of the booklet took 11 months longer than initially planned. This was due to the fact that there were exceedingly high rates of employee turnover during this phase of the project. Five employees left during this part of the project, two of which were lead researchers who took part in the survey distribution.

Steps have been taken throughout to strategically plan for issues such as this. For instance employees were cross-trained and project goals were adjusted based on time-management procedures by separating the project into manageable pieces. The booklet was passed on to the FDACS graphics team for final editing and preproduction and was distributed to a wide array of individuals and organizations.

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Funding Expended: $25,215.83

Project (17): Decision Support System for Managing Foliar Disease on Cucurbits in Florida

Project Partners: Florida Specialty Crop Foundation

Project Summary

Florida produced 27% of all cucurbits (watermelon, cucumber, squash, and cantaloupe) grown the US in 2012 and cucurbits were harvested from 18% (45,800 acres) of Florida's total of 245,000 vegetable acres. Florida ranked second, behind California, for all vegetable production in the US, but first in cucurbits valued at $272 million in 2012. Downy mildew (Pseudoperonospora cubensis), gummy stem blight (Didymella bryoniae), and powdery mildew (Podosphaera xanthii) are three of the most damaging and economically important diseases affecting cucurbits. The diseases primarily affect the leaves causing a reduction of photosynthesis and eventual loss of foliage. The reduction in foliage allows fruit to sunburn making them unmarketable. Downy mildew has been called 'wildfire' because of its ability to spread so rapidly through a watermelon field. Powdery mildew also attacks fruit directly affecting marketability and is considered the most serious disease on squash. Gummy stem blight infects leaves, stems, fruit, and causes plant death and may reduce yields by 50% or more if left unchecked.

To manage these diseases, the University of Florida recommends regular, calendar-based applications of fungicide beginning at transplant and continuing through harvest resulting in approximately 14 fungicide applications per season and, in a worst-case scenario, can be as high 24 sprays. Calendar-based spray schedules, however, are usually not the most cost-effective nor efficacious approach to pest management and can lead to pesticide overuse and poorly timed applications. Overuse of pesticides increases cost of production. Poorly timed applications reduce pesticide efficacy (because of wash-off, degradation, unprotected foliage from new growth), may increase the likelihood of selecting for fungicide-resistant pathogen strains, and frequently result in yield loss from increased disease activity.

Plant disease forecasting is used to predict the occurrence or change in severity of plant disease and can assist a grower to optimally time fungicide applications. Forecasters typically rely on weather and host susceptibility to predict disease outbreaks, and are designed to alert growers that favorable conditions exist for disease development. In many cucurbit production regions, gummy stem blight is managed with the MELCAST forecasting system. MELCAST calculates a daily environmental favorability index (EFI) and uses the cumulative EFI values to determine the interval between sprays. For downy mildew, the IPM PIPE Cucurbit Downy Mildew (CDM) Alert System is used to predict the occurrence of the downy mildew pathogen based on regional weather data and air current patterns. Additionally, prediction models for germination and infection of the downy mildew pathogen based on temperature and leaf wetness duration were published recently, but have yet to be incorporated into a forecasting system. We propose to use these models to produce EFI values to yield a MELCAST-type prediction and then combine this new model with CDM forecasts to produce local-area forecasts for downy mildew. In other crops, powdery mildew is managed using the Gubler-Thomas model (GTM) or adaptations of this model.

The model was originally developed for managing powdery mildew of grape, but has since been used for managing powdery mildew on other crops like hops and cherry. The model is used to determine the spray intervals based on fungal developmental stage, temperature and fungicide type.

The purpose of this proposal was to develop and implement a decision support system (DSS) for timing fungicide applications to manage gummy stem blight, downy mildew and powdery mildew on cucurbit crops in Florida. It was anticipated that use of the DSS would result in fewer sprays with increased disease control and significant cost savings to the industry. The DSS would integrate the outputs of three forecasting models: the MELCAST system for gummy stem blight, the Gubler-Thomas model (GTM) for powdery mildew and a new downy mildew forecaster (DMF) that was to be developed as part of this grant. The DSS will be available as a standalone program and available in an app for a smartphone.

Project Approach

We initiated trials in fall of 2015 prior to the start of the grant. Formal grants activities took place from spring 2016 to July 2017.

Objective 1. We proposed to validate and develop action thresholds for the forecasting models MELCAST and the "Powdery Mildew Crop Risk Index" (PMCRI) for managing gummy stem blight, powdery mildew, and downy mildew on cucumber, squash, and watermelon in central and south Florida. This was accomplished using disease monitoring and weather data collected in grower-cooperators fields – sampling was conducted by Glades Crop Care (GCC) and data was analyzed by Turechek – as well as from research trials conducted at Southwest Florida Research and Education Center (SWFREC) and USDA-ARS Horticultural Research Lab (USHRL). The research trials provided the most relevant information. Beginning in March 2015 and continuing for four field seasons, replicated field plots of watermelon, squash, and cucumber were established and weather monitoring equipment was set-up at SWFREC and USHRL. Treatments assigned to the watermelon and cucumber plots were established to evaluate spray schedules for managing downy mildew based on MELCAST model forecasts. Treatments assigned to the squash plots were established to evaluate PMCRI forecasts for managing powdery mildew. The fungicide regimes established for each of these crops were designed specifically for managing the target disease. Weather and plant phenology were monitored daily to collect the information necessary to run the forecasting models to time fungicide applications. Plants were checked weekly for disease symptoms and diseases were rated mid-season and at harvest.

Data was analyzed at the end of each field season. Four replicated trials were conducted at each location during the funding period. Collective results across all eight trials showed the potential of MELCAST for managing downy mildew and other fungal disease at an "EFI" threshold of 30. Powdery mildew could not be managed effectively with the PMCRI model. However, it was determined that sprays for powdery mildew can be delayed until the disease is actually spotted in the field (referred to as "early detection"). The combination of MELCAST and early detection can result in reduction of 1-3 sprays.

Objective 2. The MELCAST rules and the ability for field-level tracking of the simple presence of disease (powdery mildew, downy mildew, and gummy stem blight) were built into a standalone application

named 'EFI Tracker'. Field-level tracking of disease was built in to the app to accommodate the "early detection" rule for managing powdery mildew. The app was designed and will soon be disseminated by ZedX Inc. for both the Apple and Android operating systems. Initially, the application was intended to be incorporated into the online scouting platform AgScouter; however, AgScouter no longer exists.

Objective 3. Two field trials followed the research conducted in objective 1 to validate the Decision Support System (DSS) at each location. The field protocol was modified to include three varieties each of cucumber, squash, and watermelon. Varieties were chosen to encompass a range of resistance's (low, medium, and high) for powdery mildew (squash) and downy mildew (watermelon and cucumber). Fungicide treatments assigned to each of these crops were designed to manage ALL disease, not just the target disease (as a grower would be expected). As above, weather and plant phenology were monitored daily to collect the information necessary to run the forecasting models to time fungicide applications. Plants were checked weekly for disease symptoms and disease rated. The last trials ended in May 2017 and data is currently being analyzed. However, two additional trials are planned beyond the funding period because of unforeseen circumstances that negatively affected these trials at both locations.

Obejctive 4. We disseminated a grower survey/questionnaire to assess their current management practices and to gauge grower attitude of disease forecasting. The questionnaire was sent to grower customers of Glades Crop Car and were disseminated at extension meeting hosted by Roberts and responses collected. The return rate was low. However, the consensus among those who were replied was that they currently so not use any models to manage disease, but are willing to, particularly if they are easy to use. The growers currently rely on calendar spray schedules and do not rely on scouting and/or weather information to make decisions on their spray schedule. Educational efforts were the focus of objective 4, and education efforts to growers to identify and manage cucurbit diseases were made yearly. The development of the DSS and was included in these meetings and at two field days held at SWFREC. The completion of the app and field trials in June 2017 now means that we will be able fully complete the grower education and document DSS adoption. As proposed, we will prepare a standard talk that can be given at grower meetings throughout the state to educate growers about the DSS. Additional information will be posted on Roberts' extension website for ease of access, through emails targeting cucurbit growers, and development of written materials such as handouts and/or brochures that can also be accessed at her site. Additionally, Glades Crop Care interacts with growers representing thousands of cucurbit acreage in Florida and education for clients will be provided through GCC's annual newsletter, and where appropriate, through presentations at additional grower meetings. Florida Specialty Crop Foundation will collaborate to provide the information to industry publications, newsletters and websites such as Florida Grower and Citrus & Vegetable magazine.

Goals and Outcomes Achieved

Goal 1 was to validate and/or develop action thresholds for MELCAST, GTM, and the downy mildew forecasters for Florida. Management of downy mildew and powdery mildew using the developed DSS was done with 1 to 3 fewer sprays than the calendar based system.

Goal 2 was to develop a stand-alone, user-friendly computer program (i.e., the DSS) to run and interpret the output of the forecasting models validated in objective 1; and incorporate the DSS to be run as a

part of the AgScouter system for vegetable pest management. A completed program of the DSS and a functional DSS that exists as a standalone product was developed. An app is developed but will also be a standalone as AgScouter no longer exists.

Goal 3. Provide DSS to growers so that they more effectively combat downy mildew, powdery mildew and gummy stem blight. Since the app has just been made available and we finished with the field validation trials a season later than anticipated this year, we were not able to measure the benchmark of grower adoption.

Beneficiaries

Florida growers producing watermelon, cucumber, squash, and cantaloupe on 45,800 acres from south Florida to the Florida panhandle will be the beneficiaries of the project. All Florida cucurbit growers, whose combined crops were valued at $272 million in 2012, are potential beneficiaries. This proposal targets the cucurbit specialty crop but also benefits consumers, packers, brokers, and retail markets through increased sustainability and decreased production costs that could result through use of the DSS. Quantification of beneficiaries will be part of the grower adoption which will continue past the duration of this grant.

There are over 900 growers of cucurbits who stand to benefit from the work completed under this project.

Lessons Learned

The objectives of the grant to develop a DSS, validate and provide a tool (the app) to growers were achieved. However, the number of trials necessary to develop and validate the DSS was underestimated. Since the trials were run each season in two locations (on the east coast and west coast), we initially targeted a year to develop and year to validate. Due to low disease pressure or erratic growth conditions (weather), an extension of the grant to include an additional spring trial in 2017 delayed many of the products and events for the final objective of grower education and adoption of the DSS. The grant PI and co-PIs remain committed to conducting all the activities and encourage grower adoption beginning in fall 2017 and continuing in 2018.

Contact Person

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Funding Expended: $202,441.52

Project (18): Weed Management Plans for Strawberry Plasticulture Production

Project Partners: Florida Specialty Crop Foundation

Project Summary

The recent loss of methyl bromide as a pest management tool has resulted in the need for alternative weed management programs for strawberry growers that are effective and economically viable. This is a critical issue for strawberry growers because there are no herbicides registered for nutsedge control in strawberry and only one post emergence herbicide registered for broadleaf weed control. Hand weeding does not control nutsedge species and is cost prohibitive as a management tool for grasses and broadleaves. Growers are currently faced with weed populations that are increasing over time with very limited management options to address the problem. This issue is compounded when growers re-use plastic mulches or plant additional crops into the same plastic mulch to lower costs and increase profitability. Multiple use of plastic is desirable because it lowers costs associated with crop establishment such as labor, tillage, fumigation and plastic mulch. Relay cropping is also desirable because it lowers the risk associated with reliance on a single crop, provides an alternative source of income, and permits production of two crops with a single fumigation and bed establishment operation. The objectives of this project were to: (1) evaluate herbicides for registration and use in strawberry plasticulture systems, (2) evaluate strawberry crop termination techniques when relay cropping with vegetables, and (3) evaluate the impact of input reduction and diverse rotations on weed population dynamics. Multiple new herbicides were identified for use in strawberry and the first herbicide with activity on nutsedge was registered. In addition, research trials confirmed that relay cropping and multiple use of plastic can be a viable alternative and a new shield technology was developed that reduces the cost associated with strawberry crop termination when relay cropping.

Project Approach

A wide variety of research trials were conducted at the Gulf Coast Research and Education Center and on commercial farms. The progress achieved is briefly summarized under each objective below.

Objective 1: Registration of new herbicides for use in strawberry plasticulture systems with an emphasis on products with potential for use in double cropping. Multiple trials were conducted to evaluate pre- and post emergence herbicides. Registration for sulfentrazone was achieved which is the first preemergence herbicide registered for use in strawberry with activity on nutsedge. Many other herbicides were evaluated and proven safe for use on strawberry. We are confident that additional registrations will be achieved in the future.

Objective 2: Evaluate strawberry crop termination techniques and weed management options for cucurbits and eggplants double cropped with strawberry. A new shield technology was developed and tested that facilitates strawberry crop termination when relay cropping. This new technology has the potential to significantly reduce labor requirements and input costs associated with relay cropping.

Objective 3: Model the impact of input reduction (multiple use of plastic) and diverse rotations (monocrops versus double cropping) on weed population trends over time.

Objective 4: Develop weed management protocols that facilitate input reduction and double cropping and determine the impact on grower income and income stability.

A two year trial was conducted at two sites to evaluate multiple cropping systems. We successfully proved that weeds can be effectively managed in double cropped or relay cropped systems. We were also able to show that crop yields can be sustained when relay cropping when adequately managed.

Goals and Outcomes Achieved

Goal 1: Submission of one data set to IR-4 or an agrochemical company in support of registration of a new herbicide for strawberry. Data sets showing crop tolerance and efficacy have been submitted for multiple herbicides including S-metolachlor, fomesafen, EPTC, flumioxazin, sulfentrazone and others. Registration for sulfentrazone was achieved much sooner than anticipated due to availability of data from previous research.

We successfully developed alternative techniques for strawberry crop termination when double cropping. However, adoption has not yet occurred because we are still refining the techniques. We presented our results at a grower meeting and several growers expressed interest in on-farm trials. The project will continue past the duration of the grant.

Goal 2: Develop weed management protocols for double cropping strawberries and cucurbits or eggplant. Emphasize management plans that reduce labor required for the transition from one crop to another and maintain adequate levels of weed control. When transitioning from one crop to another growers currently rely on labor to remove the strawberry crop by hand. A new shield technology was developed that facilitates strawberry crop removal with herbicides without damaging the vegetable crop. The target was to increase grower knowledge of available tools by 20%. We believe this was achieved but it has not been measured. The new technology was presented at the annual strawberry growers meeting and a handout summarizing the new technology was distributed to growers at two separate field days. Future plans include the production of a commercial scale unit and the evaluation

of the unit on commercial farms. Several growers have already expressed interest in evaluating the new technology.

Our results found that the fallow programs adopted by 8%+ of the industry are the most effective approach for weed control. The one exception is nutsedge management. We continue to look for effective fallow programs for the problematic weed.

Goal 3: Evaluate input reduction (multiple use of plastic) and diverse rotations (monocrops versus double cropping) to facilitate adoption of techniques that reduce weed populations over time, increase grower income, and income stability. This research was completed but has taken much longer than anticipated to analyze due to the complexity of the experiments. The analysis is complete and a paper has been submitted to a peer reviewed journal. The target was to increase grower knowledge of techniques that facilitate we management in double crop or relay crop systems. This information has not been distributed to growers because the project was only recently completed. However, a summary will be distributed to growers and presentations given at future grower meetings.

The analysis of this project was far more complex than anticipated. We completed all data collection and the analysis of the crop yields and pest populations. The economic analysis is on-going. Once completed, the results will be presented to the growers.

Beneficiaries

The primary beneficiaries are strawberry, cucurbit, and fruiting vegetable growers in Florida. In addition, the identification of alternative herbicide and weed management options for strawberries, cucurbits, and fruiting vegetables should be applicable to growers throughout the US. The primary benefits will be new management tools and the development of weed management plans for strawberry based production systems that ensure adequate levels of weed control and maximize economic return and reduce revenue risk. Results have been distributed to growers in Florida via presentations at grower meetings and field days as well as the production of extension documents. Research has also been published in peer reviewed journals available world-wide and communicated with agrochemical reps from multiple states. Future plans include the publication of on-line extension documents. Potential beneficiaries number approximately 60.

Lessons Learned

We believe all goals were achieved and the research project was a success. Conducting the trials at multiple sites was useful and increased confidence in the data acquired. The only delay was associated with a crop failure due to unexpected weather conditions which is difficult to avoid in agricultural research. The greatest issue related to the goals as stated in the proposal was inadequate time between project completion and the deadline for the final report to adequately disseminate the results to growers. We were able to present the results at grower meetings and field days as the project progress

but final results which were only available at the end of the project will continue to be disseminated after submission of this report.

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Funding Expended: $152,906.21

Project (19): Miami-Dade Markets in the Park Program

Final Performance Report

Project Title

Miami Dade- Markets in Parks Program

Contract Number

21736

Specialty Crop Block Grant Funding Year

2014

Project Summary

Miami-Dade County (MDC) intended to create market space at MDC parks/government facilities to showcase local specialty crops while capitalizing on programs to benefit specialty crop producer/vendors and residents alike.

Project goals/objectives were to: Educate the public on the importance of nutrition through the consumption of specialty crops; Provide specialty crop producers/vendors convenient access to educated consumers by establishing farmers markets and County parks; track attendance and consumption and consumer needs to better serve market attendees. To enhance competitiveness of specialty crops grown in the MDC by achieving the following outcomes:
(1) Improving public access to healthy, locally grown foods
(2) Increasing overall market viability of the local specialty crop farming industry
(3) Increasing demand for local specialty crops
(3) Improving overall community health

Issues/Impediments

The Market season in Miami-Dade differs from other areas of the country due to our tropical climate. Our traditional Market season runs from November to May. The program established two markets in county parks (Amelia Earhart Park and Tropical Park). The benchmark was 2 markets and the target was 3 markets established. Unfortunately, Oriental Fruit Fly was found in the county's agricultural area in August of 2015 and much of the growing area in the county was quarantined by the USDA and the Florida Department of Agriculture beginning August 28, and did not end until February 20, 2016. This made it very difficult to continue with the markets set and start new ones. In addition to the quarantine, the entire growing area was flooded with rain the first week of December resulting in an estimated loss of 70% of the vegetable production in the County, this was a USDA Secretary declared disaster. In addition to these issues, another flood occurred in late January of 2016, for which Miami-Dade County and most of the southern half of Florida received a USDA Secretarial disaster declaration again.

Due to the lack of crops/vendors, the Amelia Earhart Park market was forced to close in the early fall of 2015, and the operators have no intention of reopening the market. The Tropical Park market continued, but with limitations on local specialty crops and a change in managers. Given this drastic and unforeseeable turn of events, the grant program has not, and could not, accomplished the projected outcomes to the levels expected.

Goals and Outcomes Achieved

None of the goals and outcomes where achieved due to the significant issues faced by the local farming area. While one market was established, and remains in operation, others closed due to unforeseeable quarantine and weather disasters which caused a lack of product and vendors. We were not able to get another market established until January 2017.

5000 Promotional handouts, in the form of bilingual postcards, were made at a cost of $915.00, for the Tropical Park Market and distributed throughout the neighboring area, promoting the market.

No further expense was incurred due to the knowledge that the goals of the grant could not be reached.

Lessons Learned

Given the series of uncontrollable and unfortunate events which made it impossible to adequately complete the task, I would urge that policy be changed to allow for at least two alternatives for grant programs in areas significantly impacted by quarantines and/or declared disasters.

1. The restructuring of timelines, that take into account the time needed for recovery of the area, so that the full project can be accomplished.
2. The allowance of the funding to be shifted to other projects and areas not impacted by the freak occurrences.

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Additional Information

- ☐ Sample of promotional material are attached.

Project (20): Fertilization Practices for Sod Production that Minimize Environmental Impact

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Project Partners

This project was completed by faculty and staff affiliated with the University of Florida Institute of Food and Agricultural Science. The research plots were located at the UF/IFAS West Florida Research and Education Center located in Jay, FL. In addition, the Turfgrass Producers of Florida wrote a letter of support for this project when it was first proposed.

Project Summary

It is well documented that nutrient leaching and runoff from established healthy turf is negligible. However, nitrogen leaching and runoff events could occur during sod production while waiting for the plants to establish. In addition to the environmental implications that result from the loss of the nutrients, there is a significant economic cost that negatively impacts the financial security of the sod producers, both individually and as an industry. While many agricultural commodities have been able to implement practices to improve nutrient management during crop production it has been difficult to translate those technologies to sod production systems in a way that would lead to measurable improvements in production, profitability, and potential environmental impact. This project replicated current sod production practices in a research setting to test nitrate-nitrogen leaching under a variety of fertilization regimens. Our results will strengthen the position and profitability of the turfgrass industry as a provider of an environmentally-friendly product that fits the state's Florida Friendly Landscaping goals. The turfgrass industry has a total economic impact in Florida amounting to $3B and is responsible for providing over 500,000 jobs, not including golf (Haydu et al., 2006). Total sod production in Florida was estimated at 103,923 acres and accounted for $736M in economic output, $436M in value added, and 5,900 jobs by the most recent sod industry survey (Satterthwaite et al., 2009). These results and the sod production guidelines that are developed from them will benefit turfgrass industries in other states in the Sunbelt US by establishing new management practices that will reduce the risk of nutrient leaching and runoff during grow-in.

Project Approach

We initiated sampling of lysimeters for NO_3-N +NO_2-N levels and volume on 29 June 2015 with samples collected on a weekly basis. Water samples were placed on ice, packaged, and sent next day delivery to the UF/IFAS Analytical Research Laboratory for certified analysis. Leachate samples were collected regularly through the end of the 2017 growing season

Fertilizer regimens were initiated 15 March 2016 (granular sources) and 04 April 2016 (foliar). Table 1 contains the treatments, application methods, and source of nutrients used in the research study. Tables 2 and 3 show the fertilizer treatments, analysis, rates, and dates of application to St. Augustinegrass and centipedegrass, respectively. Treatments continued according to the schedule presented in the "Work Plan" with a few minor deviations as noted in the semi-annual and annual reports that were previously submitted.

It was noted in the "Problems and Delays" section of the project's first semi-annual report submitted on 15 July 2015, "Prior to research project initiation, it was determined that the St. Augustinegrass sod should be replaced and the existing sod was removed and new sod was laid on 15 October 2014. The winter of 2014-15 was harsh and the new St. Augustinegrass suffered significant winter kill resulting in a nine-week delay in sod harvesting (23 June 2015 versus 15 April 2015) and subsequent delay in fertilizer application."

Similarly, as noted in the 15 December 2015 annual report, "The delay in harvesting resulted in a delay in the first fertilizer application (7 Aug 2015 – 11 Aug 2015) which has inevitably delayed the regrowth of the sod ribbons. Additionally, the growing season has essentially stopped due to the winter months. A decision will need to be made in early 2016 on whether or not to harvest the sod in April 2016 (second run initiation) or to allow the initial run to mature."

Further, it was noted in the 15 July 2016 semi-annual report that, "The decision was made to not harvest the sod in April 2016 to initiate a second run of the experiment since harvestable sod was not ready. Only conducting one run of the experiment would not have produced meaningful results that could be published in reputable scientific journals or used in Best Management Practices adopted by rule. As such, the project investigators made the decision in August 2016 to initiate a second run of the experiment (i.e., repeated in time) following the sod harvest from the project's initial run. This extended the completion date of the project and was approved through the approval of a requested six-month no cost extension.

Foliar fertilizer treatments were applied with a specialized applicator designed specifically for this research project. Even flat-fan spray nozzles are mounted directly above each sod ribbon and the applicator's boom is raised in relation to the width of the establishing sod ribbon thus changing the effective swath width of the sprayer. For the ribbon applied fertilizer treatments, a piece of PVC pipe was heated and shaped to match the diameter of a measuring wheel and then affixed with cable ties. A PVC tee was inserted into the circular pipe to which a short piece of PVC pipe with a cap was connected. The cap is removed and the fertilizer is poured into the straight piece. Holes were drilled around the perimeter of the PVC pipe allowing for the fertilizer to dribble out as the wheel is passed over the sod ribbon (Figure 2).

To determine the percentage of sod establishment, digital images were acquired using a light box. Images are taken every two weeks and digital image analysis is used to quantify speed of establishment and percentage of plot area. The percentage of plot area covered by turf is used to calculate the variable rate of nitrogen to be applied to the plots receiving "Ribbon" and "Tiered" treatments (Figure 3). The noted application rate (Tables 2 and 3) was multiplied by the percent cover to give the actual application rate for the "Ribbon" and "Tiered" treatments. For example, if the application rate was 357 lbs/acre and the coverage was calculated at 25%, then 89.25 lbs/acre was applied directly to the ribbons.

Sod was harvested from the centipede and St. Augustinegrass plots in August of 2016 and 2017 (Figure 4). One slab of sod (16”x24”) was collected from each plot above the lysimeter. Slabs were weighed to determine fresh weight and then dried to determine dry weight. Soil was separated from the plant material to determine soil dry weight and turfgrass dry weight for each slab. Sub samples of the turfgrass plant material and soil were submitted for Nitrogen analysis.

Goals and Outcomes Achieved

Results of the leachate collected from this study indicate that there may be few differences in nitrogen leaching between treatments (Figure 5). However, when considering the total number of pounds of nitrogen applied there appears to be the potential to demonstrate significant reductions in fertilizer application during regrowth through the use of ribbon-applied fertilizer treatments in both grasses when compared to the traditional broadcast-based approach of fertilizer application (Figures 6 and 7).

Outcome 1: – Identify grow in strategies that result in minimized nitrate-nitrogen leaching when compared to traditional sod grow-in fertilization programs.
Result: Ribbon-applied fertilizer treatments appear to required less overall nitrogen than traditional broadcast treatments, thereby reducing the total amount of nitrogen available for leaching into groundwater.

In the time since the project started we have had the opportunity to discuss preliminary results with industry stakeholders at several regional and state-wide conference and field day events throughout 2016 and 2017. This has allowed us to raise the awareness of the sod industry, installers, homeowners, and representatives from various extension and government/regulatory agencies of the importance of following sod-production fertilization practices that minimize the amount of nutrients applied and reduce the potential for nitrate-nitrogen leaching and runoff. In addition, we have been able to increase sod producers’ understanding of precision fertilization practices and how they can reduce fertilizer use with minimal impact on the regrowth of the grasses when compared to standard broadcast application of fertilizers during regrowth of sod fields following harvest.

Outcome 2: A 20% increase in knowledge related to production post-transplanting fertilization practices for sod producers and related stakeholders.

Result: At least 60 sod growers and 125 related stakeholders gained knowledge related to production post-transplanting fertilization practices over the course of 2 field days, 1 industry conference, and 1 industry tradeshow.

Outcome 3: A 20% increase in adoption of improved nutrient management practices by Florida Sod Producers. A 20% increase in knowledge gain about enhanced efficiency fertilizers.

Result: We estimate that at least 15 of the growers reached, who are Florida turfgrass producers, have direct experience of and have considered adopting the recommended ribbon-applied fertilizer treatments.

Beneficiaries

This project has the potential to positively impact the profitability of sod producers throughout the Sunbelt region of the United States. Total sod production in Florida was estimated at 103,923 acres and accounted for $736M in economic output, $436M in value added, and 5,900 jobs by the most recent sod industry survey (Satterthwaite et al., 2009). The outcomes of this project appear to demonstrate that nitrate-nitrogen leaching is similar between treatments While the differences in nitrate-nitrogen leaching between treatments was minimal, there was a significant reduction in total amount of fertilizer applied when site-specific (precision) fertilization was used during the regrowth of plots following harvest. Results and recommendations stemming from this work have been presented at several industry field days and conferences located throughout Florida.

Lessons Learned

Fortunately, there were very few issues that came up during the completion of this project that impacted the overall progress. The one exception to that occurred prior to the initiation of the study when it was determined that the St. Augustinegrass sod should be replaced. The existing sod was removed and new sod was laid on 15 October 2014. The winter of 2014-15 was harsh and the new St. Augustinegrass suffered significant winter kill resulting in a nine week delay in sod harvesting (23 June 2015 versus 15 April 2015) and subsequent delay in fertilizer application. The delay in harvesting resulted in a delay in the first fertilizer application (7 Aug 2015 – 11 Aug 2015) which has inevitably delayed the regrowth of the sod ribbons. Additionally, the growing season had essentially stopped due to the winter months. The decision was made to not harvest the sod in April 2016 to initiate a second run of the experiment since harvestable sod was not ready. While this delayed the overall timeline, it did not have a negative impact on the rest of the study.

While preparing for this project to begin there was a significant amount of time and effort put into developing a novel approach to site-specific granular fertilization of the research plots. The custom fertilizer applicator that was developed will prove useful for future research projects that attempt evaluate precision fertilization of ribbons during regrowth of sod fields (Figure 2).
The unexpected delay in timeline that occurred prior to the initiation of the study resulted in it not being possible to present final results/recommendations to sod producers at a point in the growing season when they were able to make changes in their production practices. As a result, we do not have survey results from sod producers demonstrating implementation of new nutrient management practices resulting from this project. We plan to revisit this performance measure in subsequent growing seasons in hopes of documenting a reduction in total number of pounds of nitrogen fertilizer applied per acre during the regrowth of sod fields.

Overall Progress and Funding Expended

The project is 100% complete, with $91,759.07 expended.

Table 1. Treatments, application methods, and source of nutrients used in the FDACS Sod Production Fertilizer BMP study conducted in 2015-17 at the UF/IFAS West Florida Research and Education Center – Jay, FL.

Treatment No.	Treatment Name	Application Method	Source of Nutrients
1.	Untreated Control		
2.	UF/IFAS Standard Recommendation[1]	Broadcast	Urea, polymer coated urea (ESN), triple super phosphate (TSP), potassium chloride (KCL)] and lime (filler) blended to meet the analysis needed and provide for a 70/30 (quick/slow) release N source.
3.	UF/IFAS Standard Recommendation	Ribbon	Urea, polymer coated urea (ESN), triple super phosphate (TSP), potassium chloride (KCL)] and lime (filler) blended to meet the analysis needed and provide for a 70/30 (quick/slow) release N source.
4.	ESN[2]	Broadcast	Polymer Coated Urea
5.	ESN	Ribbon	Polymer Coated Urea
6.	Foliar	Broadcast	Urea – dissolved prills
7.	Foliar	Ribbon	Urea – dissolved prills
8.	Agrium Rainbow Plant Food 14-4-14[3]	Broadcast	Homogenous blend of ammonium sulfate, ammonium nitrate, ammonium phosphate, potassium chloride, sulfate of potash-magnesia, sodium-calcium borate, iron oxide, manganese oxide, manganese sulfate, zinc oxide

[1]UF/IFAS recommendations are based on SL52 (http://edis.ifas.ufl.edu/ss164) using a 70% soluble (QRN) and a 30% slow release nitrogen (SRN) with rates adjusted by species and location in Florida.
[2]ESN = Environmentally Smart Nitrogen – polymer coated urea.
[3]https://www.agrium.com/products/code/1378-27217/en/Label/1378-27217_Rainbow%C2%AE_Plant_Food_14-4-14_%281T_Tote%29_US-GHS_Label_en.pdf

Table 2. Fertilizer treatments, analysis, rates, and application dates for St. Augustinegrass.

