



# VacCAP

## IMPROVING FRUIT QUALITY

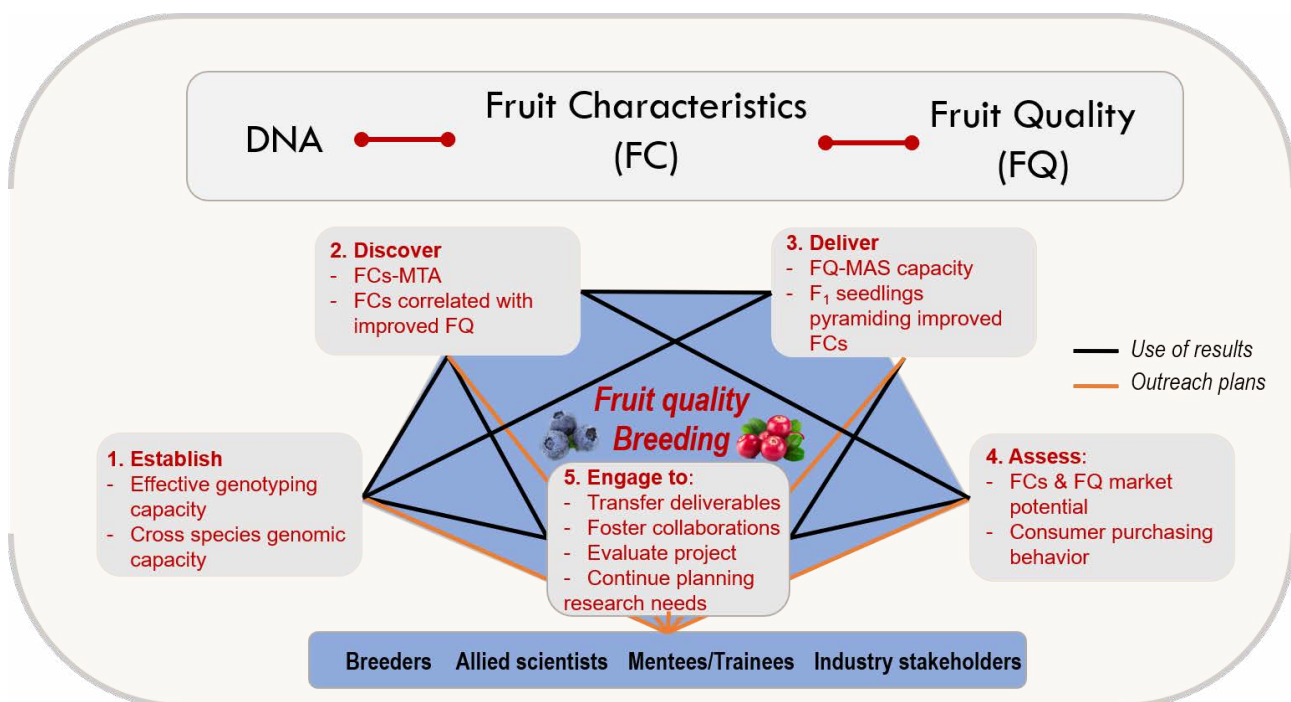
### Annual Project Report and Plan

Annual Meeting IV | March 2–3, 2023 | Hybrid



## VacCAP Objectives

*The Vaccinium Coordinated Agricultural Project (VacCAP) aims at leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes.*



United States Department of Agriculture  
National Institute of Food and Agriculture  
Award #: 2019-51181-30015

# Agenda

**Advisory Board Meeting | Thursday, March 2, and Friday, March 3, 2023 | Hybrid**

Time (EST)	March 2
7:30-8:30	Breakfast
8:30-10:00	<p>Session 1. Intro and Obj. 1 Genomics and Genotyping Moderator: Bassil</p> <ul style="list-style-type: none"> <li>• Iorizzo, Massimo - Intro annual meeting</li> <li>• Bassil, Nahla - Intro Obj. 1</li> <li>• Edger, Patrick - Goals of PanGenome and future directions</li> <li>• Yocca, Alan - Construction and analysis of pangenome</li> <li>• Bassil, Nahla &amp; Clare, Shaun - Genotyping platform</li> </ul> <p>Discussion</p>
10:00-12:00	<p>Session 2. Obj. 2-3 Cranberry: Phenotyping, Genetics, and Marker Development Moderator: Zalapa</p> <ul style="list-style-type: none"> <li>• Zalapa, Juan - Intro obj. 2, cranberry</li> <li>• Lopez, Moreno Hector - Cranberry texture method</li> <li>• Loarca, Jenyne - Cranberry diversity panel evaluation</li> <li>• Knowles, Sara - Phenotyping mapping population MP3</li> <li>• Polashock, James - Intro obj. 3, MP3 genetics and DNA assay development</li> </ul> <p>Discussion</p>
12:00-1:00	Lunch
1:00-3:00	<p>Session 3. Obj. 2-3 Blueberry: Phenotyping, Genetics, and Marker Development Moderator: Iorizzo</p> <ul style="list-style-type: none"> <li>• Iorizzo, Massimo - Intro Obj. 2, chem traits update</li> <li>• Ferrao, Felipe - Genetics of volatile and other traits</li> <li>• Oh, Heeduk - Post-harvest study 1</li> <li>• Mengist-Fentie, Molla - Post-harvest study 2</li> <li>• Giongo, Lara - Acoustic method</li> <li>• Perkins-Veazie, Penelope &amp; Li, Charlie - Bruising</li> <li>• Munoz, Patricio - Intro Obj. 3, status of DNA marker development</li> </ul> <p>Discussion</p>
3:30-4:30	<p>Session 4. Obj. 5 Extension Moderator: Atucha</p> <ul style="list-style-type: none"> <li>• Atucha, Amaya - Intro Obj. 5</li> <li>• Humann, Jodi - GDV updates</li> <li>• Atucha, Amaya - VacCAP updates</li> <li>• Coe, Michael - Evaluation summary</li> </ul> <p>Discussion</p>
4:30-5:00	<p>International Collaborator Updates</p> <ul style="list-style-type: none"> <li>• NZ team - blueberry genome assembly using trio-mating</li> </ul>
6:00	Group Dinner at Boardwalk Billy's Raw Bar and Ribs, walking distance from hotel

*\*See next page for time conversion table*

# Agenda

Time	March 3
8:30-10:00	<p>Session 1. Obj. 4 Blueberry and Cranberry Socio Economic Studies</p> <p>Moderator: Gallardo</p> <ul style="list-style-type: none"> <li>Gallardo, Karina - Intro Obj. 4</li> <li>Gallardo, Karina - Cranberry consumer studies</li> <li>Ma, Xueying - Blueberry consumer and grower studies</li> <li>Sims, Charles - Blueberry sensory and fruit characteristics</li> <li>Canales, Elizabeth - Willingness To Pay estimates for sensory parameters and fruit characteristics</li> </ul> <p>Discussion</p>
10:00-12:00	<p>Session 2. Partners and Advisory Panel</p> <p>Moderator: Iorizzo</p> <ul style="list-style-type: none"> <li>Moira, Sheehan - Support for USDA-ARS Blueberry and Cranberry breeding programs</li> <li>Rife, Trevor - GDV training</li> <li>Neyhart, Jeff - Cranberry/blueberry pre-breeding</li> <li>Ru, Sushan - Expanding Southern Highbush Blueberries to Underserved Regions of Southeastern U.S.</li> </ul> <p>Questions</p>
12:00-1:00	Lunch
1:00-3:00	Administrative meeting (Only Pls zoom link will be sent by email)

## Thursday March 2, 2023

Time zone	Breakfast	Session 1	Session 2	Lunch	Session 3	Session 4	Session 5	Dinner
PT (-3)		5:30AM	7:00AM	9:00AM	10:00AM	12:30PM	1:30PM	
CT (-1)		7:30AM	9:00AM	11:00AM	12:00PM	2:30PM	3:30PM	
ET	7:30AM	8:30AM	10:00AM	12:00PM	1:00PM	3:30PM	4:30PM	6:00PM
IT (+6)		2:30PM	4:00PM	6:00PM	7:00PM	9:30PM	10:30PM	
NZ (+17)		2:30AM	4:00AM	6:00AM	7:00AM	9:30AM	10:30AM	

## Friday March 3, 2023

Time zone	Breakfast	Session 1	Session 2	Lunch	Administrative meeting
PT (-3)		5:30AM	7:00AM	9:00AM	10:00AM-12:00PM
CT (-1)		7:30AM	9:00AM	11:00AM	12:00PM-2:00PM
ET	7:30AM	8:30AM	10:00AM	12:00AM	1:00PM-3:00PM
IT (+6)		2:30PM	4:00PM	6:00PM	7:00PM-9:00PM
NZ (+17)		2:30AM	4:00AM	6:00AM	7:00AM-8:00AM

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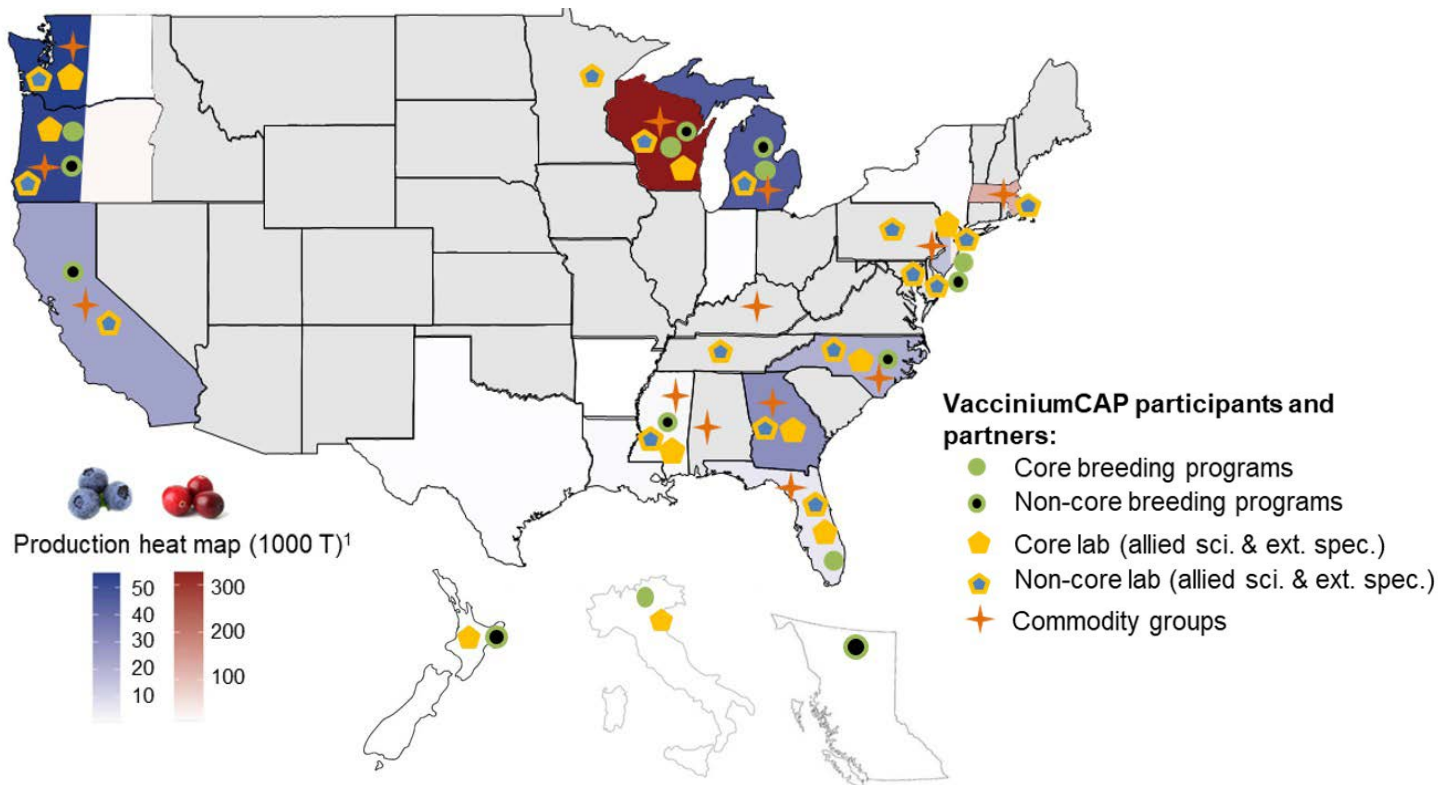
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# VacCAP PIs and Partners



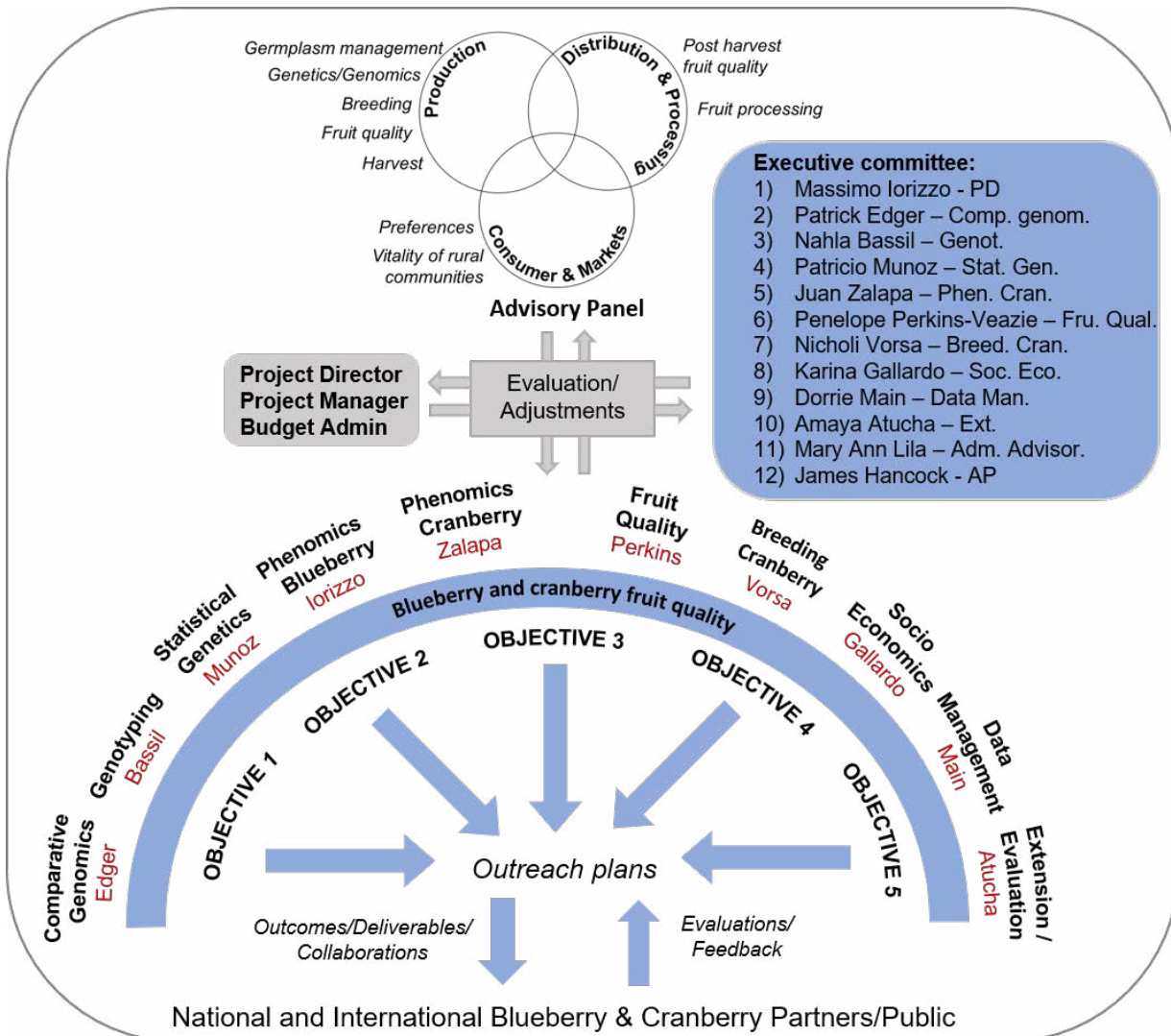
- Massimo Iorizzo, Project Director, North Carolina State University
- Amaya Atucha, Co-PD, University of Wisconsin-Madison
- Nahla Bassil, Co-PD, USDA-ARS and NCGR
- Patrick Edger, Co-PD, Michigan State University
- Karina Gallardo, Co-PD, Washington State University
- Mary Ann Lila, Co-PD, North Carolina State University
- Dorrie Main, Co-PD, Washington State University
- Patricio Munoz, Co-PD, University of Florida
- Claire Luby, Co-PD, USDA-ARS and HCRL
- Penelope Perkins-Veazie, Co-PD, North Carolina State University
- Nicholi Vorsa, Co-PD, Rutgers University

- Juan Zalapa, Co-PD, University of Wisconsin-Madison
- Elizabeth Canales, Co-PI, Mississippi State University
- David Chagné, Co-PI, Plant and Food Research Ltd
- Lisa Wasko DeVetter, Co-PI, Washington State University
- Richard Espley, Co-PI, Plant and Food Research Ltd
- Lara Giongo, Co-PI, Fondazione Edmund Mach
- Changying Li, Co-PI, University of Georgia
- James Polashock, Co-PI, USDA-ARS and GIFVL
- Charles Sims, Co-PI, University of Florida
- Michael Coe, Key Personnel, Cedar Lake Research Group
- Jennifer Johnson-Cicalese, Co-PI, Rutgers University



# How VacCAP Is Managed

Our VacCAP team is listed below and organized by project objective. However, nine project teams manage the project and work collaboratively across project objectives and with our advisory panel.



## Breeding Teams

- Team Leaders: TBD (Blueberry), N. Vorsa (Cranberry)
- Team members: P. Munoz, P. Edger, N. Vorsa, L. Giongo, J. Zalapa, M. Iorizzo, C. Luby
- Tasks: Finalize the list and maintain the material to use in this project. Collect and distribute blueberry and cranberry materials to be used in this project. Develop blueberry/cranberry F1 progenies to pyramid multiple superior fruit quality traits (Obj. 3). Coordinate the implementation of standardized phenotyping protocols for on-site fruit quality assessment in collaboration with the blueberry/cranberry Phenomic Teams (Obj. 2-3). Serve as a training group to use the data collection software (e.g. Field Book) and BIMS system in collaboration with the Data Management Team. Act as liaison between the Extension Team, the PD, and blueberry and cranberry industry organizations.

## Comparative Genomics Team

- Team Leader: P. Edger
- Team members: N. Bassil, P. Munoz, J. Zalapa, N. Vorsa, J. Polashock, D. Chagné, R. Espley.
- Tasks: Coordinate the activities required to develop and characterize the *Vaccinium* pangenome (Obj. 1a) that will be used to develop the SNP catalog. Collaborate with Genotyping Team to establish the SNP catalog (Obj. 1b) and provide bioinformatic analysis needed to select the final set of SNPs used to validate the *Vaccinium* Genotyping Platform (Obj. 1c). Liaise with Breeding and Statistical Genetic Teams to finalize the list of blueberry and cranberry material needed for the comparative genomic analysis. Liaise with Data Management and Extension Teams to deliver genomic resources through the Genome Database for *Vaccinium* (GDV) and to provide content about the comparative genomic outcomes (Obj. 1a).

# How VacCAP Is Managed

## Genotyping Team

- Team Leader: N. Bassil
- Team members: P. Edger, P. Munoz, J. Zalapa, N. Vorsa, L. Giongo, D. Main, M. Iorizzo, J. Polashock, D. Chagné, J. Johnson-Cicalese
- Tasks: Coordinate activities to develop the SNP catalog, validate the SNP set, organize the *Vaccinium* Genotyping forum, and finalize selection and validation of the *Vaccinium* Genotyping Platform (Obj. 1b-c). Collaborate with the Breeding and Statistical Genetics Teams to finalize the list of blueberry and cranberry germplasm needed for the genotyping platform validation. Extract DNA and genotype the blueberry and cranberry samples for the genetic and validation studies (Obj. 2b, 3b). Will provide content for Extension efforts on outcomes.

## Statistical Genetics Team

- Team Leader: P. Munoz
- Team members: J. Zalapa, M. Iorizzo, N. Vorsa, L. Giongo, N. Bassil, P. Edger, J. Polashock, J. Johnson-Cicalese
- Tasks: Coordinate activities required to perform marker-trait association analysis and QTL/marker validation (Obj. 2b, 3b). Will collaborate with Breeding Team to finalize the list of germplasm to be used in the project. Provide support for statistical analysis needs. Liaise with the Data Management Team to use the computational infrastructure to store and deliver markers/QTL data through the GDV (public and private partitions). Liaise with the Extension Team to provide content about the marker-trait association analysis and QTL/ marker validation outcomes (Obj. 2b, 3b).

## Phenomic Teams

- Team Leaders: M. Iorizzo/L. Giongo (blueberry), J. Zalapa (cranberry)
- Team members: P. Munoz, P. Perkins-Veazie, M.A. Lila, D. Main, J. Polashock, N. Vorsa, J. Johnson-Cicalese
- Tasks: Coordinate activities required to implement phenotyping methods (Obj. 2a, 3a). Collaborate with the Statistical Genetics Team on marker trait association analysis (Obj. 2a) and QTL/ marker validation (Obj. 3b). Collaborate with the Fruit Quality and Socio-Economic (Blueberry) Teams to correlate fruit characteristics and their performance for shelf life, resistance to bruising, sensory panel (Obj. 2c) and potential economic value

(willingness to pay) (Obj. 4a). Liaise with the Breeding and Statistical Genetics Teams to finalize the list of blueberry and cranberry germplasm needed for the phenotypic analysis (Obj. 2a-3a). Liaise with the Data Management Team to use the data management computational infrastructure to store and/or deliver phenotypic data through the GDV (public and private partitions). Liaise with the Extension Team to provide content about outcomes delivered through the phenotypic analysis (Obj. 5).

## Fruit Quality Team

- Team Leader: P. Perkins-Veazie
- Team members: C. Li, C. Sims, M.A. Lila, L. Giongo, M. Iorizzo, P. Munoz
- Tasks: Coordinate activities required for the blueberry fruit quality studies, which includes the evaluation of shelf-life, sensory panel and bruising damage (Obj. 2c) in collaboration with the Phenomic and Breeding Teams. Will collaborate with the Socio Economic Team to plan and conduct a joint consumer panel analysis. Will liaise with the Extension Team to provide content regarding the outcomes delivered through the fruit quality studies (Obj. 2c) and the Extension outreach plans.

## Socio-Economics Team

- Team Leader: K.R. Gallardo
- Team members: E. Canales, C. Sims
- Tasks: Coordinate activities required to perform the socio-economic studies (Obj. 4). Collaborate with the Breeding, Phenomic and Fruit Quality Teams to acquire blueberry plant material, phenotyping and sensory data. Work with Extension Team to provide content about the outcomes delivered through the socio-economic studies and to develop outreach activities planned by the Extension Team (Obj. 5).

