CucCAP - Leveraging applied genomics to increase disease resistance in cucurbit crops

Rebecca Grumet[1*], Zhangjun Fei[2], Amnon Levi[3], James D. McCreight[4], Michael Mazourek[5], Marco Palma[6], Jonathan Schultheis[7], Yiqun Weng[8] Mary Hausbeck[1], Shaker Kousik[3], Kai-Shu Ling[3], Cecilia McGregor[9], Lina Quesada-Ocampo[7] , Angela Linares Ramirez[10], Umesh Reddy[11], Louis Ribera[6], Christine Smart[5], Pat Wechter[3], Todd Wehner[7], Linda Wessel-Beaver[10], William Wintermantel[4]

[1] Michigan State University, East Lansing MI, USA 48824; email:grumet@msu.edu
[2] Boyce Thompson Institute, Ithaca NY, 14853, USA
[3] USDA-ARS, Charleston SC, 29414, USA
[4] USDA-ARS, Salinas CA, 93095, USA
[5] Cornell University, Ithaca NY, 14853, USA
[6] Texas A&M University, College Station TX, 77843, USA
[7] North Carolina State University, Raleigh NC, 27695, USA
[8] USDA-ARS and University of Wisconsin, Madison WI, 53706, USA
[9] University of Georgia, Athens GA, 30602, USA
[10] University of Puerto Rico, Mayaguez PR, 00681, USA
[11] West Virginia State University, Institute WV, 25112, USA

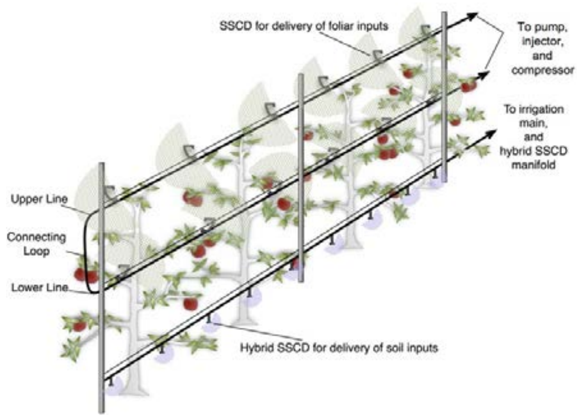
Cucurbit growers and processors consistently identify fungal/oomycete pathogens and insect-transmitted viral diseases as major production constraints causing severe reductions in yield, loss of fruit quality, increased labor and expense for control, and negative environmental impacts from application of pesticides. The most cost-effective and environmentally desirable solution to these problems is disease-resistant cultivars. The USDA-SCRI CucCAP project brings together the U.S. cucurbit community to develop and leverage applied genomics tools to increase disease resistance in watermelon (*Citrullus lanatus*), melon (*Cucumis melo*), cucumber (*Cucumis sativus*) and squash (*Cucurbita spp.*). Our primary objectives are: develop genomic and bioinformatic breeding tool kits for accelerated crop improvement; use these tools to facilitate breeding for disease resistance; perform economic analysis and provide readily accessible information to facilitate disease control. Genotyping by sequencing (GBS) has been performed on ~1000-2000 accessions from the plant introduction collections for cucumber, watermelon and melon; squash is in progress. Analysis of the GBS data has identified >25,000 high quality single nucleotide polymorphisms (SNP) markers per species. These data are being used to define phylogenetic relationships and population structure of the germplasm collections and to establish genome-informed functional panels (384 entries) for each crop. The functional panels will be re-sequenced to provide a set of diverse lines for which sequence data, SNP datasets, and genetic maps will be publically available through the CucCAP Cucurbit Genomics database (http://cucurbitgenomics.org/) allowing future analysis of any trait of interest. In parallel with genomic analyses and tool development, the CucCAP team is developing resistance to primary diseases of importance for each crop as identified by cucurbit producers. Genomic analyses are being used to identify resistance-associated quantitative trait loci (QTL) and initiate marker development. Breeding for resistances to downy mildew, *Fusarium*, gummy stem blight, *Phytophthora capsici*, powdery mildew and several viruses is in progress. Genomic and breeding efforts are complemented by a centralized CucCAP cucurbit disease website (https://cuccap.org/) with content in English and Spanish providing diagnostic information, disease control recommendations, disease alerts, and links to disease clinics and forecasting tools.