Treatment Name	Analysis	Rate	Proposed Application Date
UF/IFAS Standard Recommendation – Broadcast	16-10-12	250 lbs/A	15 Mar
	16-0-12	250 lbs/A	01 May
	16-0-12	250 lbs/A	15 Jun
	16-0-12	250 lbs/A	01 Aug
	16-10-12	250 lbs/A	15 Sep

UF/IFAS Standard Recommendation – Ribbon	16-10-12	250 lbs/A	15 Mar
	16-0-12	250 lbs/A	01 May
	16-0-12	250 lbs/A	15 Jun
	16-0-12	250 lbs/A	01 Aug
	16-10-12	250 lbs/A	15 Sep
ESN – Broadcast	44-0-0	114 lbs/A	15 Mar
	44-0-0	114 lbs/A	15 May
	44-0-0	114 lbs/A	15 Jul
	44-0-0	114 lbs/A	15 Sep
ESN – Ribbon	44-0-0	114 lbs/A	15 Mar
	44-0-0	114 lbs/A	15 May
	44-0-0	114 lbs/A	15 Jul
	44-0-0	114 lbs/A	15 Sep
Foliar – Broadcast	46-0-0	72.5 lbs/A	01 Apr
	46-0-0	72.5 lbs/A	01 May
	46-0-0	72.5 lbs/A	01 Jun
	46-0-0	72.5 lbs/A	01 Jul
	46-0-0	72.5 lbs/A	01 Aug
	46-0-0	72.5 lbs/A	01 Sep
Foliar – Ribbon	46-0-0	72.5 lbs/A	01 Apr
	46-0-0	72.5 lbs/A	01 May
	46-0-0	72.5 lbs/A	01 Jun
	46-0-0	72.5 lbs/A	01 Jul
	46-0-0	72.5 lbs/A	01 Aug
	46-0-0	72.5 lbs/A	01 Sep
Agrium Rainbow Plant Food 14-4-14 – Tiered Approach	14-4-14	357 lbs/A	15 Mar
	14-4-14	357 lbs/A	15 May
	14-4-14	357 lbs/A	15 Jul
	14-4-14	357 lbs/A	15 Sep

Table 3. Fertilizer treatments, analysis, rates, and application dates for centipedegrass.

Treatment Name	**Analysis**	**Rate**	**Proposed Application Date**
UF/IFAS Standard Recommendation – Broadcast	16-4-8	250 lbs/A	15 Mar
	10-0-10	200 lbs/A	01 May
	10-0-10	200 lbs/A	15 Jun
	10-0-10	200 lbs/A	01 Aug
	8-4-8	250 lbs/A	15 Sep

UF/IFAS Standard Recommendation – Ribbon	16-4-8	250 lbs/A	15 Mar
	10-0-10	200 lbs/A	01 May
	10-0-10	200 lbs/A	15 Jun
	10-0-10	200 lbs/A	01 Aug
	8-4-8	250 lbs/A	15 Sep
ESN – Broadcast	44-0-0	68 lbs/A	15 Mar
	44-0-0	68 lbs/A	15 May
	44-0-0	68 lbs/A	15 Jul
	44-0-0	68 lbs/A	15 Sep
ESN – Ribbon	44-0-0	68 lbs/A	15 Mar
	44-0-0	68 lbs/A	15 May
	44-0-0	68 lbs/A	15 Jul
	44-0-0	68 lbs/A	15 Sep
Foliar – Broadcast	46-0-0	43.5 lbs/A	01 Apr
	46-0-0	43.5 lbs/A	01 May
	46-0-0	43.5 lbs/A	01 Jun
	46-0-0	43.5 lbs/A	01 Jul
	46-0-0	43.5 lbs/A	01 Aug
	46-0-0	43.5 lbs/A	01 Sep
Foliar – Ribbon	46-0-0	43.5 lbs/A	01 Apr
	46-0-0	43.5 lbs/A	01 May
	46-0-0	43.5 lbs/A	01 Jun
	46-0-0	43.5 lbs/A	01 Jul
	46-0-0	43.5 lbs/A	01 Aug
	46-0-0	43.5 lbs/A	01 Sep
Agrium Rainbow Plant Food 14-4-14 – Tiered Approach	14-4-14	310 lbs/A	15 Mar
	14-4-14	180 lbs/A	15 May
	14-4-14	180 lbs/A	15 Jul
	14-4-14	180 lbs/A	15 Sep

Digital Image Analysis on 27 Jun 2016 showed the average coverage was 71% and 79% for St. Augustinegrass and centipedegrass, respectively (Table 4).

Table 4. Ground coverage (%) of St. Augustinegrass and centipedegrass from various fertilizer regimens applied to sod ribbons remaining after a sod harvest on 23 June 2015.

	St. Augustinegrass	Centipedegrass
	---------- % Coverage ----------	
Untreated Control	67	65
IFAS Broadcast	88	84

IFAS Ribbon	75	83
ESN Broadcast	69	83
ESN Ribbon	66	80
Foliar Broadcast	65	82
Foliar Ribbon	69	75
Rainbow Homogenous Broadcast	70	78
	AVG = 71	AVG = 79

GATOR
NATION

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% of Applied Nitrogen Leached

	St. Augustinegrass	Centipedegrass
IFAS B/C	10.8	9.5
IFAS RIB	10.7	6.9
ESN B/C	9.8	8.3
ESN RIB	21.2	5.9
FOLIAR B/C	5.9	4.9
FOLIAR RIB	7.5	9.3
TIERED	12.8	20.9

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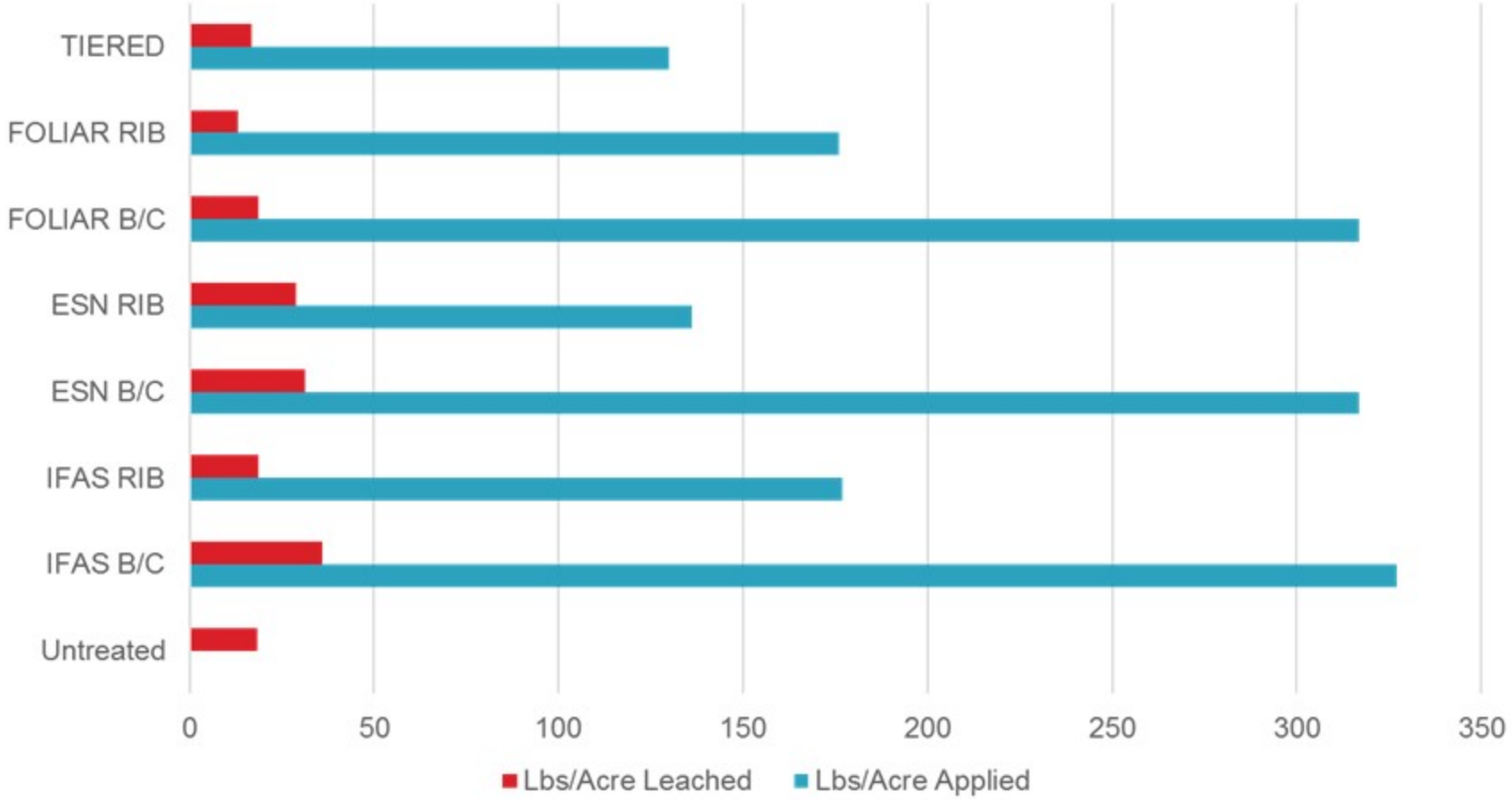
Leaching from St. Augustinegrass Sod Production



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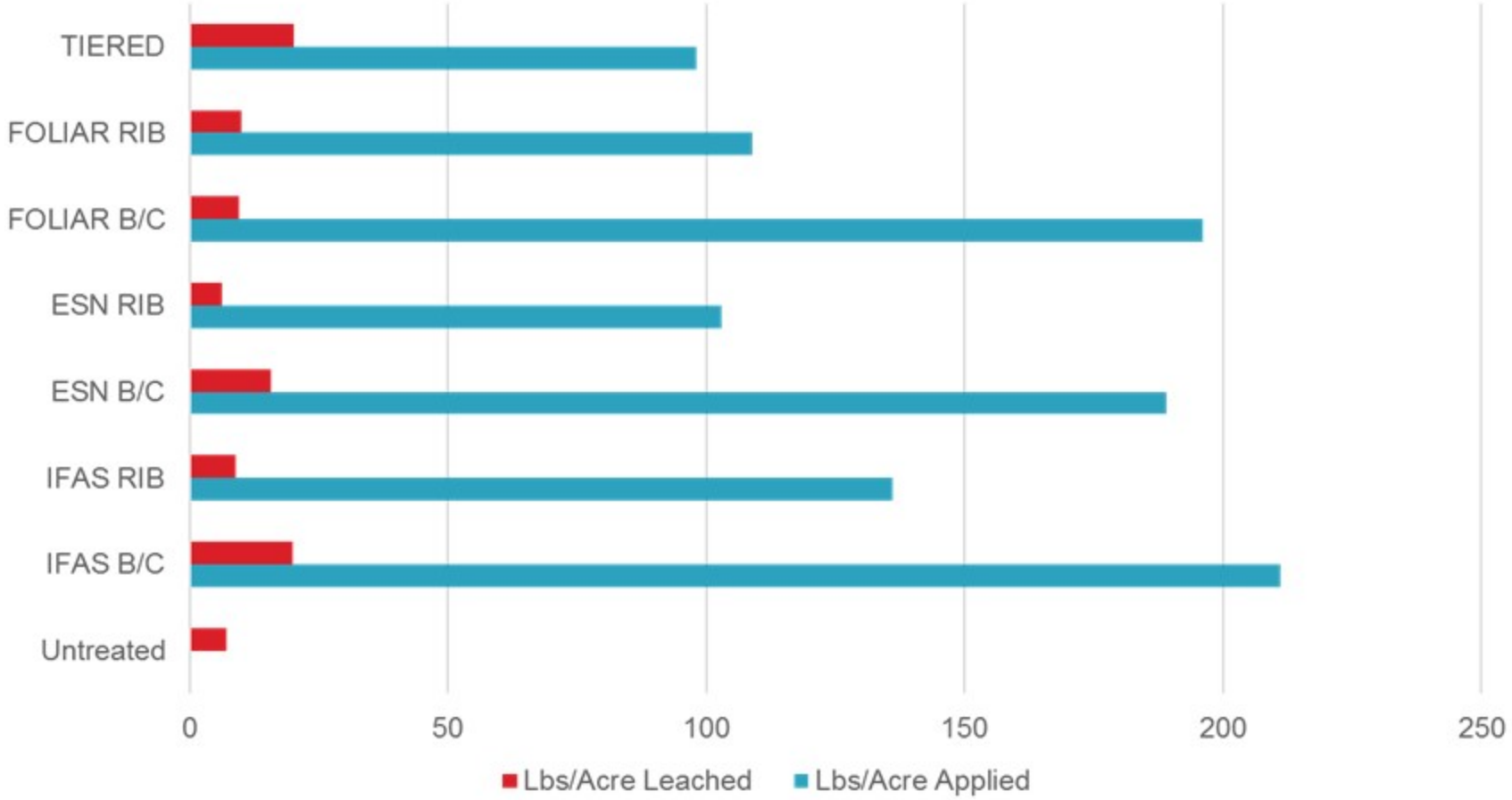
Leaching from Centipedegrass Sod Production



UF UNIVERSITY of FLORIDA TURFGRASS SCIENCE

Project (21): 'STEM'ing Up Gardening for Grades

Project Partners: Florida Agriculture in the Classroom, Inc

Project Summary

School garden grants have been hugely popular with Florida teachers for several years, and Florida Agriculture in the Classroom Inc. (FAITC) has been able to provide teachers with a steady source of school garden grant funding thanks to Specialty Crop Block Grants. The continued school garden grant funding allows teachers to either pay for materials to start a garden or refurbish an existing garden and use FAITC school garden curricula Gardening for Grades and/or Gardening for Nutrition and the school garden as a teaching tool.

The 55 $500 school garden mini grants it provided with a 2014 Specialty Crop Grant (Contract #021768) funded teachers' school garden efforts for the 2015-16 school year.

Florida Agriculture in the Classroom, Inc. began providing school garden grants during the 2011-12 school year with funding it received from a 2010 Specialty Crop Grant (Contract #106853). After that, it received a 2012 Specialty Crop Grant (Contract #019713) to distribute school garden grants during the the 2013-14 school year and a 2013 Specialty Crop Grant (Contract #020734) to distribute school garden grants during the 2014-2015 school year.

The 2014 Specialty Crop Grant (Contract #021768) called 'STEMming Up Gardening for Grades' was a continuation of our previous school garden programs, and included creating a third book in our school garden curricula called 'STEMming Up Gardening'. STEM has become very popular in schools and it was necessary to increase the rigor of our school garden curriculum by creating this book. Lessons from the book have been presented at multiple workshops throughout the past year and teachers are excited about the book. The book is currently being printed and will be ready to go to teachers this school year.

According to the applications and final reports submitted from the school garden grants, these school garden projects collectively reached nearly 11,000 students. In addition, we asked that teachers keep food diaries of their students eating habits after being exposed to the specialty crop school garden, and overall their consumption of fruits and vegetables grew at least 10 percent, which is a goal set for the grant.

Project Approach

FAITC promised to increase the number of students exposed to school gardens, increase their consumption of specialty crops grown in their school gardens and increase their STEM garden knowledge. All of these goals have been reached.

Food diary summaries from teachers who received the 55 $500 school garden grants indicated students consumption of specialty crops rose during the project. Students' views on foods also changed. Teachers stated in their final reports that students asked for fruits and vegetables as snacks versus going to the vending machines. It was also stated that students then went home and encouraged their parents to cook new fruits and vegetables. Almost all of the grant recipients had garden food tasting days where they created salads, wraps, salsa and more.

Of the 55 garden grants, 32 were new projects. That means that over 50% of our garden grants were new gardens. Which exceeded our expectations.

In addition, teachers were exposed to a few lessons from 'STEMming Up Gardening'. The book took much longer to complete than expected, therefore the only exposure that teachers have had was through workshops. FAITC has received very positive feedback from teachers regarding these lessons. We will start promoting the book this school year at all of our teacher workshops.

Goals and Outcomes Achieved

Goal 1 of the grant was to increase the consumption of fruits and vegetables by student by 10 percent. According to the mini grant final reports we exceeded this goal. Teachers used dehydrators to make fruit and vegetable chips that students has access to throughout the day. They made salsa using a blender, they made salads and brought in salad dressing. A few schools added a free vegetable to the cafeteria so all the students could try something new. And one school sent all the food home on the weekends through a backpack program. Overall a great success.

Goal 2 was to increase the reach of students by 10 percent with 'STEMming Up Gardening' and unfortunately we did not reach the goal through this book. However, we did reach the goal of increasing our student reach. From 2015 to 2016 we increased our overall students reached by 11.5 percent.

Goal 3 was to increase student knowledge by 10 percent using 'STEMming Up Gardening' and again unfortunately we did not reach this goal through the book because it was not completed in time. However, using 'Gardening for Grades' and 'Gardening for Nutrition' there was a 66 percent increase with pre test average being 53 and post test average being 88.

Beneficiaries

FAITC's mission is to increase the number of agriculturally literate students in Florida. We do that through grants, workshops and teacher resources.

Two great ways we have found to increase student knowledge is through free teacher resources and school garden grants. Teachers do not have the money to do "extra" projects on their own. Through this grant we were able to help 55 schools start or continue with their gardens. Through our school garden curriculum we have been able to help teachers more effectively use their gardens as teaching tools.

Through this grant we have been able to reach more than 1,500 teachers and 30,000 students in kindergarten through 12th grade who participated in school garden workshops and received grants. Through workshops teachers learned how to cultivate and enjoy specialty crop fruits and vegetables. We had 32 out of 55 new school gardens created, we had an increase of 11.5 percent in student reach and an increase of 66 percent in school garden student knowledge.

In addition, Florida's specialty crop producers benefited from the project because it introduced their commodities to young consumers who will be more likely to purchase them in the future. Every year FAITC produces an annual report that is accessible by the public.

Lessons Learned

In order to complete this project FAITC received a six month no cost extension. Without this extension the project would not have been completed. FAITC had more delays than expected with this book and it is now at the printers being printed. Florida teachers created the lessons and it took us longer than expected to get the lessons due to teacher's hectic schedules. Finding teachers able to pilot test the lessons, editing the book and overall graphic design took longer than expected. We are very proud of the final product and the teachers are going to love it.

In the future if we use teachers to create lessons we will not ask them to work on it during the school year when they are busy. If possible we will use FAITC staff or pay a curriculum writer. We had too many projects going on during the 2016 year and in the future we will manage our time and projects better.

In our original application we did not budget costs for our graphic designer. We had $50,000 budgeted to create and print the book. Originally we said we would print 5,000 hard copies and 5,000 digital copies but because we had to use funds for the graphic artist we were only able to print 1,500 digital copies. In the future we will budget for graphic artist costs. We decided to print fewer digital copies because those would be easiest to replicate in the future when funds are available.

We did not meet our goals as written using 'STEMming Up Gardening' as a resource but through our other school garden curricula created using past Specialty Crop Block Grant funding we were able to exceed our goals to increase student reach, student consumption and student knowledge.

Contact Person

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Funding Expended: $86,000.00

Project (22): Reducing the Threat Posed by Africanized Honey Bees to Specialty Crop Production

Project Partners: Florida Specialty Crop Foundation

Project Summary:

Since 1994, the University of Florida has actively promoted an IPM strategy utilizing barn owls (*Tyto alba*) for sustainable rodent control in the Everglades Agricultural Area (EAA) of south Florida. The program promotes the use of nesting boxes to enhance the raptor's populations, making them a significant predator. Prior to 2005, this program gained wide acceptance in the EAA and had contributed to a very real decrease in the levels of rodenticides used against rodent pests, some of which pose risks to humans and wildlife. However, starting in 2006, Africanized honey bees (AHBs) were observed taking over some of the nesting boxes, displacing the owls, and using them as hives. This created safety hazards for participating specialty crop growers and many of them were considering abandoning this environmentally friendly IPM program. Our goal was to preserve this method of natural rodent control and to provide information to producers that would educate them about the risks posed by AHBs and to develop safety programs for specialty crop workers. Timely research was paramount for the preservation of the program, before specialty crop producers abandoned it all together. Also, since growers were reporting AHB problems in sites other than nesting boxes, we realized that the scope of the problem was much greater than just preserving barn owls. It was also about education and improving worker safety.

Project Approach:

Our approach was to utilize a "push-pull" integrated management strategy to prevent AHBs from colonizing barn owl nesting boxes. The project involved the use of Perma-cap, a long-lasting permethrin insecticide that is non-toxic to mammals and avian species, inside of the owl nesting boxes to deter AHB scout bees from identifying a nesting box as a potential hive site. This is the "push" part of the strategy. AHBs swarm and split off nearly 4 to 8 times more frequently than their more docile cousins, European honey bees (EHBs, *Apis mellifera*), that are prized for their pollinating and honey producing qualities. The "pull" aspect of the strategy comes from using "nasonov" pheromone inside of strategically positioned "swarm traps" to draw feral AHB swarms to a hive site that could be easily moved, maintaining worker safety and preserving nesting boxes for only desired barn owls.

To test the effectiveness of this IPM program, we established replicated experiments at four sites, two within the EAA, and two on the perimeter of the EAA. Treatments consisted of nesting boxes left untreated, and those treated with permethrin, with those two treatments being paired with and without swarm traps located in close proximity. Three sites each consisted of 20 total nest boxes (5 replications of 4 treatments) and one site consisted of 60 total nesting boxes.

In addition, specialty crop producers were surveyed for the presence of feral AHB hives. The numbers and types of sites were recorded to measure the extent of the AHB problem in the EAA.

Throughout the entire duration of our project, we engaged both the agricultural industry and the public through extension/outreach opportunities. Events included seminars, farm tours, school tours, wildlife festivals, professional conferences, and educational booths at the South Florida Fair, the Palm Beach Agricultural Summit, and other events.

And lastly, we conducted an AHB Safety Workshop for specialty crop growers and interested parties. This workshop outlined the risks posed by AHBs to ag-workers, how to recognize the threat, and how to respond if attacked. It also instructed farm supervisors on how to safely rectify or prevent the threat by using swarm traps baited with nasonov pheromone.

Specific contributors:

Growers Management Incorporated, C & B Farms, Stein Farms, and the Everglades Research and Education Center all served as physical test sites for the project. Additional cooperators included Roth Farms, A. Duda and Sons, Hundley Farms, Wedgworth Farms, King Ranch, Hatton Farms, TKM Bengard, and Veg-Pro, who granted permission to survey their farms for AHBs and/or who participated in our questionnaire.

Goals and Outcomes Achieved:

Goal 1 *– Reducing or preventing the colonization of barn owl nesting boxes by AHBs, using a push-pull IPM strategy designed to lure feral AHBs to bait boxes.*

The outcome with regard to this goal was achieved with great success. None of the 60 total nesting boxes receiving permethrin applications were colonized by AHBs, demonstrating that the "push" strategy worked very satisfactorily. Furthermore, only eight of the 60 untreated nesting boxes were colonized by AHBs, due primarily to the strong affinity of AHB scout bees for swarm traps baited with nasonov pheromone over untreated boxes. This demonstrated the high efficiency of the "pull" strategy. By comparison, nearly 67 percent of untreated nesting boxes outside of the experimental area were colonized by AHBs during the course of the study. This last observation reveals the extent of the problem.

Goal 2 – *Measure the health of barn owls in boxes to ascertain the safety of the low-level insecticide treatments to this wildlife species.*

We observed a significant difference in the rate of nesting box colonization (nesting and/or roosting) between experimental sites, due primarily to the openness of the agricultural habitat. Our two test sites located in the heart of the EAA experienced a high level of colonization (>80%), while the two test sites on the perimeter of the EAA (Loxahatchee and Devil's Garden) demonstrated only 15% colonization. It is conjectured that there may be two reasons for this difference: 1) the strong preference by barn owls for habitat that is totally open (i.e. nearly devoid of trees and woodlands), and 2) the presence of other owl species (i.e. great horned owls and barred owls) that compete with or prey upon barn owls in more wooded areas. These two owl species were both observed at the perimeter trial sites, but were absent from the central EAA sites. Barn owls are smaller and much more docile than the aforementioned owl species, and they cannot compete.

A total of twelve nesting boxes demonstrating colonization were observed over time for nesting success, six treated with permethrin, and six untreated. The treated boxes fledged an average of 3.8 owlets per nesting box, while the untreated boxes fledged 3.5 owlets per box. There was no significant difference between the two treatments at the 95% confidence level, suggesting that the level of permethrin used in this experiment did not have a deleterious effect on this beneficial avian species.

Goal 3 *– Measure the viability of bee hives recovered from bait boxes removed from farms.*

Swarm traps baited with the nasonov pheromone proved to be extremely effective in drawing in feral scout bees looking for new hive sites. In fact, bait hives were so effective that our apiculturist was simply overwhelmed by the numbers of feral swarms. For example, during the spring 2016, 29 swarms were recovered from swarm traps, again demonstrating the extent of the problem. While feral hives were very easily removed by plugging the hive entrance and physically removing the swarm trap to the quarantine area, attempts at re-queening the hives with European honey bee queens were largely unsuccessful due to feral workers killing the newly introduced queen.

Goal 4 *– Train agricultural workers about the dangers of Africanized honey bees, improving job safety.*

During October 2016 we conducted a safety training workshop at the EREC, administering a pre- and post-workshop questionnaire to assess worker familiarity with AHBs and to determine the workshop's effectiveness . Of 26 attendees, 18 responded to our questionnaire. Half of the respondents were from large agricultural operations (40+), while the other half were from ag operations with less than 30 employees. A majority of workers (59%) had experienced feral bees at their workplace, with approximately half (47%) reporting that they had been stung on-job. Of those stung, 75% reported multiple stings, with 25% reporting 10 or more stings. Only one respondent indicated that they required medical attention.

Cryptic hives proved to be a great danger, with over 85% of those workers experiencing stings being stung by bees from a hive that had been undetected. In 90% of those cases, steps were taken to exterminate the hive, but in 75% of these instances, feral AHBs returned. This is indicative of the difficulty in eliminating AHBs from the workplace once they are established. When asked to identify sites where feral AHBs had taken up residence, the responses were many and varied. Beneath building foundations was the most frequent response with eight, followed by nesting boxes, meter boxes, and electrical boxes, each with six. Wall partitions, culverts, old tires, trash piles, irrigation pipe, and old machinery were additional responses.

Of the agricultural workers attending the safety workshop, 60% had never received bee safety training previously, revealing a further need for such training. All respondents (100%) felt that the workshop was helpful in learning how to avoid and respond to feral AHBs, and all indicated that they would recommend the workshop to a fellow employee.

Besides the safety training workshop, risks posed by AHBs to workers and wildlife were extended at dozens of extension and outreach events. Targeting more of a general and sometimes even an international audience, all of these were well-received. These are listed in an attached appendix.

1) Improve job safety for specialty crop agricultural workers by training workers about the dangers of Africanized honey bees.

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Our safety training had other definite outcomes. At least 5 of 6 project cooperators took steps to remediate Africanized honey bee hives from their work sites, totally unrelated to nesting boxes. One firm affirmed spending $7,000 during the year to do so, showing that they took the safety risk seriously.

Besides the safety training workshop, risks posed by AHBs to workers and wildlife were extended at dozens of extension and outreach events. Specialty crop growers were the specific targets at the Leafy Vegetable Growers' Seminars and the Annual Meeting of the Florida State Horticultural Society, but more general and even international audiences were reached at the Palm Beach Agricultural Summit, the International Pollinators Symposium at Penn State, and at the Caribbean Bee Keepers Association Conference in Tobago. All of these were well-received and were listed in an appendix attached to the original final report.

2) Reduce or prevent the colonization of barn owl nesting boxes by using a "push-pull" pest management program designed to lure feral AHBs to bait boxes.

The outcome with regard to this goal was achieved with great success. None of the 60 total nesting boxes receiving permethrin applications were colonized by AHBs, demonstrating that the "push" strategy worked very satisfactorily. Furthermore, only eight of the 60 untreated nesting boxes were colonized by AHBs, due primarily to the strong affinity of AHB scout bees for swarm traps baited with nasonov pheromone over untreated boxes. This demonstrated the high efficiency of the "pull" strategy. By comparison, nearly 67 percent of untreated nesting boxes outside of the experimental area were colonized by AHBs during the course of the study. This last observation reveals the extent of the problem.

The IPM strategy was also extended beyond protection of nesting boxes. Two of our primary cooperators used swarm traps baited to pheromone to rectify AHB safety concerns at loading ramps and packing houses frequented by agricultural workers. The strategy worked, preventing further bee stings.

The AHB research also stimulated investigations into alternatives to permethrin. One valuable observation has been that the use of plastic rather than wood as a substrate for nesting boxes discourages or perhaps even eliminates the threat of AHB taking over nesting boxes. Two agricultural cooperators have switched to using plastic boxes, in spite of the added cost (approx. $189 for plastic vs.

$20 for wood), just to avoid AHB safety issues. Thus far, the move has worked. No plastic boxes have been observed to be colonized.

3) Honey bees are relied upon as pollinators for numerous specialty crops, such as cucurbits and fruit trees. All over the U.S., there is currently a shortage of honey bee pollinators due to Colony Collapse Disorder. Our goal is to maintain the viability of bee hives recovered from bait boxes by re-queening them with European honey bee queens.

Swarm traps baited with the nasonov pheromone proved to be extremely effective in drawing in feral scout bees looking for new hive sites. In fact, bait hives were so effective that our apiculturist was simply overwhelmed by the numbers of feral swarms. For example, during the spring 2016, 29 swarms were recovered from swarm traps, again demonstrating the extent of the problem. While feral hives were very easily removed by plugging the hive entrance and physically removing the swarm trap to the quarantine area, attempts at re-queening the hives with European honey bee queens were largely unsuccessful due to feral workers killing the newly introduced queen. Success in re-queening was less than 25% and was not worth the time, expense (for European honey bee queens), and effort. Additionally, there is the risk to the bee worker which must be considered. For these reasons, we do not recommend attempting to re-queen feral hives colonizing swarm traps. Challenging for even experience apiculturists, this is beyond the scope of those less experienced.

Beneficiaries:

We cooperated with or are in contact with all of the major specialty crop producers in the EAA, including Hundley Farms, A. Duda and Sons, TKM Lettuce Farms, Veg-Pro, Roth Farms, Growers Management Inc., Hatton Farms, C & B Farms, and Stein Farms. All of these producers currently use barn owl nesting boxes as part of their sustainable agriculture practices. All have or will have benefited by learning how to protect their owl nesting boxes AHBs using permethrin, and by learning methods of dealing with feral AHB hives. Drawing from the success of swarm traps baited with the artificial nasonov pheromone, several of these organizations will be testing this strategy for preventing cryptic hives from establishing in or around their work areas, such as loading ramps, and packing houses. This would improve worker safety and reduce the cost of professional extermination. Such remediation can be expensive. One EAA producer stated that they had spent more than $7,000 during 2016 alone in attempts to exterminate undesired AHB hives.