## Extension Team

- Team Leader: A. Atucha
- Team members: D. Main, L. De Vetter, M. Coe (External Evaluator)
- Tasks: Coordinate activities and provide content for the extension and outreach activities/resources (Obj. 5). Will collaborate with the Data Management Team to develop and populate the VacCAP extension platform and work with External Evaluator to collect and evaluate feedback

# National and International Partners

## Breeding and Molecular Geneticist Partners

- Hamid Ashrafi, Assistant Professor, North Carolina State University
- Mark K. Ehlenfeldt, Research Geneticist, USDA-ARS
- Stephen Stringer, Research Geneticist, USDA-ARS
- Lisa J. Rowland, Research Geneticist, USDA-ARS
- Jeff Neyhart, Research Geneticist, USDA-ARS
- Kalpalatha Melmaiee, Associate Professor, Delaware State University
- Ebrahiem Babiker, Research Geneticist, USDA-ARS
- Moira Sheehan, Director of Breeding Insight, Cornell University
- Jim Hancock, Breeder, Berry Blue, LLC
- Jim Olmstead, Global Breeding Director-Blueberry, Driscoll's, Inc.
- Mathew Kramer, Director of Product Development & Commercialization, Fall Creek Farm & Nursery, Inc.
- Bob Gabriel, President, Oregon Blueberry Farm and Nursery
- Edward Grygleski, Cranberry Breeder and Producer, Valley Corp.
- Rachel Itle, Assistant Research Scientist, University of Georgia
- Michael Hardigan, Research Geneticist, USDA-ARS

## Fruit Quality Partners

- Anne Plotto, Research Plant Physiologist, USDA-ARS
- Randy Beaudry, Professor, Michigan State University
- Steve Sargent, Professor and Associate Chair, University of Florida
- Rod Serres, Manager Agricultural Science, Ocean Spray
- Andy Reitz, Director of Grower Relations, Mariani Co., Inc.
- Mike Mainland, Professor Emeritus, North Carolina State University
- Ann Colanna, Sensory Program Director, Food Innovation Center, Oregon State University

## Bioinformatics and Biotechnology Partners

- Robert Reid, Assistant Professor Bioinformatics, University of North Carolina-Charlotte
- Margaret Staton, Associate Professor of Bioinformatics, University of Tennessee
- Guo-Qing Song, Associate Director Plant Biotechnology Resource & Outreach Center, Michigan State University

## Extension Network

- Ali Sarkhosh, Assistant Professor, University of Florida
- Cassie Bouska, Assistant Professor, Oregon State University
- Carlos Garcia-Salazar, Extension Educator, Michigan State

## University

- Kim Patten, Director Pacific Co. and Extension Professor, Washington State University

## Extension Network (Continued)

- Cesar Rodriguez-Saona, Extension Specialist, Rutgers
- Renee Allen, Extension Specialist, University of Georgia
- William O. Cline, Research and Extension Specialist, North Carolina State University
- Kathleen Demchak, Senior Extension Associate, Penn State University
- Ben Faber, Advisor, Cooperative Extension Ventura County
- Mary Rogers, Associate Professor, University of Minnesota
- Hilary A. Sandler, Director of UMass Cranberry Station and Extension Associate Professor, University of Massachusetts-Amherst
- Erick D. Smith, Assistant Professor, University of Georgia
- Eric Thomas Stafne, Extension/Research Professor, Mississippi State University
- Wei Qiang Yang, Associate Professor and District Berry Extension Agent, Oregon State University
- Mike Mainland, Professor Emeritus, North Carolina State University

## Other Abiotic and Biotic Stresses Partners

- Christelle Guédot, Associate Professor, University of Wisconsin
- Jonathan Oliver, Assistant Professor-Fruit Pathologist, University of Georgia
- David Bryla, Research Horticulturist, USDA-ARS HCRU
- Scott Lukas, Assistant Professor, Oregon State University Hermiston Agricultural Research and Extension Center

## International Partners

- Michael Dossett, Research Scientist at BC Berry Cultivar Development Inc., British Columbia
- Susan McCallum, Blueberry Researcher at James Hutton Institute, Scotland
- Luis Diaz Garcia, Instituto Nacional de Investigaciones Forestales y Agrícolas y Pecuarias, Aguascalientes, Mexico
- Paul Sandefur, Manager of Breeding Operations at Fall Creek Farm & Nursery Inc., Oregon, USA
- Simon Bonin, Director of Grower Relations and Agronomy at Fruit d'Or, Quebec, Canada
- Susan Thomson, Bioinformatician at Plant and Food Research Ltd, New Zealand
- Toshi Foster, Senior Scientist, Plant and Food Research Ltd, New Zealand



# National and International Partners

## Supporting Industry Partners

- British Columbia Blueberries
- Berry Blue, LLC
- California Blueberry Commission
- Cape Cod Cranberry Growers' Association
- The Cranberry Institute
- The Dole Food Company
- Driscoll's, Inc.
- Fall Creek Farm and Nursery, Inc.
- Florida Blueberry Grower's Association
- Georgia Blueberry Commission
- Kentucky Blueberry Growers Association
- Mariani Premium Dried Fruit
- New Jersey Blueberry Cranberry Research Council
- North American Blueberry Council
- North Carolina Blueberry Council, Inc.
- Ocean Spray Cranberries, Inc.
- Oregon Blueberry Commission
- Oregon Blueberry Farms and Nursery
- Oregon Cranberry Grower Association
- U.S. Highbush Blueberry Council
- Valley Corporation
- Washington Blueberry Commission
- Wayne County Blueberry Growers Association
- Wisconsin State Cranberry Growers Association



# Advisory Panels

## Stakeholder Panel

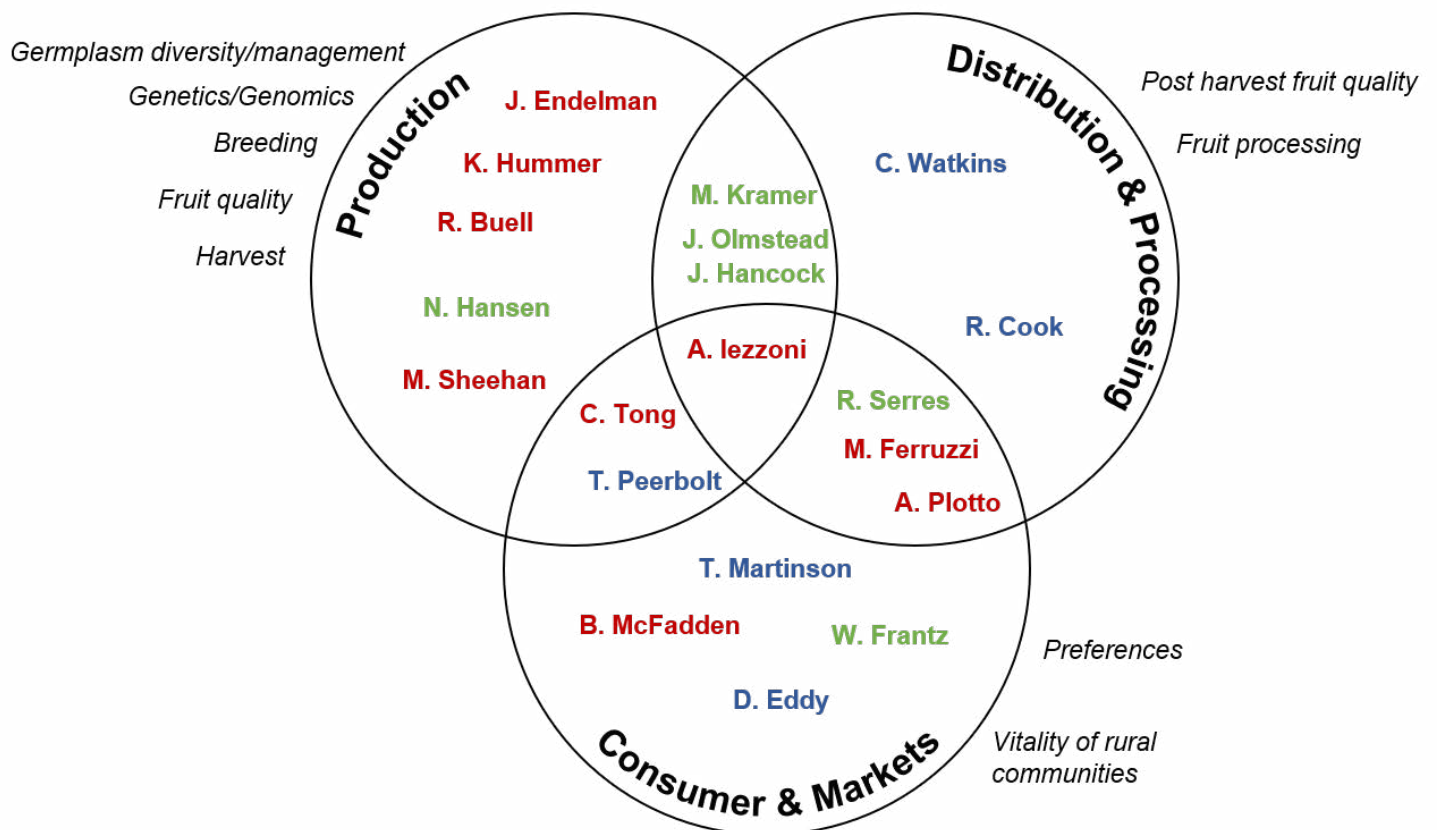
- James Hancock, Berry Blue LLC
- Nicole Hansen, Cranberry Grower
- Matt Kramer, Fall Creek Farm and Nursery
- James Olmstead, Driscoll's, Inc.
- Jessica Gilbert, Driscoll's, Inc.
- Mandie Driskill, Fall Creek Farm and Nursery
- Marivi Colle, Berry Blue LLC
- Rod Serres, Ocean Spray Cranberries, Inc.
- William Frantz, The Cranberry Institute

## Scientific Panel

- Robin Buell, Michigan State University
- Jeffrey Endelman, University of Wisconsin-Madison
- Mario Ferruzzi, Arkansas Children's Nutrition Center (ACNC)
- Michael Dossett, BC Berry Cultivar Development Inc.
- Amy Iezzoni, Michigan State University
- Brandon McFadden, University of Delaware
- Anne Plotto, USDA-ARS (FL)
- Moira Sheehan, Cornell University
- Cindy Tong, University of Minnesota
- Jeannine Lisa Rowland, USDA-ARS

## Extension Panel

- Rodney Cook, Ag-View Consulting, Inc.
- David Eddy, Master Media Worldwide
- Tim Martinson, Cornell University
- Tom Peerbolt, The Northwest Berry Foundation
- Christopher Watkins, Cornell University





# US and Global Coordination Efforts for Improving Cranberry and Blueberry

## Misson

Address major bottlenecks for growth of U.S. *Vaccinium* industry, by creating a nationwide coordinated transdisciplinary research approach to develop and implement marker assisted selection (MAS) capacity in *Vaccinium* breeding programs, to enable breeders to select and pyramid fruit characteristics (FCs) that positively contribute to fruit quality and market value. In the long term, this mission will increase production of fruit with improved characteristics that meet the ever-changing industry, market, and consumer preferences.

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## What Success Would Look Like

**Discovery.** VacCAP project outputs will increase the knowledge of:

- Cranberry and blueberry genome structure and evolution
- Genetic mechanisms and genes controlling economically important traits including fruit characteristics
- The relationships between fruit characteristics and fruit quality (shelf life, texture, bruising and sensory traits)
- Consumer behavior and interests regarding blueberry fruit quality and cranberry products
- New *Vaccinium* stakeholder priorities for the sustainability and profitability of the industry

**Engagement.** VacCAP deliverables and outcomes will be utilized by the *Vaccinium* community for the following goals:

- VacCAP DNA tools and phenotyping methods will be utilized by VacCAP PIs and the *Vaccinium* community worldwide to advance breeding and/or research programs
- VacCAP outcomes will be used by growers, processors and distributors to plan production and distribution strategies
- Funding of new off-shoot projects from VacCAP developed tools and deliverables with new collaborative alliances established

**Education.** The VacCAP team influences the next generation of breeders and scientists, increasing knowledge through collaborations:

- MS/PhD students and post-docs are trained in plant breeding, genetics, fruit phenotyping, postharvest physiology, socio-economics, sensory analysis and extension practices, to become the next generation of breeders, scientists, and agriculture liaisons

## Long-Term Impact

- Increased ability of the *Vaccinium* growers, processors and distributors to market a higher percentage of premium fruit through the use of improved varieties without increased production costs
- Increased consumption of blueberry and cranberry products in the US and worldwide due to improved fruit quality
- Increased efficiency of *Vaccinium* breeding programs for selection and improvement of fruit quality traits important to the consumer and industry
- Increased profitability, competitiveness, and sustainability of *Vaccinium* industries

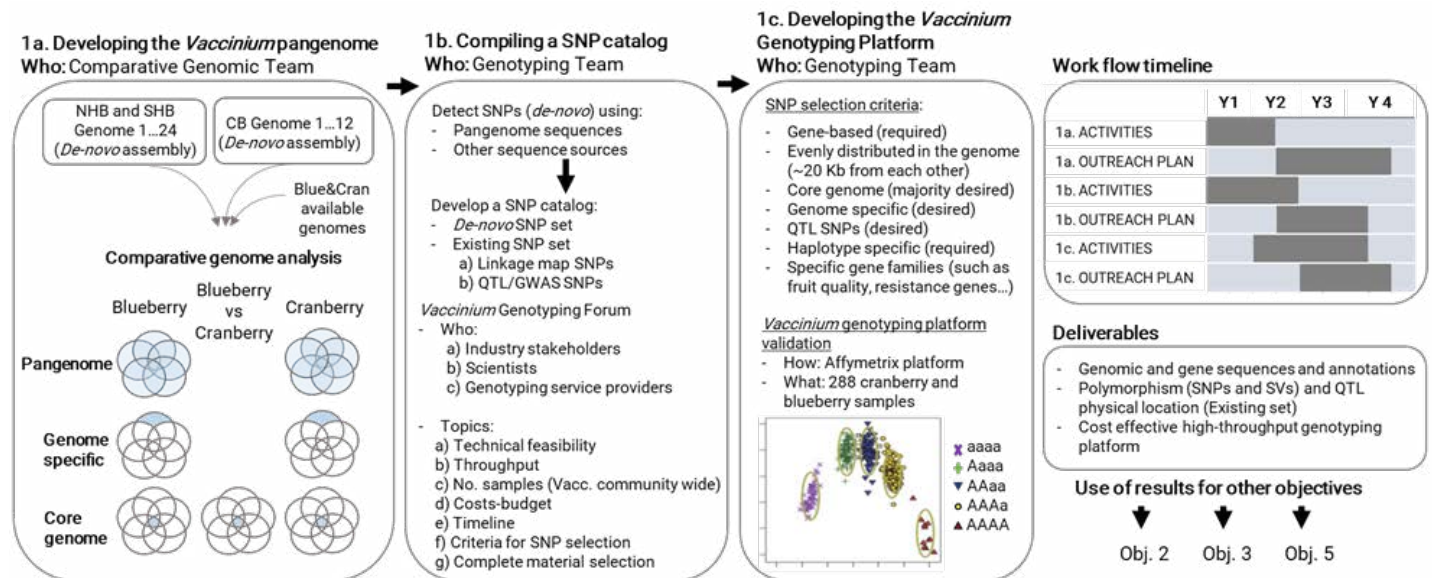
Blueberry Harvest Season

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# Objective 1

## Establish genomic resources to enable effective association mapping studies in blueberry and cranberry

The Comparative Genomic and Genotyping Teams will develop a cost effective high-density genotyping platform by mining the *Vaccinium* pangenome that represents the genetic diversity of blueberry and cranberry germplasm and their shared ancestry. In the mid and long term, this genotyping platform is expected to significantly expand our capacity to identify and validate DNA markers associated with economically important traits in blueberry and cranberry.



### Method Overview

To achieve this objective, the Comparative Genomic and Genotyping Teams will:

- 1a. Develop a *Vaccinium* pangenome. A pangenome for Northern Highbush (NHB), Southern Highbush (SHB), and cranberry (CB) will be assembled. The aim is to identify the core and dispensable portions of the genome. For each species/group, 12 genotypes that are highly representative of the pedigree of NHB, SHB and CB cultivars and that capture the greatest amount of genetic diversity were selected. This approach will limit ascertainment bias in the SNP selection.
- 1b. Compile a SNP catalog. A SNP catalog will combine *de-novo* with existing SNP sets (within linkage maps or representing QTLs). The SNPs catalog will be annotated with SNP location within genes, core or dispensable genes, gene families, alleles and haplotypes. This approach will ensure the identification of highly informative SNPs.
- 1c. Develop the *Vaccinium* Genotyping Platform. DNA regions surrounding highly informative SNPs will be selected to design a genotyping platform. Criteria for SNP selection will aim to maximize the representation of genes, markers associated with QTLs, informative haplotype blocks and to be distributed approximately 20-30Kb apart. *Vaccinium* breeders and geneticist will be engaged to establish a genotyping consortium that will help to lower the genotyping costs per sample, while ensuring application of these new molecular resources.



P. Edger



N. Bassil



D. Chagné



R. Espley



## Obj. 1 – VacCAP: Year 3 Progress Summary

Obj. 1. Establish genomic resources to enable effective association mapping studies in blueberry and cranberry	
Contributed by: Edger, Bassil, Iorizzo, Zalapa, Vorsa/Cicalese, Polashock, Chagne', Munoz, Luby	
Presented by: Edger, Yocca, Bassil	
1a. Developing the <i>Vaccinium</i> pangenome [Comparative Genomic Team]	To whom*
<b>Completed construction of the pan-genome.</b> Fully annotated (genes and repetitive features) genomes of blueberry and cranberry cultivars that were used to construct the pangenome. Using the pangenome graph, ancestral states estimated and genomic variants identified unique to blueberry, cranberry and individual genomes. The blueberry and cranberry core and dispensable genes were used by the Genotyping Team for selecting target SNPs for probe design.	Statistical Genetic Team, Breeder and Geneticist Partners
<b>Development of new genomes and genetic resources for genetic and comparative analysis.</b> Released a new blueberry genome (W85_v2) and five linkage maps. Uncovered a chromosome translocation in the blueberry cultivar 'Draper' that affects recombination behavior and demonstrated that tetraploid blueberry behaves as an autotetraploid. Completed annotation of the blueberry and cranberry pan-genomes, and conserved and genome specific genes were identified and used to design the genotyping platform. Mining of the pangenome for specific gene families is ongoing.	
<b>Impact.</b> The genomic resources developed in the VacCAP project are and will continue to: expand studies aimed at identifying candidate genes associated with fruit quality and other economically important traits; provide a solid framework to design a genotyping platform that best represents the blueberry and cranberry diversity; enable comparative studies within the <i>Ericaceae</i> and across other plant families.	
1b. Compiling SNP catalog [Genotyping Team]	To whom
<b>Compiled SNP catalog (cranberry).</b> Completed compiling and annotation of the cranberry SNP catalog. The catalog includes about 30M SNP/indels and 2.4 M mapped to a single location on the reference genome (Stevens). These variants were used to select 60,000 SNPs that were submitted to Rapid genomics for probe design/optimization which initiated the testing phase.	Statistical Genetic Team, Breeder and Geneticist Partners
1c. Developing genotyping platform [Genotyping Team]	To whom
<b>Completed testing phase and initiated genotyping phase (blueberry).</b> A total of 50,000 probes were selected, synthesized and tested in 192 blueberry samples (validation set). After screening and SNP calls, a set of 21,935 highly performing probes (containing SNPs and re-producible across samples) were selected for use in the genotyping phase. About 73% of these probes span highly conserved blueberry genes (hard and soft core genes) and only about 9% span dispensable genes. The remaining probes largely span intergenic space that were targeted to reach uniform distribution across chromosomes. Average distance between probe is 57kb, and 65 probes are cover SNPs previously associated with QTLs. Preliminary analyses of genotype data generated with the 22K platform in 192 blueberry samples indicated that this tool is not only informative in the tetraploid cultivated highbush blueberries that were targeted (4.2% missing value, on average) but that it will work well in the hexaploid rabbiteye blueberry (identical 4.2% missing value, on average) as well. This high throughput platform generated genotype data for > 150,000 SNPs in the cultivated blueberry (NHB, SHB, & RE) in addition to diploid species even in non-Cyanococcus sections. For each loci (probe) haplotype information were also extracted. 205 loci were associated with QTLs previously mapped for 16 traits (Table 2). In total, 6,696 blueberry samples were submitted by members of the <i>Vaccinium</i> Genotyping consortium for genotyping. In total 8 members from private and public breeding programs from US, France, New Zealand, Canada and Italy have submitted samples for using the platform. New partners expressed interest to use the genotyping platform and joined the consortium. Parameters and formatting needs for SNPs and haplotype call were identified. SNPs and haplotype data are being mined for population genetics, and marker traits association analysis.	Breeding, Statistical Genetic Teams, Breeder and Geneticist Partners
<b>Completed testing phase (cranberry).</b> Leaf samples were collected from 192 cranberry accessions that included representative samples from four industry partners and academic institutions in the US. Through this process 17,502 probes were selected based on data uniformity and consistency of recovery among replicates sequenced. About 80% of the probes are located in core genes, 18% in dispensable genes and 2% in intergenic region. Also, 8 SNPs were associated with known QTLs (Table 3). These probes were used to evaluate the testing set and SNPs data being mined. In total between blueberry and cranberry, a total of 7,934 samples were submitted by the <i>Vaccinium</i> Genotyping consortium for genotyping.	

**Expected impact 1b-c.** A cost effective genotyping platform that is useful to the *Vaccinium* scientific community worldwide that will enable genetic studies to identify loci and markers associated with fruit quality and other important traits.

**Challenges & changes.** The delay of funding release from the USDA-NIFA during Year 1 and COVID-19 requirements during 2020-2022, delayed the development of genotyping platforms (Obj. 1). As a result, delivery of the genotypic data for genetic studies expected in Y3 was delayed and will be completed in Year 4.

**Addressing challenges and recommendations.** A recommendation from the advisory panel and inputs from the pangenome webinar was to plan the release of the data used for the pangenome construction. Raw genomic data as well as assembled genomes for all samples included in the pangenome construction were already released on NCBI and GDV (see Table 1). This will permit various organizations to utilize that data for sequence alignment, etc. The pangenome, and each individual genome, and associated datasets and resources will be made available upon request (under the terms of a Fort Lauderdale Agreement). Activities that were delayed have already restarted and will be completed in Year 4. To compensate for some of the impacted activities, team members completed complementary activities including finalizing linkage maps and new genomes and performing comparative analysis to improve the quality of the available genomes by the Comparative Genomics Team.