Solid Set Canopy Delivery Systems: ***an efficient, sustainable and safer spray technology for perennial fruit.***

Matt Grieshop[1], Giles Brereton[1], George Zhu[1], Lav Khot[2], Steven Miller[1], John Wise[1]
[1]Michigan State University, [2]Washington State University

Our multiregion project focuses on the further development and delivery of Solid Set Canopy Delivery Systems (SSCDS) for trellised perennial fruit crops. SSCDS consist of a network of microsprayers positioned in the tree canopy/trellis and connected to a pumping/mixing station (Figure 1). SSCDS application virtually eliminates applicator exposure common to tractor-based sprayers, while increasing farmers' ability to apply sprays during critical weather periods. SSCDS will make frequent applications at low rates possible for modern agricultural chemicals, including nutrients and reduced-risk pesticides, to improve efficacy of "soft impact" IPM programs. The specific objectives for our project are: 1) Optimize SSCDS technologies for modern orchard architectures for improved spray material application efficacy; 2) Determine and test SSCDS applications for standard and novel fruit production operations; 3) Determine the economic benefits and costs associated with SSCDS and identify non-economic barriers to grower adoption of SSCDS; and 4) Develop and deliver extension and outreach activities and materials —including field scale and on-farm demonstrations— to increase producer knowledge and adoption of SSCDS technologies.

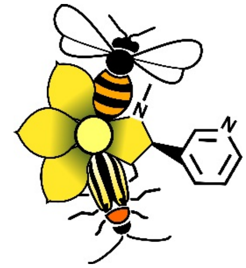
Figure 1: SSCDS Schematic



Progress to date:

1. We have identified microemitters which will allow applications to be made without placing emitters in the canopy –*Improving ease of maintenance and reducing microsprayer costs by up to 33%*
2. We have developed a proof of concept design that utilizes system piping –*Reducing pressure drop across larger SSCDS emplacements and providing more even spray volume*
3. We have compared extant proof of concept SSCDS with radial airblast sprayers –*showing up to 95% reduction in drift from the target area.*
4. We have begun evaluating the use of thermal imagery as a means of detecting faults across the system –th*is area of research is now being considered for development into fault detection on existing tractor based sprayers.*
5. We ran a "train the trainer" program on radial air blast sprayer optimization –*we trained 6 MI extension educators/personnel on techniques that can reduce spray volumes by 10-25% depending on the crop and sprayer.*

Navigating the trade-off between pest management and pollinator conservation in cucurbits



Ian Kaplan
Department of Entomology

Lead institution: *Purdue University*

Collaborating institutions: *Michigan State University, Ohio State University, Clark University, University of New Hampshire*

Abstract
Neonicotinoids are a relatively new, but now widely used, class of insecticides that are commonly applied in specialty crops as a preventative measure for managing insect pests. However, these insecticides have also been highly controversial because they are transported within crops to the flower where the chemical residues are concentrated in nectar and pollen. This results in potential unintended exposure to honey bees and other pollinating insects. Because their use has been linked with declines in pollinator health, several countries have banned or restricted their use on flowering crops. Our goal in this project is to assist specialty crop growers in controlling key insect pests with neonicotinoids, while avoiding non-target impacts on bees that may interfere with fruit development. To do so, we are studying cucurbits (watermelon, cucumber, pumpkin), which are heavily attacked by a suite of insect pests that constrain production, but are ultimately dependent upon bees for pollination and fruit set. Cucurbits present the ideal framework to address a conundrum posed by neonicotinoids in agriculture at large: Can these powerful and ubiquitous insecticides be used to effectively target pests while simultaneously preserving key pollinators? To address this broad goal, we have assembled a diverse team of research and extension scientists, from entomologists to economists, across several Midwestern and Northeastern states, combined with input from a consortium of cucurbit growers, beekeepers, and pest control representatives. Our long term goal is to develop holistic pest management regimes that are effective, profitable, and sustainable. Specifically, we will:

Objective 1: ***Identify insecticide management strategies that simultaneously optimize pest suppression while minimizing non-target exposure to cucurbit pollinators***

Objective 2: ***Determine the consequences of within- and extra-field neonicotinoid exposure for honey and wild bee health using large-scale field manipulations***

Objective 3: ***Assess the ecological and socioeconomic trade-offs among pollinators, pests, crop yield, and farm profitability resulting from alternative pesticide regimes***

Optimizing Protected Culture Environments for Berry Crops

Eric Hanson (Project Director), Rufus Isaacs, Annemiek Schilder (Michigan State University), Kathy Demchak, Dennis Decoteau, William Lamont, Kathleen Kelley and Richard Marini (The Pennsylvania State University), Lois Levitan, Laura McDermott and Marvin Pritts (Cornell University), Emily Hoover and Mary Rogers (University of Minnesota), Becky Sideman (University of New Hampshire), David Conner (University of Vermont) and AJ Both (Rutgers University).