While our specialty crop cooperators received information through our grower seminars, professional meetings, and our safety workshop, thousands of others learned of our project and progress through informal talks (i.e. South Florida Fair, Space Coast Wildlife and Birding Festival, and school presentations). Contacts from other states, such as Arizona, Colorado, and Texas indicate that our message has gotten out, and that the problem needs to be addressed in other states and countries.

Beneficiaries could be placed into several categories, listed below:

Specialty crop growers and producers, including owners, operators, and supervisors – 50 to 100. These are people who directly interacted with our program. Growers who attended our safety workshop and the seminars on AHB. They extend the benefits to others by adopting or changing current practices which may reduce or eliminate AHB exposure on the job.

Specialty crop agricultural workers exposed to AHB in the field, or at packing operations – up to 10,000. These are the people who are most at-risk and who benefit as a result of their companies or supervisor's corrective actions.

Other side beneficiaries who were educated about AHB and Bee Safety at seminars, and extension events – up to 5,000. These are people, mostly the general public, that we interacted with in less specific agricultural settings, such as the South Florida Fair, the Agricultural Summit, and the EREC Open House.

And, of course, the barn owls and other wildlife species benefit by not having to share nesting and foraging sites with AHB.

Lessons Learned:

Overall, the project was very successful, proving that the UF Barn Owl Program could be saved from AHBs by using the push-pull IPM strategy. The use of slow-release permethrin alone proved to be very effective. For this reason, growers are actually increasing their participation in the barn owl program rather than reducing their participation. Through observations and conversations stimulated by this research, the project has also given rise to another potential research project, the use of plastic barn owl nesting boxes as a means of deterring AHB colonization.

There was disappointment in that research efforts to create commercially viable honey bee hives were largely unsuccessful. Part of this failure lies in the aggressiveness of AHB workers toward an introduced EHB queen, which the AHBs considered foreign or invasive. But the large number of wild hives collected from swarm traps was also part of the problem, overwhelming our quarantine site. A contributing factor was the long distance of our apiculture specialist (Ft. Lauderdale) from the Everglades Research and Education Center (Belle Glade). Such operations require more frequent attention than could be granted given the scope of the grant.

Appendix

Presentations, Publications, and Public Relations
2015:

Raid, R. N. International IPM Symposium. Africanized honeybees: A growing threat to workers, wildlife, and IPM in agriculture. Salt Lake City, UT, March 25, 2015.

Kern, W. H. International IPM Symposium. March 25, 2015. African derived honeybees; history, problems, and future. Salt Lake City, UT.

Efstathion, C. A. International IPM Symposium. March 25, 2015. A push-pull IPM method to protect cavity-nesting birds from African-derived honey bee competition. Salt Lake City, UT.

Horsburgh, R. F. International IPM Symposium. March 25, 2015. Living with Africanized honeybees, how we are mitigating the threat. Salt Lake City, UT.

Raid, R. N. 1st Florida Bee Research Symposium. July 15, 2015. A push-pull IPM scheme for the protection of barn owl nest boxes and agricultural workers from Africanized honey bees. Gainesville, FL.

Raid, R. N. 10th European Vertebrate Pest Management Symposium. September 23, 2015. Use of barn owls for sustainable rodent control in Florida. Seville, Spain.

Raid, R. N. Leafy Vegetable Grower Seminar. October 28, 2015. Learning to live with Africanized honeybees. Everglades REC, Belle Glade, FL.

Raid, R. N. South Florida Rare Fruit Council. October 14, 2015. Use of barn owls for sustainable rodent control in Florida. Fairchild Gardens, Miami Beach, FL.

Raid, R. N. Penney Birder's Seminar. November 24, 2015. Use of barn owls for sustainable rodent control in Florida. Penney Farms, St. Augustine, FL.

Raid, R. N., Kern, W. H., Efstathion, C. A., and Horsburgh, R. F. Proceedings 8th International IPM Symposium. 2015. Reducing the threat posed by Africanized honeybees to workers, wildlife and IPM in agriculture. Program 43, Page 65.

Efstathion, C. A., Kern, W. H., Raid, R. N., and Lang, T. 1st Florida Bee Research Symposium. July 15, 2015. A push-pull IPM scheme for the protection of barn owl nest boxes and agricultural workers from Africanized honey bees. Gainesville, FL. Abstract Book.

Moore Wilmoth, K. IFAS Communication, University of Florida. June 19, 2015. Barn owls threatened by Africanized bees in South Florida.
http://news.ifas.ufl.edu/2015/06/barn-owls-threatened-by-africanized-bees-in-south-florida/#more-8853

Presentations, Publications, and Public Relations
2016:

Richard Raid and Ann Hartman. South Florida Fair Display. January 15 through January 31, 2016. The UF Barn Owl Project and the threat posed by Africanized honey bees. West Palm Beach, FL.

Richard Raid and Motti Charter. Glades Day School. January 25, 2016. Use of barn owls for sustainable rodent control. Belle Glade, FL.

Richard Raid and Motti Charter. Everglades REC. January 26, 2016. Use of barn owls for sustainable rodent control. Belle Glade, FL.

Richard Raid and Motti Charter. Green Cay Nature Center. January 27, 2016. Barn owls: Birds without Borders. Boynton Beach, FL.

Ann Hartman. School tour. January 28, 2016. Use of barn owls for sustainable rodent control. Everglades REC Belle Glade, FL.

Richard Raid. Space Coast Birding and Wildlife Festival. January 29, 2016. Barn owls, nature's mousetrap. Brevard Community College, Titusville, FL.

Ann Hartman and David Moreira. Birdapalooza. February 6, 2016. Use of barn owls for sustainable rodent control and the threat posed by Africanized honey bees. Apopka, FL.

Richard Raid. Martin County Audubon Society, March 10, 2016. Barn owls, nature's mousetrap. Blake Library, Stuart, FL.

Richard Raid. Belle Glade Chamber of Commerce, March 16, 2016. The threat posed by Africanized honey bees to wildlife and agricultural workers. Lakeside Hospital, Belle Glade, FL.

Richard Raid. FFVA Regulatory Tour, March 16, 2016. The threat posed by Africanized honey bees to wildlife and agricultural workers. Everglades REC, Belle Glade, FL.

Richard Raid and Motti Charter. American School. April 7, 2016. The UF Barn Owl Program. Haifa, Israel.

Ann Hartman and David Moreira. Earth Day Celebration. April 16, 2016. UF Barn Owl Program. Okeeheelee Nature Center, West Palm Beach, FL.

David Moreira. April 18, 2016. Reducing the threat of Africanized bees to wildlife and agricultural workers. Everglades REC, Belle Glade, FL.

Richard Raid. May 4, 2016. Palm Beach International Agriculture Summit. Barn owls, nature's mousetrap. Youth Outreach Program. West Palm Beach Convention Center, West Palm Beach, FL.

Richard Raid and Ann Hartman. May 4, 2016. Palm Beach International Agriculture Summit. The UF Barn Owl Program and the Threat Posed by Africanized Honey Bees. West Palm Beach Convention Center, West Palm Beach, FL.

Chris Miller, G. McAvoy, A. Abbate, D. Moreira, W. Kern, and R. Raid. June 3, 2016. Florida State Horticultural Society Annual Meeting. Reducing the threat of Africanized bees to wildlife and agricultural workers. Clearwater Beach, FL

Ann Hartman. June 16, 2016. Barn owls, nature's mousetrap. South Florida Fair's Summer Agucation Camp, Belle Glades, FL.

Richard Raid, D. Moreira, A. Abbate, and W. Kern. July 18, 2016. International Pollinator Conference on Biology, Health, and Regulation. Reducing the threat of Africanized bees to wildlife and agricultural workers. Penn State University, State College, PA.

Richard Raid. August 17, 2016. Addressing the threat posed by Africanized honey bees to barn owls and other avian species in south Florida. 2016 North American Ornithological Conference, Washington, DC.

Richard Raid, D. Moreira, A. Abbate, and W. H. Kern. September 14, 2016. Addressing the threat posed by Africanized honey bees to south Florida Agriculture. 8th Symposium of the Caribbean Beekeepers Association. Trinidad.

Richard Raid and Ann Hartman. September 27, 2016. Plant Pathology Teacher's Workshop. Barn owls, nature's mousetrap. Everglades REC, Belle Glade, FL.

Richard Raid and William Kern. October 19, 2016. Agricultural worker safety workshop on addressing the threat posed by Africanized honey bees. Everglades REC, Belle Glade, FL.

Richard Raid and Ann Hartman. December 2, 2016. Use of barn owls for sustainable rodent control and the threat posed by Africanized honey bees. Fl. Dept. of Agric. and Consumer Services Leadership Training for Teachers. Everglades REC, Belle Glade, FL.

Creations:
David Moreira and Richard Raid. 2016. Africanized honey bees: Safety and awareness. UF/IFAS. (Safety posters in English and Spanish, in review).

Presentations, Publications, and Public Relations
2017:

Richard Raid. Tampa Audubon Society. January 5, 2017. Use of barn owls for sustainable rodent control and the threat posed by Africanized honey bees. Hillsborough Co. Extension Office, Seffner, FL.

Richard Raid and Ann Hartman. South Florida Fair. January 13 through January 29, 2017. The Birds and the Bees: AHB in the EAA. West Palm Beach, FL.

Ann Hartman. Birdapalooza. January 21, 2017. Use of barn owls for sustainable rodent control and the threat posed by Africanized honey bees. Apopka, FL.

Richard Raid. Space Coast Birding and Wildlife Festival. January 28, 2017. Barn owls, nature's mousetrap. Brevard Community College, Titusville, FL.

Richard Raid. Everglades Day. February 11, 2017. Barn owls, nature's mousetrap. Loxahatchee Wildlife Refuge, Boynton Beach, FL.

William Kern and Richard Raid. Train-the-Trainer, In-service Training for UF Cooperative Extension. April 17, 2017. Africanized honey bees: Safety and awareness. Gainesville Hilton, Gainesville, FL.

Richard Raid and Ann Hartman. Leadership Glades tour. January 18, 2017. The UF Barn Owl Project and the threat posed by AHB. Everglades REC, Belle Glade, FL.

Ann Hartman and Juan D. Vital. Apopka Wildlife Festival and Birdapalooza. January 21, 2017. The UF Barn Owl Project. Apopka, FL.

Richard Raid. Space Coast Birding Festival. January 28, 2017. Nature's Mousetrap: The use of barn owls for sustainable rodent control. Titusville, FL.

Richard Raid. Everglades Day. February 11, 2017. Barn owls, nature's mousetrap. Loxahatchee Wildlife Refuge, Boynton Beach, FL.

Stephen Raid. EREC Open House. April 6, 2017. Barn Owls in EAA. Belle Glade, FL.

Richard Raid. EREC Open House. April 6, 2017. Addressing the Threat Posed by Africanized Honey Bees to South Florida Agriculture. Belle Glade, FL.

Raid, R., Moreira, D., Abbate, A., Vital, J., Hartman, D., and Kern, W. H. VIII International Symposium on Plant Health and Sustainability. April 10-14, 2017. Addressing the threat posed by Africanized bees to South Florida Agriculture. Havana, Cuba.

Kern, W. and Raid, R. Train-the-Trainer, In-service Training for UF Cooperative Extension. April 17, 2017. Africanized honey bees: Safety and awareness. Gainesville Hilton, Gainesville, FL.

Richard Raid. Agroecology Summit. May 15, 2017. Barn Owls and AHB in the EAA. Everglades REC, Belle Glade, FL.

Richard Raid. Dept. of Agriculture tour. May 16, 2017. Barn Owls and AHB in the EAA. Everglades REC, Belle Glade, FL.

Ann Hartman. National Extension Tourism Conference. August 8-10, 2017. Barn owls, nature's mousetrap. Princeton, NJ.

Richard Raid. Centro de Tecnologia Canavieira tour. August 14, 2017. The UF Barn Owl Project and the threat posed by AHB. Everglades REC, Belle Glade, FL.

Project (23): Integrated Use of Grafting to Improve Sustainability of FL Watermelon Industry

Project Partners: University of Florida

Project Summary

With the loss of methyl bromide, the difficulty identifying efficacious alternatives, and more stringent regulations on use of soil fumigants, watermelon producers are in critical need for integrated practices to manage soilborne diseases and improve productivity and profitability of the watermelon industry. Fusarium wilt, caused by Fusarium oxysporum f. sp. niveum, is one of the soilborne pathogens that have caused significant losses to growers in Florida and throughout the Southeast. Crop rotation is currently the best management strategy for this disease; however, F. oxysporoum f. sp. niveum can produce resilient spores that can survive in the soil for more than 5 years making this strategy impractical for most growers. Host resistance is also a less-than-optimal management option because this pathogen has 4 races which can vary in their pathogenicity and virulence. This project, which examines the effectiveness and economic feasibility of grafting as an integrated disease management tool in watermelon production, is a timely response to stakeholders' critical needs and driven by producers' keen interest in searching for sustainable approaches. To date, interest in using grafted plants is emerging among watermelon growers in Florida as they hear more about benefits of vegetable grafting. However, due to the lack of research on this topic for the watermelon production systems in Florida, up-to-date research-based recommendation is not currently available for serving the integrated disease management need of the Florida watermelon industry. The main research objectives of this project included: 1). determine the effects of using grafted watermelon transplants with resistant rootstocks for controlling Fusarium wilt in problem-fields, and in field “hot spots” where high disease pressure has led to consistent failure of previous watermelon crops; 2). assess the quality attributes of watermelon fruit from grafted plants; and 3). compare grafted and non-grafted watermelon production at different in-row spacings to determine the feasibility of reducing planting density for grafted watermelons while maintaining fruit yield; and 4). assess economic viability of grafted watermelon production. On-farm demonstration trials were also conducted in partnership with county extension agents and commercial growers. This two-year project provided up-to-date research-based information on cost-effective use of grafted plants to benefit Florida watermelon industry. Project results have been presented and disseminated at various scientific conferences, grower meetings, and field days, and through the news media. This project has played an essential role in introducing and developing the grafting tool to advance the Florida watermelon industry towards improved sustainability and profitability.

Project Approach

Objective 1. Determine the effects of using grafted watermelon transplants for controlling Fusarium wilt in problem-fields, and in field “hot spots” where high disease pressure has led to consistent failure of previous watermelon crops.

Both greenhouse inoculation studies (Fall 2015 and Spring 2016) and field inoculation experiment (Spring 2016) were conducted at the UF/IFAS Plant Science Research and Education Unit (PSREU) in Citra, FL to assess the growth and yield performance of grafted plants when inoculated with Fusarium oxysporum f.sp. niveum (FON) race 2. The root excision and regeneration treatment of grafted plants was also included in the greenhouse studies as it is a common method used by the cucurbit grafting nurseries. Seedless watermelon scion `Melody' was grafted onto different squash rootstocks, including `Super Shintosa', `Root Power' (Cucurbita maxima × C. moschata), and `Marvel' (C. moschata). Non-grafted `Melody' was used as the control (with and without FON inoculation). Field inoculation trials of the Proline fungicide were also performed in Citra and Quincy, FL during 2015 and 2016 seasons to determine integrated management strategy treatments using grafting and chemical products.

Commercial and pre-commercial rootstocks from public and private sources were screened for resistance to plant parasitic nematodes in in Quincy, FL. These screenings were performed in open field culture in fields naturally infested with nematodes. This research was conducted utilizing replicated experiments during three growing seasons. Our group also investigated the interaction between plant parasitic nematodes and Fusarium wilt. Because nematodes feed on root tissue there is potential to compromise Fusarium wilt resistance in nematode susceptible rootstocks. Replicated field experiments were conducted during two years in which nematodes and Fusarium were inoculated alone or in combination with each other.

Our greenhouse experiments consistently showed that all the inoculated grafted treatments had significantly lower presence (0-7.5% recovery) of Fusarium spp. in the crown tissue compared with the inoculated, non-grafted `Melody' treatment (70-75% recovery). Some plant growth measurements, including the longest vine length and aboveground fresh and dry weight, indicated more vigorous growth for grafted plants compared to the non-grafted controls. Significantly higher percent recovery of Fusarium spp. below the graft union was observed in the grafted plants with root excision and regeneration treatment in contrast to the intact root treatment, suggesting that the root excision method may possibly create entry points for FON infections. In the Spring 2016 field inoculation trial, the inoculated, non-grafted `Melody' control only had a 10% survival rate on average for all the plants transplanted into the FON inoculated field plots, which led to fruit production not significantly different from zero. Marketable and total yields of grafted watermelon with FON inoculation was significantly higher than that of non-inoculated, non-grafted `Melody' control by 164-334% and 154-345%, respectively. Both fruit number and size exhibited significant increases in grafted plants. However, grafted plants also demonstrated greater levels of root-knot nematode infestation as indicated by the significantly higher root galling ratings. The grafting effects varied significantly among the three rootstocks used with `Root Power' and `Marvel' showing the highest and lowest fruit number and yield,

respectively. Interestingly, `Root Power' and `Marvel' also resulted in the highest and lowest root galling ratings, respectively. Results demonstrated that grafting can effectively limit FON colonization in seedless watermelon plants, and use of grafted plants with vigorous, resistant squash rootstocks can be a promising tool for improving plant growth and fruit yield.

The basic findings for the project was that Proline can be beneficial for disease control, however it was not consistent. Proline did not provide better disease control than grafting and often yield savings with the fungicide were not significantly different from the control. Overall, it is apparent that using a fungicide alone is not adequate for managing Fusarium wilt, but it may have utility for managing multiple disease issues, e.g., in field situations where both Fusarium wilt and Anthracnose are present.

Given the susceptibility of squash rootstocks to root-knot nematodes, we also screened potential rootstocks for cucurbit grafting that may be resistant to Fusarium wilt as well as plant parasitic nematodes. Our research demonstrated that there are several options for cucurbit grafting that are resistant to at least three races of Fusarium wilt as well as nematodes. The commercial watermelon variety SP-6 (Syngenta Seeds) as well as Bulldog (USDA, US Vegetable Laboratory) both have shown consistent resistance to plant parasitic nematodes and have demonstrated resistance to multiple races of Fusarium wilt. The data gathered during this project has helped USDA determine the potential of Bulldog and they are now in the process of releasing the variety. Our research on the interaction between Fusarium wilt and plant parasitic nematodes revealed that even in the presence of nematode infestation, the Fusarium wilt resistance in some rootstocks is not compromised. Only two Fusarium wilt resistant rootstocks were tested so there may still be the potential for an interaction between these two soilborne pests.

Objective 2. Compare grafted and non-grafted watermelon production at different in-row spacings to determine the feasibility of reducing planting density for grafted watermelons while maintaining/improving fruit yield.

Three field trials of plant spacings were carried out in Fall 2015 and Spring 2016 in Citra, as well as in Spring 2016 in Live Oak, FL to explore the feasibility of reducing planting density for grafted watermelons while maintaining fruit yield. Non-grafted `Melody' and `Melody' grafted onto interspecific squash hybrid rootstock `Super Shintosa' were planted at in-row spacings of 2.5, 3.5, 4.5, and 5.5 ft, with a constant between-row spacing of 8 ft, resulting in populations ranging from 990 to 2178 plants/acre. The experiments were arranged in a split-plot design with four replications, with planting densities as the whole plot treatments and grafting as the subplot factor. In addition to fruit yield measurements, hollow heart incidence of watermelons was also evaluated. Results showed inconsistent grafting effects on watermelon fruit yield in response to spacing treatments. However, the increased average fruit weight and marketable fruit percentage, along with the reduced hollow heart severity due to grafting were consistent throughout the trials. The inconclusive results suggest that more field experiments involving different scion and rootstock combinations under various production conditions are warranted

to comprehensively understand how grafted plants respond to plant spacings as compared with non-grafted plants in terms of plant growth and yield performance.

Objective 3. Assess the quality attributes of watermelon fruit from grafted plants.

The effects of squash rootstocks on fruit quality of seedless watermelon `Melody' were assessed using both instrumental measurements and consumer sensory analysis during the field inoculation experiment and the plant spacing trials in Citra, FL. Watermelons sampled from the on-farm trial were also evaluated to determine the influence of grafting on fruit quality attributes. The results showed that fruit quality of the seedless watermelon `Melody' was not impacted by the use of the squash rootstocks, which included soluble solids content, titratable acidity, pH, and most fruit sensory properties. Watermelon flesh firmness was increased by grafting while the grafting effect on lycopene content was inconclusive. Root excision and regeneration did not influence the grafting effect, while the grafting effect on flesh firmness varied among the rootstocks under FON inoculation.

Objective 4. Analyze costs and returns of grafted watermelon production.

Partial budget analysis and sensitivity analysis were performed in the economic analysis of grafted watermelon production. Input quantity and price as well as output quantity and price for watermelon production with grafted and non-grafted plants were used in estimating costs and returns. The net return of watermelon production was calculated as the difference between revenue and production cost. The revenue is calculated as the watermelon yield (lb)/acre x price ($/lb). The key components of production cost in the partial budget analysis included the transplant cost and the cost of harvesting. Relative net income of grafted watermelon to non-grafted watermelon production system was calculated. In addition, sensitivity analysis based on grafted transplant price and watermelon price was conducted to evaluate the impact of grafted transplant and watermelon price on the profitability of grafted watermelon production relative to non-grafted watermelon production.

The analysis results of 2015 and 2016 field trials showed inconsistent net returns of grafted watermelon production in comparison with non-grafted watermelon production due to the fruit yield variability. However, when Fusarium wilt became the major disease problem, grafted watermelon production resulted in much higher income than the non-grafted watermelon production at the average watermelon price of $0.135/lb (transplant prices at $0.25 and $1.00 for non-grafted and grafted watermelons, respectively). The economic benefit of grafted watermelon production increases with increased watermelon price and decreases in grafted transplant price. On the other hand, due to the effectiveness of grafting in Fusarium wilt control, even when the grafted watermelon transplant price increases to $2.10, grafted watermelons with `Super Shintosa' and `Root Power' rootstocks can still produce higher net returns than non-grafted watermelon production. These results suggested that grafted watermelon plants can be used as an economically viable tool for Fusarium wilt management in

field production. In addition, rootstock selection may be an important factor influencing the net income of grafted watermelon production.

As the Project Director, Dr. Xin Zhao (Horticultural Sciences Department, University of Florida, Gainesville, FL) was responsible for administering the project and reporting. As the co-PI, Dr. Nicholas Dufault (Plant Pathology Department, University of Florida, Gainesville, FL) worked closely with Dr. Zhao to conduct the greenhouse experiments and on-station studies as well as the on-farm trials in relation to Fusarium wilt management. They also co-supervised the M.S. student for the graduate research project on grafted watermelon production. In addition, Dr. Zhao led the work on plant spacing studies and fruit quality assessment. As the co-PI, Dr. Josh Freeman (University of Florida - NFREC Quincy, Quincy, FL) was responsible for carrying out the on-station experiments at NFREC focused on plant parasitic nematodes and their interactions with Fusarium wilt in grafted watermelon production. As the co-PI, Dr. Zhifeng Gao (Food and Resource Economics Department, University of Florida, Gainesville, FL) supervised his graduate student to conduct all the economic analysis studies. Hodge Farms (Newberry, FL) collaborated with us to conduct on-farm trials. Bob Hochmuth (Suwannee Valley Agricultural Extension Center, Live Oak, FL), and Aparna Gazula and Tatiana Sanchez (UF/IFAS Alachua County Extension Service, Gainesville, FL) also collaborated with us to help with project dissemination at various extension and outreach events.

Goals and Outcomes Achieved

Goal 1: Increase knowledge about the effectiveness of integrated approaches involving grafting and fungicides for managing Fusarium wilt in watermelon production systems.

Performance Measure: Both on-station and on-farm trials will be conducted and key measurements include Fusarium wilt incidence, root gall index, and watermelon fruit yield including marketable fruit number and weight.

Accomplishment: Multiple greenhouse experiments, on-station studies, and on-farm trials were carried out in this project to assess the effectiveness of using grafted watermelon transplants with resistant rootstocks for controlling Fusarium wilt. Plant growth, fruit yield, and root-knot nematode infestation measurements were conducted. The targeted watermelon fruit yield increase by grafting is 20-40%, while in our field trials with FON race 2 inoculation, the marketable fruit yield increase as a result of using grafted plants reached over 150% compared to non-grafted watermelon production. Field inoculation trials of the Proline fungicide were also conducted to determine integrated management strategy treatments using grafting and chemical products. Since commercially available watermelon rootstocks possess good resistance to Fusarium wilt but lack resistance to root-knot nematodes, field trials of rootstock screening were performed to select rootstocks with resistance to plant parasitic nematodes and to investigate the interaction between plant parasitic nematodes and Fusarium wilt.

Goal 2: Provide up-to-date information on watermelon fruit quality as affected by grafting with resistant rootstocks and plant spacing recommendation for optimizing grafted watermelon production.

Performance Measure: Fruit quality attributes including fruit shape and size, firmness, titratable acidity, soluble solids content, and lycopene content; fruit number and weight at different in-row spacing treatments.

Accomplishment: Both instrumental measurements and consumer sensory analysis were conducted to determine the grafting and rootstock effects on watermelon fruit quality during the field inoculation experiment and the plant spacing trials. Fruit quality assessment was also performed during the on-farm trial. Our results demonstrated that grafting with selected rootstocks will not cause any reduction in major quality attributes of watermelon fruit. However, whether grafted plants can be grown at a wider in-row spacing without compromising fruit yield goal in order to reduce the costs of using grafted transplants could not be conclusively determined. The plant spacing studies conducted in this project showed variable results with respect to fruit yields of grafted watermelon plants across different seasons and locations. More field studies of plant spacings are needed to examine multiple rootstocks in various production systems during multiple seasons.

Goal 3: Generate real-scenario analysis of feasibility and profitability of grafted watermelon production to provide decision making assistance for adopting the use of grafted plants by growers.

Performance Measure: Production inputs and outputs will be identified and prices of inputs and outputs will be collected. Accurate costs, revenues, and profitability of grafted watermelon production in different production scenarios will be estimated.

Accomplishment: An updated economic analysis was performed in this project to provide Florida growers with research-based information on profitability of grafted watermelon production. It is clear that grafting can be used as an economically feasible tool for integrated management of Fusarium wilt. More research is warranted to optimize the use of grafted plants in order to improve the net return of grafted watermelon production under low disease pressure. While we expect to see site-specific adoption of grafting towards improved profitability by at least two watermelon growers by 2017, more and more growers in Florida have used grafted watermelon plants during the project period according to the information provided by seed companies and grafting nurseries.

Goal 4: Provide research results of how producers can utilize grafted plants in a cost effective and environmentally sound manner on a public website.

Performance Measure: How many views and downloads of the research results took place.

Accomplishment: A project website was designed and constructed (http://programs.ifas.ufl.edu/watermelon-grafting/) upon completion of the project. As we have been finalizing research manuscripts for publication, the project website still needs to be fully developed. With our funded continuation project, we will continue to develop and update the project website for

disseminating research findings. Views of the project website and downloads of the research results will then be systematically documented.

Beneficiaries

Watermelon producers in Florida and transplant operations producing or planning to produce grafted watermelon transplants as well as the extension agents serving the Florida watermelon industry are the primary beneficiaries of the project. Project dissemination has taken place at different events including scientific conferences, field days, and education sessions/displays at Suwannee Valley Watermelon Institute, and Florida Watermelon Association Annual Convention. Project information is also made available through various news media to reach out to diverse audiences and stakeholders including farmers, nurseries, seed companies, researchers, and educators. There are over 400 watermelon farms in Florida, and we believe that many of them directly benefited from this project by participating in our outreach programs and presentations and learning about our project through news media. By involving stakeholders in designing this project and conducting on-farm trials, our research findings provided up-to-date information on using grafting to manage Fusarium wilt, one of the critical production issues faced by the Florida watermelon industry, under the more stringent regulations on use of soil fumigants. Results from this project will offer research-based recommendations for growers to incorporate grafting into their IPM tool box to tackle site-specific soilborne disease management issues. Watermelon producers in other states may be impacted by our project through the outreach and extension programs established that help disseminate the project results as well as our research and extension presentations and publications coming out of this project.

Summary of Project Dissemination and Outreach:

Theses and Dissertations:

Liu, Q. 2016. Exploring the use of grafting in seedless watermelon production for improving Fusarium wilt management, yield, and fruit quality. M.S. Thesis. University of Florida, Gainesville, FL.

Refereed Publications:

Liu, Q., X. Zhao, J.K. Brecht, C.A. Sims, T. Sanchez, and N.S. Dufault. 2017. Fruit quality of seedless watermelon grafted onto squash rootstocks under different production systems. Journal of the Science of Food and Agriculture. 97: 4704-4711.

Zhao, X., Q. Liu, M.T. Sanchez, and N.S. Dufault. 2018. Performance of grafted seedless watermelon plants with and without root excision under inoculation with Fusarium oxysporum f.sp. niveum race 2. HortScience. Submitted.

Conference Presentations:

Zhao, X. 2016. Update on UF watermelon grafting research. Suwannee Valley Watermelon Institute, Gainesville, FL.

Liu, Q., X. Zhao, Z. Black, J.K. Brecht, and C.A. Sims. 2016. Grafted seedless watermelon production with different planting densities. American Society for Horticultural Science Annual Conference, Atlanta, GA.

Liu, Q., X. Zhao, T. Sanchez, Z. Black, and N. Dufault. 2016. Response of grafted seedless watermelon to root regeneration and inoculation with Fusarium oxysporum f.sp. niveum. American Phytopathological Society Annual Conference, Tampa, FL.

Liu, Q., X. Zhao, Z. Black, J.K. Brecht, and C.A. Sims. 2016. Fruit quality of seedless watermelon cultivars grafted onto an interspecific hybrid squash rootstock. Florida State Horticultural Society Meeting, Stuart, FL.

Zhao, X. 2016. Grafting for vegetable production. Vegetable grafting workshop at the Panhandle Fruit and Vegetable Conference, Marianna, FL.

Zhao, X. and Z. Black. 2016. Vegetable grafting techniques. Vegetable grafting workshop at the Panhandle Fruit and Vegetable Conference, Marianna, FL.

Field Day Demonstration and Discussions at Research Plots:

Sanchez, T. and N.S. Dufault. 2016. Plant diseases of watermelon. Watermelon Research and Extension Day, Citra, FL.

Zhao, X. 2016. Integrated use of grafting to improve sustainability of Florida watermelon industry, and economic analysis of grafted vs. non-grafted seedless watermelon production. Watermelon Research and Extension Day, Citra, FL.

Grafting Demonstration and Project Introduction at Grower Conferences:

Zhao, X. and Z. Black. 2014 and 2015. Watermelon grafting demonstration and project introduction. Suwannee Valley Watermelon Institute, Gainesville, FL

Zhao, X. and Z. Black. 2015. Watermelon grafting demonstration. Northeast District Extension Faculty Meeting, Gainesville, FL.

Hochmuth, R. and X. Zhao. 2015. Introducing the grafted watermelon project at the University of Florida. Florida Watermelon Association Convention.