\* To whom results are transferred during the project

**Table 1.** Summary of genetic and genomic resources developed during year 1-2-3.

Resource	Lab	Status	Citation	Data release status
<b>Genomes</b>				
Bilberry genome	Chagne D.	Completed*	Wu et al., 2021	Genome assembly, annotation and raw data released in GDV
Blueberry genome diploid (clone W85-23)	Iorizzo M.	Completed**	Mengist et al. 2022	Genome assembly, annotation and raw data released in GDV
Cranberry genome (Steven)	Zalapa J	Completed*	Diaz et al., 2021	Genome assembly, annotation and raw data released in GDV
Cranberry genome (Ben Lear inbred line)	Polashock J., Vorsa N.	Completed*	Kawash et al., 2021	Genome assembly, annotation and raw data released in GDV
Blueberry pangenome	Edger P.	Work in progress		Raw data released on NCBI, raw and assembled data released on GDV
Cranberry pangenome	Edger P.	Work in progress		Raw data released on NCBI
<b>Linkage maps</b>				
Reveille x Arlen (RxA) 1	Iorizzo M.	Completed*	Mengist et al. 2021	SNPs sequences released in GDV
Reveille x Arlen (RxA) 2	Iorizzo M.	Completed**	Mengist et al. 2022	SNPs sequences released in GDV
Draper Selection 44392 x Jewel	Iorizzo M.	Completed**	Mengist et al. 2022	SNPs sequences released in GDV
Draper x Biloxi	Giongo L.	Completed**	Mengist et al. 2022	SNPs sequences released in GDV
Hortblue Petite x Nui	Chagne D.	Completed**	Montanari et al., 2022	SNPs sequences released in GDV
Nui x Hortblue Petite	Chagne D.	Completed**	Montanari et al., 2022	SNPs sequences released in GDV

\* completed during the previous reporting cycle (Y1-Y2)

\*\* completed during this reporting cycle (Y3)

**Table 2.** List of traits and # of SNPs represented in the 22K blueberry genotyping probes

Trait	# SNPs*
BlueFDF	2
Scar	1
Size	21
Weight	5
Firmness	40
Flavor	3
SizeRetention	6
Color	23
Totalsolublesolids	1
Fullbloom(FB)	1
Earlygreen(EG)	14
Coldhardiness(ColdHard)	9
DeltaFDF	11
DeltaFDF/FirmRetention	4
Diameter(Dia)	58
Chillingrequirement(ChillReq)	6

\* these SNPs span QTL regions but were not validate

**Table 3.** List of traits and # of SNPs represented in the 17K cranberry genotyping probes

Trait	# SNPs*
Wax	1
FFR	4
CA	1
MA	2

\* these SNPs span QTL regions but were not validate



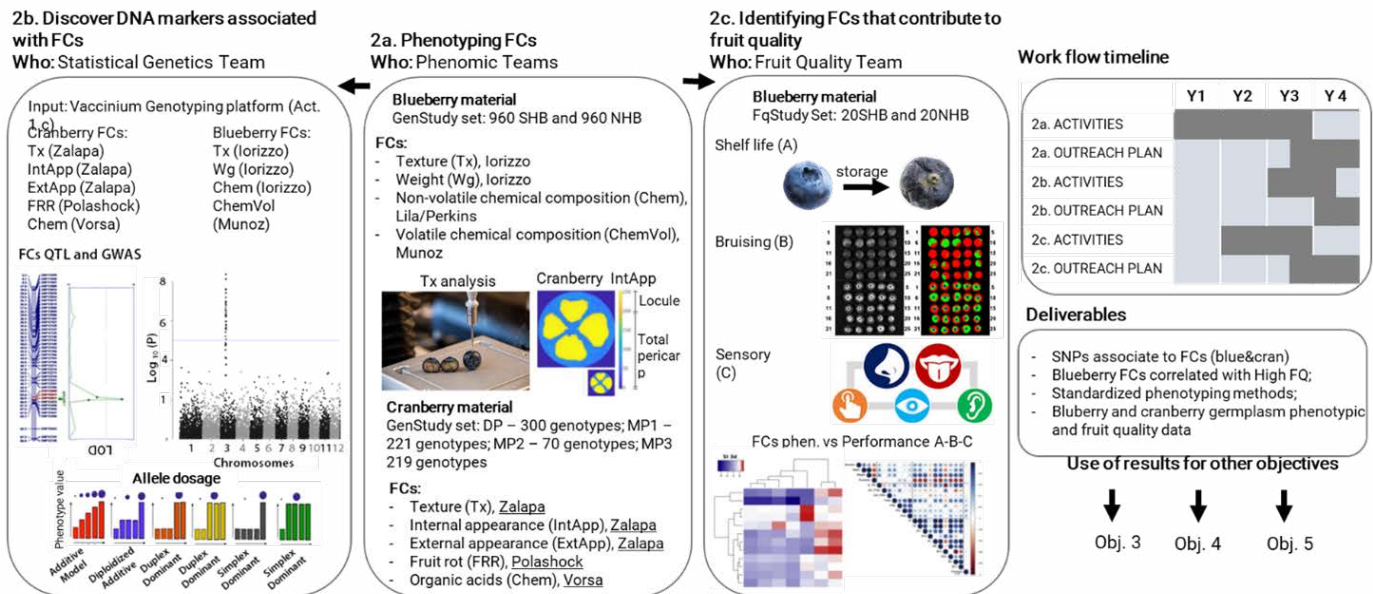
## Obj. 1 - VacCAP Plan for Year 4

<b>Obj. 1. Establish genomic resources to enable effective association mapping studies in blueberry and cranberry</b>
<b>1a. Developing the <i>Vaccinium</i> pangenome [Comparative Genomic Team]</b>
Finalize analysis of the pangenome. Identify genes (Dispensable/Core) that contribute to fruit quality traits. Understand the temporal expression patterns of these genes during fruit development & identify putative genes functions and pathways
Develop machine learning models to more easily identify dispensable genes, particularly those associated with fruit quality traits, in future <i>Vaccinium</i> Genomes.
Continue to collaborate with the VacCAP Co-PIs and partners to generate new and revised genome assemblies and annotations for various <i>Vaccinium</i> species
Communicate outcomes through publications and presentations
<b>1b-c. Developing genotyping platform [Genotyping Team]</b>
Complete genotyping phase for cranberry
Complete data analysis for testing phase blueberry and cranberry
Communicate outcomes through publications and presentations
Expected challenges. None at this time.

# Objective 2

## Discover DNA markers and fruit characteristics that maximize industry profitability and match consumer preferences in blueberry and cranberry

The Phenomics, Statistical Genetics and Fruit Quality Teams will identify DNA markers associated with fruit characteristics (FCs) and subcomponents that reduce fruit bruising, contribute to an extension of fruit shelf life, and match consumer preferences. This outcome will establish a link between DNA markers associated with FCs, and fruit quality attributes.



### Method Overview

To achieve this objective, the Comparative Genomic and Genotyping Teams will:

- 2a. Phenotype FCs. A blueberry and cranberry Genetic Study set will be phenotyped for texture, weight, appearance and chemical composition (Table 1). The blueberry GenStudy set represents the two predominant cultivated genetic backgrounds, Northern (NHB) and Southern highbush blueberry (SHB), and includes 960 NHB (120 NHB families) and 960 SHB (120 SHB families) individuals. The cranberry GenStudy set includes three bi-parental mapping populations (MP1, 2 and 3) and a diversity panel (DP) set.
- 2b. Discover DNA markers associated with FCs. Individuals will be genotyped using the *Vaccinium* genotyping platform developed in Obj. 1c. Genotyping and phenotypic data from the cranberry DP and all blueberry genotypes in the GenStudy set will be used for GWAS. Genotypic and phenotypic data from cranberry MP 1, 2 and 3 will be used to construct genetic linkage maps and identify Quantitative Trait Loci (QTLs).
- 2c. Three independent experiments will be performed to evaluate which FCs (and sub-components) contribute to the three major indicators of blueberry fruit quality, improved shelf life, matching consumer preferences, and reduction of fruit damage from mechanical harvest (Table 2). These experiments will be performed using the FqStudy set (20 NHB and 20 SHB) which was selected for variation in firmness, shelf life and sensory data; thus, increasing the discriminatory statistical power for these analyses.



M. Iorizzo



J. Zalapa



M. Lila



C. Li



C. Sims



P. Munoz



P. Perkins-Veazie



L. Giongo



N. Vorsa



C. Luby

## Obj. 2 Blueberry – VacCAP: Year 3 Progress Summary

Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in blueberry.	
Contributed by: Perkins-Veazie, Lila, Giongo, Iorizzo, Munoz, Luby, Bassil, Li, Espley	
Presented by: Iorizzo, Ferrao, Giongo, Perkins-Veazie, Oh, Mengist-Fentie	
2a. Phenotyping fruit characteristics (FCs) [Phenomic Teams]	To whom*
Finalize phenotyping protocols, equipment needs and settings. <b>Blueberry:</b> 1) tested an acoustic system to evaluate fruit texture; 2) Improved a user-friendly learning-based web application to evaluate blueberry bruise from mechanical harvesters; 3) To increase throughput for organic acid analysis in the GenStudy and ValStudy sets (SHB and NHB) a LC-MS method that use a 96 well plate system was implemented.	Fruit Quality, Statistical Genetic and Breeding Teams and Partners
<b>Phenotype FCs. Blueberry:</b> Completed evaluation of FCs (except organic acids in NHB and SHB GenStudy set) and shelf life indicators on the NHB GenStudy set (3 years data), SHB GenStudy set (2 year data), a diversity panel representing NHB from the germplasm repository (OR, Corvallis) and two mapping populations RxA (2 years data) and DSxJ (2 years data) (Table 4). Except for chemical composition all FCs were evaluated at the harvest time and after storage (six or seven weeks under controlled conditions) (Table 4). Evaluation of Organic acids in SHB adn NHB GenStudy sets is ongoing. Preliminary analysis of the data indicated: pH and TA were highly correlated; TSS and total or individual sugars were not highly correlated; the relative ratio of the different sugars (fructose, glucose, sucrose) was relatively stable across samples; Size and TSS contributed the most to separate SHB and NHB, with SHB having larger berries and lower TSS; FCs had from low to high genetic inheritance; chemistry characteristics have no or very limied impact on texture characteristisc; genetic gains for all traits was observed. Phenotipic data are being analyzed and were used for breeding purposes and genetic analysis (see Obj. 3).	Statistical Genetic and Breeding Teams
<b>Expected Impact.</b> The newly developed texture analysis methods measure multiple mechanical parameters that contribute to texture and overcome the limitation of the most commonly used blueberry and cranberry firmness analysis method (firmtech) that only evaluates external firmness. This is allowing us to better understand which texture parameters and/or other FCs contribute to fruit firmness and shelflife, and if it is genetically inherited. For instance the low or no correaltion between sugars and TSS pose questions about use of TSS measurments, a parameter commonly used by research and breeding community, as a proxy for sugar content in blueberry. Phenotypic data provided information to Oregon and Florida Breeding Programs for advancing selection and select parents to use in new crosses to develop cultivars with improved fruit characteristics and shelf life. Development of new methods for evaluating texture and chemical composition will contribute to increasing the number of the potential users of the technique used to phenotype these FCs in blueberry.	
2b. Discover DNA markers associated with FCs [Statistical Genetics Team]	To whom
Collect material, extract DNA and genotype GenStudy set: Completed DNA extraction and genotyping.	Breeding and Genotyping Teams, and geneticist partners
<b>Perform Genetic analyses. Blueberry:</b> Completed two QTL mapping study for fruit quality traits (pH, TA, TSS, Wg, anthocyanin content and composition) in two biparental populations DraperSelection x Jewel (DSxJ) and Nui x HardyBlue (NxHB)(Table 5). In total, 353 QTLs were identified, with eleven QTL regions spanning several QTLs that were stables across years. Stable QTLs across three years for TA and pH overlapped in the same regions and coincide with the same pH and TA QTL regions detected in a previous QTL study in RxA, that was completed in year 2. Similarly stable QTLs for anthocyanin acylation was indetified across multiple studies. Preliminary GWAS and QTL mapping in the GenStudyes sets (NHB, SHB, RxA, DSxJ) identified several QTLs for most of the traits, and suggests that citric acid regulate TA and pH. QTLs are being used for validation, candidate gene analysis and evaluated for use in DNA marker assay development.	
<b>Expected impact.</b> FCs-DNA marker associations are being identified and preliminary results indicated that we expect to detect more significant associations. This outcome provides the fundamental knowledge to understand the position, number of QTLs (as proxy for genes) involved in controlling FCs, and validation of some key FC-QTLs to be used for marker assisted selection.	



2c. Identifying FCs that contribute to essential fruit quality traits [Fruit Quality Team]	To whom
<p><b>Perform FQ analysis - shelf life:</b> A set of 60 cultivars (named here NC-FqStudy set) were harvested in North Carolina and held up to 6 weeks at 3°C to follow changes in texture, fruit quality, and fruit chemistry (Table 6). Completed evaluation of the following FCs include 4 Tx parameters using needle probe, 14 Tx parameters using a flat probe, 24 Tx parameters using the double compression probe, Weight (Wg), Scar Tear (ScT), Scar Diameter (ScD) and the shelf life indicators: Wrinkle, Leakage, Mold; chemistry (non-volatile) parameters: pH, TA, TSS, organic acids, sugars. All FC's were measured at harvest (T0), and two (T2), four (T4), and six (T6) weeks in post-storage. Tx with needle and double compression probes were evaluated for 1 year and all other FCs were evaluated for two years. Preliminary analysis indicates: chemistry profile did not change much during the storage; Wg has a very limited contribution for change in texture during storage; three Tx parameters (flat probe) had a large contribution on changes in texture during storage; models to predict the performance in post-harvest of these three parameters, wrinkle and weight loss using measurements collected at harvest were developed. The predictive value of the three texture parameters ranged from &gt;0.1 - 0.6 (adjusted R<sup>2</sup>), predictive value for wrinkle ranged between 0.35 - 0.48 (adjusted R<sup>2</sup>), predictive value for Weight loss was 0.85 (adjusted R<sup>2</sup>). Similar analysis are being performed using the GenStudy and ValStudy sets evaluated in Obj. 2a, at Oregon and Florida locations.</p>	Breeding, Fruit Quality and Other industry partners
<p><b>Analyze cell wall composition:</b> Three cultivars from the NC-FqStudy set were used to determine cell wall components in pulp and peel of crisp, firm, and soft cultivars at the harvest. A protocol for cell wall composition analysis was established. Data analysis indicated: monosaccharide composition differed among cultivars and tissue types; several polysaccharide linkages were identified and many differed among cultivars; firm and crisp fruits had higher amount of hemicellulosic heteromannan. Overall differences in the cell wall structure and composition in soft, firm, and crisp types may be mirroring their difference texture.</p>	Fruit Quality team and partners
<p><b>Perform FQ analysis bruising:</b> A machine learning model based web application software that can automatically determine the blueberry bruise developed during Y1-Y2 was used to evaluate the bruising rate of the NC-FqStudy set (Table 6). Preliminary analysis indicated significant variation among cultivars and ranking of cultivars with the lowest and highest bruising rate was consistent across the two years. Bruising data in this set are being used for correlation with all traits measured at harvest time.</p>	Breeding, Fruit Quality and Other industry partners
<p><b>Expected impact.</b> We expect to identify FCs subcomponents that positively correlate with extended shelf life, consumer preferences and reduced internal bruising, contributing to improved fruit quality. This outcome will enable us to establish a link between DNA markers associated with FCs, and high priority fruit quality attributes. Overall, the outcomes of this objective is enabling blueberry breeders and allied scientists to plan development of DNA marker assays to facilitate breeding for FCs and quality attributes that can lead to increased industry profitability in the long term. Phenotypic data are providing information to Oregon and Florida Breeding Programs for advancing breeding selection and about parents to use in new crosses to develop cultivars with improved fruit characteristics and shelf life. Development of new methods for evaluate texture and chem composition will contribute to increasing the number of the potential users of the technique used to phenotype these FCs in blueberry.</p>	
<p><b>Challenges &amp; Changes.</b> Due to a problem in the software used to extract the texture data from the texture analyzer data for the GenStudy and ValStudy sets had to be re-extracted and re-analyzed causing some delay with the data analysis and mining. Data from the sensory analysis that were originally planned as part of Obj. 2 were integrated into Obj. 4 as the two experiments were evaluated in parallel.</p>	

\* To whom results are transferred during the project

Table 4. Summary of blueberry phenotyping activities completed or ongoing for the GenStudy sets.

Traits	Phenotyping time	Type and # parameters	Methods	GenStudy set NHB (N=960)	GenStudy set SHB (N=960)	Draper x Jewel (DxJ)(N=196)	Reveille x Arlen (RxA)(N=364)	Diversity Panel OR NHB	New methods reference
<b>FC Traits</b>									
<b>Texture and Appearance FC</b>	Texture (TxNp) Needle probe	4 mechanical parameters	TAXTPlus***	Completed	Completed	Completed	Completed	NP	Giorgio et al. 2022, PBT 183, 111696; Iorizzo et al. 2021, ISHS presentation
	Texture (TxPp) Penetration probe	24 mechanical parameters	TAXTPlus***	Completed	Completed	Completed	Completed	NP	
	Texture (TxPp) Double compression probe	23 mechanical parameters	TAXTPlus***	Completed	Completed	Completed	Completed	NP	
	Weight (Wg) (Size**)	Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***	Completed	Completed	Completed	Completed	NP	
Scar (ScD)		Diameter (ScD)	Digital caliper***	Completed	Completed	Completed	Completed	NP	
<b>Chemical composition</b>									
Non-Volatile chemical composition (Chem)	TO	Titrateable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	NP	Completed	Completed	Perkins et al. 2021, Acta Hort.
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Completed	NP	Completed	NP	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC and LC-MS	NP	Ongoing	NP	NP	NP	
		Volatile organic composition (>60 volatile compounds)	GC-MS	NP	Completed	NP	NP	NP	
Volatile chemical composition (ChemVol)	TO and T1	Scale 0-3, and % yes/no	Visual***	Completed	Completed	Completed	Completed	NP	
		% yes/no	Visual***	Completed	Completed	Completed	Completed	NP	
		% yes/no	Visual***	Completed	Completed	Completed	Completed	NP	
		% yes/no	Visual***	Completed	Completed	Completed	Completed	NP	
Shelf life indicators	TO and T1	Avg. 10-12 berry weight (TO-T1)	High Precision Mettler Scale***	Completed	Completed	Completed	Completed	NP	Giorgio et al. 2022, PBT 183, 111696; Iorizzo et al. 2021, Proceeding of XII ISHS Int Vac Symp
		SI = log2(TIPH/TH)	TAXTPlus	Completed	Completed	Completed	Completed	NP	
		TIH= Tx at harvest		Completed	Completed	Completed	Completed	NP	
		TIPH= Tx post storage		Completed	Completed	Completed	Completed	NP	

\* TO= 12-24 hours post-harvest; T1= 6 weeks post harvest for Oregon, 7 weeks post harvest for Florida. Material was stored at the following conditions: 3°C and 95% RH in OR; 1°C and 95% RH in FL.

\*\* Fruit weight can be used as a proxy of fruit size in blueberry (Mengist et al. 2020, <https://doi.org/10.3389/fpls.2020.00370>).

\*\*\* Phenotypic data collected using the integrated phenotyping system with TAXTPlus and Exponent software.

\*\*\*\* Phenotyping not planned for this material/traits

Table 5. Summary of FC QTL studies completed in blueberry.

Crop	FC	Material	FC sub-component	# QTL	# Stable QTL/Years	Reference
Blueberry	Chem	NxHB* (N=128)	Anthocyanin types	165	3/2years	Montanari et al., 2022, F 13:965397 doi: 10.3389/fpls.2020.00605-z
			Total Anthocyanin content	172	4/3 years	
		DSxJ* (N=190)	Chlorogenic acid	5	1/3 years	
			pH	3	1/3 years	Mengist et al. 2022, Front. Pla doi: 10.3389/fpls.2020.00605-z
	Chem	RxA** (N=287)	TA	2	1/2 years	
			SSC	4	1/3 years	
		pH	pH	2	1/3 Yrs	
			TA	5	2/3 Yrs	Mengist et al. 2021, Hort F (2021). <a href="https://doi.org/10.100605-z">https://doi.org/10.100605-z</a>
	Appearance	Wg/Size	SSC	3	2/3 Yrs	
			Wg/Size	7	1/3 Yrs; 2/2 Yrs	
				371	19	

\* completed during this research cycle (N3)

Table 6. Summary of blueberry phenotyping activities completed or ongoing for the NC-FqStudy set.

Traits	Phenotyping time	Type and # parameters	Methods	NC-FqStudy set (N=62)		New methods reference
				2021	2022	
FC Traits						
Texture and Appearance FC						
Texture (TxNp) penetration needle probe	T0 and T4*	4 mechanical parameters	TA.XTPlus***	Completed	Completed	Giongo et al. 2021, PBT 183, 111696 ; Iorizzo et al. 2021, ISHS presentation
Texture (TxPp) penetration flat probe	T0 and T2, T4, T6*	14 mechanical parameters	TA.XTPlus***			
Texture (TxPp) Double compression probe	T0 and T2, T4, T6*	23 mechanical parameters	TA.XTPlus***			
Weight (Wg) (Size**)		Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***			
Scar (ScD)	T0 and T2, T4, T6*	Diameter (ScD)	Digital caliper***	Completed	Completed	
Chemical composition						
Non-Volatile chemical composition (Chem)		Titratable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	Perkins et al. 2021, Acta Hort.
	T0 and T2, T4, T6*	Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Completed	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC and LC-MS	Completed	Completed	
Shelf life indicators						
Wrinkle/Shrivel (Shr)		Scale 0-3, and % yes/no	Visual***	Completed	Completed	Giongo et al. 2021, PBT 183, 111696 ; Iorizzo et al. 2021, Proceeding of XII ISHS Int Vac Symp
Leakage (Lk)		% yes/no	Visual***			
Mold		% yes/no	Visual***			
Mold color		Visual	Visual***			
Stem scar Tear (ScTr)	T0 and T2, T4, T6*	% yes/no	Visual***			
Wet stem scar (WSc)		% yes/no	Visual***	Completed	Completed	
Weight loss (WgLo)		Avg. 10-12 berry weight (T0-T1)	High Precision Mettler Scale***			
Storage Index (SI), (estimated for all Tx and Shelf life indicators)		SI = log2(TiPH/TiH)	TA.XTPlus			Ni et al. 2022, CEA 201, 107200.
		TiH= Tx at harvest				
		TiPH= Tx post storage				
Bruising	T0	Bruising rate	Image analysis	Completed	Completed	

\* T0= 12-24 hours post-harvest; T2= 2 weeks post-harvest; T4= four weeks post-harvest; T6= six weeks post-harvest. Material was stored at the following conditions: 2°C and 80% RH.

\*\* Fruit weight can be used as a proxy of fruit size in blueberry (Mengist et al. 2020, <https://doi.org/10.3389/fpls.2020.00370>).

\*\*\* Phenotypic data collected using the integrated phenotyping system with TA.XTPlus and Exponent software.

\*\*\*\* Phenotyping not planned for this material/trait



## Obj. 2 Blueberry – VacCAP: Plan for Year 4

**Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in blueberry.**

### **2a. Phenotyping fruit characteristics [Phenomics Team]**

**Complete analysis of year 1-3 data**

**Continue testing new protocols in GenStudy set:** testing the acoustic methods for blueberry texture will continue. The team is also considering working on identifying a common set of blueberry sensory descriptors.