Demand for fresh raspberries and strawberries is strong but farmers in the Midwest and Northeast have difficulty producing profitable yields and consistently high quality due to cold winters and short, humid growing seasons. Protective tunnel structures can mitigate many climatic limitations. The purpose of this 5-year project (2015-2019) is to provide growers the knowledge needed to select and use tunnels and plastics that optimize productivity and pest management, while increase profits and minimize the generation of plastic waste. Several short-term impacts have been accomplished to date.

1. Inventories of currently available tunnel structures and plastic films were compiled. The spectral characteristics of 22 tunnel films were described to help growers choose films that meet their needs.

2. Certain high tunnel plastics were found to decrease number of Japanese beetles feeding on raspberry plants by 88% and spotted wing drosophila adults number by 71%, and have potential to suppress some pests and reduce pesticide usage.

3. Compared to uncovered strawberries, low tunnels increased total strawberry yields (25-40%) and marketable fruit (40-50%), and reduced spider mite numbers. Certain plastics on low tunnels decreased fruit anthracnose and have potential to decrease fungicide use.

4. Plastics that block ultraviolet light were shown to slow the degradation of some insecticides on raspberry leaves, indicating a potential for improved pest control in tunnels.

5. Combinations of exclusion netting, frequent harvests (daily), and timely sprays provided effective organic management of the key invasive pest, spotted wing drosophila, in high tunnel raspberries. Daily harvest has been adopted commercially by an Advisory Committee member.

6. Extension/outreach efforts have included workshops, field days, seminars, conferences, articles in scientific journals and grower publications, a TunnelBerries.org website (400 unique users, 1,500 page views/week), weekly posts on a Facebook page (reached over 1,000), and a YouTube video channel (1,400 views so far in 2017). Surveys of workshops attendees indicate most plan to adopt new tunnel management practices and expect dramatic increases in farm profitability. Extension team members and their colleagues have seen an increase in calls for information on tunnel topics.

Development of Intelligent Pesticide Spray Technology for Specialty Crop Production

Heping Zhu[1], Jennifer Boldt[1], Amy Fulcher[2], Yu Gao[3], Dan A. Herms[3], Charles Krause[1], Peter Ling[3], David Lockwood[2], Genhua Niu[4], Erdal Ozkan[3], Jay Pscheidt[3], Robin Rosetta[4], Guido Schnabel[6], Ajay Shah[3], Lingying Zhao[3], Randall H. Zondag[3]

[1]USDA-ARS Application Technology Research Unit, [2]University of Tennessee, [3]The Ohio State University, [4]Texas A&M University, [5]Oregon State University, [6]Clemson University.

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Abstract

Advancing conventional sprayer technology with precision variable-rate capability is an economically feasible method to solve current challenges associated with imprecise application and extensive waste of foliar-applied pesticides and other products. A concept-proven laser-guided intelligent sprayer was developed to adjust spray outputs based on tree canopy architectures in real time. The sprayer could apply different rates to different sections of individual plants. On-farm field tests in commercial nurseries in Ohio, Oregon and Tennessee since 2013 have demonstrated the pest control efficacies of this experimental intelligent sprayer are comparable to those of conventional sprayers, while the new sprayer reduces average pesticide use by 46% to 70%, reduces airborne spray drift by up to 87%, and reduces spray loss on the ground by 70% to 90%, with annual chemical savings by $140 to $281.

A versatile laser-guided spray control system was recently developed as a retrofit for most orchard air-blast sprayers currently used in ornamental nurseries, apple, peach and pecan orchards, small fruit plantings, vineyards and other specialty crops. The retrofit modified the control system previously developed for the concept-proven prototype sprayer. The control system enabled existing sprayers to have the capability to detect tree canopy presence, map the canopy structure, estimate the foliage density, measure the travel speed, calculate the sectional canopy volume and spray volume designated to individual nozzles, and manage variable numbers of nozzles to discharge variable spray outputs to match tree architectures. Field tests of the new spray system retrofitted on four conventional sprayers owned by growers and on six concept-proven sprayers started in 2017. Evaluations included effectiveness of insect pest and disease control and new spray system reliability under commercial nurseries, apple orchards, peach orchards, blueberry and raspberry production, and vineyards in Ohio, Oregon, Tennessee, South Carolina and California. Tests will be expanded to other commercial specialty crops under different climatic conditions across different states in 2018. This new intelligent spray system will significantly advance conventional spray technologies and offer an environmentally responsible and sustainable approach to controlling insects and diseases and applying other foliar products for specialty crop production.