Project Website: http://programs.ifas.ufl.edu/watermelon-grafting/

Project News:

Do you love seedless watermelons in the hot summer? UF scientists are on the case. http://blogs.ifas.ufl.edu/news/2017/07/12/love-watermelons-hot-summer-uf-scientists-case/

http://farmerandranchernow.com/2017/08/01/do-you-love-watermelons-in-the-hot-summer-uf-scientists/

http://www.newswise.com/articles/do-you-love-watermelons-in-the-hot-summer-uf-scientists-are-on-the-case

Scientists keying in on sweeter and stronger watermelon varieties.

http://www.growingproduce.com/vegetables/cucurbits/scientists-keying-in-on-sweeter-and-stronger-watermelon-varieties/

University solves seedless watermelon disease vulnerabilities.

http://www.freshplaza.com/article/178892/University-solves-seedless-watermelon-disease-vulnerabilities

University of Florida working on seedless watermelons.

http://www.hortidaily.com/article/36493/University-of-Florida-working-on-seedless-watermelons

Watermelon Grafting to Manage Fusarium Wilt.

http://vscnews.com/watermelon-grafting-manage-fusarium-wilt/

Lessons Learned

Lesson 1 - Improving watermelon transplant production and grafting (and graft healing) procedure. Poor quality of grafted watermelon transplants was encountered during the first two field experiments in spring 2015 and caused a delay in field planting, primarily because of the lack of experience with grafted seedless watermelon transplant production. The graduate student conducted several grafting experiments in the greenhouse during summer 2015 to develop grafting skills and the procedure for successful healing of grafted watermelon seedlings. A graft healing protocol using a walk-in cooler with temperature control was further developed to ensure that sufficient amount of high-quality grafted watermelon transplants could be used in all the greenhouse experiments and field trials in fall 2015 and spring 2016.

Lesson 2 - Refining field inoculation protocols. The field inoculation trials on Fusarium wilt and root-knot nematode control did not go quite successfully in spring 2015. Although it could be attributed to a combination of environmental and management factors, insufficient amount of inoculum in the research field was a main contributing factor. The FON race 2 inoculation protocol was improved and successfully implemented in fall 2015 and spring 2015 studies at Citra. A squash crop was planted in the experimental field at Quincy during the fall of 2015 to increase root-knot nematode populations for the 2016 season.

Lesson 3 - Strengthening partnership with collaborative growers. We expected to collect fruit yield data from the on-farm demonstration trial at Hodge Farms in 2016; however, some of the fruit were taken by the farm harvest crew due to miscommunication between the researcher and the harvest crew. We counted the number of watermelon fruit that were still in the marked field plot and conducted the assessment of root-knot nematode galling. More on-farm demonstrations of grafted watermelon production will need to be conducted to better understand growers' need for integrated use of grafted plants under site-specific conditions. We were highly encouraged to collaborate with more growers for on-farm demonstrations of grafted watermelon production rather than conducting typical on-farm research trials which can be rather difficult to implement without interrupting growers' regular operation.

Lesson 4 - Focusing on field production systems of grafted watermelon. We were not able to conduct on-farm studies of grafted watermelon transplant production as the growers involved in this project were not ready to graft watermelon plants at their operations. Given the multiple levels of work already

involved in this project, we also realized the lack of resources and personnel to take on the grafted transplant work at commercial nurseries. Because the emphasis of this project is on integrated use of grafting to improve watermelon production systems other than producing grafted watermelon transplants, we decided to focus entirely on field production systems of grafted watermelon in this project. Meanwhile, we conducted additional work that was not stated in the original proposal to help enhance the project, including consumer sensory analysis of grafted watermelon fruit and examination of the performance of grafted watermelon plants with root excision and regeneration (a practice used by some cucurbit grafting nurseries) under FON race 2 inoculation.

Lesson 5 - Actively developing and updating project website. There was a delay in initiating the project website due to the unexpected delay in getting the website design approved using the new platform. We realized that we could have been more proactive in discussing the project website development within our project team. This established project website will be further developed and updated as we continue to work on grafted watermelon research.

Despite some problems and delays encountered during the project period, we are pleased that we were able to successfully complete this project by making timely adjustments to the work plan and implementing additional work to improve the project. The no-cost extension period allowed us to finalize some research manuscripts for publication and to prepare more research and extension articles in the pipeline.

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Project (24): Expanding Avocado Production in Florida

Project Partners: University of Florida Board of Trustees

Project Summary

Avocado consumption is growing in the US. While US production shows only a slight upward trend, and is variable year to year, imported fruit has increased substantially since 2000, comprising a large majority of U.S. supply. The U.S. avocado industry is concentrated in Southern California (primarily 'Hass', small rich-fleshed, with high consumer demand) and South Florida (focused on larger, lower oil West Indian types). West Indian types are better adapted to low elevation subtropical production, with less susceptibility to fungal diseases, specifically postharvest anthracnose and root rot caused by Phytophthora spp., but are less rich tasting (lower oil content), have reduced shelf life, are more cold-tender (hence focus on Miami-Dade county production) and have a more limited consumer acceptance compared to Guatemalan/Mexican types. The South Florida industry is threatened by a newly introduced disease, Laurel Wilt (LW), and the California industry is stagnant due to water shortages and high production costs. The disease is caused by a fungus (Raffaelea lauricola) that is introduced into host trees by a non-native insect, the redbay ambrosia beetle (Xyleborus glabratus). The beetle was introduced into Savannah, GA in 2002, has spread into South Florida, and may threaten avocado production nation wide. Limited studies suggest tolerance to LW may be greater in Mexican and Guatemalan races than the West Indian genotypes traditional grown in Florida. The purpose of this project is to protect the South Florida industry with LW resistant varieties and expand US production of 'Hass'-like fruit through identification / development of cultivars with high consumer-demand that are suited for commercial production in Florida.

Project Approach

Objective 1 (UF Fort Pierce, USDA Fort Pierce): Approximately 800 trees for subsequent LW susceptibility screening were planted in 2015 at a commercial site west of Fort Pierce. Unfortunately, the field experienced great mortality due to rain and soggy field conditions. In April, 2016, 25 surviving trees, representing 10 different selections, were transplanted to the IRREC to attempt to rescue surviving selections. Interestingly, 12 of the trees were of the cultivar 'Nabal', whereas three cultivars had two surviving trees, and the rest only one. Thus, 'Nabal' was particularly heaty in surviving these environments. Unfortunately, almost all the trees, except one 'Nabal' tree survived the transplant process. A new materials transfer agreement between the University of Florida and University of California, Riverside was signed, but the trees were not ready for receipt before the grant ended. Expenses for replacement plants were not charged to the grant.

Using half-sib populations (open pollinated) of avocado germplasm planted in 2012 in Fort Pierce and inoculated with an isolate (RL4) of Raffaelea lauricola, causing organism of avocado Luarel wilt (LW) disease, a total of three times between 2013 and 2014, the trees were evaluated for symptom development. New tree disease development continued to be evaluated with most previously inoculated trees showing no new laurel wilt symptoms, some trees with new symptoms, and a few

additional trees that died. Out of 18 families, with an average of 29 trees each, family 'No. 21' was most susceptible to the disease and 'Ettinger' had the highest proportion of trees die to laurel wilt without recovery. Both cultivars are G-M hybrids. Lowest disease severity was observed for 'Argui 1' (WI-(G-M)), 'Booth 8' (G-WI), and 'Melendez (G-WI). In contrast, Ploetz et al. (2012) found that cultivars with WI background developed most severe symptoms. Regression analysis shows that there is a correlation between disease severity and trunk size, which corroborates with previous reports. Tree samples for genetic mapping were sent to the USDA Miami for genetic mapping.

To confirm the survivability and systemic activity of R. lauricola in previously inoculated avocado trees, efforts were made to isolate the fungus from the tissues of inoculated avocado trees in this block, even after almost 2 yrs after the last inoculation. Multiple samples (at 1.5 and 5 ft.) were collected in April, June, and August of 2016 from each of three control trees (in a different block that was never inoculated or showed symptoms), three inoculated trees showing new disease symptoms, and three inoculated trees that once showed severe symptoms after inoculation, but no longer show symptoms. PCR was run and the results suggest that the pathogen can remain systemic in avocado trees and continue to cause new disease symptoms long after initial infection. Of even more interest was the finding that R. lauricola could still be recovered even from those trees no longer show symptoms.

Objective 2 (UF Fort Pierce, USDA Fort Pierce): Using a 2009 plantings of Guatemalan/Mexican hybrids, growth data was collected and flowering evaluated every two week during the bloom period in 2015, and tree health evaluated in April and July 2016. While most of the 200 hybrid trees in Fort Pierce grew well through the first half of 2016, with most over 10' tall and started cropping in 2013, those growing in Miami did not, with many of the trees needing to be replanted and very few flowering. In Fort Pierce, minimum and maximum temperatures did not vary much during the study, and they were similar to those recorded in the past ten years in the Fort Pierce area. Since 2005, average temperatures were between 21-22˚C (70-73F) with average lows between 9-12˚C (49-54F) and average highs between 31-33˚C (88-91F). Years of this study can therefore be considered normal and not due to warm or cold years, and can be considered typical as temperatures averages seem to only vary by a few degrees throughout the past ten years. Clearly, fertilization and fruit set were successful in the east-central Florida climate during the study.

Fatty acid composition was analyzed on fruit from bearing hybrids and found to be similar to previous reports of fatty acid composition of mesocarp tissue of ripe avocado. Oleic acid was found to be the most abundant fatty acid followed by palmitic, linoleic, and palmitoleic acids. Linolenic, stearic, and myristic were found in very small and/or trace amounts. Values found in this study confirm that the east-central Florida climate supports good quality fruit based on lipid content as fruit had a minimum of 8% oil content at harvest (except R5T35 in 2014) as set by the California avocado industry. Oil content is highly correlated with percent dry weight and both are generally used as maturity indices in avocado producing areas (except Florida). In previous findings, acceptable taste was noted at a minimum of 20.0% and 22.8% dry weight for 'Bacon' and 'Hass', respectively and percent oil for acceptable taste was 8.7% for 'Bacon' and 11.2% for 'Hass'. Hybrids in this study varied greatly in oil content (from 9.0% to 20.5% in 2014) and fruit from trees that showed better horticultural traits, such as fruit quality and yield were selected and included in trained sensory panels.

For fruit quality, postharvest performance and sensory evaluations, the reciprocal crosses of California-type avocado cultivars 'Hass' and 'Bacon' grown in east-central Florida showed similarities with

commercial ‘Hass’. Fruit from the crosses reached good maturity and were ready for harvest towards the end of October through mid-November when California ‘Hass’ fruit is off the market. Flesh mean percentage dry weight ranges were within values accepted in California (17.7% for ‘Bacon’ and 20.8% for ‘Hass’). Some trees had fruit with darker skin color upon ripening to mask imperfections and resembled ‘Hass’, the most common cultivar on the market. Optimal eating ripeness stage was reached within 10-14 days.

Trees with better horticultural traits were chosen as preferred selections and included in trained taste panels. None of these selections were disliked except store-bought ‘Hass’ (Chile) in 2015, which may be due to the lack of ripeness. R7T54 had the lowest dry weight (18.4%) and among the lowest oil content (11.8%). However, the opposite is true for store-bought ‘Hass’ (Chile) that had the highest dry matter (26.0%) and among the highest oil content (16.0%). Since almost all the selections evaluated were of similar or better acceptability compared to store-bought and Florida grown ‘Hass’, further studies are needed to evaluate the effect of harvest date on oil content and consumer acceptance of these selections. Most noteworthy was the fact that favorability of almost all of the hybrid selections chosen for sensory evaluation were similar to ‘Hass’.

A storm on July 5, 2016 caused flooding in the Fort Pierce planting of Guatemalan/Mexican hybrids resulting in tremendous tree mortality. However, promising selections were rescued and grafted on new rootstock in 2016 and planted in 2017 to another block on the USDA research farm.

Objective 3 (UF Fort Pierce & Homestead, USDA Fort Pierce, Fellsmere Farms): Approximately 18 different avocado scion selections were propagated on three rootstocks (‘Walden,’ ‘Duke’ or ‘Dusa’). ‘Walden’ seedling is widely used in Florida, while ‘Dusa’ and ‘Duke’ clonal rootstocks are Phytophthora-resistant and widely used in California. Tree mortality in the nursery limited the project to three planting sites within Florida. The trees were planted in June 2015 at, 1) at the University of Florida (UF) Indian River Research and Education Center (IRREC) in Fort Pierce, 2) at a commercial site in the Indian River area (Fellsmere), and 3) at the UF Tropical Research and Education Center (TFREC) in Homestead.

Unfortunately, the first planting of trees at the commercial site in Fellsmere was a complete loss, as all trees died in relation to wet conditions and Phytophthora infections. However, the grower planted 105 remaining trees from the nursery in a single, outer row spanning two blocks in November 2015 that were better drained. Most surviving trees were on Waldin rootstock. Tree growth and health were measured and evaluated in August 2016 and July 2017, at which time trees in one of the blocks were stunted and chlorotic. The reason for this was not clear, as they received the same care and horticultural practices. The grower attempted transplanting the affected trees, but their ultimate survival does not appear promising.

The trees planted at the University of Florida researcher centers in Fort Pierce (IRREC) and Homestead (TFREC) survived and grew reasonably well, with substantial variability depending on rootstock/scion combination. Overall, tree losses were 16% and 18% at TFREC and at IRREC, respectively. By Spring 2017, only a few trees flowered slightly, but no fruit were produced. Avocado tree growth at IRREC was evaluated in May 2016, and January and May 2017. At TFREC, tree growth was measured June and December 2015, and August 2016. At both locations, trees grown on Walden rootstock were more likely to survive. Thus, even though Duke and Dusa are phytophthora resistant, it is the traditional Florida rootstock, Walden, which remains most viable for the current trials. In January 2017 at IRREC, average tree height and trunk diameter were greatest for selections grafted on Walden (111.5 cm and 38.2 mm,

respectively), then on Dusa (101.4 cm and 31.5 mm, respectively) or Duke (79.1 cm and 26.2 mm, respectively). At this time, there were 13 scion selections still surviving on Walden, 9 on Dusa, and 11 on Duke. In August 2016 at TFREC, average tree height and trunk diameter were greatest for selections grafted on Duke (average of 110.1 cm and 39.8 mm, respectively), then on Dusa (average of 99.9 cm and 34.1 mm, respectively) or Walden (average of 95.4 cm and 35.9 mm, respectively). However, there were only 4 scion selections surviving on Duke, while Dusa had 10 and Walden had 12. Of the scions evaluated, 'Brogdon' performed particularly well on most rootstocks and at both locations. The other scions performed variably depending on rootstock and location.

Goals and Outcomes Achieved

Goal 1: Identify parent genotypes and associated molecular markers that confer a higher degree of LW tolerance.

Target: Identify at least one molecular marker associated with greater LW tolerance.

Outcomes achieved: Laurel wilt susceptible and tolerant families were identified with the highest proportion of trees to die to laurel wilt being G-M hybrids. Lowest disease severity was observed in one WI-(G-M) hybrid, and two G-WI hybrids. Tree samples for genetic mapping were sent to the USDA Miami for genetic mapping, but the results not yet completed and returned. PCR analysis of surviving trees suggest that the pathogen can remain systemic in avocado trees and continue to cause new disease symptoms long after initial infection and that R. lauricola can still be recovered, even from trees no longer showing symptoms.

Goal 2: Identify new cultivars from Hass x Bacon progenies that appear to be well-adapted (including better cold tolerance) to East-central Florida and South Florida conditions.

Target: With two additional years of additional evaluation, it is expected that at least 5 priority selections will be identified with excellent fruit quality and horticultural traits conducive to efficient and profitable Florida production.

Outcomes achieved: Depending on the year, between four and eight new selections were identified with fruit quality, postharvest handling characteristics, and sensory quality comparable to commercial 'Hass'.

Goal 3: Establish performance evaluation trials of Hass-like varieties on three rootstocks to identify superior cultivars for Florida production.

Target: Within the two-year life of this grant, 5 trials will be established evaluating three rootstock and different scion combinations, and initial data collected.

Outcomes achieved: Tree mortality during nursery production of rootstock and scion combinations resulted in only enough trees for three trials: one located in the Homestead area at the UF TFREC, and two in the Indian River area. The reduced number of trial locations is a primary reason for unexpended funds.

Beneficiaries

The benefits from this project are anticipated to be long term. Phytophthora root rot is currently the biggest impediment to expanded plantings. This includes plantings by commercial cooperators. Presentations to state and national horticultural societies (2), through trade (2), refereed (2) and non-refereed (1) publications, and publication on our website (http://irrec.ifas.ufl.edu/postharvest/Avocado.shtml) have gotten the word out about our work. See the website for details. Meetings have occurred with individuals representing different companies interested in planting test blocks of the promising avocado selections. One grower in Indian River County is interested in putting in a test planting of our most successful selections using an open-hydroponics system and work is underway to obtain a materials transfer agreement from USDA and produce trees to plant a test block of these new selection. Growers need to become experienced with growing these new avocado selections (especially in preventing loss due to Phytophthora) in Florida before commercial adoption will accelerate.

There are 1,014 Florida avocado growers, as numbered in the 2012 Census of Agriculture. In addition, at least one new grower has expressed interest in starting avocado production outside Florida's current Commercial Avocado Production Area in Miami-Dade County.

Lessons Learned

Contrary to an earlier publication, West Indian avocado hybrids did not appear more susceptible to laurel wilt than Guatemalan and Mexican hybrids. With Half-sib families, we need the genetic analysis to help confirm the race of the other parent before making final conclusions. Such results from USDA Miami were nearing completion by the end of the grant, but still not available. In addition, the pathogen was found to remain systemic in avocado trees and continue to cause new disease symptoms long after initial infection, and R. lauricola can still be recovered from trees no longer showing symptoms.

Guatemalan/Mexican hybrids grew better in Fort Pierce than they did in Miami. Of the 200 Guatemalan/Mexican hybrids in Fort Pierce, they grew well through the first half of 2016, during what can be considered typical for temperature extremes. Hybrids in this study varied greatly in oil content (from 9.0% to 20.5% in 2014) and fruit from trees that showed better horticultural traits, such as fruit quality and yield were selected and found, for the most part, to possess fruit and sensory quality comparable to commercial 'Hass'.

Tree production in the nursery, especially using Duke and Dusa rootstock, was a limitation that reduced the number of planned rootstock/scion trials from five, to three initial plantings. Of these, the commercial planting became a total loss because of wet soil conditions and phytophthora, while the two planted at University of Florida research centers continue to progress. Of these, selections planted on Walden rootstock have survived best.

Phytophthora root rot problems were a common problem throughout many of the trials. One thing appears clear, growers will need to understand that for a successful planting, these avocado selections need to be planted in well drained areas and vigilance maintained to head off potential losses due to Phytophthora (e.g., regular fungicidal treatments).

Contact Person

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Funding Expended: $102,473.64

Project (25): Finding Viable Labor Solutions for Florida Specialty Crop Growers

Project Partners: Florida Specialty Crop Foundation

Project Summary

The production of specialty crops, notably fresh fruits and vegetables, is highly labor intensive. Over the past decades, fruit and vegetable farms have relied on domestic workers who are recent immigrants into the US. Many of these workers, unfortunately, are not legally authorized to work in the US. As the political scrutiny over immigration reform and the use of undocumented workers has heightened, labor shortages are being reported by agricultural operations, particularly from Florida strawberry, citrus and tomato growers. Growers rate labor availability as one of the top three challenges to their industries. Labor shortages pose a direct threat to the specialty crop industry. As a result of labor shortage, use of illegal labor force is a widespread problem. The annual National Agricultural Worker Survey (NAWS) and audits of employers' social security numbers indicate that more than 70% of the current domestic workers are not legally authorized to work in the United States. Labor shortages and the legal issue are causing significant uncertainties for the specialty crop industry. The most likely solution for addressing the existing labor shortfall and legal issue will be through a foreign guest worker program.

The H-2A program provides growers with a legal means to hire foreign workers to supplement their work force. The guest worker program is at the heart of the current national debate over immigration reform. Underlying the current political debate over amendments to the current H2A program are lingering concerns about foreign workers displacing domestic workers. The likelihood of immigration reform and securing a viable flow of legally authorized foreign guest workers remains high. Equally likely, though, is that specialty crop growers will face higher labor costs from any future version of a guest worker program. Results from this project will provide growers and industry leaders with quantitative estimates of their labor requirements and the likelihood that a foreign guest worker program will satisfy their needs in a cost-effective manner.

Project Approach

Objective 1. Estimate labor requirements for strawberries, citrus and tomato operations and evaluate the extent of current labor shortages and the economic impacts on those industries.

We designed questionnaires and conducted a growers survey. The survey protocol was approved by UF Institutional Review Board (IRB) in January 2016. Information regarding H2A program from both the demand side (i.e., grower) and the supply side (i.e., worker) are collected. Strawberry growers were visited to conduct the survey from January through March 2016. Detailed information about labor

requirement for different strawberry production operations and information about monthly employment were collected to evaluate the technical demand for labor. Data have been analyzed and summarized in several UF/EDIS publications.

Two paper abstracts was accepted by the annual Agricultural and Applied Association (AAEA) Meeting in Boston (July 31-August 2, 2016). The papers entitled "Imperfect Substitution between Immigrant and Native Farm Workers in the United States" and “Foreign Guest Workers or Domestic Workers? Farm Labor Decisions and Implications” were completed in May 2016 and presented in July 2016 at the AAEA Meeting.

Objective 2. Document growers' experience and perceptions about the current H2A program and identify barriers to adoption of the program.

We initiated a survey among farm labor stakeholders as to their perspectives on H-2A guest workers. Perspectives solicited from growers, worker advocates, government agencies, and farm labor contractors.

Strawberry growers with and without H2A experiences were interviewed, and information was collected on their experience and H2A problems in Jan-Mar 2016. Four citrus growers and two vegetable growers with H2A experience were interviewed as to their recruitment and management experiences. Notes have been incorporated into a new teaching unit for the UF Farm Labor Supervisory (FLS) training program

We conducted extensive discussions with Dept. of Labor Wage & Hour investigators and farm worker advocates as to their concerns about the current H-2A program. All notes have been incorporated into a training module for the FLS program.

We organized the Farm Labor Supervisor training classes to be held at 4 locations in south Florida between mid-October and mid-November 2017 and presented at the Southeast Regional Fruit & Vegetable Conference in Savannah, GA on January 8, 2016 about regulatory compliance and H-2A workers.

The paper “Lessons Learned Developing an Extension-Based Training Program for Farm Labor Supervisors” was accepted for publication by the Journal of Extension in May 2017.

Objective 3. Develop an enterprise budget that outlines the costs associated with recruiting, hiring, transporting and housing foreign agricultural guest workers through the H-2A program.

We designed and completed a cost survey to citrus harvesters using the program in 2012 and 2013. From that survey we were able to document nearly $2,000 dollars of pre-employment costs associated with hiring H-2A workers from Mexico. Pre-employment costs include all fees associated with the petition, recruitment of foreign workers, advertisement for domestic workers, visa costs, transportation and housing expenses. Documenting these costs provide a reference point by which we can evaluate the feasibility of specific growers utilizing the current form of the program. Follow-up interviews with citrus and vegetable growers outline the advantages and disadvantages of the current program. Clearly the longer a contract is for an individual H-2A worker, the more cost-effective the program will be for employers.

Goals and Outcomes Achieved

Goal 1.Estimate labor requirements for strawberries, citrus and tomato operations and evaluate the extent of current labor shortages and the economic impacts on those industries.

Two sets of documents were published. The first set was detailed descriptions of labor requirements and costs for strawberries, citrus and tomato operations. It includes:

1. Guan, Z., F. Wu, F. Roka, and A. Whidden. 2015. Agricultural Labor and Immigration Reform. Choices, 4th Quarter 2015 30(4): 1 - 9. http://www.choicesmagazine.org/magazine/pdf/cmsarticle_459.pdf;

2. Wu, F., Z. Guan, and M. Garcia-Nazariega 2017. Comparison of Labor Costs in Florida and Mexican Strawberry Production. accepted for UF/IFAS EDIS Extension;

The second document estimated the extent of labor shortfalls in strawberries, citrus and round tomatoes along with the associated economic issues. It includes

1. Biswas, T., Z. Guan, and F. Wu. 2017. Labor Shortages in Florida Strawberry Industry. Submitted to UF/IFAS EDIS Extension;

2. The paper entitled "Imperfect Substitution between Immigrant and Native Farm Workers in the United States" was submitted to the 2016 annual AAEA Meeting;

3. The paper entitled “Foreign Guest Workers or Domestic Workers? Farm Labor Decisions and Implications” was submitted to the 2016 annual AAEA Meeting;

Information was disseminated to the major commodity groups, stakeholders, professionals and legislators. Presentations include:

1. Wei, X., Z. Guan, G. Onel, and F. Roka. Imperfect Substitution between Immigrant and Native Farm Workers in the United States. 2016 Agricultural & Applied Economics Association (AAEA) Annual Meeting, Boston, MA, July 31-August 3, 2016;

2. Wu, F. and Z. Guan. Foreign Guest Workers or Domestic Workers? Farm Labor Use Decisions and Implications. 2016 Agricultural & Applied Economics Association (AAEA) Annual Meeting, Boston, MA, July 31-August 3, 2016;

Goal 2.Document growers' experience and perceptions about the current H2A program and identify barriers to adoption of the program.

Survey responses have been summarized into qualitative descriptions of growers' experience, perceptions and barriers to the adoption of the current H-2A program. They have been published at refereed journals, trade journals, conference proceedings and other non-refereed publications. These publications include:

1. Roka, FM. 2015. Recruiting H-2A workers into Florida vegetable operations. Proceedings of the Florida Tomato Institute (2015): 20-22.

2. Thissen, CA, MT Bayer, and FM Roka. 2016. Transporting Farm Workers. Citrus Industry Magazine (May).

3. Thissen,CA and FM Roka. 2016. Sexual Harassment. The Vegetarian Newsletter. Issue 610. Mar 2016. http://hos.ufl.edu/newsletters/vegetarian/.

4. Roka, FM. 2016. SA8000: Social Accountability coming to a farm near you. Proceedings of the Florida Tomato Institute (2016):21-22.

5. Roka, FM. 2017. Farm labor management in southwest Florida – Challenges and opportunities. Proceedings of the 21st Congress of the Inter Farm Management Association, Edinburugh, Scotland, July 2017.

6. Farm Labor Supervisor Training website: http://www.imok.ufl.edu/programs/economics/

We participated in grower meetings and design training courses to disseminate findings. Presentations include:

1. Roka, FM. Process of recruiting and employing foreign agricultural guest workers (H-2A). SWFREC Spring Vegetable Field Day, Immokalee, FL. Apr 23, 2015.

2. Roka, FM. Farm Labor Supervisor (FLS) Training Academy and the Certificate of Farm Labor Management. FFVA Labor Committee, Sarasota, FL. May 28, 2015.

3. Roka, FM. Farm Labor Supervisor Training Program. SWFREC Foundation, Immokalee, FL. July 31, 2015.

4. Roka, FM. Farming in South Florida. Bayer Crop Science WPS compliance group (organized by Steven Riniker, Bayer Crop Science). SWFREC, Immokalee, FL. Aug 4, 2015.

5. Roka, FM. H-2A Foreign Agricultural Guest Workers. Tomato Institute, Naples, FL. Sep 9, 2015.

6. Roka, FM. Farm Labor Supervisor Training Program Demographics. Florida Citrus Mutual Harvesting and Labor Compliance Seminars, Lake Alfred, FL. Nov 18, 2015.

7. Roka, FM. Human Resource Management Strategies for Specialty Crop Growers. UF/FRE In-Service Training, Apopka, FL. Jan 19, 2016.

8. Roka, FM. DBPR "Best Practice" Criteria –Initial Draft. DBPR Conference call, Tallahassee, FL. Jan 26, 2016.

9. Roka, FM. FLS training and social accountability. Florida Pepper Growers Exchange, West Palm Beach, FL. Mar 15, 2016.

10. Roka, FM. Farm Labor Supervisor Training Program. Florida Citrus Mutual – 2016 Workforce Symposium, Lake Alfred FL. Oct 26, 2016.

11. Roka, FM. Farm Labor Supervisor Training Program. Gulf Citrus Growers' Association – 2016 Workforce Symposium, Immokalee FL. Oct 27, 2016.

12. Roka, FM. Navigating Wage/Hour Rules with and without H-2A Workers. Ridge Citrus Production School. Lake Alfred, FL. Nov 29, 2016.

13. Roka, FM. Evolution of Farm Labor Management in Florida. Sustainability, Farm Labor, Immigration, ALRB, and Cannibas - UC-Davis Conference, Davis CA. Apr 14, 2017.

14. Roka, FM. H-2A Basics Part 1 and 2. FLS Training Workshop, Immokalee, FL. Apr 27, 2017.

15. Roka, FM. Competing Perspectives Regarding Citrus Harvesting with H-2A Workers. Annual Meeting of the Florida State Horticultural Society, Tampa FL. Jun 5, 2017.

16. Roka, FM. Farm Labor Management in Southwest Florida – Challenges and Opportunities. 21st International Farm Management Congress, Edinburgh UK. July 3, 2017.

Goal 3. Develop a cost and benefit framework to evaluate the cost-effectiveness of a foreign guest worker program.

We developed an “enterprise” budget that delineates the costs and anticipated productivity benefits for foreign guest workers as they are employed specifically in strawberry, citrus and tomato operations. The findings were drafted and published in:

1. Roka, FM, D Farnsworth, and S Simnitt. 2017. Estimating Costs of Employing Citrus Harvesters through the H-2A Guest Worker Program. Selected paper Annual Meeting of the Southern Agricultural Economics Association, Mobile, AL, Feb 4-6, 2017.

2. Roka, FM, S Simnitt, and D Farnsworth. 2017. Pre-employment costs associated with H-2A agricultural workers and the effects of the ‘60-minute rule.’ International Food and Agribusiness Management Review 20(3):335-346.

The results were distributed through attending conferences, meetings and workshops.

1. Roka, FM. Estimating Costs of Employing Citrus Harvesters through the H-2A Program. Annual Meeting of the Southern Agricultural Economics Association, Mobile, AL. Feb 7, 2017

2. Roka, FM. Improving harvest efficiency and worker safety. Presented at FGCU Science Colloquium. Immokalee, FL. Sep 23, 2016

3. Roka, FM. Wage-Hour Concerns among Florida Fern Growers. Volusia County Extension Workshop, Pierson, FL. Aug 10, 2016.

4. Guan, Z. Fruit and Vegetable Industry: Threats, Challenges and Opportunities. 2017 Annual Florida Agricultural Policy Outlook Conference, Wimauma, FL, Feb 9,2017

5. Guan, Z. H2A guest workers versus domestic migrant workers: Issues and growers’ choices. 2017 Florida Agritech Conference, Plant City, FL, April 18-19, 2017.