### **2b. Discover DNA markers associated with FCs [Statistical Genetic Team]**

**Complete QTL analysis for multiple FCs in all GenStudy sets.**

**Prepare manuscripts for dissemination of results.**

### **2c. Identifying FCs that contribute to essential fruit quality traits [Fruit Quality Team, Penelope Perkins Lead]**

**Complete data analysis for the following studies:**

**1. Variation and predictability of FCs changes during storage using Double compression probe.**

**2. Variation of bruising rate across cvs, stability across years and texture parameters that contribute to low bruising rate**

**3. Evaluation of texture profile by sensory analysis and mechanical texture.**

**Prepare manuscripts for dissemination of results.**

**Excepted challenges.** Expect some delay in completing the GWAS studies.

## Obj. 2 Cranberry – VacCAP: Year 3 Progress Summary

Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in cranberry.	
Contributed by: Zalapa, Polashock, Vorsa, Cicalese, Bassil	
Presented by: Zalapa, Lopez Moreno, Loarca, Knowles, Polashock	
2a. Phenotyping fruit characteristics (FCs) [Phenomic Teams]	To whom*
<b>Finalize phenotyping protocols, equipment needs and settings.</b> Finalized data analysis for texture methods. Results indicated that 30 fruits are enough to evaluate texture in cranberry. Kramer method has the highest reproducibility measured, followed by the blade. Temperature and fruit orientation have a significant effect on texture measurements. Tested a new fruit harvester to collect samples that has increased speed of collection, allowing phenotyping of more accessions. Also tested a hyperspectral imaging system for higher throughput phenotyping to evaluate fruit rot, color, shape, size, waxiness. Methods were developed for UHPLC of organic acids.	Fruit Quality, Breeding, Statistical Genetic and Breeding Teams and Partners
<b>Phenotype FCs.</b> Evaluated fruit weight, yield, % fruit rot, total anthocyanin, brix and titratable acidity, organic acids, epicuticular wax on berries, leaf disease and multiple morphological and phenological traits (e.g. percent bloom, #flowers, #fruit per upright) on MP3 (N=219). I Initiated evaluation for resistance to fruit scald (Table 7). Cranberry Y1-3 data are being integrated and analyzed; this mapping population is segregating for all traits analyzed. Samples were collected from the Diversity Panel (N=300) in 2022 for analysis of texture, fruit chemistry and other FC traits.	Statistical Genetic and Breeding Teams
<b>Expected Impact.</b> The newly developed texture analysis methods measure multiple mechanical parameters that contribute to texture and overcome the limitation of the most commonly used blueberry and cranberry firmness analysis method that only evaluate external firmness. This will allow a better understanding of which texture parameter and/or other FCs contribute to fruit firmness, and if it is genetically inherited. Phenotypic data are providing information to Breeding Programs for advancing selection and selecting parents to use in new crosses to develop cultivars with improved fruit rot resistance and other characteristics. Development of new methods for evaluate texture and other FCs are contributing to increasing the number of the potential users of the technique used to phenotype these FCs in cranberry.	
2b. Discover DNA markers associated with FCs [Statistical Genetics Team]	To whom
<b>Collect material, extract DNA from GenStudy set.</b> Genotyping of the cranberry GenStudy sets was initiated. A new genetic study set, that includes a wide array of accessions and breeding populations (N=847), was sent for genomic analysis.	Breeding and Genotyping Teams, Breeders and geneticist partners
<b>Perform Genetic analysis.</b> Completed two genetic studies for upright traits, berry shape/size, yield, fruit rot resistance, and other fruit characteristics (TAcy, brix, titratable acidity, PAC, epicuticular wax) (Table 8). Highlights from these studies were: yield traits positively correlated with plot and upright traits and negative correlate with PAC; QTLs were identified for all the the traits, some QTLs were stables across the years. Three QTL for yield, one for TAcy and one for fruit rot resistance overlap with those identified in previous studies.	
<b>Expected impact.</b> FCs-DNA marker associations are being identified. This outcome is providing the fundamental knowledge to understand the position, number of QTLs (as proxy for genes) involved in controlling FCs, and validation of some key FC-QTLs. If reliable markers for fruit rot resistance are identified, this could expediate breeding and release of resistant cultivars, significantly impacting the sustainability of cranberry production.	
<b>Challenges &amp; Changes.</b> Delay in the delivery of genotypic data is in turn delaying some of the genetic studies.	
<b>Addressing challenges and recommendations.</b> To ensure success of the genetic studies, additional mapping populations were evaluated for FCs. Evaluation of the Diversity panel, that was delayed due to COVID-19, was completed this year. Based on preliminary data analysis a second year of evaluation will be considered.	

\* To whom results are transferred during the project

Table 7. Summary of cranberry phenotyping activities completed or ongoing for the GenStudy sets.

Table 7. Summary of cranberry phenotyping activities completed or ongoing for the GenSturdy sets.																											
Traits	Type and # parameters	Methods	GenStudy MP1 (N=172)			GenStudy MP2 (N=71)			GenStudy MP3 (N=211)			GenStudy MP4 (N= 141)			GenStudy MP5 (N= 68)			DP (N=293)	New methods reference								
			2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021										
FC Traits																											
Texture and Appearance FC																											
Texture (TxGp) compression probe	31 mechanical parameters	TA.XTPlus**																								Lopez-Moreno et al., 2023. Horticulture publication in review	
	Length vs Width, Projected Fruit Volume, Eccentricity, Solidity, Black and White Color Scale, Black and White Color Scale Variance, Fruit Length, Fruit Width, Projected Area, Projected Perimeter	Image analysis																									
	External Appearance (ExtApp)																										
Internal Appearance (IntApp)	Wall Size, Locule Size, Flesh Size, Internal Flesh area, Fruit Width, External to Internal Flesh Ratio, Flesh Area to Locule Area Ratio	Image analysis																								Diaz-Garcia et al., 2020. PlosOne, 14(9): e0222451.	
	Berry Weight (Wg)	Avg. Wg	Precision scale																								
Chemical composition	Fruit wax	Visual rating	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*	NP*		
	Fruit Shape	Visual rating	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
	Total Anthocyanin	Spectrophotometric	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**		
		Organic acids: quinic, citric, and malic	HPLC	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
		Brix	Refractometer	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	NP**	
	Non-Volatile chemical composition (Chem)	TA	Titration	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
		% of rotted fruit/sq ft	Precision scale	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done		
	Fruit Rot Resistance (FRR)	Total Wg/sq. ft.	Precision scale	NP**	NP**	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
	Yield (total Wg)																										
	Leaf disease	% of open & past flw/total flw in 10 uprights	Visual rating																								
Bloom time	Count	Count	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
Fruit set	#fruit per 10 uprights	Count																									
NP* indicates that evaluation of the trait was not planned in this set of material NP** indicates that this trait was already evaluated outside of VacCAP for this plant material																											

NP\* indicates that evaluation of the trait was not planned in this set of material  
NP\*\* indicates that this trait was already evaluated outside of VacCAP for this plant material

**Table 8.** Summary of FC QTL studies completed in cranberry.

Crop	FC	Material	FC sub-component	# QTL	# Stable QTL/Years	Reference
Cranberry	Fruit Weight	DP (N=293)*	Avg Fruit Weight	6	NA	Diaz-Garcia et al., 2021. Front Plant Sci.;11:607770. <a href="https://doi.org/10.3389/fpls.2020.607770">https://doi.org/10.3389/fpls.2020.607770</a>
	Fruit rot resistance		Fruit rot	5	NA	
	Yield		Total Yield	1	NA	
	Chem - organic acids	CM151* (N=49)	Low Malic acid (mala) < 2.5 mg/g	1	1 / 2 Yrs	Fong et al. 2021, Tree Genetics & Genomes 17, 4. <a href="https://doi.org/10.1007/s11295-020-01482-8">https://doi.org/10.1007/s11295-020-01482-8</a>
		CM100* (N=33)	Low Malic acid (mala) < 2.5 mg/g	1	1 / 2 Yrs	
	Fruit rot Resistance	MP3** N=200	Fruit rot	1	2	Erndwein et al. 2023 Submitted to BMC Plant Biology
	TA		Titrateable Acidity	1	2	
	TACY		total anthocyanins	3	2	
	brix		soluble solids	1	2	
	Epicuticular Wax	MP4** (N=141)	Epicuticular Wax	1	1	

\* completed during the previous reporting cycle (Y1-Y2)

21

6

\* completed during this reporting cycle (Y3)

## Obj. 2 Cranberry – VacCAP: Plan for Year 4

**Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in cranberry.**

### 2a. Phenotyping fruit characteristics [Phenomics Team]

*Continue testing and developing new methods for phenotyping FC:* continue testing phenotyping methods for harvest and image analysis.

*Continue phenotyping FCs.* Consider phenotyping DP for one additional year.

*Prepare manuscripts for dissemination of results.*

*Complete analysis of year 1-2-3 data*

### 2b. Discover DNA markers associated with FCs [Statistical Genetic Team]

*Complete genotyping GenStudy sets*

*Perform QTL mapping analysis for data collected in year 1-2-3.*

*Prepare manuscripts for dissemination of results.*

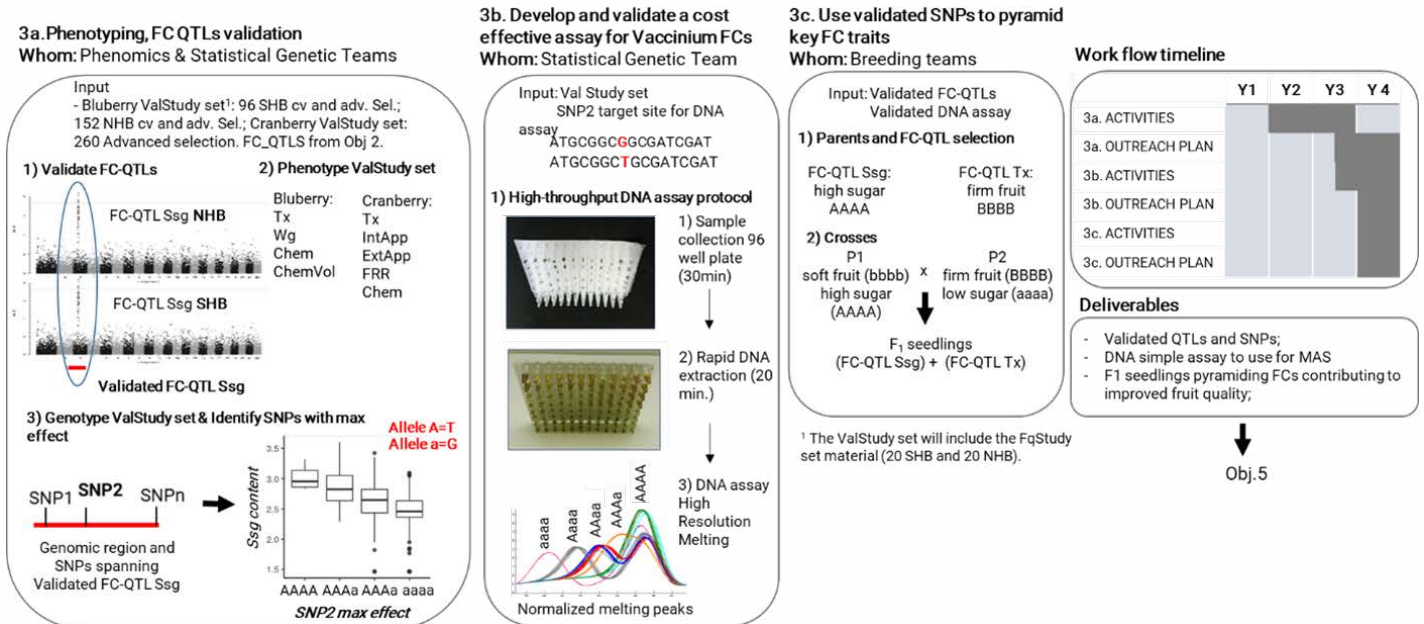
**Expected challenges.** Delays in delivery of genotypic data



# Objective 3

## Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences

The Breeding and Statistical Genetic Teams will validate fruit characteristics (FCs) QTLs in blueberry and cranberry and develop cost effective DNA assays to select parents with FCs that positively contribute to fruit quality and market value. Phenotypic data from Obj 2a-2c, 3a, 4a-b will also be used to select breeding lines with desirable FCs to establish new crosses. These outcomes will provide breeders empirical data to assign a level of importance to FCs relative to consumer preferences, decay during production, processing and distribution, and provide new tools to select for high fruit quality.



### Method Overview

To achieve this objective, the Breeding and Statistical Genetic Teams will:

- 3a. Phenotype and validate FC-QTLs. A validation study set (ValStudy set) that will include cultivars used in breeding programs for both blueberry and cranberry, will be phenotyped for all of the FCs evaluated in Obj. 2a and genotyped using the *Vaccinium* genotyping platform. FC-QTLs and existing FC-QTLs from Obj 1b and 2b will be validated in the Validation Set. FC-QTLs will be considered validated when markers show predictive ability for the targeted trait in the ValStudy set. SNPs confirming the genetic association and with max effect will be used as targets to design high-throughput DNA assays.
- 3b. Develop and validate high-throughput cost effective assay for *Vaccinium* FCs. The aim of this activity will be to develop a high-throughput protocol that is fast, cheap and enables the rapid sampling of plant tissue, DNA extraction and precise genotyping. A plate-based DNA assay using the validated FC-SNPs from Obj.3a will be used for targeted genotyping (such as High Resolution Melting, KASP or rhAMP). Markers developed from this objective will be evaluated for consistency to confirm marker-trait associations to be used for marker-assisted selection (MAS) of elite breeding materials.
- 3c. Pyramid key traits using validated SNPs and phenotypic data. Progenies with the desired FC markers or desired FC phenotypic profile evaluated in Obj 2a-b and 3a will be crossed to 'pyramid' multiple positively associated markers into superior genotypes. Breeding priority will be given to genotypes that inherit the highest number of superior FCs, determined by SNP-genotyping and phenotypic data.



P. Munoz



N. Vorsa



M. Iorizzo



J. Zalapa



J. Polashock



C. Luby

### Obj. 3 – VacCAP: Year 3 Progress Summary

Obj. 3. Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences	
Contributed by: Munoz, Vorsa, Polashock, Luby, Perkins-Veazie, Iorizzo, Lila	
Presented by: Munoz (blueberry), Polashock (cranberry)	
3a. Phenotyping, FC QTLs validation and fine mapping [Phenomic and Statistical Genetic Teams]	To whom*
<p><b>Phenotype ValStudy Set. Blueberry.</b> Completed evaluation of FCs (except organic acids in NHB and SHB ValStudy set) and shelf life indicators on the NHB ValStudy set (3 years data), SHB GenStudy set (2 year data) (Table 9). Except for chemical composition all FCs were evaluated at the harvest time and after storage (six or seven weeks under controlled conditions) (Table 9). Evaluation of Organic acids in SHB adn NHB ValStudy sets is ongoing. <b>Cranberry:</b> Phenotyping carried out on several mapping populations and a diversity panel for multiple cranberry traits, including yield, fruit rot, fruit weight, fruit shape and texture, organic acids, fruit wax, Brix, total anthocyanins, titratable acidity, leaf disease, bloom time, and upright traits.</p>	Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.
<p><b>Collect material, extract DNA from ValStudy set.</b> Completed genotyping the validation study set both for blueberry and cranberry.</p>	
<p><b>Develop list of target existing FC-QTL. Blueberry:</b> Anchored stable QTL identified across three mapping populations to the blueberry genome. Three QTL regions associated with pH/TA, anthocyanin acylation and anthocyanin glycosylation are being considered as validated, as they were detected across multiple genetic backgrounds. Also QTL for volatiles that overlapped across multiple studies were identified. Some were considered as validated QTL and used to design DNA assays to test their prediction ability, and thus, their potential for Marker Assisted Selection. <b>Cranberry:</b> Two regions harboring major QTL for total anthocyanin and color variation, that were mapped in two populations, overlap on the same physical map region and are being considered as validated. Three QTL for yield, one for TAc, and one for fruit rot resistance overlap with those identified in previous studies and will be evaluated further.</p>	
3b. Develop and validate a high-throughput affordable assay for Vaccinium FCs [Statistical Genetic Team]	To whom
<p><b>Finalize selection and protocol for simple DNA assay. Blueberry:</b> continued testing of a rapid DNA extraction method and two genotyping high-throughput assays including High Resolution Melting (HRM) and Kompetitive allele-Specific PCR (KASP). Cost analysis estimates indicated that outsourcing DNA assay is more cost effective. Two genes associated with the control of Linalool and Eucalyptol volatiles were targeted for these assays. Preliminary analysis indicated that low to high level of allele vs phenotype (high vs low Linalool or Eucalyptol) predictability were obtained. The results highlighted that additional work is needed to optimize primer design, especially in understanding variation at the genomic level in regions surrounding genes where primers are placed, which affect their amplification. Other challenges with these methods is represented by the dosage estimates. Also ideal target genes will be those that are functionally characterized. <b>Cranberry:</b> validated a DNA assay using PACE technology targeting SNPs associated with epicuticular wax within a mapping population. The marker is highly sensitive for predicting waxy fruit (Table 10).</p>	Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.



3c. Pyramid key traits using validated SNPs and phenotypic data [Breeding Teams]	To whom
<p><b>Leverage FC and FQ phenotypic data for advancing breeding selections.</b> Blueberry and cranberry: continued making selections for genotypes with good performance for FC and propagated selections made in Y2 for trialing. Crosses between superior individuals were also performed and will be germinated in early 2023.</p>	<p>Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.</p>
<p><b>Expected impact 3a-c.</b> Validated QTL will provide opportunities to evaluate these markers for MAS and also to perform functional characterization of candidate genes. With these validated QTL we can also plan future ad-hoc experiments to evaluate genotype × environment effects for FCs targeted by validated DNA assays. DNA assays for FCs, and new crosses made based on molecular and phenotypic data will provide foundational work to accelerate breeding for fruit quality in blueberry and cranberry breeding programs.</p>	
<p><b>Challenges &amp; changes.</b> Due to the delay in completing genetic studies, validation of QTL was also delayed. To facilitate integration of the novel QTL that are likely to be detected from these genetic studies, team members initiated efforts to anchor QTLs identified during Y1-Y3 in mapping populations, and from previous studies into the blueberry and cranberry physical maps. As new QTL studies are being completed, this framework will facilitate identification of QTL that overlap across multiple studies and will be considered as validated across multiple genetic stocks.</p>	

\* To whom results are transferred during the project

**Table 9.** Summary of blueberry phenotyping activities completed or ongoing for ValStudy sets.

FC Traits	Phenotyping time	Type and # parameters	Methods	ValStudy set NHB (134)			ValStudy set SHB (N=109)		
				2020	2021	2022	2021	2022	
FC Traits									
Texture and Appearance FC									
Texture (TxPp) Penetration probe	T0	24 mechanical parameters	TA.XTPlus***	Completed	Completed	Completed	Completed	Completed	
Texture (TxPp) Double compression probe		23 mechanical parameters	TA.XTPlus***	NP	NP	Completed	NP	Completed	
Weight (Wg) (Size**)		Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***	Completed	Completed	Completed	Completed	Completed	
Scar (ScD)		Diameter (ScD)	Digital caliper***	Completed	Completed	Completed	Completed	Completed	
Chemical composition									
Non-Volatile chemical composition (Chem)	T0	Titrateable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	Completed	Completed	Completed	
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Completed	Completed	Completed	Completed	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC	NP	Ongoing	NP	Ongoing	NP	
		Volatile organic composition (>60 volatile compounds)	GC-MS	NP****	Completed	NP	Completed	NP	
Volatile chemical composition (ChemVol)									
Shelf life indicators									
Wrinkle/Shrivel (Shr)	T0 and T1	Scale 0-3, and % yes/no	Visual***						
Leakage (Lk)		% yes/no	Visual***						
Mold		% yes/no	Visual***						
Mold color		Visual	Visual***						
Stem scar Tear (ScTr)		% yes/no	Visual***						
Wet stem scar (WSc)		% yes/no	Visual***						
Weight loss (WgLo)	Avg. 10-12 berry weight (T0-T1)	High Precision Mettler Scale***							
Storage Index (SI), (estimated for all Tx and shelf life indicators)	SI = log2(TiPH/TiH) TiH= Tx at harvest TiPH= Tx post storage	TA.XTPlus							

\* T0= 12-24 hours post-harvest; T1= 6 weeks post harvest for Oregon, 7 weeks post harvest for Florida. Material was stored at the following conditions: 3°C and 95% RH in OR; 1°C and 95% RH in FL.

\*\* Fruit weight can be used as a proxy of fruit size in blueberry (Mengist et al., 2020, <https://doi.org/10.3389/fpls.2020.00370>).

\*\*\* Phenotypic data collected using the integrated phenotyping system with TA.XTPlus and Exponent software.

\*\*\*\* Phenotyping not planned for this material/trait

Table 10. Summary of DNA assay developed for FCs.

Crop	FC sub-component	Traits	Marker ID	Marker type	Material tested	Sensitivity	Specificity	Reference
Cranberry	Chem - organic acids	Low vs Moderate vs High Citric Acid	scf258d	SSR	Biparental populations	0.94	0.99	Fong et al. 2020. Tree Genetics & Genomes 16: 42 <a href="https://doi.org/10.1007/s11295-020-01432-4">https://doi.org/10.1007/s11295-020-01432-4</a>
		Low CA < 2.5mmg/g; Moderate CA 3-6 mg/g; High CA >6 mg/g	SNP CA_609	KASPs	Biparental populations	0.91	0.98	
		Low vs Moderate vs High Malic Acid	SNP MA_271	KASPs	Biparental populations	0.94	0.81	Fong et al., 2021. Tree Genetics & Genomes 17, 4. <a href="https://doi.org/10.1007/s11295-020-01482-8">https://doi.org/10.1007/s11295-020-01482-8</a>
		Low MA < 2.5mmg/g; Moderate MA 3.5-5 mg/g; High CA >5 mg/g	SNP MA_476	KASPs	Biparental populations	0.94	1	
	Epicuticular Wax	Epicuticular Wax	SNP	PACE	Biparental populations	–	–	Erndwein et al. 2023 Submitted to BMC Plant Biology

### Obj. 3 – VacCAP: Plan for Year 4

**Obj. 3. Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences**

**3a. Phenotyping, FC QTLs validation and fine mapping [Phenomic and Statistical Genetic Teams]**

**3b. Develop and validate a high-throughput affordable assay for Vaccinium FCs [Statistical Genetic Team]**

Finalize protocol for the fast and simple DNA assay

Continue testing protocols for simple DNA assay on a set of existing FC-QTLs

Analyze DNA assay data (blueberry and cranberry)

Test DNA assays for organic acids, wax, fruit rot resistance, and fruit shape that were developed for cranberry in more diverse populations to evaluate sensitivity and specificity.