Building Market Foundations for Sustainable Vegetable Production and Processing: A Consumer and Metrics-Based Approach (USDA-SCRI Project)

Paul Mitchell, Ag and Applied Econ, UW-Madison, pdmitchell@wisc.ed, 608-265-6514

Prepared for USDA Specialty Crop Committee Meeting, Traverse City, MI August 28-30, 2017

Our long-term project outcome is improved environmental performance and profitability of vegetable production and processing based on an enhanced understanding of the market for sustainably produced and processed vegetables. Identifying the market foundations for agricultural sustainably is a critical need for the industry – whether a price premium can be pursued or an efficiency-based approach for sustainability should be promoted.

The project assembled collaborating faculty and staff from UW-Madison, University of MN, Cornell University and Washington State University, plus Del Monte Foods, Seneca Foods, Allens and Lakeside Foods, and the Midwest Food Processors Association, plus multiple growers in the Midwest, New York, and the Pacific Northwest.

We have found that a price premium likely does not exist, but consumers have clear preferences for the type of sustainability program they want (not the production practices, but the program characteristics). We have also developed and refined an innovative and practical approach for measuring agricultural sustainability with strong farmer engagement. Our struggle has been supply chain engagement since we are not marketing experts.

What have we gotten done?

- Analysis methods for practice-based sustainability metric refined and published
- Several sustainability assessments completed, including sweet corn in WI, MN, IL and green bean in WI and NY
- Ecosystem restoration handbook completed, pollinator practices survey in progress,
- Consumer survey conducted and results written up
- Field research by collaborators in WI, MN and NY completed, some written up
- Our struggle: supply chain engagement.

Project Title: Identifying phenotypes, markers, and genes in carrot germplasm to deliver improved carrots to growers and consumers
Award number: 2016-51181-25400
Period of funding: September 1st, 2016 – August 31st, 2020
Primary Institution: Agricultural Research Service, USDA, University of Wisconsin, Madison
Project Director Name: Philipp Simon
Co-Project Directors: Micaela Colley, Julie Dawson, Sherry Tanumihardjo, David Spooner, Edgar Spalding, Joe Nunez, Allen Van Deynze, Daniel Sumner, Philip Roberts, Lindsey du Toit, Tim Waters, Massimo Iorizzo, William Matthews, Hyunok Lee, Laurie McKenzie

The US carrot crop provides consumers with 12-13% of their dietary vitamin A and is worth ~$750M annually to growers. Based upon a survey of carrot stakeholders that identified key traits important for improving carrot quality and productivity, a team of 16 researchers was assembled. We will assess and tabulate variation for nine key traits (phenotypes) identified in the survey, including disease and stress tolerance, productivity, color, and flavor, in a collection of ~700 diverse open-pollinated heirloom and landrace carrot cultivars from 57 countries maintained in the USDA germplasm system, and in 70 inbreds from public breeding programs. We will also assess and tabulate variation at the DNA level (genotype) for phenotyped plants from each of the ~770 entries. Using this information, this project will: 1) evaluate the phenotypic data assembled from diverse carrot germplasm and breeding stocks to identify and characterize previously uncharacterized gene sources that we discover in the germplasm collection for traits important for the US market; 2) develop an expanded carrot genomic and phenotypic database for breeders and other researchers to catalogue genomic variation and track genes underlying important traits; 3) initiate the development of breeding pools that include this recently discovered genetic variation, to provide the foundation for future improved carrot production and consumer quality, and we will test those breeding pools for field performance with growers, and for flavor and nutritional value with consumers; and 4) evaluate the market value and impact of carrot traits on grower and consumer decisions. The breeding stocks and genomic tools from this project will be used by seed companies, growers, and processors to develop carrots and carrot products with increased market value; enhanced field performance including yield, disease and pest resistance, and abiotic stress tolerance; and improved flavor and nutritional quality to better meet consumer needs. We will engage stakeholders during this project to solicit their input, and develop outreach materials during the course of this project to engage and educate consumers. We anticipate that this project will contribute to reduced pesticide use and increased farm value for carrot growers, increased vegetable consumption, improved nutrition and a broader agricultural knowledge base for consumers, and novel plant improvement strategies applicable to other crops.