Beneficiaries

Current labor shortages are posing direct threats to all Florida specialty crop industries as nearly all fruit and vegetable crops grown in Florida rely on a significant amount of manual labor for production and harvesting. Understanding the extent of labor shortages and the feasibility of utilizing foreign guest workers should have applicability to all Florida specialty crops, in particular, citrus, strawberries and tomatoes. Citrus, strawberries and tomatoes generate more than $2.6 billion of annual farm gate values or more than 64% of Florida specialty crop value. The importance of these crops cannot be overstated. Finding viable and legal labor solutions will address the critical need of the specialty crop industry and will have significant economic, political and social ramifications. This research has directly benefited the growers of citrus, strawberries and tomatoes through developing knowledge and disseminating information to address labor issues. Major activities include:

1. Estimated labor requirements for strawberries, citrus and tomato operations

2. Evaluated the extent of current labor shortages and the economic impacts on those industries;

3. Documented growers' experience and perceptions about the current H2A program

4. Identified barriers to adoption of the H2A program;

5. Documented pre-employment costs of H-2A workers;

6. Identified an increasing movement within the specialty crop supply chain toward incorporating measures of "social accountability."

The information generated from this project was disseminated to growers. At the direction of the Farm Labor Supervisor Training Program advisory committee, we developed and implemented several training workshops involving the H-2A program. The training has been split into two parts: Part One, which covers the petition and recruitment process, and Part Two, which focuses on management responsibilities once the workers arrive in-country. Department of Labor Wage & Hour investigators, along with worker advocates, are very concerned that H-2A employers, particularly farm labor contractors, will fail to be in full compliance with the mandated provisions of the program and at worst subject foreign workers with bad working conditions. These training workshops have promoted information dissemination. Roka organized the Farm Labor Supervisor training classes at 4 locations in South Florida between mid-October and mid-November 2017. For example, 72 people attended the April H-2A workshop. More than 15 vegetable and citrus operations were represented. Pre and post tests indicated 85% of the participants gained some knowledge about the administration and management of the H-2A guest worker program.

Another issue related to farmworkers which may be relevant to H2A workers is the aspect of social accountability, which connects with the ongoing training efforts of farm labor supervisors (FLS). Not only is the goal of the FLS training program to bring farm labor supervisors into greater compliance with existing regulations, but also create a mechanism to publicly acknowledge the good-faith efforts of those employers who try to meet and enhance those regulations.

Lessons Learned

The strawberry growers survey was delayed but eventually it was successfully completed. Some growers could not participate either because farm labor is a sensitive issue or because of the heavy workload during peak season. Better planning and communication could be used in the future to address these issues. However, we understand growers' concerns regarding farm labor because of potential legal responsibility. The US Department of Labor survey indicated over 70% of farmworkers in the United States were undocumented, and we believe the percentage is higher in some industries here in Florida.

Further work is needed in the future to study domestic farm workers working with different crops in Florida and study their labor supply pattern and plan to forecast overall industry labor supply situation and the trend of demand for H2A workers.

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Funding Expended: $92,137.35

Project (26): Redefining Early Strawberry Varieties for Florida

Project Partners: University of Florida IFAS Strawberry Breeding Program (implementor) Florida Strawberry Growers Association (partner)

Project Summary

Imports of strawberries from central Mexico have more than doubled in recent years, reaching a record of 350 million pounds by 2012, approximately four times higher than a decade ago and twice as much as total Florida production (USDC, 2013). As a result, strawberry growers have experienced more price crashes and lower profits in recent years. It is now extremely urgent that Florida strawberry growers are able to produce higher yields during late November and early December when supplies from Mexico and southern California are low and market prices are high.

Current Florida strawberry varieties are not suited to the earlier planting dates and rapid yield increases that this new situation requires. In short, the season must start at least two weeks earlier and yield must rise rapidly. In order to address this challenge, the UF breeding program will need to make much more rapid progress for early yield than in the past.

This project is not a continuation of a previously funded project. However, our research group was awarded previous SCBG funding (2012) to develop enhanced flavor in new strawberry varieties. This helped support the development of the new variety 'Florida127' (branded as Florida Sensation™) with documented higher flavor than previous commercial varieties. This previous project addressed an important aspect of market differentiation for Florida strawberry products as an answer to international competition. hus, the current project built on the previous project toward industry sustainability and profitability.

Project Approach

Objective 1. Rapid Genetic Progress: Employ new genome scanning technology for strawberry and new software and statistical approaches to accelerate breeding for early yield.

More than 720 seedlings and selections have been been field tested with early yield data and data on other traits were obtained. These have been genome scanned for more than 30,000 usable DNA markers per individual.

FlexQTL software was used to detect important genetic loci contributing to the traits in the first year of data, under the direction of Dr. Sujeet Verma, including larger-effect genetic loci for fruit size and

soluble solids content. Genomic Selection methodologies have been concurrently developed and tested under development by Dr. Luis Osorio and Dr. Salvador Gezan. Bayes B was determined to be the best model for all traits, and a strategy for implementing genomic selection has already been applied for choosing parents for current season crosses.

Objective 2. Field Testing: Test early yielding prototype varieties in grower fields.

In early 2015 we selected and propagated three early yielding genotypes from the UF strawberry breeding program in preparation for the grower trial which was planted on September 25 at a commercial field owned by Sam Astin near Plant City, FL he first harvest occured during the last week of October, and yield data was recorded multiple times weekly at each harvest in units of 1 lb clamshells until the conclusion of the commercial season in March, 2016.

Objective 3. Feasibility: Perform an economic analysis to ensure that the new breeding strategy is optimized for both the breeding program and grower profitability.

For the new genomic selection breeding strategy the genetic gain efficiency was 50% of traditional methods for early yield and up to 75% of traditional methods for other traits. A breeding strategy has been developed for early parent selection to apply in the breeding program based on these results.

For the economic analysis of the grower trial data, one selection was identified that produced higher early yield compared to the commercial standard, and if planted on 100% of industry acreage would increase industry profit by 28%. Unfortunately this selection was a prototype that did not have fruit quality sufficient to commercialize. The selection was used as a parent in multiple crosses to combine its excellent early yield potential with other necessary traits. Ultimately, this shows that the genetic yield potential exists within the UF breeding program to make a large impact in the next few years. A second selection had sufficient fruit quality for commercial release and provided a marginal ~5% improvement in profit due to early yield. This selection will be commercially available during the 2017-18 season and a patent has been applied for under the name 'Florida Beauty'.

Goals and Outcomes Achieved

Expected Outcome 1: The long-term goal is to commercialize new, early-yielding strawberry varieties to boost grower profit. Since it takes 5-7 years from cross to commercialization, we have established an intermediate goal for the 2-year project period: increase the rate of genetic gain for early yield in the UF breeding program using new breeding strategies.

Genetic gain efficiency from the new developed methods was determined to be 40-50% for early yield. Since this is achieved with a reduction of the breeding cycle from 3 to 2 years, we estimate that gain for early yield will increase by approximately 5% over current methods, which is equal to the target set.

Expected Outcome 2: Determine the potential advantage of early-yielding prototypes (advanced selections) for commercial production.

We were very pleased to find that an early yielding prototype yielded 100% greater than the commercial control by the middle of December. A selection with sufficient fruit quality that was commercialized represented a 50% increase over the same period. These numbers far outpaced our expected target of 15% within the project period.

Expected Outcome 3: Ensure that the direction of the breeding program and selection of new varieties are economically feasible.

Because DNA marker costs are now sunk costs due to annual expenditures on objectives outside the scope of this proposal, this means that the new methods do not represent additional marginal cost to the breeding program for genotyping. For new selections, the early yielding prototype yield is estimated to produce an increase of 28% in profit whil the newly released variety 'Florida Beauty' achieves at least a 5% profit increase. This did not reach the target of 15% within the project period, but this should certainly be reached in the next 5 years.

Expected Outcome 4: Communicate research findings to strawberry growers and other industry personnel at the Agritech conference, an annual meeting of the Florida Strawberry Growers Association. This event has a high attendance and is therefore an effective means of distributing the findings.

Research findings have been communicated at one Agritech meeting and one field day, reaching 140 growers and industry personnel, which is greater than the target of 40 strawberry growers.

Beneficiaries

The direct beneficiaries of early yield varieties are Florida strawberry growers, their associated shippers and handlers, and the many support industries that depend on the Florida strawberry industry.

Strawberries are second in total farm gate value for fruit crops in Florida (~$350 million/yr), behind only citrus. The overall economic contribution of the strawberry industry to the Florida economy is estimated at over $1 billion by the Florida Strawberry Growers Association. At present there are over 100 individual strawberry growers making up the 11,000 acre Florida strawberry industry and thousands of individuals directly employed in associated and support industries.

These growers benefitted from the commercial release of 'Florida Beauty' which will be fully commercial during the 2017-18 season. The release and commercial nursery stock availability of this variety was communicated to growers through Agritech, annual Field Days and individual communications with the executive director and board members of the Florida Strawberry Growers Association. Because this variety represents a 5% profit increase due to early yield, the potential impact of this variety, if widely adopted in the next two years, would be a gross profit increase to the industry of $15 million (farm gate value).

For a brief popular description of the new variety see the following link:

http://www.growingproduce.com/fruits/berries/new-florida-strawberry-shaping-up-to-be-a-thing-of-beauty/

Lessons Learned

Thankfully almost all proposed timelines were met. For Objective 2, only 2 early yielding prototypes were tested compared to the expected 3 during the 2015-16 season. However, we were able to repeat this test and include the missing prototype during the 2016-17 season (extending beyond the project period). This, along with the commercialization timeline for 'Florida Beauty' of the 2017-18 season, illustrates the typical delays experienced in outcomes for a large industry like the Florida strawberry industry. Once new early-yielding breeding selections are approved for release by IFAS, the commercialization timeline typically requires 2 additional years for nursery bulk-up of planting stock and gradual increase in adoption by growers. Thus, the urgency of realizing genetic improvement is very real.

Contact Person

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Funding Expended: $200,381.55

Project (27): Connecting Specialty Crop Producers with Consumers

Project Partners:

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Blake Thaxton, Commercial Horticulture Extension Agent UF/IFAS Extension, Santa Rosa County

Ginny Hinton, Family & Consumer Sciences Extension Agent Santa Rosa County

Libbie Johnson, Family & Consumer Sciences Extension Agent Escambia County

Dorothy Lee, Family & Consumer Sciences Extension Agent Escambia County

Matthew Orwat, Horticulture Extension Agent Washington County

Judy Corbus, Family & Consumer Sciences Extension Agent Washington and Holmes County

Marjorie Moore, Family & Consumer Sciences Extension Agent Bay County

Jennifer Bearden, Agriculture Extension Agent, Okaloosa County

Jill Breslawski, Family & Consumer Sciences Extension Agent Okaloosa and Walton County

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Matt Smith, Nutrition Program Assistant & Field Technician, WFREC

Christina Walmer, Farm to School

Andrea Byars, Former Field Technician WFREC

Abby Marshall, Nutrition Program Assistant WFREC

Project Summary

Recent research has shown that >20% of food purchased for in-home consumption is grown locally. However, consumers lack knowledge of production timing and availability. The increased demand for locally grown food has altered marketing channels. Farm-to-school initiatives, the Women, Infants, and Children (WIC) Fruit and Vegetable voucher program, the Farmers' Market Nutritional Program, and demand for fresh vegetables for local restaurants all bode well for FL small farms. However, farmers must identify how their operations can cater to these markets that are not part of traditional distribution channels. New and established small farms are aware of the changing market but are limited by their lack of knowledge of how to access these markets. New farmers have experienced difficulties keeping up with demand for local produce because of lack of adoption of the most productive methods of growing produce.

The UF/IFAS West Florida Research and Education Center (WFREC) and local growers have identified systems for increasing supply and availability of specialty crops in northwest Florida through a previous FDACS grant. Protected culture (greenhouse, shade and high tunnels) was shown to extend the growing season and increase supply and availability of vegetable crops. Despite advances in marketing and production opportunities, challenges currently limit further growth of the specialty crop industry. Challenges include farmers' access to new market channels and maximizing production in each cropping system. New markets (Farm-to-school, WIC, etc.) are emerging at a rapid pace to meet the demand for locally grown food, but farmers have found it difficult to enter new non-traditional markets. Additionally, maximizing use of each cropping system through diversified crop scheduling and management will enhance specialty crop production and increase profits for small farmers.

Previously the UF/IFAS WFREC was awarded a specialty crop block grant (2011-2013) to increase supply of specialty crops and expand markets to meet consumer demand. That project sought to increase supply by exploring use of protected agriculture in the western panhandle. This work built on the previous work by identifying more specific practices within cropping systems as well as promoting use of the FDACS BMP program. Panhandle Fresh Marketing Association (PFMA) was developed by the previous project to help farmers better market their products. PFMA targeted large markets that required more food safety requirements and limited the number of medium and small specialty crop producers who could participate. Since then PFMA successfully moved beyond UF/IFAS WFREC and is currently operating under farmer led leadership. This project is different in that it targeted traditional markets, much like PFMA, and also the new emerging markets by utilizing a "marketing toolkit". This work also focused on the demand side of the specialty crop market by educating consumers and chefs/buyers. The work was carried out by new WFREC personnel and the addition of the Gulf Coast Small Farms and Alternative Enterprises initiative group. Utilizing county extension faculty fostered improved adoption due to local connections each agent has with local producers.

The previous project demonstrated the efficacy of growing in protected structures and the demand for local specialty crops. This project built upon these accomplishments by further connecting producers with emerging and traditional markets and by discovering how high tunnels and shade structures can best be utilized in the western Florida panhandle climate. What the first project did through farmer education and market exploration, this project expanded by creating marketing materials, new networks of buyers and producers, educated consumers, and detailed production information.

Project Approach

Comprehensive Formal Survey

As described in the original proposal a comprehensive formal survey was to be developed for electronic and traditional mail out distribution. The initial survey (sent April 2015) was taken to capture baseline data to determine markets currently utilized by specialty crop producers and which markets they find difficult to enter. It was also to determine the number of current producers using protected structures for maximizing production and the most important informational needs related to those production systems. Two additional surveys were sent December 2015, and December 2016 to measure changes that had happened due to grant related activities.

February 2015

- 42 electronic recipients were sent to email addresses of local farmers via the Qualtrics distribution service.
- 115 U.S. mail recipients, residing within the westernmost five counties of Florida, were sent the survey along with their invitations to the Gulf Coast Small Farms and Alternative Enterprises (GCSF) 2015 Spring Field Day. A pre-paid return envelope was included for return of the survey and the RSVP for the field day.
- 12 electronic responses, 8 U.S. mail responses.
- The survey was also directly distributed to attendees at the GCSFE Field Day, from which we received 8 more responses.
- 28 total respondents.

Findings:

- 58% (16/28) of respondents are currently engaged in protected structure production
    - 13 use high tunnels, while 3 use greenhouses, 2 use shade structures, and another 2 use low tunnels.
- Of those respondents who do not currently engage in protected structure production, 80% (9/12) intend to within the next 3-5 years.
- 52% (15/28) consider themselves predominantly farmer's market growers.
- Half of respondents use conventional growing methods. No respondents are USDA certified Organic, but 38% use organic methods.

December 2015

- Surveys were sent to 78 email addresses of local farmers via the Qualtrics distribution service. This represents more than a doubling of previous electronic recipients.
- 15 electronic responses.

Findings:

- 27% (4/15) of respondents built a protective structure this year, of which most were high tunnel/hoop houses.
- Of those respondents who do not currently engage in protected structure production, most intend to construct a high tunnel/hoop house within the next 3-5 years.

- Survey respondents showed knowledge gains over the past year for all markets (Farmers Market, Wholesale, Direct/On-Farm Sales, Farm to School, Women Infant and Children (WIC), and Direct Restaurant Sales).
- When asked about entering new markets over the past year, 9% (1/15) of respondents entered Farmers Markets for the first time and 9% (1/15) entered Famers' Market Nutrition Program for WIC participants for the first time.

December 2016

- 78 electronic recipients were sent to email addresses of local farmers via the Qualtrics distribution service.
- 115 U.S. mail recipients, residing within the westernmost five counties of Florida, were sent the survey. A pre-paid return envelope was included for return of the survey.
- 10% (19/193) specialty crop producers responded to the survey.

Findings:

- Respondents indicated the following increases in knowledge of marketing to niche specialty crop markets from grant educational events and grant developed materials:
    - Farmers Market – 83% indicated slight increase to strong increase in knowledge
    - Wholesale – 47% indicated slight increase to strong increase in knowledge
    - Direct/On-Farm Sales – 75% indicated slight increase to strong increase in knowledge
    - Farm to School – 19% indicated slight increase to strong increase in knowledge
    - Farmers' Market Nutrition Program – 31% indicated slight increase to strong increase in knowledge
    - Restaurant Sales – 36% indicated slight increase to strong increase in knowledge
- 50% (9/18) indicated entering a new specialty crop market in 2016.
- 31% (6/19) indicated building a protected agriculture structure for production in 2016 and 60% (9/15) indicated wanting to add protected agriculture to their farms in the future.
- 55% (10/18) indicated slight increase to strong increase in knowledge of protected agriculture production.
- 46% (7/15) slight increase to strong increase in knowledge of FDACS BMPs.
- 11% (2/18) indicated enrolling in the FDACS BMP program in 2016, while 27% (5/18) indicated intending to enroll in 2017.

Component 1 Marketing Tools and Nutrition Education

The project aimed to expand marketing opportunities for local specialty crop farmers through marketing education and consumer education. Educational materials were developed to better inform growers of proper planting and harvesting dates and how to enter new markets. Consumer materials aimed to teach which specialty crops can be grown in the region and their availability, and the proper nutrition, preservation, and preparation of locally grown specialty crops.

- "Marketing Toolkit"
    - Materials developed for the "marketing Toolkit" include:
        - Harvest Calendar – A 1 page graphic display of the availability of locally grown specialty crops. Useful to growers as a marketing tool to educate consumers of

availability of locally grown crops. http://wfrec.ifas.ufl.edu/panhandle-produce-pointers/production-calendar/

- Production Calendar – A 1 page graphic display of the appropriate planting date ranges. The fact sheet is useful to beginning and new specialty crop producers. http://wfrec.ifas.ufl.edu/panhandle-produce-pointers/production-calendar/
- Marketing Checklist - 6 full-color Marketing Checklists pamphlets were created and distributed to local farmers. Farmers' Markets, Farm to School, Wholesale, Farms' Market Nutrition Program (WIC), Restaurants, and Roadside Stands. These fact sheets give growers the basic steps that need to be taken to enter each market. Along with the professionally printed versions that are in each of the seven most western counties in the Florida panhandle, there are printable PDF versions available at the website. http://wfrec.ifas.ufl.edu/panhandle-produce-pointers/marketing-checklists/

- Gulf Coast Farm to Table Events ("Chef/Buyer Events")
  - Three events were held to educate chefs and other buyers of local produce how to best prepare local produce and educate the attendees of the capabilities of local agriculture. Growers were also invited to attend and network with the buyers. At each event the attendees were given the Harvest Calendar and the Panhandle Produce Pointer Fact sheets. The events were not as well attended as anticipated. Although there would be much interest in the event which is consistent with the strong interest in local foods, many of the restaurateurs and other buyers would not attend the event. Much effort was given to advertise with very little success.
    - May 23, 2016 at the Escambia County 4H Center, Cantonment, FL – 37 Participants
    - September 2, 2016 at the South Walton Area Chamber of Commerce, Santa Rosa Beach, FL – 11 Participants
    - October 24, 2016 at the West Florida Research and Educational Center, Jay, FL. – 24 Participants.

- Panhandle Produce Pointers
  - Fact Sheets
    - 12 Panhandle Pointers One-page info sheets – bell peppers, corn, cucumber, eggplant, okra, southern peas, snap beans, squash, tomatoes, blueberries, melons, and strawberries. http://wfrec.ifas.ufl.edu/panhandle-produce-pointers/produce-pointers-sheets/
    - Sheets have been distributed at multiple events throughout the seven counties including canning classes, the Chef/Buyer Events, the Pensacola State College Festival of Flowers, Each Chef/Buyer networking event, by request on the website, etc.
  - Signage & Recipe Tear Cards
    - Four 22''x28'' poster versions of the Greens, Blueberry, Squash, and Satsuma Panhandle Produce Pointers fact sheet were designed to be displayed at local specialty crop markets.

        - Recipe tear cards were attached to the four 22”x28” posters to direct consumers to the website for more information of local produce nutrition, preparation, and preservation.
    - **Panhandle Produce Pointers Website –** http://www.PanhandleProducePointers.com/
        - The website contains content for consumer education of local specialty crops:
            - 12 Panhandle Pointers One-page info sheets and the Harvest Calendar – to educate consumers of availability of locally grown crops.
            - Farmers Markets link that directs users to the Fresh From Florida’s list of community farmer’s markets.
        - The website consists of the following content for specialty crop growers marketing and production education:
            - Marketing Checklists
            - Production Calendar
            - Variety Testing results

Component 2 Maximizing Production Practices

Trials

- Summary: Trials were conducted in the high tunnel system to better inform growers and potential growers of better crop selection. The work done through this project has shown many good crop options for local fresh sales production in a high tunnel including tomatoes, cucumbers, kale, Swiss chard, and carrot. Along with the work done in the high tunnel, a variety demonstration was conducted for the emerging Florida crop, Hops, in the shade system utilizing a new production technique. Also, several of the trials and other demonstrations were used to showcase FDACS BMPs at various events.

    - 2015 High Tunnel Beit Alpha Cucumber Variety Study
        - Six varieties of Beit Alpha cucumbers (Socrates, Jawell, Diva, Amiga, Perseus, and Manar) were grown in a high tunnel system on plasticulture with fertigation.
        - Full trial report: http://wfrec.ifas.ufl.edu/media/wfrecifasufledu/docs/pdf/2015-High-Tunnel-Beit-Alpha-Cucumber-Variety-Study.pdf

    - 2015 High Tunnel Hybrid Tomato Variety Study using Organic Production Methods
        - Six varieties of hybrid tomatoes (Dixie Red, Red Morning, BHN 589, Early Girl, Mountain Fresh Plus, and Bella Rosa) were grown in a high tunnel system using organic methods.
        - Full trial report: http://wfrec.ifas.ufl.edu/media/wfrecifasufledu/docs/pdf/High-Tunnel-Organic-Hybrid-Tomato-Variety-Study.pdf

    - 2015 Seedless Watermelon variety trial and BMP demonstration
        - Ten seedless watermelon varieties were grown in a field trial in a plasticulture production system. The trial was used at the 2015 spring field day to showcase nutrient and irrigation monitoring techniques as a BMP.

        - Full trial report: http://wfrec.ifas.ufl.edu/media/wfrecifasufledu/docs/pdf/Watermelon-Variety-Study.pdf

    - 2015 High Tunnel Heirloom Tomato variety trial
        - Five varieties of heirloom tomatoes (Striped German, Black Krim, Cherokee Purple, Great White, and German Johnson) were grown in a high tunnel system.
        - Full trial report: http://wfrec.ifas.ufl.edu/media/wfrecifasufledu/docs/pdf/Heirloom-Tomatoes-Grown-in-a-High-Tunnel-System-using-Conventional-Practices.pdf

    - 2016 High Tunnel and Field Strawberry Trials
        - An experiment in the field and the high tunnel was conducted with six varieties in each trial (Camarosa, Chandler, Festival, Sensation, Radience, and Winterstar).
        - Full trial report: http://wfrec.ifas.ufl.edu/media/wfrecifasufledu/docs/pdf/Strawberry-variety-trails-Report.pdf

    - 2016 Shade Tunnel Hops production variety demonstration
        - A demonstration of two varieties of hops (Neo1 and Centennial) grown in a shade tunnel system on an innovative low trellis system.
        - Full Trial Report: http://santarosa.ifas.ufl.edu/wp-content/uploads/2017/02/Hops-Report.pdf

    - 2016 High tunnel high value greens variety trials
        - Five varieties of Kale (Winterbor, Siberian, Red Russian, Toscano, and Red Russian) were grown in a high tunnel no-till system for trial.
        - Three varieties of Swiss chard (Fordhook Giant, Bright Yellow, and Ruby Red) were grown in a high tunnel no-till system for trial.
        - The trial is ongoing and will have a full report drafted summer 2017.
    - 2016 High Tunnel carrot variety trial
        - Six varieties of carrots (Apache, Mokum, Napoli, Sugar Snax 54, Purple 68, and Maverick) were grown in a high tunnel system for trial.
        - The trial is ongoing and will have a full report drafted summer 2017.

    - 2016 Fall Tomato BMP demonstration
        - 4 tomato varieties (La Roma III, BHN 871, BHN 876, and Tastee-Lee) were planted in the field (30’ x 80’ plot) on plasticulture and managed as a conventional system.
        - The demonstration was utilized at the 2016 fall field day and the Gulf Coast Farm to Table Event to show potential of double cropping on plasticulture, petiole sap testing, moisture meter use for irrigation, and IPM scouting techniques.

Field Days and Workshops

- Summary: Five field days and one workshop was held to showcase the trials and marketing materials developed from the project.

    - Organic Vegetable Production Series
        - Educational seminars included topics of organic certification, cover crops, fertilization, integrated pest management, disease management, and production systems (including high tunnels).
        - 23 growers participated in the series and there was a 54% increase in knowledge of high tunnel cropping systems (before: 23%, After: 77%, an increase of 54%)

    - 2015 Spring Gulf Coast Small Farms Field Day
        - 39 attendees were given a tour of the high tunnels and watermelon field and listened to presentations on organic high tunnel tomato production, high tunnel cucumber production, petiole sap testing and soil moisture meters, and watermelon disease and their control.
        - Field Day pre-evaluations provided baseline data for producers' current knowledge of intensive protected agriculture and FDACS BMPS.
            - Of the 39 persons, 27 evaluations were received.
            - Of the 5 categories participants started the day least knowledgeable in watermelon disease and control and most knowledgeable in organic high tunnel tomato production. Participants finished the day least knowledgeable in vegetable disease diagnostics and remained most knowledgeable in tomatoes.

    - 2015 Gulf Coast Small Farms and Alternative Enterprises Fall Field Day
        - Focused on high tunnel production of organically produced hybrid tomato varieties and conventionally produced heirloom tomato varieties.
        - Field day pre-evaluations provided baseline data for producers' current knowledge of high tunnel tomato agriculture.
            - Of the 17 persons, 9 evaluations were received.
            - Of the four categories participants started the day least knowledgeable in high tunnel tomato economics and most knowledgeable in high tunnel tomato production. Participants finished the day least knowledgeable in high tunnel tomato production and covered crops.

    - Strawberry Field Day
        - 13 attendees were given a tour of the strawberry variety trials in the high tunnel and in the field and listened to presentations on strawberry production, proactive management of spring/summer crops, selling crops through healthy food preparation, and best management practices for vegetables farms.

        - Pre-evaluations provided baseline data for producers' current knowledge of intensive protected agriculture and FDACS BMPS.
            - Of the 13 persons 10 evaluations were received.
            - Of the 5 categories, participants started the day least knowledgeable in strawberry disease management, and most knowledgeable in selling to local markets. Participants finished the day least knowledgeable in a tie between high tunnel strawberry production, strawberry disease, and using nutrition to market agricultural products and were most knowledgeable about the FDACS BMP Program.

    - WFREC Extension Farm Field Day
        - The UF/IFAS Gulf Coast Small Farms Team participated in the 2016 WFREC Extension Farm Field Day on August 25, 2016.
        - 97 Attendees were given a tour of the WFREC including the trials by the GCSF team highlighting protected agriculture. The GCSF team also set up a booth for attendees to see marketing checklists, harvest calendar posters, trial reports, etc.

    - 2016 Fall Gulf Coast Small Farms Field Day
        - GCSF hosted the 2016 Fall Gulf Coast Small Farms Field Day on November 17, 2016.
        - 26 attendees were given a tour of the high tunnels and tomato field and listened to presentations on Using Protected Agriculture and Hydroponics to meet demand for high value specialty crops, FDACS BMP program, and marketing to niche markets. Marketing checklists and trial reports were disseminated to the attendees.
        - Pre-evaluations provided baseline data for producers' current knowledge of intensive protected agriculture and FDACS BMPS.
            - Of the 26 persons, 16 evaluations were received.
            - Of the 6 categories, participants started the day least knowledgeable in a tie between nutrient/irrigation management and water protection/backflow prevention and most knowledgeable in integrated pest management. Participants finished the day least knowledgeable in protected agriculture and hydroponics and were most knowledgeable about the integrated pest management.

January 2017

During the final month of the project, the project funded employees had the following tasks:

- Specialty Crop Technician
    - Finalized research projects with carrots and specialty greens.
    - Finalized previous research project reports and posted to the website.
- Nutrition/Marketing Program Assistant
    - Collected information from PPP website and survey.
    - Worked on project final report.

Goals and Outcomes Achieved

Component 1 – Marketing Tools and Nutrition Education

- Goal: Increase specialty crop producers' knowledge of new and emerging markets and the requirements of selling to them.
  Target: 200 small farmers will increase their knowledge of how to enter new markets.
  Outcome Achieved: 78% (63/80) of specialty crop producers who attended educational events or responded to surveys indicated having gained knowledge of marketing to new specialty crop markets.

- Goal: Producers will begin to sell in a new or emerging markets.
  Target: Of the 200 producers, 20% (40 producers) will begin to sell in a newly acquired market.
  Outcome Achieved: 32 specialty crop producers who attended grant educational events or responded to surveys indicated having begun to sell to a new market.

- Goal: Increase the knowledge of chefs/buyers from various markets on the capabilities of growing local produce.
  Target: 75 chefs/buyers from various markets will increase their knowledge regarding the selection and availability of local produce.
  Outcome Achieved: 100% (12/12) of the chef and buyers of fresh produce who attended the grant educational events indicated gaining knowledge regarding the selection, availability, and production capabilities of fresh locally grown produce.

- Goal: Chefs/buyers will make informed decisions on which local products to offer and will make purchases from local producers.
- Target: Of the 75 chef/buyers, 15% (12) will make informed decisions on which local products to offer on their menu and will make purchases based from local producers.
  Outcome Achieved: 10 chefs or buyers of fresh produce indicated they will begin to make efforts to purchase locally grown produce to utilize at their establishments.

- Goal: Increase consumers' knowledge of locally grown specialty crops – their nutritional value, preservation methods, food safety, and preparation.
  Target: 2000 hits/year on educational website.
  Target: 40% of survey participants increased their knowledge for nutrition, preservation, and preparation of crops.
  Outcome Achieved: Because of setbacks in website development (discussed in more detail in the Lessons Learned section) the website went live in 2016 and web hits tracked in August 2016. Since then 619 web hits have been recorded with 63 responses to the web survey. 85% (54/63) of respondents indicated increasing their knowledge of nutrition, preservation, and preparation of locally grown specialty crops because of the Panhandle Produce Pointers materials. 80% (51/63) indicated they plan to use the information learned from Panhandle Produce Pointers.

Component 2 – Maximizing Production Practices

- Goal: Increase producer knowledge of intensive specialty crop production under protected structures.
  Target: 200 producers will increase knowledge of intensive vegetable production under protected structures.
  Outcome Achieved: 80% (154/192) of specialty crop producers who participated in field days, educational events, or surveys indicated increasing knowledge of cropping systems in protected agriculture.