**3c. Pyramid key traits using validated SNPs and phenotypic data [Breeding Teams]**

Validate performance of genotypes selected during year 1-3 for advancing them into trial or to use as a parent in new crosses

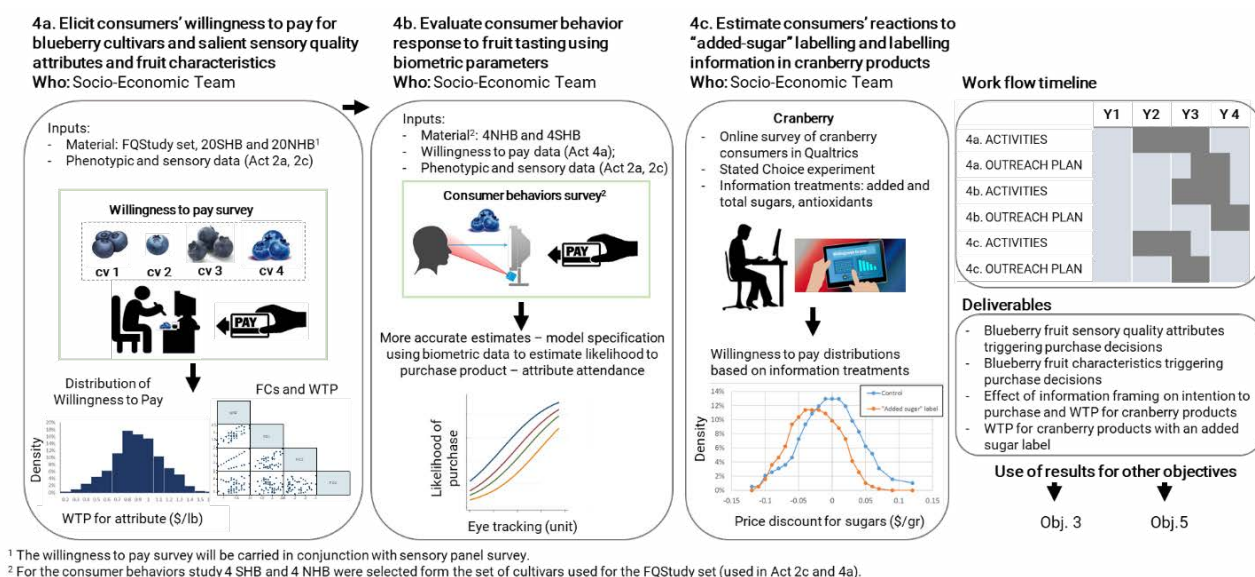
Plant seedlings in nurseries so they are evaluated for their potential contribution to FC

Possible challenges. None at this time

## Objective 4

### Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand

The Socio-Economic team will evaluate the willingness to pay (WTP) for specific sensory quality characteristics and fruit quality attributes associated with consumer preferences for fresh blueberry and processed cranberry products. Estimates of WTP surveys will inform breeding programs to target the traits of maximum value to consumers. Insights from WTP estimates for cranberry products will inform breeding efforts, specifically to sugar content and acidity in cranberries. Outcomes from this study will provide marketers and stakeholders with insights on new messaging strategies to market blueberry cultivars with improved fruit qualities and cranberry products with nutrition facts.



#### Method Overview

To achieve this objective, the Socio-Economic team will:

- 4a. Elicit consumers' willingness to pay for blueberry cultivars and salient sensory quality attributes and fruit characteristics. Sensory tasting and willingness to pay elicitation will be combined via the use of sensory taste tests and choice experiments. The study will use 20 NHB and 20 SHB blueberry cultivars, complementing the activities conducted in Act. 2c (fruit quality studies). The selection of these cultivars is based on differences in fruit firmness and sensory profiles that will enable a statistical correlation of sensory characteristics, consumers' preferences and willingness to pay.
- 4b. Evaluate consumer behavior response to fruit tasting using biometric parameters. A subset of four SHB and four NHB cultivars representing a subset of the material used in Obj. 4a, will be used to measure consumers' behavioral reactions to the blueberry sensory quality profile via the collection of biometric data. Respondents will be asked to complete a sensory evaluation questionnaire and their WTP. Data from Obj. 2c, 4a, 4b will be integrated to identify possible FCs that contribute to consumer preferences and WTP.
- 4c. Estimate consumers' reactions to "added-sugar" labeling and labeling information in cranberry products. In this objective an online survey and a choice experiment with a representative sample of U.S. consumers will be conducted to, (a) quantify consumers discount for cranberry products with an "added-sugar" line on the nutrition facts panel label, (b) measure heterogeneity in responses across consumer segments, and (c) evaluate the effect of information framing. The responses will be used to assess consumers' accuracy in evaluating sugar content and evaluate how this affects purchase intent and willingness to pay.



K. Gallardo



E. Canales



C. Sims



### Obj. 4 – VacCAP: Year 3 Progress Summary

Obj. 4 Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand.	
Contributed by: Gallardo, Canales, Sims, Munoz, Iorizzo, Lila, Perkins-Veazie, Bassil, Colonna, Luby, Paul Sandefur	
Presented by: Gallardo, Ma, Canales, Sims	
4a. Elicit consumers' willingness to pay for blueberry cultivars and salient sensory quality attributes and fruit characteristics [Socio Economic Team]	To whom*
<i>Perform WTP and consumer preference questionnaire.</i> A second year of WTP and consumer preference surveys were performed for 22 NHB and 20 SHB varieties, which total 42 NHB and 40 SHB samples across the two years, with 27 varieties assessed for both years. Data is being used to identify salient sensory attributes and fruit characteristics.	Breeding, Fruit Quality and Statistical Genetic teams, Blueberry industry partners
<i>Evaluated fruit characteristics.</i> Fruit characteristics (FC) including pH, SSC, TA, texture, sugars, organic acids, volatiles content and profile are measured for integration with sensory and WTP data. Texture was evaluated using the penetration flat probe and double compression probe as described in Obj. 2. Measurements of texture, pH, SSC, TA, organic acids and sugars for both sets FL and OR, both years were completed. Volatile analysis for the 2022 sets are being completed.	
Expected Impact: the willingness to pay for selected fruit sensory quality attributes associated with different cultivars will provide useful information about the attributes that trigger purchase decisions and repeated purchases. The quantitative value (in \$/lb) for each cultivar and quality attribute will inform fruit growers and marketers about the attributes sought by consumers and will also provide information for blueberry breeding programs about fruit traits that maximize consumer value.	
4b. Evaluate grower and consumer behavior response to fruit quality attributes [Socio Economics Team]	To whom
<i>Finalized blueberry industry and consumer preference survey questionnaires.</i> The grower survey was first disseminated with the support of the USHBC on FEB 6. On FEB 14 there were 23 responses. We plan to request USHBC if they can send reminders to increase our response rate. The grower survey goal is to estimate growers' willingness to-pay considering blueberry quality traits and information that growers in other countries are adopting new blueberry varieties. Also this first study will re-asses industry breeding priorities. The consumer blueberry survey was first implemented FEB 8. By FEB 14, the survey collection was finalized and data collected was being checked for quality control. The goal of the consumer survey is to measure consumers' propensity to purchase blueberries considering different labels that inform buyers about blueberry quality traits (e.g. "Sweety").	Breeders, growers, distributors,
Expected Impact. Information about blueberry quality traits preferred by GROWERS and information on what taste-related word that would trigger consumers' purchase, will be useful for breeders and growers in identifying quality traits with higher consumer acceptance and potential market performance, and distributors to develop marketing strategy for preferred quality traits.	



4c. Estimate consumers' reactions to "added-sugar" labelling and labelling information in cranberry products [Socio Economics Team]	To whom
<p><b>Finalized a cranberry study assessing WTP discount for added sugars.</b> Focused on dried cranberries and cranberry juice. Responses from 4,000 cranberry consumers was collected. Three products were included: dried cranberries, unlabeled cranberry juice (referred to as cranberry juice) and labeled cranberry juice (refers to 100% juice, cocktail, and blend). The study indicated that consumers discount for increases in added sugars in cranberry products (dried and cranberry juice), and such discount was not offset by health claims about consumption of cranberries. Also, consumers preferred other fruit juices as a sweetener compared to the addition of regular sugar. A second study assessing WTP for cranberry products from fruit developed using CRISPR technology with the result in a reduction in total sugar content is being completed. Results show that consumers will discount more for regular sugar content in relation to reduced sugar content, compared to the discount for CRISPR in relation to conventional breeding.</p>	<p>Breeding and Statistical Genetics teams, cranberry industry partners (nurseries, processors, growers, commodity group organizations)</p>
<p><b>Expected Impact.</b> Information on the potential impact of the added-sugar label on consumers' purchase decisions, the distribution of these impacts across segments of the population, and the impacts of communication strategies (i.e., health benefits messages to counteract the negative effect of "added-sugar" information on the Nutrition facts panel) on consumers will be helpful for cranberry breeding programs and the cranberry industry in formulating targeted marketing strategies for the promotion of cranberry products.</p>	
<p><b>Challenges &amp; Changes:</b> Due to logistic difficulties in accessing large amounts of fruit from selected blueberry cultivars, as well as feedback from stakeholders on research questions with higher priorities, the proposed research on consumer behavioral response to fruit tasting using biometric parameters was re-designed into a two-part study described in 4b.</p>	

\* To whom results are transferred during the project

**Table 11.** Summary of blueberry phenotyping activities completed or ongoing for SensoryStudy sets.

FC Traits	Phenotyping time	Type and # parameters	Methods	SensoryStudy set NHB		SensoryStudy set SHB	
				2021 (N=20)	2022 (N=22)	2021 (N=20)	2022 (N=20)
FC Traits							
Texture and Appearance FC							
Texture (TxPp) Penetration probe	T0	14 mechanical parameters	TA.XTPlus***	Completed		Completed	
Texture (TxPp) Double compression probe		23 mechanical parameters	TA.XTPlus***	NP****		NP****	
Weight (Wg) (Size**)		Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***	Completed	Completed	Completed	Completed
Scar (ScD)		Diameter (ScD)	Digital caliper***	Completed		Completed	
Chemical composition							
Non-Volatile chemical composition (Chem)							
T0	T0	Titrateable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	Completed	Completed
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Ongoing	Ongoing	Ongoing
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC	Completed	Completed	Completed	Completed
		Volatile organic composition (>60 volatile compounds)	GC-MS	Completed	Completed	Completed	Ongoing
Volatile chemical composition (ChemVol)							

\* T0= 12-24 hours post-harvest;

\*\* Fruit weight can be used as a proxy of fruit size in blueberry (Mengist et al., 2020, <https://doi.org/10.3389/fpls.2020.00370>).

\*\*\* Phenotypic data collected using the integrated phenotyping system with TA.XTPlus and Exponent software.

\*\*\*\* Phenotyping not planned for this material/trait

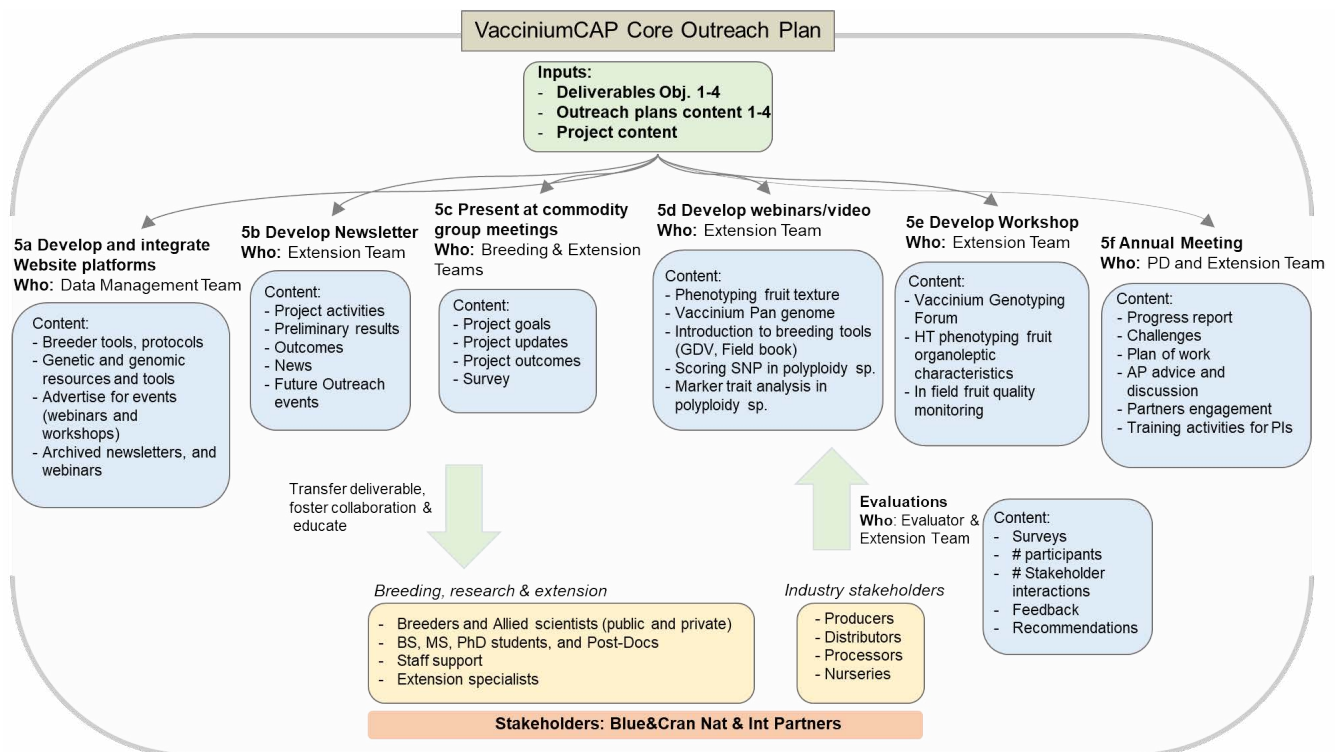
### Obj. 4 – VacCAP: Plan for Year 4

Obj. 4 Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand.
4a. Elicit consumers' willingness to pay for blueberry cultivars and salient sensory quality attributes and fruit characteristics [Socio Economic Team]
<i>Analyze the data and prepare manuscripts for dissemination of results.</i>
4b. 4b. Evaluate grower and consumer behavior response to fruit quality attributes [Socio Economics Team]
<i>Complete analyze the data from the two studies, prepare manuscripts for dissemination of results</i>
4c. Estimate consumers' reactions to "added-sugar" labelling and labelling information in cranberry products [Socio Economic Team]
<i>Communicate outcomes through publications and presentations. One manuscript (added sugar) is in revised and resubmit. The other is being submitted soon.</i>
<b>Excepted challenges:</b> Current challenge is the delay for the dissemination, as researchers prefer to have the manuscripts accepted for publication prior to dissemination.

# Objective 5

## Engage U.S. *Vaccinium* stakeholder groups to transfer advanced phenomic and genomic tools to build a more efficient cultivar development system

The Extension and Data Management Teams in collaboration with all VacCAP PIs will use background information and deliverables from the outreach plans of Objectives 1-4 to develop six outreach activities, which will represent our core outreach plan to engage stakeholders. Outreach activities will be developed to engage *Vaccinium* stakeholders by: 1) transferring knowledge and training on project deliverables; 2) educating about project outcomes; 3) fostering new collaborations; and 4) soliciting feedback on the project to fine-tune research and extension activities. Target stakeholders are national and international blueberry and cranberry partners that represent breeders, researchers (breeder's allied scientists), mentees/trainees (staff, mentored students and post docs), extension specialists, and industry stakeholders (producers, processors, distributors, and nurseries), as well as the members of the Advisory Panel (AP) that represent these audiences. Training activities will also target members of VacCAP core labs.



To achieve this objective, the extension and data management teams will:

- 5a. Update and expand online platforms. The existing Genome Database for *Vaccinium* website (GDV, <https://www.vaccinium.org/>) will provide open access to genetic (e.g., all QTLs) and genomic (e.g., pangenome sequences) resources developed in Obj. 1-3. A new VacCAP project website will serve as a repository of information for project participants and *Vaccinium* stakeholders.
- 5b. Develop newsletters. A biannual electronic newsletter will highlight project activities, preliminary results, outcomes, news, and future outreach events.
- 5c. Develop webinars. Webinars will inform breeders, researchers, and mentees/trainees about project results and deliverables, provide technical instructions on how to gain access and use these new resources, which will complement Obj. 5d.
- 5d. Develop workshops and forums. Workshops will train and educate breeders, researchers, mentees/trainees and industry stakeholders on high-throughput phenotyping methods developed and used in the project to evaluate fruit quality traits of blueberry and cranberry.
- 5e. Participate in commodity group meetings. Presentations will be delivered at annual regional grower meetings by members of the Breeding and/or Extension Team and will be facilitated by our extension collaborator network. Presentations will highlight project goals, and relevance to specific industry groups, and will provide opportunities for communication and feedback between the project team and stakeholders.



## Objective 5 (Continued)

### Engage U.S. *Vaccinium* stakeholder groups to transfer advanced phenomic and genomic tools to build a more efficient cultivar development system

- 5f. Annual meeting. Annual meeting extension activities will include: 1) disseminating project accomplishments to the Advisory Panel and partners; 2) promoting collaborative efforts with partners; 3) hosting workshops specific to the phase of the project.
- 5g. Engage the public (Outreach). To educate the general public about the project outcomes and impacts, team members' will present the VacCAP project and related activities through established outreach activities such as science fairs, guest lectures, and supporting high school science programs.



**A. Atucha**



**L. Wasko DeVetter**



**D. Main**



**M. Coe**

## Obj. 5 – VacCAP: Year 3 Progress Summary

**Obj. 5: Engage U.S. Vaccinium stakeholder groups to transfer advanced phenomic and genomic tools to build a more efficient cultivar development system**

**Presented by: Atucha, Main, Coe**

**Reported by: Atucha, DeVetter, Main and all other PIs**

### 5.a. Update and expand online platforms [Data Management team]

**To whom**

**Update VacCAP project website:** Updates that were done to the VacCAP website in YR3:

- created specific categorized content for user groups such as breeders and stakeholders and using icons to organize information on these pages.

- Development of VacTrait and VacCAP for all deliverables

- Updated webinar videos and newsletters

- Website stats summary (September 1, 2021–August 31, 2022): 5,719 pageviews; 2,614 users; 3,211 sessions (1.23 sessions per users).

VacCAP core labs and the Vaccinium genomics, genetics and breeding research community

**Update Genome Database for Vaccinium (GDV):** During year 3 of the project, new GDV data included: 33 genomes, 2,685,225 annotated genes, 2,717,231 annotated transcripts, 5 genetic maps, 126,348 markers, and 203 QTLs. GDV was accessed by 6,037 users from 99 countries, with 11,054 visits and 100,439 pages served (Google Analytics).

### 5.b. Develop material for newsletters and other social media [Extension Team]

**To whom**

**Develop and release newsletters:** Two VacCAP newsletters and three GDV newsletters were issued during year 3. Newsletters are archived on the VacCAP and GDV websites and are delivered by email to our stakeholders (breeders, researchers, extension specialists, and industry stakeholders, as well as project participants). Newsletter stats: 325 subscribers get the newsletter directly by email, with an opening rate of >50% (compared to an average of 45% among similar email campaigns).

**Maintained VacCAP accounts on social media:** A Twitter account (@VacciniumCAP) was maintained to disseminate information about the project as part of the social media strategy, in conjunction with a YouTube channel. (<https://www.youtube.com/channel/UCpAdtvTEebzZjvJ4SJcoXwg>). Twitter Stats (August 2021–August 2022): 347 followers; 7,118 (average 593/month) profile visits. Youtube stats: 774 video views, 65.9 hours of watch-time.

VacCAP core labs, partners, stakeholders, general public

### 5.c. Develop webinars [Extension Team]

**To whom**

**Deliver webinars:** delivered three webinars (see VacCAP pub and presentations for titles and link), attended by 170 participants.

VacCAP core labs, breeding and genetic partners

### 5d. Protocols and methodology training videos [Extension Team]

**To whom**

**Develop video training.** Eight instructional videos were produced during Year 3 and posted on the project's YouTube channel (see VacCAP pub and presentations for title and link). (<https://www.youtube.com/channel/UCpAdtvTEebzZjvJ4SJcoXwg>). These videos feature the use of new methodology to evaluate fruit quality of blueberries and how to use tools and resources available on GDV.

VacCAP core labs, partners, and stakeholders

### 5e. Participate in commodity group meetings or field days [Extension Team]

**To whom**

**Attend commodity group meetings [meetings in collaboration with industry extension network team]:** Delivered 10 presentations at grower association meetings and field days across US states. Developed handouts flyer that summarized the the objectives of the VacCAP project.

Blueberry and cranberry growers, processors, distributors, nurseries and breeding partners

5f. Annual meeting [Extension Team]	To whom
<p><b>Facilitate annual meetings targeting project participants, AP members, and national and international partners:</b> An annual report that summarized Year 3 activities and plans for Year 4 was prepared and shared with members of the advisory panel prior to the meeting. Information collected during the annual meeting will be used to integrate recommendations from the AP and plan Year 4 activities. The annual report was posted on the VacCAP web site at <a href="https://www.vacciniumcap.org/annualreport">https://www.vacciniumcap.org/annualreport</a>.</p>	<p>Team members, AP members, USDA program officers</p>
External Evaluation [Extension Evaluator]	To whom
<p><b>Coordinate the design and implementation of surveys for webinar, workshop and meeting participants and assist with annual report forms for project participants:</b> Participant surveys for the webinars noted in Obj 5c were developed with input from team members. Online surveys were used to collect feedback from webinar participants with a combination of standardized questions across webinars and customized questions related to each webinar topic. Resulting data was aggregated and summarized across webinars. Assisted with the updated design and implementation of the annual project report form for project Co-PIs and Co-PDs.</p>	<p>Team members, AP members, USDA program officers, extension audiences</p>
<p><b>Manage, analyze, interpret and report project evaluation feedback, recommendations, and related data:</b> survey data, feedback and recommendations were collected from 48% of webinar participants, including breeders and scientists from public and private organizations, technical staff members, post-docs and students. Two thirds or more reported that each webinar “greatly” or “moderately” improved their understanding of the topics (66% to 97%) and almost all would recommend the webinars to others (83% to 100%). Over 11,700 users/viewers and 325 newsletter subscribers from &gt;99 countries accessed these updated products/information in VacCAP and GDV. Overall, evaluation matrix indicates that the project is reaching a very broad audience and the resources/information generated in the project have a positive impact on this community. Feedback and recommendations for the project from webinar participants, Advisory Panel and Working Group participants were reported back to the team and are being used to inform future project activities.</p>	<p>Team members, AP members, extension audiences, stakeholders, USDA program officers</p>
<p><b>Expected impact.</b> Breeders, researchers, trainees/mentees will benefit from the adoption of the genetic and genomic tools developed in this project that will facilitate the application of Marker Trait Association studies, and over the long term will result in a next generation of blueberry and cranberry cultivars with improved fruit quality traits. Extension specialists and industry stakeholders will learn and implement accurate high-throughput phenotyping methods to effectively select fruit with desired quality characteristics. Industry stakeholders will learn which fruit quality traits affect market demand, leading to new marketing strategies to increase and sustain consumer demand. The extension activities will also foster team collaboration and new collaborations outside the scope of this project, providing further value to stakeholders by ensuring that related activities continue beyond the length of this project.</p>	
<p><b>Challenges &amp; changes.</b> Engagement with the public and commodity groups was still limited due to limited in person events organized at each location due to COVID-19.</p>	
<p><b>Addressing challenges and recommendations.</b> We will continue to develop training videos for new methodologies developed by the team. Grower engagement at meetings and conferences will be done in a hybrid model with both virtual and in-person presentations.</p>	



## Obj. 5 – VacCAP: Plan for Year 4

**Obj. 5: Engage U.S. Vaccinium stakeholder groups to transfer advanced phenomic and genomic tools to build a more efficient cultivar development system**

### 5.a. Update and expand online platforms [Data Management Team]

**Update VacCAP and GDV:** continue updating VacCAP and GDV content. Updates will include: new genetic and genomic data, links to peer-reviewed publications, newsletter articles, short publications on fruit quality traits, video recordings of webinars and trainings, and social media updates.