- Goal: Increase number of producers engaged in specialty crop production in high tunnels and shade house systems.
  Target: A 5% increase each year in the adoption of new cropping systems.
- Outcome Achieved: 42% (11/26) of producers at field days indicated that they planned to add protected agriculture to their farms after having attended a grant project educational event. According to the December 2015 survey, 27% (4/15) of respondents built a protective structure the previous year, of which most were high tunnel/hoop houses. According to the December 2016 survey, 31% (6/19) indicated building a protected agriculture structure for production in 2016 and 60% (9/15) indicated wanting to add protected agriculture to their farms in the future. Baseline data was very difficult to achieve but increase every year in structures built was very encouraging.

- Goal: Increase producer knowledge of basic production practices and FDACS BMPs.
- Target: 200 producers will increase knowledge of modern production practices and FDACS BMPs.
  Outcome Achieved: 71% (55/77) of the producers who attended educational events featuring the FDACS BMP program and specific BMPs for different specialty cropping systems or attendees who responded to surveys indicated a knowledge gain of modern production practices and FDACS BMPs.

- Goal: Increase the number of producers adopted of FDACS BMPs program.
- Target: A 15% increase each year in the adoption of FDACS BMPs.
  Outcome Achieved:

  The following chart shows the FDACS enrollment at the start of the project January 1, 2015 through January 1, 2017 in the 7 counties a part of the project.

County	Acreage Enrolled 1/1/15	Acreage Enrolled 1/1/16	Acreage Enrolled 1/1/17
Escambia	0	294.18 ↑	7,493.42 ↑
Santa Rosa	101	9,269.76↑	17,577.88 ↑
Okaloosa	3.14	232.4 ↑	5,435.78 ↑
Walton	1,351.43	2481.51 ↑	5,940.53 ↑
Washington	1,820.07	2,456.2 ↑	6,964.01 ↑
Holmes	18,184.3	2,788.72 ↓*	22,465.29 ↑
Bay	0	0*	1,391.96 ↑

Every county, outside of Holmes and Bay in 2016, achieved an increase of 15% or more of acreage enrolled in the FDACS BMP program. Also, at field days when FDACS BMPs were discussed, 17/26 attendees of events indicated that they planned on enrolling in the FDACS BMP programs based on the knowledge they gained.

Summary:

In the original proposal the team set ambitious goals based on past events conducted on similar topics. Attendance was down for many of the events but as shown, the results were very good in terms of knowledge gained. Although the team did not get near its goal of reaching 200 producers on marketing topics, 32 have taken steps to sell at new markets which can be considered a great success. Also, chefs and buyers, a new audience for Extension, were very difficult to get to attend the events but 10 indicated beginning to make efforts to buy local fresh produce. The FDACS enrollment has been a point of great success with most counties growing well beyond the 15% increase indicated in the goals. Although some of the goals were not reached in this report, much of the work will continue through the website and the marketing materials developed that have been placed in each of the seven counties.

Beneficiaries

The project aimed to benefit both new and established specialty crop growers in the seven most western counties of the panhandle of Florida. Project field days and production workshops attracted 241 attendees. These attendees and others were informed about project events, surveys, and results by email (79 email addresses) and mail (127 mailing addresses). Project surveys yielded best responses from Community Farmers' Market specialty crop producers (46%), while Commercial Growers (28%) and Market Gardeners (26%) also had favorable responses. Growers from outside the target area were also exposed to the project by the High Tunnel Tomato trial using organic methods was presented on a poster at the 2016 Southeast Regional Fruit and Vegetable Conference (attendance 3,500) and presented through a 45 minute seminar at the 2016 Mobile (AL) Fruit and Vegetable Growers Association meeting (attendance 35). A booth was set up at the 2016 Alabama Fruit and Vegetable Growers Conference in Clanton (AL) showcasing the marketing materials and the trial reports to the 214 in attendance. At the same meeting project personnel were invited to present in the educational session on the work that has been done for the project with high tunnel production, there were 15 in attendance.

Along with the intended specialty crop producer's audience, other audiences benefited as well including chef and buyers of local producer's fruits and vegetables and consumers who came into contact with the Panhandle Produce Pointers campaign. For example many school children and staff of Escambia County Schools were exposed to the "Panhandle Produce: In Season" poster with all 48 schools having received a poster to post in their cafeteria. Also, the Panhandle Produce Pointers poster "A frame" displays with tear off recipes were placed in produce buying location throughout the 7 most western counties. Countless numbers of people have seen these and were likely encouraged to purchase local produce and prepare it correctly.

As stated in the outcomes section, there were some very positive developments for local specialty crop growers that came from this project such as the following:

- 32 specialty crop producers who attended project educational events or responded to surveys indicated having begun to sell to a new market.
- 10 chefs or buyers of fresh produce indicated they will begin to make efforts to purchase locally grown produce to utilize at their establishments.
- 10 small fresh produce farmers built a protected agriculture structure for production after attending project events.

Lessons Learned

- Producer Survey
    - The Spring Producer Survey was intended to be distributed by the end of February 2015, but this was delayed to April 30, 2015. As this project required the use of human subjects, it was necessary for the survey, survey email text, and informed consent document to be submitted to and approved by the University of Florida Institutional Review Board. These documents were submitted on February 26, 2015. Approval was granted March 16, 2015. Difficulties with acquiring email addresses further delayed us until April 30, 2015 to launch the survey online. Paper copies of the survey were mailed to recipients who did not have or use email.

Component 1

- Panhandle Producers Pointers Website
    - The switching of the University of Florida to a new web hosting company caused the complete removal of all content from the website.
    - Following the transition, issues regarding the Marketing/Nutrition Assistant's ability to build or edit the web pages within the web developer resulted in considerable delays. The website has now been launched with all Panhandle Produce Pointers sheets, Harvest Calendar, and the Marketing Checklists.
- Chef/Buyer Events
    - Attendance was much lower at these events than anticipated in the planning of the project. This clientele group is a new audience for UF/IFAS Extension and although response about the event s was very favorable the people who had committed to attend consistently would not show up for the events. Although multiple efforts and strategies for advertisement were tried, we had very little success of attracting a large number of buyers or chefs.

Component 2

- Hot set tomato variety demonstration
    - Due to high heat and other pressures the plants did not grow normally and were very stunted. There was some fruit production, though harvest was minimal.
    - On September 25, 2015 we called this demonstration a failure.
- High tunnel heirloom tomato variety study
    - The tomato selected to act as the control, the hybrid variety 'Panzer' failed during the transplant production phase. The variety was removed from the study.
- High Tunnel Organic Tomato variety study: Grafted and non-grafted
    - About 80% of the plants did not grow and remained at transplant size, with no respect of variety or if the plant was grafted. Tissue samples were sent to the University of Florida to evaluate for disease but none was identified. The lab sent back a recommendation that the reason may have been residual herbicide in the high tunnel from previous use.

    - The trial was terminated with no data taken. The report on this experiment will focus on the irrigation method, which was very economical and successful. A publication is being developed for high tunnel growers to use this irrigation method.
- Shade tunnel hops production variety demonstration
    - Considerable soil erosion at the beginning of the season contributed to channeling of water and nutrients away from many plants leading to growth stunting and significantly limited yields. The addition of cypress mulch had a rapid positive effect on plant growth. However, this was not enough of offset stunting of many plants. Year 2 production will need to be monitored closely on these plants.
    - A suspected fungal infection was identified at the end of August and diagnosed by UF plant pathologists as Anthracnose (*Colletotrichum* spp.). The infection spread rapidly, though as its symptoms are similar to normal bine dieback after harvesting it is difficult to determine the exact number of plants affected. Pathologists advise stringent winter cleanup of the hop yard to minimize spring re-emergence.

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Additional information:

See the Draft Impact Report at: http://santarosa.ifas.ufl.edu/wp-content/uploads/2017/02/17_Connect_Specialty_Crop_Prod_Consumers_Report.pdf

Project (28): Florida Flower Trials – FNGLA's Floriculture Field Days and Performance Trials

Contact Person

Project Partners

The Florida Nursery, Growers and Landscape Association served as the primary organization implementing the project. Harry P. Leu Gardens, UF/IFAS Orange County Convention Center and Walt Disney World Nursery.

All locations are located in Orlando (USDA zone 9b). There are 68 varieties of annuals and perennials being
tested to see how they perform in the heat and humidity of Central Florida's climate. There are both sun and
shade options with the trial.

Brad's Bedding Plants; Knox Nursery and Speedling all participating in growing the new varieties into
4"size plants and ready to be transplanted into the trial gardens.
• Brad's Bedding Plants grew out new varieties seen in the Trial Gardens from BallFlora Plant, Selecta, Greenfuse, and Sakata varieities.
• Knox Nursery grew out new varieties seen in the Trial Gardens from PanAmerican Seed varieties
• Speedling grew out new varieties seen in the Trial Gardens from Hem Genetics and Benary varieties
• Caladiums varieties from Bates Sons and Daughters, University of Florida and Classic Caladiums were grown independently.
• Suntory varieties were grown by SunFire Nurseries.
• Ruellia varieites were grown by Riverview Flower Farms

Project Summary

Florida is the nation's second largest floriculture crops producing state with farm gate cash receipts of $1.3 billion in foliage, potted flowering plants, annuals, bedding plants and floriculture propagated materials according to the USDA-NASS 2010 report. The need for research on new varieties and to understand their marketability to the end-consumer is critical to the continued success of the Floriculture industry in Florida. The Florida Nursery, Growers and Landscape Association continues to partner with the University of Florida and industry breeders from across the country to conduct research on the feasibility of planting, cultivating, and growing annual crops in a Central Florida area, the results of which can be shared with many growers throughout the state and showcased to the industry's end-user such as garden centers and landscape professionals.

A Spring/Summer plant palette of new varieties are selected by industry breeders. The performance trials are the means by which the industry gathers the newest research information needed to see whether these varieties will survive and thrive in this specific temperate zone. Florida has a unique environment with its heat and humidity. It requires continued year-in and year-out breeder testing for characteristics such as the strength and durability of the plants.

Three test sites have been established and will offer different growing environments – Walt Disney World's EPCOT; Harry P. Leu Gardens; and UF.

Industry breeders' goal is to continue to develop a stronger variety of annual crops. Whether they are breeding for disease resistance, more brilliant colors, or larger blooms, there is a need to have a venue to conduct research on new varieties and then a forum to expose a greater number of industry end-users such as landscape and garden center professionals to what will survive and thrive in specific conditions. Not only does this proposal provide the research element needed to know what should be grown and utilized in Florida but it also provides an educational venue to tell the story of how our industry tests and trials new varieties.

This project continues to be a very timely and important venue for the Floriculture Industry. The three trial sites have been designed and developed to expose end-users to new innovations in floriculture crops. A segment of the trials are planted in conjunction with Epcot's International Flower and Garden Festival where over 2.5 million people visit Epcot each year to see cutting-edge varieties of flowering annuals. Its direct and pass-along impacts on residential living will fill in the information gap with Florida's homeowners and gardening consumers. Harry P. Leu Gardens, second trial site is an amazing 50-acre botanical oasis just minutes from downtown Orlando. All areas will be the equivalent to 132 sq ft featuring six varieties but will not be designed in exact square plots which will allow landscape professionals to see how colors and textures can add inspiration to their job sites. University of Florida Extension Services is the third trial location and offers a special micro-climate which is consistently 5 degrees cooler than the surrounding areas! It is full sun. There is potential to expand into the football-shaped area as shown in the picture to the right. Container options would also be available. All areas will be equivalent to 132 sq ft featuring six varieties but will not be square plots so that these efforts would showcase combinations ideas for landscape professionals.

Project Approach

Work Plan:
August 2014 - Deadline for commitment and payment from Breeders – Breeders will be asked to sign a commitment form to participate in the trials. Breeders will then be sent invoices for a per-bed cost or cost of a single entry will be in the ground. October 2014 - Seeds to Contracted growers to sow and grow out
December 2014 - Develop landscape plan, educational components, volunteer guidelines FNGLA staff/WDW staff January 2015 - Cuttings to contracted grower. March 2015 - Coordination of the installation of all three trial gardens. April 2015 - Actual installation. May 2015 - Educational program.

An industry one-day educational program was established to highlights the research and evaluations from the three trial sites which creates a platform for breeder companies to share with growers and landscape professionals the key information about new floriculture varieties in return increasing the amount use of the varieties in the current market. See the full attached schedule for more details. Link below is the full gallery of conference pictures
https://picasaweb.google.com/112578394231502451597/FNGLASFloricultureFieldDays2015?feat=flashalbum#6149119110578694722

Increase awareness of new floriculture varieties to the industry end-consumer by producing an electronic flipbook of all of the new varieties also took place and was ready to be presented at the conference in May. This flipbook was also be used in a hard copy format and produced for all attendees of the one-day
educational program. http://issuu.com/fngla/docs/2015planttrialbooklr Since April, there have been 2007 impression and 176 reads. The average time spent on the book is 3:59 minutes. One of the goals was to broaden the reach of the educational resources by creating a mobile/video program of the one-day educational program that could be in turn offered to all FNGLA chapter members during their monthly chapter meetings. A presentation was developed that can be used to highlight the results of the trials. Arrangement are being made to visit Chapter's to talk about the new varieties in the 2015 trials and promote 2016 program. Based on the grant proposal, success would be measured by increasing attendance by 25% or reaching over 200 attendees for the on-site program. Attendance was only 111 so we fell short of our goal.

Goals and Outcomes Achieved

Goal #1 - Establish three strong and efficient test sites offering different growing environments so that national breeders can participate in a non-biased evaluations of their new variety releases and pass that research information down to Florida's Floriculture Industry.

All locations are located in Orlando (USDA zone 9b). There are 68 varieties of annuals and perennials being
tested to see how they perform in the heat and humidity of Central Florida's climate. There are both sun and
shade options with the trial.

See attached descriptions of the trial sites:
Walt Disney World Trial Site: This site offers full sun options but the varieties are planted in raised beds with a
different soil mix. By moving backstage to Disney's newly-renovated area at the Walt Disney World Nursery, the
trials can remain in the raised beds longer than previous years offering a better trial environment; receive more
team attention; and, the results will be added to the list of varieties being evaluated and included in the National Plant Trial Database. Disney's Horticulture team is also showcasing the trial process during the Epcot® International Flower & Garden Festival.
• The majority of the beds were planted in early April and will remain in until mid-June.
• Soil mix is 50% peat, 10% ¾ Pine bark, and 40% Sand
• Full-time cast member will maintain the gardens
• Evaluations will be taken three times at this site.

Harry P. Leu Garden Trial Site This garden is the trial's shade option. The location serves as a strong outlet to
the public. During the months of April through August, approx. 50,000 people come to visit Harry P. Leu Gardens
and have the opportunity to visit the trials.
• The majority of the gardens were planted the week of March 30 and will remain in the ground until mid-June.
• Soil mix used at the site is Fafard 3B which consists of 48%Peat, 10% perlite, 11% vermiculite, 31% bark.
• Valencia Community College student oversaw the gardens to keep at its best for approximately 10 weeks for 10 hours a week. Weeding and minimal plant maintenance were done.
• Evaluations will take place three times at the site.

University of Florida/IFAS - Orange County Extension Services Trial Site: University of Florida's Orange
County Cooperative Extension Service was the newest site to develop. Area was cleared, soil added and irrigation system put in place. It offered a more organized format with varieties placed in plots so industry members can review the performance of each variety separately. This location serves as a strong resource for
local landscape professionals.

This location offers a special micro-climate consistently 5 degrees cooler than the surrounding areas! It is full sun. This organized format has varieties placed in plots in the ground so industry members can view the
performance of each variety separately. This location serves as a strong resource for local landscape professionals.

- The majority of the gardens were planted the week of March 30 and will remain in the ground until mid-June.
- Soil mix used at the site is Fafard 3B which consists of 48%Peat, 10% perlite, 11% vermiculite, 31% bark.
- Valencia Community College student oversee the gardens to keep at its best for approximately 10 weeks
for 10 hours a week. Weeding and minimal plant maintenance is done.
- Evaluations will take place three times at the site.

Goal #2 - Establish an industry one-day educational program that highlights the research and evaluations from the three trial sites which creates a platform for breeder companies to share with growers and landscape professionals the key information about new floriculture varieties in return increasing the amount use of the varieties in the current market. Based on the grant proposal, success would be measured by increasing attendance by 25% or reaching over 200 attendees for the on-site program. Attendance was only 111 so we fell short of our goal.

Goal #3 - Broaden the reach of the educational resources by creating a mobile/video program of the one-day educational program that could be in turn offered to all FNGLA chapter members during their monthly chapter meetings. A presentation was developed that can be used to highlight the results of the trials. Arrangement are being made to visit Chapter's to talk about the new varieties in the 2015 trials and promote 2016 program.

Goal #4 - Increase awareness of new floriculture varieties to the industry end-consumer by producing an electronic flipbook of all of the new varieties. This flipbook was also be used in a hard copy format and produced for all attendees of the one-day educational program.
http://issuu.com/fngla/docs/2015planttrialbooklr

Beneficiaries

The intended beneficiaries of this project are industry consumers defined as floriculture production nurseries, landscape contracting firms, landscape maintenance companies, and retail garden centers. It will also expose new varieties to Walt Disney World park guests who are the ultimate end-consumers. Staging this event at public gardens such as Epcot and Harry P. Leu Gardens allows the industry to identify consumer preferences in color, texture and preferable attributes of new varieties in 2015 and any such changes in consumer preference in 2014. The conference will attract 250 of the industry's leading business owners and managers together for the educational component. Having the program during the Festival will expose 2.5 million end-consumers to future floriculture market releases.

Florida is the nation's second largest floriculture crops producing state with farm gate cash receipts of $1.3 billion in foliage, potted flowering plants, annuals, bedding plants and floriculture propagated

materials. The educational program that serves at an opportunity to showcase the new varieties has the potential to reach 250 people but its impact will be felt by the entire Floriculture Industry in Florida.

Florida Flower Trials are the means by which the industry gathers the newest research needed to see whether the new unique varieties bred each year will survive and thrive in this specific temperate zone. Florida is a unique environment with its heat and humidity. It requires continued year-in and year-out breeder testing and development of the strength and durability of of the plants that can be made available to Florida's end-consumer.

From a consumer standpoint, the exposure to brand new varieties will increase awareness and provide consumers much desired information on the benefits and values that nursery products bring to their home environments. It also continues to build a recognized presence with Florida's gardening consumers and positions Florida nursery and landscape industry professionals as the recognized authorities and experts. Homeowners and general consumers crave details on edible gardening, gardening for enjoyment, and gardening for home improvement—and we seek to provide answers and guidance.

Continued education will be the key in strengthening business growth through awareness of the potential risks to professionals from production, financial and marketing standpoints. Educating specific segments of the nursery industry will: (1) ensure a more cohesive industry and a greater understanding of business risks and liabilities; (2) offer leadership training skills to build stronger business relationships; and, (3) provide innovative ways to market products and services. All areas will build a stronger business infrastructure to help safeguard against risks including pest and disease risks.

Lessons Learned

No delays in the activities took place but it was listed that a consumer survey would take place at
EPCOT during the festival and did not happen. Due to the fact that the trial gardens were relocated
backstage stage, there was not a venue to conduct the surveys. This decision was made for the benefit of breeders and sustainability of the trial gardens. The development of a permanent trial site
backstage allowed the trial gardens to be left in the ground through a full life-cycle and evaluated for
their performance. There was a substantial cost saving for future programs because the 2013 and
2014 trial site at EPCOT has to be retrofitted every year. The sod has to be striped, soil added and it
has to be planted during non-park hours which caused an increase in labor cost.

This is an event that FNGLA would like to continue to plan on an annual basis. Over the past five
years, FNGLA has worked hard to establish a strong rapport with industry breeders and has built the
level of confidence with companies introducing the new varieties to Florida. We have increased awareness of these varieties to industry users and continued to strengthen the Floriculture industry
from behind the scenes.

We are working to try and establish a better online system for evaluating the trials. We have changed

our name for the 2016 trials to Florida Flower Trials and continue to look for new interest from breeders
to participate.

Overall Progress and Funding Expended

The project is 100% complete, with $59,218.57 expended.

Project (29): Temperature Management for Quality and Safe Florida Blueberries and Peaches

Project Partners: Florida Specialty Crop Foundation (Maitland Florida)

University of Florida/IFAS: Horticultural Sciences Department, Food Science & Human Nutrition Department (Gainesville, Florida), and Gulf Coast Research & Education Center (Balm, Florida)

Project Summary

Project duration: January 2015-December 2016 plus 6-month no-cost extension until July 2017.

The continued success of Florida blueberry and peach grower/shippers has led to significant increases in the acreage of these specialty crops around the state. Blueberry acreage has doubled in the past 8 years to 4,500 acres with a farm-gate value of $62 million (USDA/NASS, 2013), while peach acreage has increased over 200% in the past 5 years to over 1,200 acres and approximately 300 additional acres coming into production in 2014 (Olmstead, 2014). These crops fill a critical supply gap from March to May, between the seasons of major producers Chile and Georgia/North Carolina, and command high wholesale prices: blueberry at $3.63/pound (Williamson et al., 2012) and peach at $1.25/pound. Other drivers for increased production include the availability of new blueberry and peach cultivars from the UF/IFAS breeding programs that are firmer, more flavorful and better adapted to Florida's varied microclimates; also citrus growers have begun to trial these new fruit crops. For best flavor blueberries must be picked ripe and peach growers have elected to pick at advanced maturity ("tree-ripe"). Thus, both fruits have higher quality but are also more susceptible to softening, mechanical damage and decay. To continue making market gains, blueberry and peach grower-shippers will be tempted to harvest their crops at a less advanced ripeness in order to keep losses at a minimum – but at the cost of lower culinary quality.

Proper temperature management has been shown to be critical to maintain postharvest fruit quality (Kader, 2003); however, current cooling procedures used by blueberry and peach growers often result in cooling delays up to 24 hours, compromising potential quality. Florida blueberries are typically cooled day of harvest to an intermediate temperature, held overnight then packed unwashed, and forced-air cooled for approximately one hour to final storage temperature of 34-35 degrees F. While this practice would seem to be counterproductive to fruit quality, no studies have actually been conducted to determine final effects. Peaches should be cooled to 43-45F for in-state markets or to 34-37F for distant buyers. Peaches are currently picked, packed and placed in a cold room the day of harvest, but this form of cooling, room cooling, is the slowest method and requires 20 or more hours for fruit to reach optimal temperature. Previous studies by Nunes et al. (1995) showed a delay to cooling of only 6 hours was

sufficient to noticeably reduce strawberry fruit quality after 7 days of storage; our preliminary data indicate that blueberries are equally sensitive to delays to cooling. Tree-ripe peaches are already undergoing rapid, climacteric ripening when they are harvested, which makes them very perishable and necessitates excellent temperature management for long distance marketing to be successful. In addition to ripening, the longer the delay to cooling, the more moisture blueberry and peach fruit lose and the more sensitive they are to bruising.

Thus, the need exists to investigate the impact of cooling practices on postharvest quality and shelf life of blueberry and peach and then compare them with fruit cooled with fewer delays. Blueberries are not washed with water during current packing operations due to potential for promoting decay during subsequent shipping. However, use of sanitized water did not enhance decay during our previous tests hydrocooling strawberries. When strawberries inoculated with Salmonella were hydrocooled in sanitized water, survival on both agitated and non-agitated berries was significantly reduced compared with those forced-air cooled and were close to enumerable levels (1.5 CFU/strawberry) by day 1. We feel there is the same potential to hydrocool blueberries packed in clamshells in less than 5 minutes and peaches in plastic lugs in less than 20 minutes.

Florida blueberries and peaches have the potential to have far better quality than anything else on the market during the Florida harvest seasons. Increased production and demand is leading grower-shippers to explore ever more distant markets. With increased success in expanding acreage and markets comes the need for our growers to expand packing and cooling facilities. They currently lack essential decision-making information to assist in the upgrading of these facilities and the implementation of improved handling procedures. This project proposes to address both of these needs. Now is the time to capitalize on our state's growing reputation for producing high-quality blueberries and peaches by increasing our grower/shippers' capability to consistently ship high-quality fruit to new, more distant markets.

This project is not a continuation of our previous SCBGP grant, but rather has evolved from the results of it. ("Development of an Integrated System to Reduce Harvest Costs, and to Rinse, Sanitize and Cool Fresh-Market Strawberries and Vegetable Crops"; Grant #018022). Results from that project confirmed that strawberries field-packed in clamshell containers could be immersion-hydrocooled with sanitized water in 1/5 the time required for forced-air cooling while significantly reducing decay and human pathogen populations. Subsequent fruit quality was comparable to that for strawberries that were forced-air cooled under current conditions. For that project, a novel 1,500-gallon immersion hydrocooling system was designed and constructed. At the end of the project it was retrofitted to fit onto a trailer for portability. For this new project with blueberry and peach, this system wasmodified to add shower hydrocooling as a cooling option. Peaches were hydrocooled on a pallet scale with sanitized water and compared to fruit that were room-cooled or forced-air cooled. Blueberries were forced-air cooled under commercial conditions or hydrocooled under laboratory conditions.

We assembled an experienced, interdisciplinary team to tackle this project from research, extension and teaching perspectives. Our goal was to increase the competitiveness of Florida growers, packers and

shippers of fresh-market blueberries and peaches by extending postharvest quality and ensuring safety by investigating novel cooling methods and postharvest temperature-management scenarios.

Project Approach

Project overview: To accomplish the ambitious objectives outlined above, we assembled research groups headed by each Co-PI. The main harvest time is mid-March-mid-April (blueberry) and early April to mid-May (peach). Due to this overlap in harvest schedules, in Year 1 we focused on blueberry. Survey information of from growers was collected prior to harvest, and actual cooling tests, microbial analyses and cost/benefit studies were performed during the harvest season. In Year 2, we focused on peach. Survey information was collected prior to the Florida harvest (March/April), at which time the cooling, microbial and cost/benefit studies were conducted. Because of the 6-month extension approved in late 2016, we were able to conduct further tests with blueberry cooling and sanitation in spring 2017.

Our industry cooperators for blueberry studies were: 1) Dudley Calfee, President. Florida Blueberry Growers Assn.; 2) Ferris Farms, Floral City FL; 3) Alto Straughn, owner; Mark Mattson, farm manager. Alto Straughn Farms, Archer FL; 4) Chuck Allison, owner, Okahumpka FL; 5) Gary Wishnatski, Wish Farms, Plant City FL. Cooperators for peach studies were: 1) Steven Callaham, CEO, Dundee Citrus Growers, Dundee FL; 2) John Sizemore, owner, Sizemore Farms, Mulberry FL. Designer/Fabricator for the hydrocooling equipment: Mark Dobes, owner. Joe Dobes. American Machinery & Parts, Orlando FL.

Sonia Tighe served as the project manager and Steven Sargent as the P.I. for the duration of this project.

The project Co-PI's and research/supervisory responsibilities from the University of Florida were:

P.I.: Steven A. Sargent, professor of postharvest horticulture: Blueberry Cooling Team; overall project management

Co-P.I.: Jeffrey K. Brecht, professor of postharvest horticulture: Peach Cooling Team

Co-P.I.: Keith R. Schneider, professor of food microbiology and safety: Food Safety Team

Co-P.I.: Zhengfei Guan, assistant professor of agricultural economics, Gulf Coast Research & Education Center, Balm: Economic Analysis Team

Project Results:

Objective 1: Conduct postharvest time/temperature studies at grower/shipper facilities, then determine effects on fruit quality of major Florida cultivars commercially packed and stored: a) delays to forced-air cooling the day of harvest or day after harvest (blueberry); b) room-cooled overnight day of harvest and

packed the following day (peach). (Dr. Steven Sargent, Dr. Jeff Brecht, Dr. Mildred Makani, Adrian Berry, Merce Santana, Sonya Stahl)

Activities: significant results, accomplishments, conclusions and recommendations.

Blueberry Studies

Blueberry sensitivity to handling impacts. Impact tests were completed in Spring 2016 with blueberry ('Meadowlark'), where freshly harvested fruit were conditioned for 5 hr or 24 hr at 5, 10, 15, 20, 25 or 30 ºC, then were dropped once from 60 cm onto an unpadded surface and immediately evaluated. Weight loss was higher in dropped fruit (0.11% to 0.35%) than in undropped fruit (0.03% to 0.26%) for all pulp temperatures and delay periods. Fruit dropped at 30 °C were 12% softer than undropped fruit. Holding fruit for 24 hr prior to dropping resulted in more softening compared to undropped fruit after 5 hours. Soluble solids content and total titratable acidity were not affected by impact (14.3 °Brix and 0.26%, respectively. These results indicate that even short exposures of blueberries to higher ambient temperatures increase subsequent weight loss and susceptibility to handling impacts.

Blueberry time/temperature tracking tests.

Two tests were conducted in April and May 2015 on commercially harvested, southern highbush (Vaccinium corymbosum) blueberries (mixtures of `Farthing', `Sweetcrisp', `Emerald'). Within 1 hr of harvest all fruit were partially forced-air (FA) cooled (18°C); half were commercially packed into rigid, “clamshell” containers (312 g each; 8/carton), and FA cooled (7/8 Cooling) to final storage temperature about 5 hr later. The other half were held overnight in the refrigerated packing area (11°C), then packed and FA cooled the following day (27 hr after harvest). Following final cooling, all cartons were stored at 1°C/88% R.H. and analyzed over 21 d. Blueberry quality was more affected by storage time than by the 24-hr delay to packing and cooling. Weight loss roughly doubled each 7 d to 1.83% after 21 d. Although fruit appearance was acceptable after 14 d, incidence of shriveling increased from 7.0% (14 d) to 46% (21 d) of storage. Fruit remained firm throughout storage (1.67 N mm-1); soluble solids content remained constant (10.2%), whereas total titratable acidity decreased by approximately 20% to 0.44% (citric acid basis). Decay was minimal after 21 days (4%). Based on these results, rapid cooling to 18°C within 90 min of harvest permitted blueberries to be held overnight and packed the following day with minimal negative effects on quality during subsequent storage. However, though not tested here, delays from harvest to initial cooling may negatively affect quality during shipping.

In Spring, 2017 several of the most widely grown blueberry cultivars were hydrocooled (7/8 Cooling) shortly after harvest and stored at 1°C. Berries were hand harvested and packed into 6 oz clamshells in the field. After each harvest the berries were transported to the UF Postharvest lab then either placed directly into 1°C for room cooling (1 hr) and subsequent storage or hydrocooled then placed into storage at 1°C. For hydrocooling, clamshells were submersed in ice water (0-1°C) containing 200 ppm CL for 5min. Berries were stored for 14d. Evaluations were conducted at o, 7 and 14d for appearance, shrivel, decay, splitting and firmness. Samples were then frozen for later analysis of SSC, TTA, pH. Moisture content was measured after 14 d only. During the 14 d storage blueberry appearance, shrivel and decay remained similar to initial quality for hydrocooled and forced-air cooled fruit. However, splitting was

more prevalent in hydrocooled berries, especially Patricia (17-27%) and Sweetcrisp (24%) varieties. There was no effect of cooling treatment on moisture content (59-76%), SSC (13-16%),TTA (0.5-0.9%) or pH (3.2-3.8).

b) Peach cooling studies

Time/temperature tracking; partial cooling.

An early-maturing, non-melting flesh peach cultivar, UF Sun, was commercially harvested into field lugs from orchards with similar management conditions in Dundee, Florida on May 5, 2016 and May 11, 2016. Individual fruit pulp temperatures were tracked in fruit at top, middle and bottom layers of a pallet from the field to a nearby facility for cooling treatments. Fruits were either forced-air (FA) cooled or hydrocooled (HC) to 7/8 Cooling (2ºC) or were partially cooled by FA or HC to 8-10ºC. All fruit were then transferred to 0-2 ºC for overnight room cooling. As a control, another set of fruit was completely cooled using room cooling (RC).

Following the cooling, fruit from each cooling treatment were separated into tree ripe (TR) and advanced ripe (AR) maturity stages, based on average ground color, then were stored at 2-3°C, 80-90% RH, simulating commercial conditions. Fruit quality was evaluated initially and every 7 d during a 21-d storage period. The fastest 7/8 cooling times were for fruit in lugs on the top pallet layer; the HC treatment was 36 min, while FA required about 25% more time (45 min), and RC was about 7 times longer (262 min). Cumulative weight loss during storage was 10.6% for TR fruit, with no effect of cooling treatment. However, the riper AR fruit cooled by RC or FAP lost 14% after 21 d compared to 9.5% for the other cooling treatments. Tree-ripe FAC fruit and RC fruit softened by16.N and 14.2 N during storage, while firmness in HCC only decreased by 0.9 N. A similar trend was observed in advanced ripe fruit, where HCC and HCP fruit only softened 2.0 N, compared to 11.7 N with the other cooling treatments. By rapidly cooling the fruit, HC or FA generally prolonged the shelf-life of `UF Sun peaches', compared to room cooling. Fruit either partially or completely cooled by HC or FA had comparable storage quality. However, neither HY nor FA mitigated quality losses for peaches harvested at advanced ripeness stage.

Objective 2: Compare the results of the above tests with postharvest quality and microbial populations of blueberries and peaches cooled day of harvest by: a) hydrocooling with sanitized water or b) forced-air cooling; c) develop best temperature management practices (BTMPs). (Drs. Keith Schneider; Jaysankar De and Mohammad Jubair)

a) Blueberry cooling studies

Field testing for microbial load:

Blueberries were harvested from local farms in Alachua County, FL and split into two groups. The first group was sampled from the field, force-air cooled (FAC) to approximately 50ºF, then either packed that same day and forced-air cooled overnight to 34-35F (Day0) or held overnight at 50ºF, then packed and forced-air cooled to 34-35ºF (Day1). Force air-cooled post-packed samples (both from Day0 and Day1)

were stored at 34-35ºF and examined on days 7, 14 and 21 for assessing microbiological quality. Blueberries were analyzed for aerobic plate count (APC) and yeast and mold (Y&M) counts. For this study 10 g of blueberries were placed in a stomacher bag and 90 ml 0.1% peptone water was added. The berries were homogenized in a stomacher for 1 min and serial dilutions were performed. Aerobic place counts were determined on Plate Count Agar (PCA) and Y&M counts were determined on Potato Dextrose Agar (PDA), amended with 0.01% of chloramphenicol. Colonies of microbes were counted after proper incubation of the media plates.

The results of the field testing did not show any significant ($p>0.05$) difference in the average counts of APC or Y&M in the blueberries from field, packed and cooled on day of harvest (Day0) or packed and cooled the following day (Day1). The APC counts remained steady between log 4-5 CFU/g over the 21 days of storage period. Also, no differences were seen between pre- and post-packed berries. The yeast and mold counts were similar to the APC in numbers, though they started out slightly lower in the 3-4 CFU/g range and increased slightly to 4-5 log CFU/g at the end of the 21-day storage. The initial average counts of APC for field, pre-packing and post-packing line samples were 4.2, 3.8 and 4.5 log CFU/g, respectively. Force air-cooled post-packed samples from Day0 and Day1 reached 4.6 and 4.8 log CFU/g, respectively after 21 days. The average counts of Y&M for field, prepack or post-packing lines were 3.9, 3.6 and 3.9 log CFU/g, respectively. After 21 days of incubation FAC samples from Day0 and Day1 reached 4.1 and 4.2 log CFU/g, respectively.

Additionally, one more testing was conducted during the blueberry growing season (2017) in Florida to complete the remaining third trial for field testing for microbial load. Data from this field trial and previous trials are being compiled and analyzed together.

Hydrocooling efficacy for fruit inoculated with human pathogens.

For this study, a cocktail of five rifampicin resistant Salmonella enterica strains consisting of 10 ml of each of the following:

a. S. Newport (ATCC 6962)

b. S. Javiana (ATCC BAA-1593,

c. S. Enteritidis (ATCC 4931,

d. S. Typhimurium (ATCC 13311, and

e. S. Braenderup (ATCC BAA-664)

Inoculum was centrifuged and washed twice in 50 ml Difco™ buffered peptone water (BPW) (Becton Dickinson and Co), resuspended in 50 ml resulting in approximately 9 log CFU/ml Salmonella cocktail.

Then 170 g of blueberries (freshly harvested, within 4 h of harvest) were added to fill a 6-oz clamshell (Highland Corp, Inc., Mulberry, FL) for each rep. The culture was then spot-inoculated onto the berries with 9 log CFU/ml inoculum (10 µl), resulting in a 7 log CFU/berry inoculum level, then allowed to dry for 1 h in a biosafety hood.

A set of three clamshells were placed under a modified forced-air cooling unit for 60-90 min in a walk-in cooler. One each set of three clamshells of inoculated blueberries were placed in a wire basket and hydrocooled for 6 min (with agitation) by complete immersion in a) water without sanitizer (HC) or b) water containing 150 ppm HOCl sanitizer solution (HCS), both chilled to 33-34ºF. As a positive control, a fourth set of three clamshells were placed directly into the cooler without any treatment. After hydrocooling, drained clamshells were placed on paper towels and weighed. All four sets of berries were incubated at 33-34ºF (covered with plastic wrap to minimize moisture loss). Salmonella was enumerated on days 0, 1, 3, 5, 7, 14 and 21 after inoculation.

The results of the hydrocooling study show that of the four test groups (inoculated controls, forced-air cooled, hydrocooling with water only and hydrocooling with water+sanitizer) only the use of sanitizer decreased the number of inoculated Salmonella consistently over the 21-day trial. Hydrocooling with water only reduced the initial number of Salmonella, most probably due to simply washing the inoculum off the surface of the berries. However, over time, especially at the 21-day sampling time, the levels of Salmonella steadily decreased, even in the untreated inoculated controls.

b) Peach cooling studies

Fresh peaches were sampled from the Dundee Citrus Growers Association on four occasions (April-May 2016). Samples were taken directly from the field, post-cooling (pre-pack) and post-packing lines. Samples were analyzed for enumeration of APC, and Y&M counts. Three different types of post-harvest treatments, namely, room cooling (RC), hydrocooling with sanitizers (HCS) and forced air cooling (FAC) were analyzed. Peaches treated by RC have been analyzed three times (with three replicate samples taken during each trial, n=9), whereas samples treated by HCS and FAC were analyzed for two times (with three replicate samples taken during each trial, n=6). Each sample was a composite of five peaches (diameter approximately 6.5 cm) collected in triplicate in sterile plastic bags. Bags containing the peach samples were transported in ice-chest to the lab and immediately analyzed. One hundred ml 0.1% sterilized peptone water was added to each plastic bag containing five peaches. The microbes were dislodged from the surface of the peaches by a rub-shake-rub process. Serial dilutions of the rinsate were performed and aliquots of 100 µl sample from each dilution (from undiluted to 10-5) were spread plated. Aerobic plate counts were determined on PCA and Y&M counts were determined on PDA, amended with 0.01% of chloramphenicol. Samples of peaches from the post-pack lines were incubated at 33-34ºF for 21 days. Representative samples were withdrawn on days 0, 7, 14, 21, and were analyzed for enumeration of the APC and Y&M. Results of these observations have been processed and are currently being rechecked for evaluation and reporting.

Objective 3: Determine the costs and benefits of current cooling practices and compare with those necessary to implement the proposed BTMPs; disseminate all information to clientele groups. Economic Analysis Team (Dr. Zhengfei Guan)

Activities: significant results, accomplishments, conclusions and recommendations.

a) Blueberry cooling studies

The quality of blueberries that are cooled immediately after harvested (for example, left in the storage overnight) did not show significant difference from those cooled immediately. This result was not anticipated. The cost data collected during several site visits were not of high quality due to inability of growers to provide detailed cost information on cooling practices. Thus cost/benefit analysis was not conducted.

b) Peach cooling studies

We employed three different approaches, including partial budgeting, net present value (NPV) and breakeven analysis, to evaluate the economic benefit of adopting hydrocooling practice for Florida peach growers. As the proposed hydrocooling practice is still in the pilot stage, this study only considered the direct short-run benefit of adopting hydrocooling practice, including reduced shrinkage rate, increased marketable fruits due to less incidence of decay, and reduced costs due to improvement of energy efficiency.

Based on the cost-benefit comparison using the scenario of cooling 11,000 pounds of fruits over the harvest season of 50 days for a representative peach operation, we concluded that hydrocooling is significantly more cost effective and superior to existing room cooling practice that is widely used in the peach industy.

If we assume improved quality attributes will be highly valued by retailers and customers, growers could receive additional revenues from increased prices, repeated orders, and increased demand. In addition, improved shelf life could further increase sales due to the ability to ship to more distant markets. If these potential benefits were considered, hydrocooling should be more cost-effective and profitable.

PROJECT TIMELINE:

YEAR 1: Conducted blueberry cooling & microbiological tests for Season 1; complete cost data surveys. Complete data analyses for cooling, microbiological and costs; present data to growers; write up completed data.

YEAR 2: Conducted peach cooling & microbiological tests for Season 2: complete cost and benefit data.

YEAR 3 (6-month extension): Completed data analyses for cooling, microbiological and cost/benefits; present to growers; publish results.

EXPECTED MEASUREABLE OUTCOMES:

GOAL1: Understand the effects of commercial temperature management strategies currently used by Florida blueberry and peach grower, packers and shippers on postharvest fruit quality, shelf life and safety.

Performance Measure: Fruit should maintain marketable quality for a minimum of 21 days to ensure sufficient time for distribution and sales.

Benchmark: There should be differences in fruit quality and microbial populations present on fruit due to differences in existing temperature management practices employed by growers, packers and shippers.

Target: Potentially reduce postharvest losses to Florida blueberry and peach growers, packers and shippers by more than 1% by selecting the most effective current cooling method/scenar

GOAL 2: Evaluate the potential for using immersion or shower hydrocooling with sanitized water to rapidly cool and sanitize Florida-grown blueberries and peaches.

Performance Measure: Quantify fruit quality, postharvest life and microbial populations resulting from this cooling method.

Benchmark: Fruit quality obtained by current temperature management practices (Goal 1) will be compared with resultant quality and sanitation from hydrocooling treatments.

Target: Increase postharvest quality and safety of Florida blueberries and peaches by determining efficacy of hydrocooling as a means to cool 5X faster than current methods while reducing postharvest microbial counts by more than 60%.

GOAL 3: Assess costs and benefits for current and proposed temperature management scenarios for Florida blueberry and peach growers, packers, shippers and determine potential of industry to adopt the new information.

Performance Measure: Determine cost and benefit data for fruit cooled via room cooling, forced-air cooling and immersion or shower hydrocooling.

Benchmark: Cost and benefit data developed for currently used methods and systems will be considered as benchmark data.

Target: Provide Florida blueberry and peach growers, packers and shippers with findings via writing/publication of online bulletins in the EDIS system at the University of Florida, and via

presentations made at grower group meetings. County extension faculty will disseminate via their list serves that reach more than 1,500 Florida growers.

Knowledge gained and receptivity of stakeholders to adopt these BTMPs will be quantified via pre/post-tests given at outreach activities. Means for sharing results has included use of electronic newsletters, extension bulletins (University of Florida/IFAS EDIS system), industry trade publications (Years 1, 2) and to the scientific community via publications in high-impact journals (Yr. 2). Florida Specialty Crop Foundation will assist with providing information to trade publications, newsletters and websites.

The beneficiaries of the results from this project are Florida's approximately 250 blueberry and 50 peach growers, and more than 30 packers and shippers, whose sizes range from small, family operations to large commercial shippers. Additionally, University of Florida county extension agents, whose clientele and stakeholders include seasoned and new blueberry and peach growers and shippers, will have access to this information to utilize in their own outreach programs at the county, regional and state levels.

Progress results were disseminated to beneficiaries/stakeholders at Fall and Spring Blueberry Workshops, the Peach Workshop, and demonstrations of hydrocooling and forced-air cooling principles at AgExpo in 2015 and 2016 and at two Small Farms Conferences. Scientific presentations were made at the annual meeting of the Florida State Horticulture Society, the American Society for Horticultural Science and the International Association for Food Protection in 2015, 2016 and 2017. Two manuscripts from the blueberry data and one manuscript from the peach data are in preparation and are targeted for publication in peer-reviewed journals.(See details in Beneficiaries Section.)

Goals and Outcomes Achieved

The Project Timeline and Expected Goals are listed below. Each target was met in this project, as described in the Project Approach section above.

PROJECT TIMELINE:

YEAR 1: Conduct blueberry cooling & microbiological tests for Season 1; complete cost data surveys. Complete data analyses for cooling, microbiological and costs; present Yr 1 data to growers; write up preliminary data.

YEAR 2: Conduct peach cooling & microbiological tests for Season 2: complete cost and benefit data.

YEAR 3 (6-month, no-cost extension): Conduct repeat tests for blueberry cooling and sanitation; complete data analyses for cooling, microbiological and cost/benefits; develop materials to present to growers; publish results.

EXPECTED MEASUREABLE OUTCOMES:

GOAL1: Understand the effects of commercial temperature management strategies currently used by Florida blueberry and peach grower, packers and shippers on postharvest fruit quality, shelf life and safety.

Performance Measure: Fruit should maintain marketable quality for a minimum of 21 days to ensure sufficient time for distribution and sales.

Benchmark: There should be differences in fruit quality and microbial populations present on fruit due to differences in existing temperature management practices employed by growers, packers and shippers.

Target: Potentially reduce postharvest losses to Florida blueberry and peach growers, packers and shippers by more than 1% by selecting the most effective current cooling method/scenario.

GOAL 2: Evaluate the potential for using immersion or shower hydrocooling with sanitized water to rapidly cool and sanitize Florida-grown blueberries and peaches.

Performance Measure: Quantify fruit quality, postharvest life and microbial populations resulting from this cooling method.

Benchmark: Fruit quality obtained by current temperature management practices (Goal 1) will be compared with resultant quality and sanitation from hydrocooling treatments.

Target: Increase postharvest quality and safety of Florida blueberries and peaches by determining efficacy of hydrocooling as a means to cool 5X faster than current methods while reducing postharvest microbial counts by more than 60%.

GOAL 3: Assess costs and benefits for current and proposed temperature management scenarios for Florida blueberry and peach growers, packers, shippers and determine potential of industry to adopt the new information.

Performance Measure: Determine cost and benefit data for fruit cooled via room cooling, forced-air cooling and immersion or shower hydrocooling.

Benchmark: Cost and benefit data developed for currently used methods and systems will be considered as benchmark data.

Target: Provide Florida blueberry and peach growers, packers and shippers with findings via writing/publication of online bulletins in the EDIS system at the University of Florida, and via presentations made at grower group meetings. County extension faculty will disseminate via their list serves that reach more than 1,500 Florida growers.

Knowledge gained and receptivity of stakeholders to adopt these BTMPs will be quantified via pre/post-tests given at outreach activities. Means for sharing results has included use of electronic newsletters, extension bulletins (University of Florida/IFAS EDIS system), industry trade publications (Years 1, 2) and

to the scientific community via publications in high-impact journals (Yr. 2). Florida Specialty Crop Foundation will assist with providing information to trade publications, newsletters and websites.

Beneficiaries

The beneficiaries of the results from this project are Florida's approximately 250 blueberry and 50 peach growers, and more than 30 packers and shippers, whose sizes range from small, family operations to large commercial shippers. Both of these crops are increasing in production area and, as a result, production volume. Importantly, many citrus growers have planted significant acreages to offset losses due to the citrus greening disease. Additionally, University of Florida county extension agents, whose clientele and stakeholders include seasoned and new blueberry and peach growers and shippers, will have access to this information to utilize in their own outreach programs at the county, regional and state levels.

Progress results were disseminated to beneficiaries/stakeholders at 2015, 2016 and 2017 Fall and Spring Blueberry Workshops, the 2016 Peach Workshop, and demonstrations of hydrocooling and forced-air cooling principles at AgExpo field day in 2015 and 2016 at the UF Gulf Coast Research & Education Center in Balm, FL, and at two UF/IFAS Small Farms Conferences in Jacksonville and Apopka.

Scientific presentations and publications:

Santana, M.T.A., S.A. Sargent and A. D. Berry. 2015. Effect of Pulp Temperature and Drop Height on Blueberry Quality. Proc. Florida State Horticulture Society 128: (in press)

Sargent, S.A., A.D. Berry, J.K. Brecht, M. Santana, S. Zhang, N. Ristow. 2016. Studies on Quality of Southern Highbush Blueberry Cultivars: Effects of Pulp Temperature, Impact and Hydrocooling".XI International Vaccinium Symposium, Orlando FL. (poster and meeting paper, in press).

Sargent, S.A., A.D. Berry, J.K. Brecht, M.T.A. Santana and S. Zhang. 2016. Delays to Blueberry Cooling and Effects on Storage Quality Under Commercial Conditions. Annual meeting of the American Society for Horticultural Science, Atlanta GA. (poster)

Schneider, K.R., J. De, A. Sreedharan, Y. Li, S. Sargent.2016. Evaluation of temperature management on the microbial quality control of Florida blueberries. Annual meeting of the International Association for Food Protection, St. Louis, MO, USA . (poster)

De, J., A. Sreedharan, Y. Li, A. Gutierrez, S. Sargent, K.Schneider. 2017. Comparison of forced-air cooling and hydrocooling on the microbial quality control of Florida blueberries. To be presented at the Annual meeting of the International Association for Food Protection, Tampa, FL, USA.

De, J. B. Bertoldi, A. Gutierrez, J. Mohammad, S. Sargent, K. Schneider. 2017. Effect of postharvest cooling on the microbial quality and storage of Florida peaches. To be presented at the Annual meeting of the International Association for Food Protection, Tampa, FL, USA. (poster)

Wei, X, Z. Guan, S.A. Sargent. Adoption of Hydrocooling Practice in Florida Peach Industry: A Cost and Benefit Analysis. The draft is currently under the second-round internal review and is intended to be submitted to HortTechnology in 2017.

Lessons Learned

Problems and Delays:

Due to the concentrated harvest season during the months of April and May, we requested and were granted a 6-month, no cost extension. This enabled us to conduct further testing with blueberries, as summarized above. There was no cost/benefit analysis conducted for blueberry. With further testing, it became obvious that this some blueberry varieties have potential for splitting due to hydrocooling; therefore more testing needs to be conducted in the future - perhaps partial hydrocooling to 10 degrees C (50F) might be practical.

There were no other problems or delays in this project that were not overcome.

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Project (30): Rational strategies to improve gray mold and ripe rot management for Florida blueberries

Project Partners: University of Florida Board of Trustees

Project Summary

This project addressed pre- and post-harvest diseases of blueberries, a valued and expanding specialty crop in Florida. Botrytis fruit rot (BFR), blossom blight, ripe rot, and anthracnose leaf spot (ALS) are among the most important diseases that can threaten blueberry production in the Southeastern United States. Blossom blight and BFR are caused by the fungus Botrytis cinerea. The latter can severely damage blueberry flowers, especially when favorable weather conditions, such as extended wetness and mild temperatures, occur during peak bloom period starting late February to mid-April. The fungus attack blossoms, tender green twigs, and leaves. Because of similarities between blossom blight and freeze injuries, a portion of losses due to freeze injuries may be actually caused by B. cinerea. Furthermore, the beginning of the bloom period in blueberry coincides with late strawberry season when a large amount of B. cinerea inoculum is released into the air. Therefore, blossom blight on blueberry can be aggravated by inoculum originating from strawberry fields, especially in central Florida, a region where the blueberry industry has been expanding greatly in recent years. Ripe rot, also known as Anthracnose Fruit Rot (AFR), and ALS can be caused by two Colletotrichum species, C. acutatum and C. gloeosporioides. Crop losses due to ripe rot can range from 10 to 20% in pre-harvest, however; losses can approach 100% in storage because of cross-contaminations between infected and healthy fruits. Knowing that most of Florida blueberries are used for fresh market and require storage periods, AFR can be very problematic for producers. ALS develops early in the summer and can cause severe defoliation and consequent yield reduction, especially on susceptible highbush blueberries, widely planted in Florida. Because of the explosive nature of these diseases, growers rely heavily on preventative fungicide applications to insure appropriate control and to produce marketable fruit. However, frequent or inadequate use of fungicides can led to widespread resistance to multiple fungicides commonly used, as seen in some other crops such as strawberry, and therefore disease control efficacy is reduced particularly under highly favorable weather conditions. Thus, there is a need to provide growers with rational disease control recommendations that will reduce fungicide use without risking yields.

Under this project, isolates of Botrytis cinerea were collected from blueberry and strawberry fields to determine their resistance to fungicides from six registered chemical groups and to investigate whether there is a population drift between strawberry and blueberry fields in central Florida. Our results indicate that highbush blueberry in Florida may be at moderate risk for blossom blight infections depending on weather condition occurring during the growing season. However, potential drift of Botrytis populations from other highly-susceptible hosts, such strawberry grown extensively in a one geographic area, may increase risk of infections on blueberry. Overall, there was 12 to 16% higher Botrytis infection in blueberry fields close to strawberry, compared to blueberry fields far from

strawberry. Abundant numbers of receptive blueberry flowers are present in blueberry fields from February to April, a period when inoculum of Botrytis are abundant in the strawberry fields.

Similarly, resistance frequencies were significantly higher in blueberry fields close to strawberry compared to blueberry fields far from strawberry for most fungicides tested. Among the 107 B. cinerea isolates collected from blueberry fields far from strawberry fields during the first season, 6, 18, 19, 21, 24, 41 and 98% were resistant to penthiopyrad, fenhexamid, cyprodinil, boscalid, iprodione, pyraclostrobin and thiophanate-methyl, respectively. The respective resistance frequencies were 10, 65, 30, 57, 74, 92 and 98% among the 231 isolates collected from blueberry fields close from strawberry fields.

A web-based advisory system to advice growers on the need for fungicide sprays for control of Botrytis and anthracnose on strawberries based on weather conditions had been previously developed and has been proved to help strawberry growers to reduce fungicide applications without compromising disease control or yields. In this project, a similar system has been developed and implemented for the identified weather stations in the FAWN (Florida Automated Weather Network) that are close to important blueberry production areas. The system is available at http://agroclimate.org/tools/Blueberry-Advisory-System/ and was named the Blueberry Advisory System (BAS) following the previously developed Strawberry Advisory System (SAS).

Project Approach

Task 1.

Sample collection:

Twelve blueberry fields, planted to two southern highbush cultivars predominantly grown in Florida, Jewel or Emerald, were surveyed during two consecutive seasons. Six fields grown at least 30 to 50 km away from strawberry fields were located in Hillsborough, Alachua, Orange and Polk Counties (Table 1). Six other blueberry fields planted close to strawberry fields, within a few meters to 1 km- distance, were located in Hillsborough, Citrus and Hernando Counties (Table 1). In Florida, 90% of strawberry fields are located in Hillsborough County.

Blossoms were surface-disinfested, placed inside sealed boxes, frozen overnight at -20°C, incubated at 24°C for 5 days, and examined under a stereoscope for Botrytis and Colletotrichum. Fungal colonies were transferred to agar media and single-spored. However, mostly Botrytis isolates were recovered.

Task 2.

Fungicide sensitivity screening:

Seven fungicides, from six chemical groups registered on blueberry, i.e. pyraclostrobin (Cabrio EC, BASF Crop Protection), boscalid (Endura, BASF Crop Protection), penthiopyrad (Fontelis, DuPont Crop Protection), fenhexamid (Elevate 50 WDG, Arysta Life Science), cyprodinil (Vangard WG fungicide, Syngenta Crop Protection), fludioxonil (Medallion WDG, Syngenta Crop Protection) and the multi-site captan (Captec 4L, Arysta LifeScience) were used in this study (Table 2). Additionally, two fungicides, i.e.

fluopyram SC 500 (Luna Privilege, Bayer CropScience) and thiophanate-methyl (Topsin-M 70WP, Cerexagri-Nisso LLC), non-registered on blueberry but registered on strawberry were tested (Table 2). Formulated products were dissolved in sterile distilled water to make 2,000 µg/ml stocks which are stored at 4°C. Salicylhydroxamic acid (SHAM) was added at a 100 mg/liter to the appropriate medium (Table 2) to inhibit alternative oxidase pathway when testing for sensitivity to pyraclostrobin.

Task 3.

State-wide fungicide resistance monitoring program:

Sensitivity to the aforementioned fungicides was evaluated based on conidial germination assays. For boscalid, the discriminatory dose of 5 µg/ml was selected, whereas the two other doses for penthiopyrad and fluopyram were developed after comparing several B. cinerea isolates with different mutations in the SdhB subunit. For captan, preliminary in vitro tests were conducted using 0.5, 2.5 and 5.0 µg/ml doses on a subsample of 40 B. cinerea isolates. All isolates germinated and grew equally on 0.5 and 2.5 µg/ml of captan, whereas some isolates only inhibited at 5.0 µg/ml were selected for further sensitivity tests.

Autoclaved molten (55°C) media amended with discriminatory doses of each fungicide (Table 2) were poured into 15-cm diameter Petri dishes. Plates were placed on self-adhesive transparent cellophane sheet (12 x 12 cm), previously divided into 30 (~1 x 1 cm) squares using a permanent marker. Two 7-µl droplets of conidial suspension (106 conidia/ml) from each isolate were inoculated in each square allowing testing up to 30 isolates per plate. Plates containing respective media non-amended with fungicides were used as control. Germination was microscopically evaluated after 16 to 20 h of incubation at 22°C. Four different sensitivity phenotypes were distinguished based on the germination rate and germ tube length assessed visually under the microscopic using a scale of 0 to 4 where 0= total inhibition, 1 low resistance (1 to 1.5 times diameter of the conidium), 2 moderate resistance (2 to 4 times the diameter of the conidium), 3 highly resistant (>4 times diameter of the conidium), and 4 (germ tube length similar to control plates).

To evaluate the efficacy of preventive application of captan to control different sensitivity phenotypes, eight Botrytis isolates, i.e. 4 isolates completely inhibited and 4 isolates that grew in vitro, were selected for detached fruit assays. Efficacy tests were conducted on detached blackberry fruit prepared and inoculated as described previously (Amiri et al., 2014). Blackberry fruit were used because blueberry fruit were not available all times and some preliminary tests on blueberry yielded a large number of contaminations. Test fruit were sprayed preventively with captan (Captec 4L) at 2.5 and 6.4 µl/ml, corresponding to the low and maximum label rates, respectively. Control fruit were sprayed with sterile water. Fruit were inoculated with 40 µl of a spore suspension of each isolate at 105 spore/ml. Six replicate fruit were used for each isolate-fungicide combination and the experiment was done in duplicate and repeated twice. Fruit were incubated at 20°C for 5 days in saturated boxes and gray mold incidence and severity were recorded.

Task 4.

Data analysis:

Botrytis resistance frequencies from in vitro screening and gray mold incidence and severity from in vivo fruit tests, expressed as percentage, were log-transformed for ANOVA analysis and mean separation using the JMP software (JMP statistical software version 12.1.0).

Task 5.

Development and implementation of the web Blueberry Advisory System:

The Blueberry Advisory System was developed and implemented as a new tool in the AgroClimate Decision Support System (http://agroclimate.org). Weather stations belonging to the Florida Automated Weather Network (FAWN) that were close to blueberry production fields were initially identified and leaf wetness sensors were added to two of them (Frostproof and Starke). Leaf wetness is a key observation for disease warning systems but currently is not a standard observation at FAWN stations. For those stations were leaf wetness sensors were not available, a model was implemented to estimate leaf wetness duration based on other available weather parameters such as relative humidity, temperature, and solar radiation. The selected disease models used leaf wetness duration and temperature to estimate disease risk and were implemented using the R statistical analysis software system (http://www.r-project.org). The system interface was based on the Google Maps API, such as in the Strawberry Advisory System. Disease risk levels are presented in tabular and graph formats to facilitate user interpretation and analysis are represented by different colors (green = low risk; yellow = moderate risk; red = high risk) in the weather stations marks appearing in the map. Short-term weather forecasts from the National Weather Service-National Digital Forecast Database (NWS-NDFD) are used to forecast disease incidence for the following two days.

Goals and Outcomes Achieved

Goal 1.

Develop knowledge on the sensitivity/resistance of Botrytis cinerea and Colletotrichum sp. to the most common fungicides used on blueberries in Florida by state-wide monitoring.

Outcome

Samples were collected from 12 different locations across the state i.e. North Central, Central Florida, and South Central Florida and fungicide resistance levels and frequencies (%) were determined for Botrytis isolates and linked to the grower's spray programs or adjacent fields. Weather conditions were not favorable and only a few Colletotrichum isolates were recovered during the period of this project.

Multi-fungicide resistant to the most common fungicides used in blueberry were observed for isolates recovered from all the three regions surveyed, indicating a wide spread fungicide resistance problem.

Goal 2.

Determine whether fungicide-resistant inoculum from strawberry fields can serve as a source of inoculum for blueberry fields.

Outcome

Samples were collected from six blueberry fields located next to strawberry fields and from six locations where blueberries are grown as a single crop (no strawberry field within 30 to 50 miles radius). Fungicide resistance frequencies (%) were higher in blueberry fields close to strawberry fields indicating an impact of inoculum introduced from other crops.

A lack of disease pressure this season meant that growers had fewer occasions naturally to apply fungicide, and for this reason, this outcome was not met, or rather that reduced fungicide applications cannot be attributed to the advisory system.

Goal 3.

Develop and evaluate a web system to predict anthracnose and gray mold risk and advise on fungicide applications; similar to the Strawberry Advisory System implemented at agroclimate.org/tools/strawberry.

Outcome

The web advisory system was developed in the second year of the project. Growers were identified for field trials but due to dry weather conditions no disease was observed in the field during the 2016-17 season. We would like to conduct additional field trials during the upcoming season but our request for a project extension was not granted.

A cursory estimate of web traffic to the advisory system shows approximately 258 visits and doucmenbt downloads referred to that site from a University of Florida website. This falls short of our goal of 500 visits, but a lack of disease pressure is likely the cause of the reduction.