### 5.b. Develop newsletters and other social media [Extension Team]

**Release additional VacCAP newsletter editions:** During Year 4 we will issue 3 editions of our VacCAP Newsletter that will be distributed to our stakeholders and partners. Also new issues of the GDV newsletter will be released to update national and international partners on new tools and resources available on GDV.

**Prepare article for trade magazines:** We plan to release one article in a trade magazine during Year 4.

**Maintain VacCAP accounts on social media:** The team will continue to actively engage stakeholders and partners through our Twitter account.

### 5.c. Develop webinars [Extension Team]

Five webinars are planned for Year 4: genotyping platform (Dr. Bassil); W85 genome and polyploid genetics (Dr. Iorizzo); Cranberry socio economic studies (Dr. Gallardo and Canales); cranberry fruit quality traits genetics (TBD); Blueberry fruit quality genetics (TBD).

### 5d. Protocols and methodology training videos [Extension Team]

Two instructional videos will be produced during Year 4, posted on the VacCAP project website and YouTube channel, and distributed to our audience through our newsletter and social media posts. These videos will feature the use of new methodologies for fruit quality phenotyping developed by our team members, as well as evaluation and comparisons of equipment available to stakeholders. In conjunction with the training videos, and when applicable, PDF files with step-by-step protocols will be available on our website. Also new training videos on how to use GDV will be posted on our website by the team monthly.

### 5e. Participate in commodity group meetings [Extension Team]

In collaboration with the industry extension network team, presentations will be delivered at commodity group meetings to update stakeholders on project progress. These meetings will also serve as an event to re-assess industry breeding priorities.

### 5g. Annual meeting [Extension Team]

The extension team will facilitate annual meetings targeting project participants, AP members, and national and international partners.

### 5h. Engage the public (Outreach) [Extension Team, all teams]

The team expects that activities to engage and educate the general public about the project outcomes and impacts will re-start during year 4.

### External Evaluation [Extension Evaluator]

**Coordinate the design and implementation of surveys for webinar, workshop and meeting participants and assist with annual report forms for project participants.** Continue to develop and update surveys, feedback forms, report forms and related instruments and systems as needed during Year 4.

**Manage, analyze, interpret and report project evaluation feedback, recommendations, and related data.** Continue to report findings and recommendations from stakeholders, advisors and project team members as needed for project management and planning during Year 4.

**Assist with integration of evaluation data into project reports, annual meeting and Advisory Panel materials, and outreach materials.** Continue to help with the integration of findings and recommendations from stakeholders, advisors and project team members into project reports, meeting materials, and outreach materials.



# VacCAP Team Publications and Presentations

## Journal Article

- Montanari S, Thomson S, Cordiner S, Günther CS, Miller P, Deng CH, McGhie T, Knäbel M, Foster T, Turner J, Chagné D and Espley R. (2022) High-density linkage map construction in an autotetraploid blueberry population and detection of quantitative trait loci for anthocyanin content. *Frontiers in Plant Science*. 13:965397. <https://doi.org/10.3389/fpls.2022.965397>
- Dare AP, Günther CS, Grey AC, Guo G, Demarais NJ, Cordiner S, McGhie TK, Bolding H, Hunt M, Deng C, Karppinen K, Jaakola L and Espley RV. (2022). Resolving the developmental distribution patterns of polyphenols and related primary metabolites in bilberry (*Vaccinium myrtillus*) fruit. *Food Chemistry* 374, 131703. <https://doi.org/10.1016/j.foodchem.2021.131703>
- Lafferty DJ, Espley RV, Deng CH, Günther CS, Plunkett B, Turner JL, Jaakola L, Karppinen K, Allan AC and Albert NW. (2022). Hierarchical regulation of MYBPA1 by anthocyanin- and proanthocyanidin-related MYB proteins is conserved in *Vaccinium* species. *Journal of Experimental Botany*. 73, 1344-1356. <https://doi.org/10.1093/jxb/erab460>
- Lafferty DJ, Espley RV, Deng CH, Dare AP, Günther CS, Jaakola L, Karppinen K, Boase MR, Wang L, Luo H, Allan AC and Albert NW. 2022. The coordinated action of MYB activators and repressors controls proanthocyanidin and anthocyanin biosynthesis in *Vaccinium*. *Frontiers in Plant Science*. 13:910155. <https://doi.org/10.3389/fpls.2022.910155>
- Samkumar A, Karppinen K, McGhie TK, Espley RV, Martinussen I, Jaakola L. 2022. Flavonoid biosynthesis is differentially altered in detached and attached ripening bilberries in response to spectral light quality. *Frontiers in Plant Science*. 2529. <https://doi.org/10.3389/fpls.2022.969934>
- Günther CS, Plunkett BJ, Cooney J, Jensen D, Trower T, Elborough C, Nguyen HM, Deng C, Lafferty DJ, Albert NW, Dare AP and Espley RV. 2022. Biotic stress-induced and ripening-related anthocyanin biosynthesis are regulated by alternate phytohormone signals in blueberries. *Environmental and Experimental Botany*. <https://doi.org/10.1016/j.envexpbot.2022.105065>
- Edger PP, Iorizzo M, Bassil NV, Benevenuto J, Ferrão LFM, Giongo L, Hummer K, Lawas LMF, Leisner CP, Li C, Munoz PR, Ashrafi H, Atucha A, Babiker EM, Canales E, Chagné D, DeVetter L, Ehlenfeldt M, Espley RV, Gallardo K, Günther CS, Hardigan M, Hulse-Kemp AM, Jacobs M, Lila MA, Luby C, Main D, Mengist MF, Owens GL, Perkins-Veazie P, Polashock J, Pottorff M, Rowland LJ, Sims CA, Song G, Spencer J, Vorsa N, Yocca AE and Zalapa J. 2022. There and back again; historical perspective and future directions for *Vaccinium* breeding and research studies. *Horticulture Research* 9, 10.1093/hr/uhac083. <https://doi.org/10.1093/hr/uhac083>
- Ni X, Takeda F, Jiang H, Yang WQ, Saito S and Li C. 2022. A deep learning-based web application for segmentation and quantification of blueberry internal bruising. *Computers and Electronics in Agriculture*. 201:107200. <https://doi.org/10.1016/j.compag.2022.107200>
- Alan E, Yocca, Patrick P, Edger PP. 2022. Current status and future perspectives on the evolution of cis-regulatory elements in plants. *Current Opinion in Plant Biology*. 65: 102139. <https://doi.org/10.1016/j.pbi.2021.102139>
- Teresi SJ, Teresi MB and Edger PP. 2022. TE Density: a tool to investigate the biology of transposable elements. *Mobile DNA*. 13, 11 <https://doi.org/10.1186/s13100-022-00264-4>
- Mengist MF, Bostan H, De Paola D, Teresi SJ, Platts AE, Cremona G, Xinpeng Q, Mackey T, Bassil NV, Ashrafi H, Giongo L, Jibrán R, Chagné D, Bianco L, Lila MA, Rowland LJ, Iovene M, Edger PP and Iorizzo M. 2022. Autopolyploid inheritance and a heterozygous reciprocal translocation shape chromosome genetic behavior in tetraploid blueberry (*Vaccinium corymbosum*). *New Phytologist*, in press. <https://doi.org/10.1111/nph.18428>
- Fong SK, Kawash J, Wang Y, Johnson-Cicalese J, Polashock J, Vorsa N. 2021. A low malic acid trait in cranberry fruit: genetics, molecular mapping and interaction with a citric acid locus. *Tree Genetics & Genomes* 17:4 <https://doi.org/10.1007/s11295-020-01482-8>
- Ma X, Gallardo RK, Canales E, Atucha A, Zalapa J and Iorizzo M. 2022. "Consumers' discount for added sugars: An application to cranberry products under different nutrition-related information treatments. *Applied Economic Perspectives and Policy*
- Trandel M, H Oh, Johanningsmeier S, Iorizzo M and Perkins-Veazie P. Cell wall polysaccharide linkage assembly in blueberry peel and pulp reveals hemicelluloses specifically associated with the 'Indigocrisp' cultivar. *Frontier in Plant Science*. <https://doi.org/10.3389/fplants10030553>

## Conference Papers and Presentations

- Ma X, Gallardo RK and Canales E. 2022. "Consumer's willingness to pay for gene editing breeding: Application to cranberry products." Annual Meetings of the Agricultural and Applied Economics Association. Anaheim, CA. August 1-2.

# VacCAP Team Publications and Presentations

- Trandel-Hayse M, Oh H, Johanningsmeier S, Iorizzo M, Perkins-Veazie P. 2022. Cell wall polysaccharide composition in the peel and pulp of blueberry cultivars differing in fruit texture quality. 135th Florida State Horticulture Conference, June 5-7, Sarasota, FL.
- Ma X, Canales E, Gallardo RK. "Consumers discount for added sugars: An exploratory analysis of two cranberry products under different nutrition-related information treatments." Online Agricultural and Resource Economics Seminars (OARES). December 1, 2021.
- Boase MR, McGhie T, Wang L, Zhang H, Luo H, King I, Lafferty DJ, Albert NW, Allan AC and Espley RV. 2022. Overexpression of VcMYBA1, a key anthocyanin transcription factor in highbush blueberry elevated anthocyanins, turning leaves dark red. Society of In Vitro Biology Meeting, 4-7 June 2022 in San Diego, California
- Munoz P. 2022. Genome wide association of blueberry fruit quality traits. International Horticultural Congress. August 14-19, 2022.
- Xueping N, Takeda F, Jiang H, Yang WQ, Saito S and Li C. 2022. A deep learning-based web Application to quantify blueberry internal bruising. International Horticultural Congress. August 14-19, 2022.
- Iorizzo M, Lila MA, Perkins-Veazie P, Luby C, Vorsa N, Edger P, Bassil N, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, De Vetter L, Coe M, Chagné D, Colonna A and Espley R. 2022. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Acta IHC ISHS 2022
- Knowles S, Kawash J, Johnson-Cicalese J, Polashock J, Vorsa N. 2021. Relationships between fruit rot resistance and horticultural traits in American cranberry (*Vaccinium macrocarpon* Ait.). 12th International Vaccinium Symposium, International Society for Horticultural Sciences. Remote. August 30 – September 1, 2021.
- Mengist MF, Grace M, Mackey T, Bassil N, Luby C, Ferruzzi M, Lila MA and Iorizzo M. Dissecting the genetic basis of anthocyanins accumulation and diversity in blueberries (*Vaccinium corymbosum* L). ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.
- Yalcin O, Finn C, Mackey T, Pottorff M, Giongo L, Iorizzo M, Mengist MF, Coe K, Hardigan M, Luby C, King R and Bassil N. 2022. QTL Analysis of phenological and fruit quality traits in a tetraploid highbush blueberry population. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.
- Iorizzo M, Molla MF, Bostan H, De Paola D, Teresi S, Teresi A, Cremona G, Qi X, Mackey T, Bassil N, Ashrafi H, Giongo L, Jibrán R, Chagné D, Bianco L, Lila MA, Rowland LJ, Iovene M and Edger P. 2022. Comparative genome analysis in blueberry revealed autopolyploid recombination behavior and a heterozygous reciprocal translocation. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.
- Iorizzo M, Lila MA, Perkins-Veazie P, Pottorff M, Mengist MF, Colonna A, Vorsa N, Edger P, Bassil N, Luby C, Mackey T, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, DeVetter L, Chagne D, Espley R and Coe M. 2022. Vaccinium CAP status and updates: advancing genetic and genomic tools to improve fruit quality in blueberry and cranberry. NABREW conference, June 27-29, 2022, virtual.
- Mengist MF, Bostan H, De Paola D, Teresi SJ, Platts A, Cremona G, Qi S, Mackey T, Bassil NV, Ashrafi H, Giongo L, Jibrán R, Chagné D, Bianco L, Finn C, Lila MA, Rowland LJ, Iovene M, Edger PP and Iorizzo M. 2022. Autopolyploid inheritance and a heterozygous reciprocal translocation shapes chromosome genetic behavior in tetraploid blueberries. XXIX Plant & Animal Genome, January 8-12, 2022, San Diego, California, USA.
- Iorizzo M, Lila MA, Perkins-Veazie P, Pottorff M, Mengist MF, Colonna A, Vorsa N, Edger P, Bassil N, Luby C, Mackey T, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, DeVetter L, Chagne D, Espley R and Coe M. 2022. Vaccinium CAP: A community-based project to develop advanced genetic and genomic tools to improve fruit quality in blueberry and cranberry. Acta Horticulturae, Proceeding of the International Symposium on Breeding and Effective Use of Biotechnology and Molecular Tools in Horticultural Crops, August 14-20, 2022, Angers, France.
- Iorizzo M, Mengist MF, Bostan H, Curaba J, Pottorff M. 2021. From genome to genes and DNA markers to improve agronomic performance and quality of fruit and vegetables crops. Genetyka Aplikacyjna Roślin XXI, September 22-24, 2021, Warsaw, Poland.
- Iorizzo M. 2022. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Southeast Regional Fruit & Vegetable Conference, January 69, 2022, Savannah, GA.
- Perkins-Veazie P, Ma G, Oh H, Trandel-Hayse MA, Bassil N, Luby C, Munoz PR and Iorizzo M. Development of a high-throughput method to evaluate soluble sugar content of large sets of blueberry fruit. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.

# VacCAP Team Publications and Presentations

## Conference Posters

- Oh H, Pottorff M, Giongo L, Iorizzo M, Perkins-Veazie P. 2022. Texture characteristics associated with fruit shelf-life in blueberry. Southern Region Meeting, American Society for Horticultural Science, February 11, 2022, New Orleans, LA. Poster
- Bassil et al., 2022 VacCAP. Produces a targeted capture genotyping platform for blueberry. International Horticultural Congress. August 14-19, 2022. ePoster
- Oh H, Pottorff M, Mengist MF, Giongo L, Iorizzo M and Perkins-Veazie P. Examination of texture characteristics at harvest and postharvest and identification of QTLs in blueberry. The 31st International Horticultural Congress (IHC). August 14-20, 2022, Angers, France. Poster
- Trandel-Hayse MA, Oh H, Johanningsmeier S, Iorizzo M and Perkins-Veazie P. 2022. Peel and pulp texture parameters are negatively correlated to pectin and cellulose content in ten highbush blueberry cultivars. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster
- Oh H, Pottorff M, Giongo L, Iorizzo M and Perkins-Veazie P. 2022. Dissecting the texture characteristics determining the phenotypic variation and postharvest change of fruit texture in blueberry. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster
- Perkins-Veazie P, Oh H, Trandel M, Ma G, Mainland CM, Lila MA and Iorizzo M. 2022. Changes in blueberry fruit chemistry after six weeks cold storage. Acta Horticulturae, Proceeding of the International Symposium on Advances in Berry Crops, August 14-20, 2022, Angers, France. Poster
- Pottorff M, Coe K, Giongo L, Bassil N, Luby C, Munoz PR, Ferrao F, Perkins-Veazie P and Iorizzo M. 2022. Analysis of northern highbush and southern highbush blueberry populations using an integrated phenotyping system to capture fruit texture characteristics and other traits at harvest and post-harvest. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster
- Oh H, Pottorff M, Mengist MF, Giongo L, Iorizzo M and Perkins-Veazie P. Examination of texture characteristics at harvest and postharvest and identification of QTLs in blueberry. Acta Horticulturae, Proceeding of the International Symposium on Advances in Berry Crops, August 14-20, 2022, Angers, France. Poster

## Webinars

- Perkins-Veazie P, Giongo L and Zalapa J. 2022. Exploring firmness and texture in blueberry and cranberry. February 3, 2022. 76 participants. [https://www.youtube.com/watch?v=Xnmvefb\\_X9c&t=1s](https://www.youtube.com/watch?v=Xnmvefb_X9c&t=1s)
- Yocca A. 2022. Generating a *Vaccinium* pangenome to unlock previously hidden genetic variation. August 22, 2022. 41 participants. <https://www.youtube.com/watch?v=dUnFxrzZAY0>
- Munoz P. Making sense of volatiles and their effect on blueberry flavor. May 26, 2022. 53 participants. <https://www.youtube.com/watch?v=JReCVw2cJk0&t=131s>

## Presentations for Growers or Other Industry Stakeholders

- Iorizzo M. VacCAP project updates. North Carolina Blueberry Council – 56th Annual Open House and Trade Show, January 11, 2022, Harrells, NC, USA. Presentations for Growers or Other Industry Stakeholders
- Knowles S, Kawash J, Johnson-Cicalese J, Polashock J, Vorsa N. 2022. Phenotyping and genotyping CNJ14-31: A unique population segregating for fruit rot resistance, fruit chemistry and other traits (Bog 18). Annual Summer Meeting of the American Cranberry Growers Association. P.E. Marucci Center, Chatsworth, NJ. August 18, 2022. Presentations for Growers or Other Industry Stakeholders.
- Kawash J, Polashock J, Vorsa N, Johnson-Cicalese J. 2022. Identifying genetic markers for defense mechanisms in cranberry fruit. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.
- Johnson-Cicalese J, Vorsa N, Polashock J, Oudemans P, Knowles S. 2022. Update on breeding for fruit rot resistance in cranberry. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.
- Polashock J, Kawash J. 2022. Visualizing cranberry fruit rot in a different light. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.

# VacCAP Team Publications and Presentations

- Phillips M, Lopez-Moreno H, Diaz-Garcia L, Grygleskic E, Giongo L, Atucha A, Iorizzo M, and Zalapa J. 2022. Cranberry school presentation. Cranberry fruit quality genetic research and the VacCap project: distinguishing soft and firm berries. Cranberry School Proceedings 30, January 19-20, 2022. Presentations for Growers or Other Industry Stakeholders. <https://fruit.wisc.edu/cranberries/cranberry-school-proceedings/>
- Blueberry Field Day, Oregon State University, North Willamette Research & Extension Center, July 20, 2022, 2022. Improving Fruit Quality Through VacCAP <https://extension.oregonstate.edu/sites/default/files/documents/11671/field-day-agendablueberry2022.pdf> Oregon Blueberry Conference, Salem Convention Center, Salem, OR, February 14, 2022. Presentations for Growers or Other Industry Stakeholders.
- Luby C. Innovative blueberry breeding: thoughts, priorities, and insights for the future. Oregon Blueberry Conference. Salem Convention Center, Salem, OR. February 14, 2022. Presentations for Growers or Other Industry Stakeholders.
- DeVetter LW, Luby C and Bassil N. 2022. Improving blueberry fruit quality through VacCAP. Oregon State University Blueberry Field Day. 20 July, 2022. Aurora, OR. Presentations for Growers or Other Industry Stakeholders.
- Atucha A. 2022. Cranberry fruit quality traits. Wisconsin Cranberry State Growers Association Field Day. 10 August, 2022. Black River Falls, WI. Presentations for Growers or Other Industry Stakeholders.

## VacCAP newsletters

- Atucha A, Russo J, DeVetter L and Giongo L. Breaking down fruit quality - Texture and its role in blueberry. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/textureinblueberry>
- Atucha A, Russo J, DeVetter L and Edger P. Some assembly required: how the VacCAP team is developing the first Vaccinium pangenome. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/firstvacciniumpangenome>
- Atucha A, Russo J, DeVetter L and Luby C. Get to know VacCAP team member Dr. Claire Luby. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/clairelubyfeature>
- Atucha A, Russo J, DeVetter L and Chagné D. A chromosome-scale assembly of the bilberry genome identifies a complex locus controlling berry anthocyanin composition. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/bilberrygenome>
- Atucha A, Russo J, DeVetter L and Iorizzo M. High-density linkage map construction and identification of loci regulating fruit quality traits in blueberry. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/highdensitymap>
- Atucha A, Russo J and DeVetter L. There and back again; historical perspective and future directions for *Vaccinium* breeding and research studies. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/thereandbackagain>
- Humann JL and Main D. Genome database for *Vaccinium* newsletters, Issues 2, (January 2022). <https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-January2022.pdf>
- Humann JL and Main D. Genome database for *Vaccinium* newsletters, Issues 3, (April 2022). <https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-April2022.pdf>
- Humann JL and Main D. Genome database for *Vaccinium* newsletters, Issues 4, (July 2022). <https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-July2022.pdf>

## Other Products

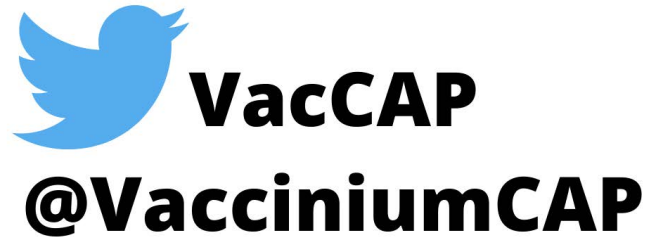
- Zalapa J, Russo J, Atucha A. 2022. VacTrait: Color in cranberries. April 5, 2022. Online (<https://www.vacciniumcap.org/sites/default/files/inline-files/Vactrait%20Color%20in%20Cranberries.pdf>). Handout
- Perkins-Veazie P, Iorizzo M, Russo J, Hancock J. VacTrait: Soluble solids concentration. April 5, 2022. Online: <https://www.vacciniumcap.org/sites/default/files/inline-files/VacTrait%20SSC.pdf>) Handout.
- Humman JL and Main D. Humman JL and Main D. Learn how to go from BLAST to mRNA details to JBrowse. <https://www.youtube.com/watch?v=FBN9s4-a7BU>
- Humman JL and Main D. Learn how to use MegaSearch for Genetic Maps. <https://www.youtube.com/watch?v=a8iMUo8i1po>



# VacCAP Team Publications and Presentations

- Humman JL and Main D. Learn how to use MegaSearch for QTL. <https://www.youtube.com/watch?v=zihzFcngoqY>
- Humman JL and Main D. Learn how search markers on GDV. <https://www.youtube.com/watch?v=5O80zt614vA>
- Humman JL and Main D. Learn the basics of how to use the MapViewer tool to explore genetic maps. <https://www.youtube.com/watch?v=byG8fq62M2E>
- Humman JL and Main D. Learn how to use MegaSearch. <https://www.youtube.com/watch?v=la3v650TZAq>
- Humman JL and Main D. Learn how to use the Synteny Viewer Tool. [https://www.youtube.com/watch?v=t6Kl2z\\_dCqs](https://www.youtube.com/watch?v=t6Kl2z_dCqs)

# Join Us on Social Media



Do you want to stay up to date on all the latest news and resources? Follow us on Twitter [@VacciniumCAP](https://twitter.com/VacciniumCAP). You will be able to:

- Get the latest articles and resources
- Find webinar announcements and registration links
- Check out photos from the field
- And so much more!

Also check out our new website [www.vacciniumcap.org](http://www.vacciniumcap.org) and [YouTube channel](#) to see articles and videos as they go live.

## Partners: Do You Want to Contribute to the VacCAP Newsletter?

If you are interested in contributing or have announcements for events, publications, or another other initiative that you want to share, contact Josie Russo at [jrusso2@wisc.edu](mailto:jrusso2@wisc.edu) with the subject line "VacCAP Newsletter Contribution"



United States Department of Agriculture  
National Institute of Food and Agriculture  
Award #: 2019-51181-30015

[www.vacciniumcap.org](http://www.vacciniumcap.org)  
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# USDA-NIFA Annual Report

# Year 3

## Progress Report

<b>Title:</b> VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes	
<b>Sponsoring Agency</b>	NIFA
<b>Funding Source</b>	Non Formula
<b>Accession No.</b>	1020223
<b>Project No.</b>	NC09879
<b>Project Start Date</b>	09/01/2019
<b>Reporting Period Start Date</b>	09/01/2021
<b>Submitted By</b>	
<b>Project Status</b>	ACTIVE
<b>Reporting Frequency</b>	Annual
<b>Grants.gov No.</b>	
<b>Award No.</b>	2019-51181-30015
<b>Proposal No.</b>	2019-03177
<b>Project End Date</b>	08/31/2023
<b>Reporting Period End Date</b>	08/31/2022
<b>Date Submitted to NIFA</b>	

**Program Code:** SCRI**Program Name:** Specialty Crop Research Initiative**Project Director**

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**Non-Technical Summary**

This project will establish a nationwide coordinated transdisciplinary research approach to develop and implement marker assisted selection (MAS) capacity in Vaccinium breeding programs, to enable breeders to select and pyramid fruit characteristics (FCs) that positively contribute to fruit quality and market value. Vaccinium crops (blueberry and cranberry) provides vital contributions to human health and well-being, and collectively constitutes the economic backbone of many U.S. rural communities. Vaccinium genetic and genomic resources are developing rapidly but have not been translated to routine practical application. Specific objectives are to: (1) establish a cost effective genotyping platform to expand marker-trait association analysis (MTA) in Vaccinium, exploiting the shared ancestry of Vaccinium crops; (2) identify DNA markers linked to fruit characteristics and elucidate how and which fruit characteristics affect fruit quality, relative to consumer preferences, decay during mechanical harvest, processing and distribution; (3) develop DNA assays to implement MAS in core Vaccinium core breeding programs with a common focus on fruit quality traits; (4) enlarge market potential, and increase consumption of Vaccinium fruits by using socio-economic knowledge of consumer preferences to inform breeding; and (5) enhance sustainability of cultivar development by transferring MAS technologies to public and private U.S. Vaccinium breeding programs through training current and future breeders as well as engaging the production, distribution, processing and marketing sectors, allied scientists, and consumers. This Coordinated Agricultural Project proposal addresses SCRI Focus Area 1 (70%) and Focus Area 2 (30%).

**Accomplishments****Major goals of the project**

**Status:** Vaccinium (blueberry and cranberry) breeders have little empirical data to assign level of importance to fruit characteristics (FCs) relative to consumer preferences, decay during production, processing and distribution, and few tools to select for high fruit quality. As a result, blueberry and cranberry cultivars often produce fruit with inconsistent appearance, texture and sensory profiles that do not consistently meet consumer expectations, processing and production quality needs. The Vaccinium industry recognized the need to improve fruit quality as the key breeding target for continued success.

**Mission statement:** Address major bottlenecks for growth of U.S. Vaccinium industry, by creating a nationwide coordinated



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transdisciplinary research approach to develop and implement marker assisted selection (MAS) capacity in *Vaccinium* breeding programs, to enable breeders to select and pyramid fruit characteristics (FCs) that positively contribute to fruit quality and market value. In the long term, this mission will increase production of fruit with improved characteristics that meet the ever-changing industry, market, and consumer preferences.

Specific project objective are: 1) Establish genomic resources to enable effective association mapping studies in blueberry and cranberry; 2) Discover DNA markers and fruit characteristics that maximize industry profitability and match consumer preferences in blueberry and cranberry; 3) Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences; 4) Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand; 5) Engage U.S. *Vaccinium* breeders and stakeholder groups to transfer advanced phenomics and genomics tools to build a more coordinated and efficient cultivar development system.

### What was accomplished under these goals?

Obj. 1. Expanded Genomic resources. Released a new blueberry genome (W85\_v2) and five linkage maps. Uncovered a chromosome translocation in the blueberry cultivar 'Draper' that affects recombination behavior and demonstrated that tetraploid blueberry behaves as an autotetraploid. Completed annotation of the blueberry and cranberry pan-genomes, and conserved and genome specific genes were identified and used to design the genotyping platform. Advanced development of the *Vaccinium* Genotyping platform. Finalized testing of a 22K target capture genotyping platform for blueberry. Preliminary results indicated that this tool is highly informative across cultivated as well as wild blueberry germplasm. For cranberry, designed a 17K target capture genotyping platform which is being tested on 192 samples. A consortium that includes 14 members representing private and public breeding programs from the U.S., France, New Zealand, Canada and Italy have committed to genotype samples with these genotyping platforms. The project is expanding use of molecular tools in blueberry and cranberry breeding and research programs.

Obj. 2. Advanced phenotyping methods. Blueberry: 1) Continued testing an acoustic system to evaluate fruit texture; 2) Improved a user-friendly learning-based web application to evaluate blueberry bruise from mechanical harvesters. Cranberry: 1) Tested a hyperspectral imaging system for higher throughput phenotyping to evaluate fruit rot, color, shape, size, and wax; 2) Finalized data analysis for texture methods in cranberry. Results indicate that 30 fruits are enough to evaluate texture in cranberry and that temperature and fruit orientation have a significant effect on texture measurements. Phenotyped genetic study sets (GenStudy). Blueberry: completed evaluating fruit characteristics (FCs) representing texture (puncture and double compression), appearance traits (size, scar diameter/tear, wet scar), shelf-life indicators (wrinkle/shrivel, mold, leakage and weight loss) and chemistry (pH, TA, SSC, sugars, organic acids, volatiles). During Y3 evaluated Northern Highbush (N=950), and Southern Highbush (N=980) GenStudy sets, and one mapping population (N=364). Cranberry: evaluated fruit weight, yield, % fruit rot, total anthocyanin, Brix and titratable acidity, organic acids, epicuticular wax on berries, and multiple morphological and phenological traits (e.g. number of fruit per upright branch) on MP3 (N=219) and a new genetic study set that included self-pollinated plants (N=847). Initiated evaluation for resistance to fruit scald. Advanced FC genetic studies. Blueberry: completed multiple studies for anthocyanin regulation and QTL studies for pH, TA, TSS, chlorogenic acid anthocyanin content and composition. Nine QTLs for TSS, TA, pH, total anthocyanin, chlorogenic acid, anthocyanin acylation and glycosylation were stable across years. Comparative analysis indicated that the regulation of anthocyanin- and proanthocyanidin-related by MYB proteins is conserved in *Vaccinium* species. Cranberry: completed two genetic studies for upright traits, berry shape/size, plot traits (e.g. yield) and other FC (TAc, proanthocyanin-PAC, epicuticular wax). Highlights from these studies were: yield traits were positively correlated with plot and upright traits and negative correlated with PAC; QTLs were identified for all the traits, some QTLs were stable across the years, and three QTLs for yield, one for TAc, and a QTL for fruit rot resistance overlap with those identified in previous studies. Fruit quality (FQ) studies. 1) Completed a second-year analysis of 60 blueberry cultivars in NC to identify FCs that contribute to extended shelf-life and reduced bruising. 2) Completed a study on cell wall composition in pulp and peel of crisp, firm, and soft blueberry cultivars at harvest. Differences in cell wall composition in the pulp and peel could explain differences in mechanical texture profiling.

Obj.3. Phenotyped germplasm for FC-QTL validation. Blueberry: phenotyped FCs and shelf-life indicators on NHB (N=132), and SHB (N=101) ValStudy sets. Advanced validation of FC-QTLs. Blueberry: three QTL regions associated with pH/TA, anthocyanin acylation and anthocyanin glycosylation were considered validated since they were detected across multiple genetic backgrounds. Cranberry: two regions harboring major QTLs for total anthocyanin and color variation that were mapped in two populations overlap on the same physical map region and are being considered as validated. Advanced simple DNA assay design. Blueberry: optimized two high throughput DNA extraction protocols. HRM and KASP assays targeting SNPs associated with volatile accumulation were tested. Preliminary results indicated a mid to high level prediction accuracy, and the need to optimize primer design to amplify in more diverse germplasm. Cranberry: validated a DNA assay using PACE technology targeting SNPs associated with epicuticular wax within a mapping population. The marker is highly sensitive for predicting waxy fruit. Leveraged FC phenotypic data for breeding selection. Blueberry and cranberry: continued making selections for genotypes with good performance for FC and propagated selections made in Y2 for trialing based. Crosses of superior individuals were also performed and will be germinated in the fall of 2022.

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Obj. 4. Completed blueberry willingness to pay (WTP) and sensory surveys. A second year of WTP and consumer preference surveys were performed for 22 NHB and 20 SHB varieties, which total 42 NHB and 40 SHB samples across the two years, with 27 varieties assessed for both years. The phenotypic evaluation of texture was completed and chemistry analysis for all of the samples is being completed. Data will be used to identify salient sensory attributes and fruit characteristics. Finalized a cranberry study assessing WTP discount for added sugars. The study indicated that consumers discount for increases in added sugars in cranberry products (dried and cranberry juice), and such discount was not offset by health claims about consumption of cranberries. Also, consumers preferred other fruit juices as a sweetener compared to the addition of sugar. A second study assessing WTP for cranberry products from fruit developed using CRISPR technology with the result in a reduction in total sugar content is being completed. The outcomes of these studies are intended to inform breeders and producers about possible strategies to reduce the negative impact of the added sugar labels on cranberry consumption.

Obj. 5. Updated On-line platforms: added new data and information in the GDV and VacCAP websites. Products made available through these platforms include: 1) five newsletters; 2) eight instructional videos; 3) two VacCAP traits information sheets. Maintained the VacCAP Twitter account that has 347 followers and had 7,118 visits in Y3. Webinars: delivered three webinars (see other products), attended by 170 participants. Provided project updates at 10 grower association meetings in U.S. Project evaluation: survey data, feedback and recommendations were collected from 48% of webinar participants, including breeders and scientists from public and private organizations, technical staff members, post-docs and students. Two thirds or more reported that each webinar "greatly" or "moderately" improved their understanding of the topics (66% to 97%) and almost all would recommend the webinars to others (83% to 100%). Feedback and recommendations gained from Y2 were integrated into Y3 activities, and feedback received in Y3 is being considered in planning Y4 activities. Over 11,700 users/viewers and 325 newsletter subscribers from >99 countries accessed these updated products/information in VacCAP and GDV. Overall, evaluation matrix indicates that the project is reaching a very broad audience and the resources/information generated in the project have a positive impact on this community.

#### What opportunities for training and professional development has the project provided?

Project participants include 5 post-doctoral researchers, 12 professionals and technicians, along with 15 graduate students and undergraduate students fully or partially funded by the project across all the VacCAP team programs. These trainees and technicians are participating in VacCAP activities for phenotyping, genomic analysis, DNA profiling, development of DNA-informed breeding strategies, data management and communication. These personnel are gaining knowledge, experience, and skills in accurate measurement of fruit characteristics, fruit physiology, phenotyping engineering, statistical analyses, quantitative genetics, bioinformatics, design and implementation of genetic tests, and breeding program planning and management. In addition, these participants are members of project teams and undertake targeted training through webinars, workshops and one-on-one in-person training on texture analysis. During year 3, three students completed their degree (Masters and PhD).

#### How have the results been disseminated to communities of interest?

Updates about the VacCAP project and preliminary results were disseminated to the scientific community, including the U.S.-wide community of Vaccinium crop breeders, through 14 peer reviewed publications and 25 posters and oral presentations at regional, national and international conferences (including the American Society of Horticultural Science and Plant & Animal Genome conferences). The information was also disseminated to the broader Vaccinium community (producers, processors and distributors) through 10 oral presentations at commodity group meetings, 9 VacCAP/GDV newsletter articles, and two articles in trade magazines. Three webinars and eight instructional videos were delivered to transfer project outcomes/deliverables. Stakeholders and the general public were also engaged by feeding project updates and new information related to the project mission through two web sites (VacCAP and GDV) and a Twitter account (@VacciniumCAP). To engage the public and students, VacCAP PIs participated in and/or organized 12 outreach events targeting K12 middle and high schools, college students and the general public. Events included blueberry and cranberry field days, science fairs, and short lab training classes. Outreach activities were aimed at introducing students and general public to plant science and horticulture, food science, and scientific lab experiences based on protocol/research. All these activities emphasized the importance of breeding programs for blueberry and cranberry production and general crop production. These events contribute to enhance public understanding and interest in learning and careers in plant science and specifically in plant breeding.

#### What do you plan to do during the next reporting period to accomplish the goals?

Objective 1. Establish genomic resources to enable effective genome wide association mapping studies in blueberry and cranberry.

- Finalize annotation of the Vaccinium pan-genome to identify cultivar-specific genes associated with fruit quality
- Complete testing and genotyping phase for cranberry
- Analyze blueberry and cranberry testing data

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- Re-asses genotyping needs with members of the genotyping consortium to consider a new cycle of sample submission
- Prepare manuscripts for dissemination of results

Objective 2. Discover DNA markers and fruit characteristics that maximize industry profitability and match consumer preferences in blueberry and cranberry.

- Analyze phenotypic data collected for FqStudy sets to identify FCs that contribute to longer shelf-life and reduced bruising

- Continue testing new protocols and evaluate new traits in GenStudy and FqStudy sets
- Perform QTL mapping in biparental populations and GWAS in GenStudy sets
- Prepare manuscripts for dissemination of results

Objective 3. Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences.

- Analyze phenotypic data collected during year 1-3 from the ValStudy sets
- Continue testing protocols for simple DNA assay on a set of existing FC-QTLs
- Analyze blueberry DNA assay data (KASP)
- Test DNA assays for organic acids, wax, and fruit shape that were developed for cranberry in more diverse populations to evaluate sensitivity and specificity

- Validate performance of genotypes selected during year 1-3 for advancing them into trials or for use as a parent in new crosses

- Plant seedlings so they are evaluated for their potential contribution to FC

Objective 4. Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand.

- Finalize the analyses of the blueberry sensory and willingness-to-pay data collected in year 3 and prepare manuscripts for dissemination of results

- Finalize new blueberry survey design, distribute the survey and analyze data
- Prepare/submit new manuscripts using cranberry survey data collected in year 1-2
- Re-assess industry breeding priorities

Objective 5. Engage U.S. Vaccinium breeders and stakeholder groups to transfer advanced phenomics and genomics tools to build a more coordinated and efficient cultivar development system.

- On-line platforms: Update VacCAP and GDV and train core and non-core labs on GDV through new training videos. Develop new issues of the GDV newsletter to update national and international partners on new tools and resources available on GDV

- Continue developing new VacCAP trait information sheets
- Newsletter and other media: release three newsletters; publish articles in trade magazines; maintain VacCAP accounts on social media

- Webinars: deliver four webinars
- Workshops: deliver two in-person workshops/trainings focusing on fruit texture and fruit quality analysis
- Develop instructional videos on the use of new methodologies for fruit quality phenotyping developed by our team members, as well as evaluation and comparisons of equipment available to stakeholders

- Commodity group meetings: disseminate progress and results to commodity group meetings
- Annual meeting: organize the VacCAP 4<sup>th</sup> annual meeting (in-person and Zoom accessible, Kannapolis or Raleigh, NC)
- Continue to engage and educate the general public about the project outcomes and impacts through outreach activities on our website, newsletter, and social media

- Project evaluation: continue project evaluation activity to improve stakeholder engagement, communication, and effectiveness of extension activities

### Participants

#### Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	14.9	4.5	5.5	2.7	27.599999999999998

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## Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Professional	2.3	0	0	1	3.3
Technical	6.2	0.5	0	0.2	6.9
Administrative	0.1	0	0	0	0.1
Other	0	1	0.5	0	1.5
Computed Total	23.5	6.0	6.0	3.9	39.399999999999998

## Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
6	6	4	01.11 Plant Sciences.

## Target Audience

Blueberry and cranberry breeders; post-harvest physiologists, food scientists, germplasm collection curators, molecular geneticists, and other allied scientists of these crops; nurseries, producers, processors, marketers, and marketing organizations of Vaccinium crops; and consumers of these crops.

## Products

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Montanari S, Thomson S, Cordiner S, Günther CS, Miller P, Deng CH, McGhie T, Knäbel M, Foster T, Turner J, Chagné D and Espley R. (2022) High-density linkage map construction in an autotetraploid blueberry population and detection of quantitative trait loci for anthocyanin content. *Frontiers in Plant Science*. 13:965397.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Dare AP, Günther CS, Grey AC, Guo G, Demarais NJ, Cordiner S, McGhie TK, Boldingh H, Hunt M, Deng C, Karppinen K, Jaakola L and Espley RV. (2022). Resolving the developmental distribution patterns of polyphenols and related primary metabolites in bilberry (*Vaccinium myrtillus*) fruit. *Food Chemistry* 374, 131703.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

: Lafferty DJ, Espley RV, Deng CH, Günther CS, Plunkett B, Turner JL, Jaakola L, Karppinen K, Allan AC and Albert NW. (2022). Hierarchical regulation of MYBPA1 by anthocyanin- and proanthocyanidin-related MYB proteins is conserved in *Vaccinium* species. *Journal of Experimental Botany*. 73, 1344-1356.



## Progress Report

Accession No. 1020223

Project No. NC09879

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Lafferty DJ, Espley RV, Deng CH, Dare AP, Günther CS, Jaakola L, Karppinen K, Boase MR, Wang L, Luo H, Allan AC and Albert NW. 2022. The coordinated action of MYB activators and repressors controls proanthocyanidin and anthocyanin biosynthesis in *Vaccinium*. *Frontiers in Plant Science*. 13:910155.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	NO

## Citation

Samkumar A, Karppinen K, McGhie TK, Espley RV, Martinussen I, Jaakola L. 2022. Flavonoid biosynthesis is differentially altered in detached and attached ripening bilberries in response to spectral light quality. *Frontiers in Plant Science*. 2529.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Günther CS, Plunkett BJ, Cooney J, Jensen D, Trower T, Elborough C, Nguyen HM, Deng C, Lafferty DJ, Albert NW, Dare AP and Espley RV. 2022. Biotic stress-induced and ripening-related anthocyanin biosynthesis are regulated by alternate phytohormone signals in blueberries. *Environmental and Experimental Botany*.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Edger PP, Iorizzo M, Bassil NV, Benevenuto J, Ferrão LFV, Giongo L, Hummer K, Lawas LMF, Leisner CP, Li C, Munoz PR, Ashrafi H, Atucha A, Babiker EM, Canales E, Chagné D, DeVetter L, Ehlenfeldt M, Espley RV, Gallardo K, Günther CS, Hardigan M, Hulse-Kemp AM, Jacobs M, Lila MA, Luby C, Main D, Mengist MF, Owens GL, Perkins-Veazie P, Polashock J, Pottorff M, Rowland LJ, Sims CA, Song G, Spencer J, Vorsa N, Yocca AE and Zalapa J. 2022. There and back again; historical perspective and future directions for *Vaccinium* breeding and research studies. *Horticulture Research* 9, 10.1093/hr/uhac083.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Ni X, Takeda F, Jiang H, Yang WQ, Saito S and Li C. 2022. A deep learning-based web application for segmentation and quantification of blueberry internal bruising. *Computers and Electronics in Agriculture*. 201:107200.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Alan E, Yocca, Patrick P. Edger PP. 2022. Current status and future perspectives on the evolution of cis-regulatory elements in plants. *Current Opinion in Plant Biology*. 65: 102139.

## Progress Report

Accession No. 1020223

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Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	YES

## Citation

Teresi SJ, Teresi MB and Edger PP. 2022. TE Density: a tool to investigate the biology of transposable elements. Mobile DNA. 13, 11

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Awaiting Publication	2022	YES

## Citation

Mengist MF, Bostan H, De Paola D, Teresi SJ, Platts AE, Cremona G, Xinpeng Q, Mackey T, Bassil NV, Ashrafi H, Giongo L, Jibrán R, Chagné D, Bianco L, Lila MA, Rowland LJ, Iovene M, Edger PP and Iorizzo M. 2022. Autopolyploid inheritance and a heterozygous reciprocal translocation shape chromosome genetic behavior in tetraploid blueberry (*Vaccinium corymbosum*). New Phytologist

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2021	YES

## Citation

Fong SK, Kawash J, Wang Y, Johnson-Cicalese J, Polashock J, Vorsa N. 2021. A low malic acid trait in cranberry fruit: genetics, molecular mapping and interaction with a citric acid locus. Tree Genetics & Genomes 17:4

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2022	YES

## Citation

Ma X, Gallardo RK, Canales E, Atucha A, Zalapa J and Iorizzo M. 2022. "Consumers' discount for added sugars: An application to cranberry products under different nutrition-related information treatments. Applied Economic Perspectives and Policy

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2022	YES

## Citation

Trandel M, H Oh, Johanningsmeier S, Iorizzo M and Perkins-Veazie P. Cell wall polysaccharide linkage assembly in blueberry peel and pulp reveals hemicelluloses specifically associated with the 'Indigocrisp' cultivar. Frontier in Plant Science.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

## Citation

Ma X, Gallardo RK and Canales E. 2022. "Consumer's willingness to pay for gene editing breeding: Application to cranberry products." Annual Meetings of the Agricultural and Applied Economics Association. Anaheim, CA. August 1–2.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

## Citation

Trandel-Hayse M, Oh H, Johanningsmeier S, Iorizzo M, Perkins-Veazie P. 2022. Cell wall polysaccharide composition in the peel and pulp of blueberry cultivars differing in fruit texture quality. 135th Florida State Horticulture Conference, June 5-7, Sarasota, FL.