Beneficiaries

This project directly affect the blueberry growers in Florida. New information was developed on fungicide resistance problems that are similar to those observed across strawberry fields in the state. In addition, the Blueberry Advisory System has been developed which could help blueberry growers to reduce number of fungicide applications, an important strategy to manage fungicide resistance. A presentation of preliminary results was given at the 2015 FL Annual Blueberry Growers Meeting. Final results from this project will be presented at the upcoming Florida Blueberry Growers Association meeting to be held in Plant City on October 26, 2017.

The 2012 Census of Agriculture recorded 825 blueberry growers in the state. These, as well as 612 additional growers in Georgia, can benefit from reduced need for fungicides, from both an economic and an environmental vantage.

Lessons Learned

Weather conditions were not favorable for Colletotrichum fruit rot for the duration of this project and very few isolates were obtained. Thus, goals 1 and 2 were only were partially completed since it was only done with Botrytis isolates.

Also, the postdoc who was initially working on this project, Dr. Achour Amiri, accepted a position as an Assistant Professor at Washington State University and left before the end of the first year. The research was then assigned to a graduate student who had assisted Dr. Amiri on this project but progress was a bit slower since the student also had other course work commitments.

In reality, I think this should have been a 3-yr project since it was dependent of field work and favorable weather conditions for disease development.

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Funding Expended: $64,857.64

Project (31): Increased Water Use Efficiency and Quality of Florida Hybrids

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Project Partners

Florida Agricultural and Mechanical University

Project Summary

The purpose of this project was to correct a dearth of research on the effects of regulated deficit irrigation (RDI) practices in Florida hybrid bunch grapes. The practice is already widely used in bunch grapes in other growing regions to improve the quality of wine and other grape products. The objectives of the project were to: 1) Determine the RDI effects on wine quality and composition, 2) to determine the optimum duration and berry development stage for imposing RDI that results in superior wines, and 3) to identify Florida hybrid bunch grape cultivars which respond positively to RDI.

Project Approach

Year 1: Grape cultivars, Florida hybrid bunch cv. Blue Lake, and Blanc du Bois plants were exposed to regulated water stress. The plant samples, leaf and berries were collected at weekly intervals of treatments and stored at -70 C, for further analysis. Detailed studies on physiological, proteome and metabolome changes due to regulated water stress have been carried out to determine the pathways associated with the stress tolerance mechanism. Project partner is a Grape Grower, has provided access to the vineyard and supported in the field research, plant sample collection and field data analysis. Regulated water deficit conditions resulted in changes in protein composition affecting specific metabolite pathways. Both cultivars showed differential responses in their physiological parameters. Several endogenous hormones played significant role in the water stress response. There is a linear decrease of the photosynthesis rate, and IAA, while abscisic acid, superoxide dismutase increased with the decrease in water potential in both cultivars. Cultivar, Blanc Du Bois showed relatively higher contents of total soluble sugars, and low anthocyanin content to water stress when compared to cultivar Blue Lake. Similarly, the content of the organic acids are reduced more rapidly in cultivar BDB than in Blue Lake. This influence by the variety indicates their difference in their ability to accumulate and degrade these acids to abiotic stress such as water deficit. Both cultivars showed high expression level of active energy and secondary metabolism that enhanced the synthesis of active compounds.

The physicochemical results of leaf tissue suggest distinct physiological and biochemical behavior between the cultivars during the plant development. These differences of the source tissue (leaf) are expected to reflect changes in the sink tissue (berry). Total Titratable Acids decreased considerably during, increased levels of water deficit while pH increased in both cultivars, attributing to the synthesis of Malic and Tartaric acids, that are used as energy source in cellular respiration and leaf development.

Mass spectrometry studies identified 79 differently expressive protein spots, involved in metabolism, photosynthesis, signal transduction, response to stimulus, calcium signaling pathway, anti oxidative systems and related to epigenetic modifications in leaf proteins. Kinase like protein was increased to water stress in Blue Lake suggesting a chromatin modification. Thus, the preliminary data on leaf tissue establishes the role of metabolites in stress mechanism and possible influence in the alteration of metabolic pathways. Tolerant characteristics of cultivar Blue Lake is associated with the more abundance in proteins and metabolites involved in epigenetic modifications. Based on the information outlined above, detailed investigation will be carried out in berry samples of Florida hybrid bunch and muscadine cultivars to determine the impact of water deficit effects on enological and nutraceutical properties.

Year 2: Muscadine cultivars, Carlos and Noble were treated with regulated water deficit from early flowering for 4-week period. The treatment was given at weekly intervals. The samples, leaf and berry from the control and treated cultivars were collected, processed and stored at -70 C until use for proteome and metabolite investigations. Physiological parameters (e.g. photosynthetic rate) were collected from the field studies, and rainfall was recorded during the period of treatment. Project partner is a Grape Grower who has provided access to the vineyard and supported in the field research, plant sample collection and field data analysis. Biochemical studies include indole-acetic acid, abscisic acid, superoxide dismutase, sugars were analyzed from leaf and berry samples of both control and treated from both cultivars. The data suggested that, both cultivars have not shown significant differences in total sugars, and other biochemical parameters such as organic acid content. However, anthocyanin content was recorded high in Noble cultivar. It is noteworthy that all the biochemical values were significantly high in muscadine cultivars compared to Florida hybrids studied previous year. The studies compared between leaf and berry tissue suggest that, leaf data of muscadine cultivars and Florida hybrids were more similar and that of berry were significantly high in muscadine cultivars. Thus, as per the project goal 1, a brief evaluation of biochemical composition of leaf and berry of muscadine and Florida hybrid cultivars were accomplished. Detailed comparison and significance towards enological importance is evaluated during the extended period of the project. Wine derived from berries that were harvested from treated and control plants were extracted for total untargeted metabolites.

Goals and Outcomes Achieved

1. Evaluate the changes in molecular and biochemical composition of leaf and berry due to RDI

   Mass spectrometry studies identified 125 differently expressive proteins over the time course of water deficit treatment in cultivar Carlos, while 96 in cultivar Noble. Majority of these proteins were involved in sugar metabolism, flavonoid compounds and stress related proteins. The data suggested more proteins in muscadine cultivars as compared to Florida hybrids. Based on the biochemical and proteome data available, both muscadine cultivars proven promising for water deficit stress and they exhibited higher number of proteins and biochemicals in berry tissues.

2. Determine the optimum duration and berry development stage for imposing RDI that results in superior wines.

   The treatment applied during this set of experiments, beginning at the early flowering stage and continuing for 4 weeks thereafter, appeared to produce positive results in muscadine cultivars. The effect upon bunch grapes was more ambiguous. Pending further study, the treatment applied to muscadine grapes could possibly be a good recommendation.

3. Identify the Florida hybrid bunch cultivars and stage of development positively responding to RDI.

   Muscadine cultivars Carlos and Noble responded positively and with approximately the same magnitude of effect.

4. Dissemination through public database of research information on the effect of RDI on Florida bunch grape and wine quality. Better understanding the benefits of RDI by wine industry and grape growers.

   Results of this study were presented by graduate assistants at the 2017 conference of the American Society of Mass Spectrometry. The proceedings are available to the society's approximately 8,500 members.

Beneficiaries

The 2012 Census of Agriculture recorded 380 grape growers in Florida with acreage bearing. These include approximately 43 farm wineries. All of these stand to benefit from knowledge of the option to use RDI to possibly improve the quality of their wines or nutraceutical products.

Lessons Learned

Expression of certain metabolites and molecules were expected to change during the time course of water deficit treatments. The outcome of our experiments were measured both qualitative and quantitatively. As expected, the preliminary results indicated that there are changes in leaf metabolites and proteins, which are directly correlated to decreased water potential. Our future directions will include analysis of targeted metabolites and proteins on berry tissues of both Florida hybrid bunch and muscadines. Most of the enological properties are associated with the metabolites synthesized in phenylpropanoid biosynthesis pathways. Therefore, we include certain enzyme assays that are directly involved in this biosynthesis and compare the enzyme activities across the cultivars to observe significant changes.

Overall Progress and Funding Expended

The project is 100% complete, with $45,552.79 expended.

Project (32): Florida Agriculture Financial Management Conference

Project Partners: Farm Credit, Florida Specialty Crop Foundation, Dean Mead, UF-IFAS, McGladry, Wells Fargo, Florida Fruit & Vegetable Association, FNGLA

Project Summary

The purpose of the program was to provide essential financial risk management education to enhance the sustainability of Florida's agricultural producers. Specialty crop producers deal with uncertainty every day, from not knowing how the weather will impact production, or how the global market supply will impact prices, or dealing with tax and regulatory issues to fluctuations in variable and fixed costs among other financial risk factors out of their control.

Strengthening the financial risk management skills of Florida's ag producers will help ensure the continued viability and sustainability of the diverse ag population. This critical seminar was timely given the turbulent economic state and its impact on the agriculture industry and the state's economy.

While earlier FAFMC conferences raised the awareness and demand for financial learning opportunities, the registrations grew this year also due to the high level of expertise of the speakers (a major draw) as well as attendees not only returning but bringing additional staff from their companies. The advisory group reviewed the 2014 survey results to help plan the sessions to meet the attendees' needs. The results of the 2015 post-survey clearly show the value to the attendees: 100% of respondents said that would attend the conference again; most sessions were rated as either Excellent or Good.

Results from the 2014 survey were used to search for different speakers and topics to make sure the conference remains relevant and does not duplicate previous work.

Project Approach

All work outlined in the Work Plan was completed in year 1 of the grant.

Past participants were surveyed and results were used to plan the 2015 conference. The format was reviewed by the committee and realigned to better meet participants' suggestions. Meister Media managed the marketing and promotion, which included e-newsletter information, editorial coverage, e-mail blasts, and updated website coverage.

Conference logistics were studied carefully to maximize participation and engagement. The location and date were agreeable to survey respondents and helped increase the registration for 2015.

The committee held regular conference calls to discuss speakers and logistical details. New speakers were selected and highly popular speakers were re-invited. Consideration was given to new topics that needed to be addressed.

Karen Keene with Dean Mead developed the press release for the conference and Meister Media and participating committee members promoted it to their members/clients as well as industry publications.

The FAFMC 2015 was held on August 27-28, 2015 at the Omni Championsgate, which necessitated accerlating the schedule previously outlined in the grant proposal. A post-survey was performed, and the results are attached as an addendum to this report.

Goals and Outcomes Achieved

1) Young and beginning specialty crop producers were invited to attend the conference with personal invitations, and the attendance was higher than in past year.

2) Significantly increasing the knowledge of ag financial management concepts was achieved, as indicated by the survey results:

1.*72 Rule *Cash reserves *Impact of food on polotics/Terrorism *Business Metrics *Strategic scorecard *Communication *additional insight to help more effectively *Plan your work and work your plan. * Liquidity *Tax * IF it grows too fast, it's a weed. *water per unit (production) *diversity *Tax Info *Transitional planning *Employee contract *3000/500 Rule *Confidence in Florida real estate values. *Economic update * Importance of strategy *water issue resolution *working capital self-insurance *added dashboard metrics *key Kols should be monitored & shared * water and it's importance *Insights into Cuba *Financial dashboards and metrics to use for ag businesses *Think out of the box *water *Find your target audience & market to them *Better Manager - looking to future * Value of ag land Risk/round of Ag Land *If it grows to fast it's a weed. *opportunities are out there *It's not about prediction but position *Econ update *agriculture prosperity is a better investment than s & Proors *Financial strategy for adjusting our business *Ag land pre positive investments

2.*Strategic planning *Follow Key ratings *Financial metrics for decision making *Metric for Ag businesses / Dashboards *Human Resource (People skills)*educate future growth opportunities *Can't manage what you can't measure * Data Mgmt *Dr. Genho *1031 in tax *plan for succession

*Accounting Methods *Estate planning considerations *Water treatments informat *Concern for water quality *Benchmarking *Ag Land good investment *Energy independence *If you leave for a month in your business it should still be running effectively *Dr. Ed provided an excellent sheet and analysis of key ecomomic indicators *key financials indicators are critical *that N America and S America have great soil *Potential export support opportunities *Economic outlook facing and drivers *Positioning rather than predicting *land still a good investment *Soils we can grow on (Dr. Genho)* Sweat small stuff but keep big picture *Estate planning *use the accrued basics * Posture outlook *Great American tailwind - energy independence *Tax changes in pipe *the reminder that food will be a vital issue worldwide *Estate planning is critical to keeping ag production/land in ag!

3.*FL water issues *Move with market *Risk-return model *Software *ideas for strategic planning for a family business * ideas for strategic planning for a family business * Efficiency *easements * Investing in land *Ag Trends *financial dashboard *tax information *Financial measurements *Power of Benchmarking * Interest rates will stay remain the same *soft skills are imperative in business *An understand of the potential water issues that will face land owners in the future. *need to think outside of the box!! *The importance of succession planning *Great financial refresher for someone who doesn't work in the field * Water issues facing Florida ag *pay attention to what consumers want this affects every segment of the value gain. *increase productivity per unit of water *Current economic condition *Gold is the Joker *70% of Ag land will transfer in the next 20 years *Details on Tampa port changes *export ability through FDACS - good opportunities *comparison of farming to other forms of income

3)Reaching 15,000 Florida producers was achieved by partnering with Meister media, who reach 10,000+ readers with Florida Grower magazine, as well as extended coverage through their electronic newsletter. Additional coverage was achieved by committee members sending the information to their own membership and clients. The registration list of August 21 reflected 218 registrants, up from 148 - up 47%.

Beneficiaries

All specialty crop producers in the state had the ability to be exposed to the content of the FAFMC 2015 not only by attendance, but also by the website (www.fafmc.org) and the editorial coverage provided by Florida Grower magazine and its electronic products. As noted earlier, Meister Media reaches over 10,000 growers in the state. Florida has over $133 billion in ag sales revenue.

Lessons Learned

The only significant change from the plan was a change in the date from late 2015 to August 2015. This proved to be very positive change to attract more attendees (while they were not busy in the field or

with production issues), and has allowed us to confirm that August time frame for future meetings. Continuing the host the meeting in the same time frame each year assists us with building attendance.

Another positive experience is that the Orlando/Champsiongate location is an ideal location for growers across the state to reach without significant driving time.

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Project (33): Identify Sterile, Non-invasive Lantana Varieties for the Florida Nursery and Landscape Industry

Project Partners: University of Florida Board of Trustees

Project Summary

1) The specific issue, problem, or need that the project addressed

Lantana (Lantana camara) is a very important specialty crop for the Florida nursery and landscape industry. Beginning in 2001, the Florida Exotic Pest Plant Council (FLEPPC) has listed lantana as a Category I invasive species "that are altering native plant community by displacing native species, changing community structures or ecological functions, or hybridizing with natives." Subsequently, the IFAS (Institute of Food and Agricultural Sciences) Assessment of Non-Native Plants in Florida's Natural Areas recommends "No Use" of lantana in South and Central Florida and "Caution" in using lantana in North Florida. The invasive species status of lantana was the most significant barrier to Florida nurseries and landscapers. It caused substantial losses of lantana sales volume, and severely limited the marketability of lantana produced by Florida nurseries and restricting the use of lantana by Florida landscapers.

The invasive potential of lantana also severely limited Florida nurseries and plant propagators to market lantana plants in all southeast states where lantana's invasive potential is also a serious concern. Florida is a leading producer of lantana cuttings and potted plants and ships large numbers of lantana cuttings and finished plants to as many as 10 states to the north and west of Florida.

All cultivars of lantana fall under the IFAS Recommendation, unless subjected to the IFAS Infraspecific Taxon Protocol (ITP) and approved for use. In this this project, we evaluated 21 commercial Lantana camara cultivars at two sites in Florida and generated scientific data on the male and female fertility of these cultivars, identified three male and female-sterile cultivars. We have prepared ITP requests for these cultivars and submitted them to the IFAS Invasive Plant Working Group for its review and approval. After the Working Group approves these cultivars, UF extension specialists and county extension agents can recommend these lantana cultivars to the public who want to buy and grow lantana in their gardens or yards.

2) The importance and timeliness of the project

Lantana is a major crop for more than 900 Florida nurseries, bringing in an estimated wholesale value of greater than $40 million each year and providing hundreds of job opportunities to Floridians. Lantana is also one of the most widely used plants by hundreds of Florida landscapers and one of the most popular plants grown by the general public in Florida.

Lantana flowers year-round, requires low maintenance, demonstrates strong tolerance to drought and heat, and attracts many species of butterflies. Because of these good attributes, the popularity of lantana has been soaring, and the demand for lantana in Florida and southeast U.S. has been strong. The potential market for Florida-produced lantana plants is huge.

Lantana has been widely promoted for landscape use since the early 1800s. Old lantana varieties produce a lot of fruit (berries) and seeds (more than thousands per plant per a year), and can escape cultivation easily and invade large areas of natural and agricultural lands, including citrus groves and pasture lands. Old lantana varieties also produce highly viable pollen, allowing hybridization with Florida native lantana. Prolific fruit and seed production and viable pollen are the cause of lantana's invasive potential.

From this project, we have collected scientific data that are necessary to show the identified lantana varieties are male and female sterile and unable to hybridize with Florida native lantana. With these data, the IFAS Invasive Plants Working Group will approve commercial production and landscape use of these sterile, non-invasive cultivars in Florida. With the availability of these lantana varieties, Florida growers and landscapers can overcome the biggest market barrier faced by Florida lantana nurseries and landscapers.

3) If the project built on a previously funded project with the SCPGB or SCBGP-FB describe how this project complemented and enhanced, but is not duplicate, previous work.

This project was a new project.

Project Approach

Brief summary:

We successfully completed all the proposed activities, evaluated two more commercial lantana varieties, and identified three sterile, non-invasive varieties for Florida nurseries, growers, and landscapers. The results were much better than we anticipated, and these varieties will benefit Florida specialty crop

industry considerably. We have disseminated our accomplishments to a diverse group of stakeholders and audience using various approaches. This project benefits only nursery and landscape plants.

Details are provided below.

Objective 1: Evaluate the male and female fertility of 21 lantana varieties to identify varieties with consistent sterility.

A total of 23 varieties were installed at two sites in Florida, Gulf Coast Research and Education Center (GCREC) in Balm and Indian River Research and Education Center (IRREC) in Fort Pierce. To determine male fertility, multiple flower clusters were collected from field-grown plants at each site. Together, more than 100,000 pollen grains were examined. The sterile variety UF-T3, a sterile variety that was developed at University of Florida, had around 5.0% pollen viability at both sites. The pollen viability of 'Carlos', 'Luscious Pink Landscape', 'Luscious Citrus Blend', 'Luscious Berry Blend', 'Luscious Bananarama', 'Bandito Red', 'Bandito Orange Sunrise', 'Luck Lemon Glow', 'Lucky Lavender', 'Landmark Rose Sunrise', and 'Landmark Gold' was lower than the pollen viability of 'UF-T3'. 'Little Lucky Pot of Gold', 'Bandana White', 'Luscious Marmalade', and 'Luscious Pina Colada' showed similar pollen viability with 'UF-T3'.

The female fertility of lantana varieties was determined by collecting and counting the number of fruit (berries) produced by each plant at the two sites over a period of nearly 4 months. The invasive variety 'Pink Caprice' produced an average of 10.3 berries per cluster at the GCREC and an average of 7.9 berries per cluster at the IRREC. 'UF-T3' plants produced an average of 0.04 fruit per peduncle over two sites. 'Luscious Marmalade', 'Carlos', and 'Bandana Landscape Yellow' produced the lowest number of fruit per peduncle among all varieties at both sites, less than 0.05 berries per cluster.

Seeds extracted from lantana fruit were germinated in incubators. Seeds of 'Pink Caprice' and 'UF-T3' showed a germination percentage of 45% and 11.1%, respectively. Very few seeds (less than 5 from both sites over 4 months) were collected for seven varieties, and their seeds did not germinate. These varieties are 'Bandana Landscape Yellow', 'Bandana White', 'Bandito Orange Sunrise', 'Bandito Red', 'Carlos', 'Lucky Flame Improved', and 'Luscious Pina Colada'.

Experimental lantana lines were grown and evaluated for male and female sterility. Two lines were confirmed as having high levels of male sterility and female sterility. Their pollen stainability was between 3.0% and 9.7%, which represent 85% reduction from the pollen stainability of 'Pink Caprice'. The two lines produced less than 0.05 berries per cluster, greater than 99% reduction from the fruiting capability of 'Pink Caprice'. Fewer than 5 seeds were collected from these lines at two sites over 4

months, and none of these seeds germinated. These data show that both lines are male and female sterile.

Objective 2: Assess the hybridization potential of lantana varieties with Florida native lantana to identify non-invasive varieties.

Twenty-one lantana varieties were grown in containers in a greenhouse at the GCREC. When pollinated with the Florida native lantana, 'Pink Caprice' had the high rate of fruit production (19.9%, number of fruit/number of flower pollinated), and 'UF-T3' had 0.8% fruit production. 'Bandana Landscape Yellow' did not produce any fruit. 'Bandito Orange Sunrise', 'Luscious Marmalade', and 'Luscious Pina Colada' produced few fruit (0.7% to 1.3%) like 'UF-T3'. When native lantana flowers were pollinated with pollen from commercial lantana varieties, 'Pink Caprice' affected 8.6% fruit production and 'UF-T3' effected 0.3% fruit production. 'Bandana Landscape Yellow', 'Bandito Orange Sunrise', 'Luscious Berry Blend', 'Luscious Citrus Blend', 'Luscious Marmalade', and 'Luscious Pink Landscape' showed similarly low hybridization potential (0.2% to 1.0%) with sterile 'UF-T3'.

All seeds from the above crosses were germinated in incubators and checked for germination rates. Seeds of these varieties produced by pollination with the native lantana did not germinate: 'Bandana Landscape Yellow', 'Bandana White', 'Bandito Orange Sunrise', 'Lucky Lemon Glow', 'Luscious Marmalade', and 'Luscious Pina Colada'.

Objective 3: Prepare ITP request forms and submit them to the IFAS Invasive Plants Working Group to obtain non-invasive status for newly identified sterile, non-hybridizing lantana varieties.

The nuclear DNA contents of 23 lantana varieties were determined by flow cytometry. Their DNA contents varied from 3.1 to 7.7 picograms per nucleus, indicating a ploidy range from diploidy to pentaploidy. Overall, three lantana varieties are both male and female sterile, and do not hybridize with native lantana.

Plants of these three varieties have been compared to 'Pink Caprice' to reveal morphological differences between them. The morphological differences have been used in conjunction with DNA content and ploidy level, and three ITP request forms and one document describing the main characters, fertility, and hybridization potential of the identified sterile, non-invasive lantana varieties have been prepared. These documents have been submitted to the IFAS Invasive Plants Working Group for review and approval.

Objective 4. Disseminate results on lantana varieties' male sterility, female sterility, and hybridization potential to the Florida Exotic Pest Plant Council and the IFAS Invasive Plants Working Group, and to Florida growers and stakeholders.

Three sterile lantana varieties, 'Bandana Landscape Yellow', 'Bandito Orange Sunrise', and 'Luscious Marmalade', plus the invasive variety 'Pink Caprice' and 'UF-T3', were put in the 2016 Florida Flower Trials and installed in early April, 2016 at three demonstration sites, Walt Disney Nursery, Leu Gardens, and Orange County Extension Service. These trials and demonstrations were directly organized and supervised by Florida Nursery, Growers and Landscape Association (FNGLA). The sterility of these lantana varieties was shown to the attendees. Plants of these varieties were maintained at these sites for several more months. At least thousands of people visited these sites.

The three sterile varieties, plus the invasive variety 'Pink Caprice' and 'UF-T3', were grown in containers and the plants were displayed at the 2016 Landscape Show, which was organized by the FNGLA and has been the largest landscape trade show in Florida and the southeast USA. In addition to the plants on display, one poster was prepared and shown there, and a one-page handout was prepared and distributed to attendees who visited the lantana plants and the poster. We spoke directly to attendees about sterile lantana varieties during the Show.

Presentations were made to a diverse group of professionals. One PowerPoint presentation was made to the Florida Exotic Pest Plant Council (FLEPPC) 2016 Annual Conference on March 9-11, 2016 in Melbourne, FL. The audience include many members of the FLEPPC and the IFAS Invasive Plants Working Group and many land and park managers and weed scientists. One presentation was made to the FNGLA 2016 Florida Floriculture Field Day on May 12-13, 2016 in Orlando, FL. The audience were mainly growers, nurserymen, landscapers, etc. One presentation was made at the Florida State Horticultural Society 2016 Annual Meeting on June 12-14, 2016 in Stuart, FL. The audience was extension agents and horticultural researchers. One presentation was invited to the University of Florida/IFAS In-service Training. The audience was UF extension agents and researchers. Three abstracts on this project have been published. One copy of the presentation has been posted at the FLEPPC website (http://bugwoodcloud.org/CDN/fleppc/Symposia/2016/DENG-FLEPPC-050616.pdf).

In addition, the Southern Region International Plant Propagators Meeting was attended in Virginia Beach, VA on October 22-26, 2016. Research findings from this project were communicated to registered attendees including major nursery growers in addition to faculty and students from land grant southeastern universities. This annual conference serves as an excellent networking venue.

Six presentations have been made in 2017 at the following extension and outreach events:

1) Ornamental Invasives in Florida and Safe Alternatives, Florida Friendly Landscaping In-Service Training, Invited Oral Presentation, May 16th 2017, UF, Gainesville.

2) Alternatives to Ornamental Invasives in Florida, Master Gardener Webinar Series, March 30th, 2017.

3) Use of plants as alternatives to invasive or potentially invasive non-natives. Florida Association of Native Nurseries, April 20th, 2017.

4) Infertile, non-invasive Lantana camara cultivars, UF/IFAS Master Gardener Coordinator Skills In-service Training, May 17, 2017.

5) Ploidy manipulation for plant breeding, UF/IFAS extension workshop and in-service training, Wimauma, FL, June 15, 2017.

6) Development and releasing of infertile, non-invasive Lantana camara cultivars, Florida State Horticultural Society annual meeting, Tampa, FL, June 4-5, 2017.

Goals and Outcomes Achieved

Goals / Activities / Expected outcomes / Achieved outcomes

1 / Evaluate male and female fertility of lantana varieties / Expected to evaluate 21 varieties / Actually evaluated 23 varieties.

2 / Assess hybridization potential of lantana varieties with native lantana / Expected to assess 21 varieties / Actually evaluated 23 varieties.

2 / Identify sterile, non-invasive varieties / Expected to identify 1 variety / Actually identified 3 varieties.

3 / Prepare ITP request forms and submit them to IFAS Invasive Plants Working Group / Expected to prepare 1 ITP request / Actually prepared 3 ITP requests & 1 document

4 / Disseminate scientific data / Expected to do 2 demonstration trials; 3 presentations; 2 articles; 1 refereed paper / Actually 3 public demonstration trials; some 20 demonstrations at extension service centers; 11 presentations; 2 articles; 3 abstracts; 1 refereed paper; 1 presentation posted at the Florida Exotic Pest Plant Council website

Beneficiaries

This project directly benefits Florida nurseries that propagate/produce lantana for wholesales and retails, wholesale plant distributors, and their employees. This project also benefits Florida landscaping companies and their employees who install or manage lantana plants in the landscapes. This project benefits local businesses and communities that engage in or serve the nursery production and landscape services.

Florida nurseries benefit from this project in multiple ways. The invasiveness issue of lantana has been the biggest barrier to market lantana in Florida and other states. Outcomes from this project result in sterile, non-invasive lantana varieties for Florida nurseries. Lantana's invasiveness is also a major concern10 southeast states where lantana is very popular. Florida nurseries are major suppliers of lantana in these states. The adoption and production of sterile, non-invasive lantana varieties by the Florida nurseries improve their image in the general public's eyes. Invasive species have become a hot issue to the general public, and many people are aware of the negative impacts of invasive species to the native species, the environment, and the economy. Nurseries have been recognized as the primary source of invasive plant species. Active adoption and production of non-invasive lantana varieties by Florida nurseries have shown the industry's commitment of curbing the spread of invasive species and being a good steward of the environment.

Lantana has many good attributes as a landscape/garden plant. It is drought tolerant, saves water, needs little fertilizer, requires low maintenance, and attracts wildlife, especially butterflies. With added sterility and non-invasiveness, lantana will help Florida landscapers attract more customers and service contracts. Florida customers and the general public will benefit from less water and fertilizer input and expenses needed for caring their plants in the landscapes.

Nurseries and landscapers that produce/use lantana plants are distributed across the entire state, essentially in every county. These nurseries and landscapers are important contributors to local economies, generating significant sales taxes and providing employment to thousands, which is especially valuable for many Florida rural areas where job opportunities are needed badly.

Demonstrations and presentations made in 2016 reached a diverse group of professionals. Audience include:

1) approximately 200 attendees, including many members of the FLEPPC and the IFAS Invasive Plants Working Group and many land and park managers and weed scientists attending the Florida Exotic Pest Plant Council (FLEPPC) 2016 Annual Conference on March 9-11, 2016 in Melbourne, FL;

2) about 120 attendants to the FNGLA 2016 Florida Floriculture Field Day on May 12-13, 2016 in Orlando, FL, mainly growers, nurserymen, landscapers, etc.;

3) about 30 extension agents and horticultural researchers at the Florida State Horticultural Society 2016 Annual Meeting on June 12-14, 2016 in Stuart, FL;

4) about 50 UF extension agents and researchers at the University of Florida/IFAS In-service Training;

5) over 200 registered attendees to the Southern Region International Plant Propagators Meeting was attended in Virginia Beach, VA on October 22-26, 2016, which includes major nursery growers in addition to faculty and students from land grant southeastern universities.

6) About 215 attendees at the 2016 FNGLA Florida Landscape Show, mainly nurserymen, growers, landscapers, etc.

Six presentations made at 2017 extension and outreach events reached the following audience:

1) About 30 extension agents and master gardeners at Ornamental Invasives in Florida and Safe Alternatives, Florida Friendly Landscaping In-Service Training, Invited Oral Presentation, May 16th 2017, UF, Gainesville.

2) About 50 master gardeners at Alternatives to Ornamental Invasives in Florida, Master Gardener Webinar Series, March 30th, 2017.

3) About 50 people attending the "Use of plants as alternatives to invasive or potentially invasive non-natives". Florida Association of Native Nurseries, April 20th, 2017.

4) About 30 extension agents and master gardeners at the UF/IFAS Master Gardener Coordinator Skills In-service Training, May 17, 2017.

5) About 25 extension agents and master gardeners at the UF/IFAS extension workshop and in-service training, Wimauma, FL, June 15, 2017.

6) About 30 extension agents, students, and industry representatives at the Florida State Horticultural Society annual meeting, Tampa, FL, June 4-5, 2017.

In addition, lantana plants installed at demonstration sites, our publications, published abstracts, posted presentation should have reached even greater numbers of audience, including the professionals and the general public.

Lessons Learned

Lantana varieties, particularly those partially or highly sterile varieties, had misshaped, deformed, and/or aborted pollen grains. These pollen grains did not look like typical pollen grains, and they were much harder to recognize and score. To obtain reliable data, images of pollen grains had to be cross-examined by multiple researchers, which took two to four times more time and effort than we initially planned.

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