## Progress Report

Accession No. 1020223

Project No. NC09879

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Oh H, Pottorff M, Giongo L, Iorizzo M, Perkins-Veazie P. 2022. Texture characteristics associated with fruit shelf-life in blueberry. Southern Region Meeting, American Society for Horticultural Science, February 11, 2022, New Orleans, LA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2021	YES

**Citation**

Ma X, Canales E, Gallardo RK. "Consumers discount for added sugars: An exploratory analysis of two cranberry products under different nutrition-related information treatments." Online Agricultural and Resource Economics Seminars (OARES). December 1, 2021.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Boase MR, McGhie T, Wang L, Zhang H, Luo H, King I, Lafferty DJ, Albert NW, Allan AC and Espley RV. 2022. Overexpression of VcMYBA1, a key anthocyanin transcription factor in highbush blueberry elevated anthocyanins, turning leaves dark red. Society of In Vitro Biology Meeting, 4-7 June 2022 in San Diego, California

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Bassil et al., 2022 VacCAP. Produces a targeted capture genotyping platform for blueberry. International Horticultural Congress. August 14-19, 2022. ePoster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Munoz P. 2022. Genome wide association of blueberry fruit quality traits. International Horticultural Congress. August 14-19, 2022.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Xueping N, Takeda F, Jiang H, Yang WQ, Saito S and Li C. 2022. A deep learning-based web Application to quantify blueberry internal bruising. International Horticultural Congress. August 14-19, 2022.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Iorizzo M, Lila MA, Perkins-Veazie P, Luby C, Vorsa N, Edger P, Bassil N, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, De Vetter L, Coe M, Chagné D, Colonna A and Espley R. 2022. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Acta IHC ISHS 2022

## Progress Report

Accession No. 1020223

Project No. NC09879

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2021	YES

**Citation**

Knowles S, Kawash J, Johnson-Cicalese J, Polashock J, Vorsa N. 2021. Relationships between fruit rot resistance and horticultural traits in American cranberry (*Vaccinium macrocarpon* Ait.). 12th International Vaccinium Symposium, International Society for Horticultural Sciences. Remote. August 30 – September 1, 2021.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Mengist MF, Grace M, Mackey T, Bassil N, Luby C, Ferruzzi M, Lila MA and Iorizzo M. Dissecting the genetic basis of anthocyanins accumulation and diversity in blueberries (*Vaccinium corymbosum* L). ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Yalcin O, Finn C, Mackey T, Pottorff M, Giongo L, Iorizzo M, Mengist MF, Coe K, Hardigan M, Luby C, King R and Bassil N. 2022. QTL Analysis of phenological and fruit quality traits in a tetraploid highbush blueberry population. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Iorizzo M, Molla MF, Bostan H, De Paola D, Teresi S, Teresi A, Cremona G, Qi X, Mackey T, Bassil N, Ashrafi H, Giongo L, Jibrán R, Chagne D, Bianco L, Lila MA, Rowland LJ, Iovene M and Edger P. 2022. Comparative genome analysis in blueberry revealed autopolyploid recombination behavior and a heterozygous reciprocal translocation. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Iorizzo M, Lila MA, Perkins-Veazie P, Pottorff M, Mengist MF, Colonna A, Vorsa N, Edger P, Bassil N, Luby C, Mackey T, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, DeVetter L, Chagne D, Espley R and Coe M. 2022. Vaccinium CAP status and updates: advancing genetic and genomic tools to improve fruit quality in blueberry and cranberry. NABREW conference, June 27-29, 2022, virtual.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Mengist MF, Bostan H, De Paola D, Teresi SJ, Platts A, Cremona G, Qi S, Mackey T, Bassil NV, Ashrafi H, Giongo L, Jibrán R, Chagné D, Bianco L, Finn C, Lila MA, Rowland LJ, Iovene M, Edger PP and Iorizzo M. 2022. Autopolyploid inheritance and a heterozygous reciprocal translocation shapes chromosome genetic behavior in tetraploid blueberries. XXIX Plant & Animal Genome, January 8-12, 2022, San Diego, California, USA.



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Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Iorizzo M, Lila MA, Perkins-Veazie P, Pottorff M, Mengist MF, Colonna A, Vorsa N, Edger P, Bassil N, Luby C, Mackey T, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, DeVetter L, Chagne D, Espley R and Coe M. 2022. Vaccinium CAP: A community-based project to develop advanced genetic and genomic tools to improve fruit quality in blueberry and cranberry. Acta Horticulturae, Proceeding of the International Symposium on Breeding and Effective Use of Biotechnology and Molecular Tools in Horticultural Crops, August 14-20, 2022, Angers, France.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2021	YES

**Citation**

Iorizzo M, Mengist MF, Bostan H, Curaba J, Pottorff M. 2021. From genome to genes and DNA markers to improve agronomic performance and quality of fruit and vegetables crops. Genetyka Aplikacyjna Roślin XXI, September 22-24, 2021, Warsaw, Poland.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Iorizzo M. 2022. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Southeast Regional Fruit & Vegetable Conference, January 69, 2022, Savannah, GA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Oh H, Pottorff M, Mengist MF, Giongo L, Iorizzo M and Perkins-Veazie P. Examination of texture characteristics at harvest and postharvest and identification of QTLs in blueberry. The 31st International Horticultural Congress (IHC). August 14-20, 2022, Angers, France. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Trandel-Hayse MA, Oh H, Johanningsmeier S, Iorizzo M and Perkins-Veazie P. 2022. Peel and pulp texture parameters are negatively correlated to pectin and cellulose content in ten highbush blueberry cultivars. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Perkins-Veazie P, Ma G, Oh H, Trandel-Hayse MA, Bassil N, Luby C, Munoz PR and Iorizzo M. Development of a high-throughput method to evaluate soluble sugar content of large sets of blueberry fruit. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA.

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Accession No. 1020223

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Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Oh H, Pottorff M, Giongo L, Iorizzo M and Perkins-Veazie P. 2022. Dissecting the texture characteristics determining the phenotypic variation and postharvest change of fruit texture in blueberry. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Perkins-Veazie P, Oh H, Trandel M, Ma G, Mainland CM, Lila MA and Iorizzo M. 2022. Changes in blueberry fruit chemistry after six weeks cold storage. Acta Horticulturae, Proceeding of the International Symposium on Advances in Berry Crops, August 14-20, 2022, Angers, France. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Pottorff M, Coe K, Giongo L, Bassil N, Luby C, Munoz PR, Ferrao F, Perkins-Veazie P and Iorizzo M. 2022. Analysis of northern highbush and southern highbush blueberry populations using an integrated phenotyping system to capture fruit texture characteristics and other traits at harvest and post-harvest. ASHS 2022 Annual Conference, July 29-August 3, 2022, Chicago, IL, USA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2022	YES

**Citation**

Oh H, Pottorff M, Mengist MF, Giongo L, Iorizzo M and Perkins-Veazie P. Examination of texture characteristics at harvest and postharvest and identification of QTLs in blueberry. Acta Horticulturae, Proceeding of the International Symposium on Advances in Berry Crops, August 14-20, 2022, Angers, France. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Giongo L, Ajelli M, Iorizzo M. La texture di mirtillo: saperla misurare è un primo passo per fare qualità. Dossier September 2022 Rivista di Frutticoltura. Trade magazine.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Eddy D, Iorizzo M. Nationwide project going in search of better berries. Growing Produce, Jan 18, 2022. <https://www.growingproduce.com/fruits/nationwide-project-going-in-search-of-better-berries/>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Atucha A, Russo J, DeVetter L and Giongo L. Breaking down fruit quality - Texture and its role in blueberry. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/textureinblueberry>

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Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Atucha A, Russo J, DeVetter L and Edger P. Some assembly required: how the VacCAP team is developing the first *Vaccinium* pangenome. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/firstvacciniumpangenome>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Atucha A, Russo J, DeVetter L and Luby C. Get to know VacCAP team member Dr. Claire Luby. VacCAP Newsletter Issue 4, April 2022. <https://www.vacciniumcap.org/clairelubyfeature>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Atucha A, Russo J, DeVetter L and Chagné D. A chromosome-scale assembly of the bilberry genome identifies a complex locus controlling berry anthocyanin composition. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/bilberrygenome>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Atucha A, Russo J, DeVetter L and Iorizzo M. High-density linkage map construction and identification of loci regulating fruit quality traits in blueberry. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/highdensitymap>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Atucha A, Russo J and DeVetter L. There and back again; historical perspective and future directions for *Vaccinium* breeding and research studies. VacCAP Newsletter Issue 5, August 2022. <https://www.vacciniumcap.org/thereandbackagain>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Humann JL and Main D. Genome database for *Vaccinium* newsletters, Issues 2, (January 2022). <https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-January2022.pdf>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Humann JL and Main D. Genome database for *Vaccinium* newsletters, Issues 3, (April 2022). <https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-April2022.pdf>

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Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Humann JL and Main D. Genome database for Vaccinium newsletters, Issues 4, (July 2022).  
<https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-July2022.pdf>

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Iorizzo M. VacCAP project updates. North Carolina Blueberry Council – 56th Annual Open House and Trade Show, January 11, 2022, Harrells, NC, USA. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Knowles S, Kawash J, Johnson-Cicalese J, Polashock J, Vorsa N. 2022. Phenotyping and genotyping CNJ14-31: A unique population segregating for fruit rot resistance, fruit chemistry and other traits (Bog 18). Annual Summer Meeting of the American Cranberry Growers Association. P.E. Marucci Center, Chatsworth, NJ. August 18, 2022. Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Kawash J, Polashock J, Vorsa N, Johnson-Cicalese J. 2022. Identifying genetic markers for defense mechanisms in cranberry fruit. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Johnson-Cicalese J, Vorsa N, Polashock J, Oudemans P, Knowles S. 2022. Update on breeding for fruit rot resistance in cranberry. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Polashock J, Kawash J. 2022. Visualizing cranberry fruit rot in a different light. Winter Meeting of the American Cranberry Growers Association. January 20, 2022 (virtual). Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

## Citation

Phillips M, Lopez-Moreno H, Diaz-Garcia L, Grygleskic E, Giongo L, Atucha A, Iorizzo M, and Zalapa J. 2022. Cranberry school presentation. Cranberry fruit quality genetic research and the VacCap project: distinguishing soft and firm berries. Cranberry School Proceedings 30, January 19-20, 2022. Presentations for Growers or Other Industry Stakeholders.



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Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Blueberry Field Day, Oregon State University, North Willamette Research & Extension Center, July 20, 2022, 2022. Improving Fruit Quality Through VacCAP <https://extension.oregonstate.edu/sites/default/files/documents/11671/field-day-agendablueberry2022.pdf> Oregon Blueberry Conference, Salem Convention Center, Salem, OR, February 14, 2022. Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2022	YES

**Citation**

Luby C. Innovative blueberry breeding: thoughts, priorities, and insights for the future. Oregon Blueberry Conference. Salem Convention Center, Salem, OR. February 14, 2022. Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

DeVetter LW, Luby C and Bassil N. 2022. Improving blueberry fruit quality through VacCAP. Oregon State University Blueberry Field Day. 20 July, 2022. Aurora, OR. Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Atucha A. 2022. Cranberry fruit quality traits. Wisconsin Cranberry State Growers Association Field Day. 10 August, 2022. Black River Falls, WI. Presentations for Growers or Other Industry Stakeholders.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Zalapa J, Russo J, Atucha A. 2022. VaCTrait: Color in cranberries. April 5, 2022  
Status: Online (<https://www.vacciniumcap.org/sites/default/files/inline-files/Vactrait%20Color%20in%20Cranberries.pdf> ). Handout

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

**Citation**

Perkins-Veazie P, Iorizzo M, Russo J, Hancock J. VaCTrait: Soluble solids concentration. April 5, 2022. Status: Online: <https://www.vacciniumcap.org/sites/default/files/inline-files/VaCTrait%20SSC.pdf>

Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Published	2021	YES

**Citation**

Yurah K. 2021. Segregation of chlorogenic acids and flavonol glycosides in interspecific (*Vaccinium corymbosum* x *V. darrowii*) diploid F2 blueberry population. MS Thesis, Rutgers University. <https://rucore.libraries.rutgers.edu/rutgers-lib/67084/>

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Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Other	2022	YES

**Citation**

Yalcin O. 2022. Quantitative trait loci analysis and cultivar identification in blueberry. MS Thesis, Oregon State University.

Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Other	2022	YES

**Citation**

Yocca AE. 2022. "Leveraging angiosperm pangenomics to understand genome evolution". PhD Thesis, Michigan State University.

**Other Products****Product Type**

Databases

**Description**

The Genome Database for Vaccinium (GDV, <https://www.vaccinium.org>) is an online community database providing access to integrated Vaccinium peer-reviewed genomic, genetic, and breeding data and analysis tools. During year 3 of the project, new GDV data included: 33 genomes, 2,685,225 annotated genes, 2,717,231 annotated transcripts, 5 genetic maps, 126,348 markers, and 203 QTLs. GDV was accessed by 6,037 users from 99 countries, with 11,054 visits and 100,439 pages served (Google Analytics).

**Product Type**

Databases

**Description**

Vaccinium CAP project website (<https://www.vacciniumcap.org/>).

Changes to the VacCAP website in YR3:

- Continued to refine website design for optimal access to project information. This included creating specific categorized content for user groups such as breeders and stakeholders and using icons to organize information on these pages.
- Development of VacTrait and VacCAP for all deliverables.

Website stats summary (September 1, 2021–August 31, 2022)

- o 5,719 page views

- o Top 5 Pages Based on Views

- Home | VacCAP (1,795 views)

- About | VacCAP (235 views)

- Team | VacCAP (227 views)

- Newsletters | VacCAP (184 views)

- News | VacCAP (169 views)

- o 2,614 users

- o Top 5 Countries Based on User Locations

- United States (1,834 users, 69.92%)

- China (197 users, 7.51%)

- Canada (52 users, 1.98%)

- India (35 users, 1.33%)

- Germany (33 users, 1.26%)

- o 3,211 sessions (1.23 sessions per users)

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**Product Type**

Physical Collections

**Description**

A catalog of 2,411,908 variants with single mapping on cranberry chromosomes compiled and resulted in 60K variants after filtering. These 60,000 variant loci in cranberry consisted of one marker every 8kb from all 12 chromosomes were submitted to RAPID Genomics for probe design and testing in a diversity panel of 192 cranberry genotypes.

**Product Type**

New Germplasm

**Description**

We developed a selfing high density cranberry breeding nursery and collection (same as above, 847 genotypes, Selfs ST, BL, HY, SU, PIL, PilxNLM, and Wild). This is the first large effort to develop selfing lines in cranberry to study inbreeding and develop inbred-hybrid progenies. Selfing is the primary mode of reproduction during cranberry production, yet cranberries prefer outcrossing and naturally possess different levels of self-incompatibility. We have identified several selfed backgrounds and genotypes that are performing comparable to commercial controls and that are allowing us to study the effects of selfing in cranberry fruit production. Developing selfed backgrounds will allow the purging of deleterious genes and the development of improved hybrids. We are collecting phenotypic data for fruit quality based on VacCAP methods and techniques and will use the genotyping platform to obtain genetic data.

**Product Type**

New Germplasm

**Description**

A Wisconsin Cranberry Genetics and Breeding Collection was developed. We organized and finished planting the largest collection of cranberry genotypes (~350) ever assembled in Wisconsin. Many genetic backgrounds and interesting mutants are segregating in the collection. Our goal is to explore and collect traits and obtain genetic data based on the VacCAP project goals. We will use the VacCAP traits and genetic data to make strategic crosses using these genotypes and populations. The VacCAP genetic data will allow us to work to create, replicate, and preserve a core collection in cranberry based on the three collections available, the Cranberry National Clonal Repository Collection, the Rutgers Collection, and the Wisconsin Collection.

**Product Type**

New Germplasm

**Description**

9 blueberry plants were selected for future crosses and trials based on flavor, texture and post-harvest data and observations made in the VacCAP project.

**Product Type**

Protocols

**Description**

A new method and protocol was developed to evaluate cranberry fruit texture using the TA.TxPlus texture analyzer. The method was implemented at two USDA labs and three university labs (UW-Madison, Rutgers, and U. Mass) where staff and students were trained. Building upon this first implementation step, new training activities are planned to transfer the method to other core and non-core labs during Y4.

**Product Type**

Audio or Video

**Description**

Video training. Seven "how to" videos for GDV were released. These short videos provide instruction and training on how to use the tools and features available on GDV. The following videos were released:

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Citation: Humman JL and Main D.

1. Humman JL and Main D. Learn how to go from BLAST to mRNA details to JBrowse.

<https://www.youtube.com/watch?v=FBN9s4-a7BU>2. Learn how to use MegaSearch for Genetic Maps. <https://www.youtube.com/watch?v=a8iMUo8i1po>3. Learn how to use MegaSearch for QTL. <https://www.youtube.com/watch?v=zihzFcngoqY>4. Learn how search markers on GDV. <https://www.youtube.com/watch?v=5O80zt614vA>

5. Learn the basics of how to use the MapViewer tool to explore genetic maps.

<https://www.youtube.com/watch?v=byG8fq62M2E>6. Learn how to use MegaSearch. <https://www.youtube.com/watch?v=la3v650TZAq>7. Learn how to use the Synteny Viewer Tool. [https://www.youtube.com/watch?v=t6KI2z\\_dCqs](https://www.youtube.com/watch?v=t6KI2z_dCqs)**Product Type**

Audio or Video

**Description**

Video training. Visualizing compounds in fruit, Plant & Food Research (plantandfood.com). Using mass spectrometry imaging (MSI) in conjunction with other complementary analytical techniques, VacCAP Co-PIs at Plant & Food Research and the University of Auckland were able to chemically profile primary sugars and flavonoids in bilberries and map their locations at a cellular level as the fruit developed. In the future, this application could provide important insights into the development of other fruit crops.

<https://www.youtube.com/watch?v=FlnhgPMYTPY>**Product Type**

Other

**Description**

Genotyping technology. The blueberry genotyping platform was validated and used to genotype by 10 consortium partners. New partners expressed interest in using the platform and joined the consortium, which grew to a total of 14 members from both private and public breeding programs. The platform is available for use through RapidGenomics.

**Product Type**

Other

**Description**

Social Media. Twitter and YouTube channel: A Twitter account (@VacciniumCAP) was created to disseminate information about the project as part of the social media strategy, in conjunction with a YouTube channel.

<https://www.youtube.com/channel/UCpAdtvTEebzZjvJ4SJcoXwg>.

- Twitter Stats (September 2021–August 2022)

- o 347 followers

- o Profile visits: 7,118 (average 593/month)

- o Impressions: 32,632 impressions (average 2,719/month)

- YouTube (September 2021–August 2022)

- o 774 video views

- o 65.9 hours of watch-time

**Product Type**

Other

**Description**

Webinar. The following three webinars were delivered:

1. Perkins-Veazie P, Giongo L and Zalapa J. 2022. Exploring firmness and texture in blueberry and cranberry. February 3, 2022. 76 participants. [https://www.youtube.com/watch?v=Xnmvefb\\_X9c&t=1s](https://www.youtube.com/watch?v=Xnmvefb_X9c&t=1s)

2. Yocca A. 2022. Generating a Vaccinium pangenome to unlock previously hidden genetic variation. August 22, 2022. 41 participants. <https://www.youtube.com/watch?v=dUnFxrzZAY0>

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3. Munoz P. Making sense of volatiles and their effect on blueberry flavor. May 26, 2022. 53 participants.  
<https://www.youtube.com/watch?v=JReCVw2cJk0&t=131s>

**Product Type**

Other

**Description**

New collaborations fostered by the project. The need to focus more on “crispness” in blueberry within the VacCAP network arose during the 2021 Second Annual Meeting, which generated a two year collaboration between Anne Plotto, Charlie Sims and Lara Giongo, to correlate sensory training, texture and acoustic parameters which were validated during the VacCAP project, with particular emphasis on crispness.

**Product Type**

Other

**Description**

New collaborations fostered by the project. To develop the SNP catalog for cranberry (Obj. 1b), partners shared published and unpublished sequencing data with the genotyping team. The SNPs catalog that include >2.4M SNPs was used to select and develop the cranberry marker loci for genotyping. This enabled us to develop a platform that represents a wide genetic diversity for DNA polymorphisms that are relevant to potential end users (core and non-core labs).

**Product Type**

Other

**Description**

Student graduates in agricultural sciences. These three students graduated:

1. Alan Yocca (PhD). Supervisor: Co-PD Patrick Edger, Michigan State University.
2. Ozge Yalcin (MS). Supervisor: Co-PD Nahla Bassil, Oregon State University.
3. Yurah Kim (MS). Supervisor: Co-PD Nicholi Vorsa, Rutgers University.

**Changes/Problems**

Obj. 1. The delay of funding release from the USDA-NIFA during Year 1 and COVID-19 requirements during 2020-2022, delayed the development of genotyping platforms (Obj. 1). As a result, delivery of the genotypic data for genetic studies expected in Y3 was delayed and will be completed in Year 4. To compensate for some of the impacted activities, team members completed complementary activities including finalizing linkage maps and new Vaccinium genomes and performing comparative analysis to improve the quality of the available genomes by the Comparative Genomics Team.

Obj. 2. Delay in the delivery of genotypic data is in turn delaying some of the genetic studies. To ensure success of the genetic studies and expand our capacity to detect and validate QTLs across studies, additional materials including four mapping populations and a new cranberry diversity panel were added to the project for genetic studies. A new method with increased throughput to evaluate organic acids (OA) using HPLC is under evaluation and if validated will be used during year 4 to evaluate FL and/or OR GenStudy sets. To compensate for possible delays in OA genetic analysis from the large GenStudy set material, a lower throughput HPLC assay was used to evaluate a mapping population. Due to COVID-19, transplanting of the cranberry diversity panel at Dr. Nick Vorsa's location in NJ had to be postponed, delaying phenotyping FCs in this material. Activities that were delayed will be completed in Year 4.

Obj. 3. Due to the delay in completing genetic studies, validation of QTLs was also delayed. To facilitate integration of novel QTLs that are expected to be detected from genetic studies that are being delayed, team members imitated efforts to anchor QTLs identified during Y1-Y3 in mapping populations, and from previous studies into the blueberry and cranberry physical maps. As new QTL studies are being completed, this framework will facilitate identification of QTLs that overlap across multiple studies and will be considered as validated across multiple genetic stocks.

Obj. 4. Due to logistic difficulties in accessing large amounts of fruit from selected blueberry cultivars, as well as feedback from stakeholders on research questions with higher priorities, the proposed research on consumer behavioral response to fruit tasting using biometric parameters was re-designed into a two-part study. First is an assessment of growers' willingness-to-pay considering blueberry quality traits and information that growers in other countries are adopting new



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blueberry varieties. Second, we will assess consumers' propensity to purchase blueberries considering different labels that inform buyers about blueberry quality traits. The outcomes expected from these two studies are similar to the originally proposed research and will provide additional information that seems to be more relevant to the blueberry industry.

Obj. 5. Outreach to the general public and stakeholders through in-person events continued to be limited due to Covid-19.

We have responded with additional webinars and publications to help disseminate project results to our stakeholders.

Overall: Due to health conditions and/or professional career opportunities, multiple PIs, students and post-docs left their positions and are moving out of the project, creating some challenges to manage the different experiments. Administrative and program activities to manage the personnel turnover have been and are being evaluated and actions will be taken to ensure project outcomes are not affected.