VacCAP

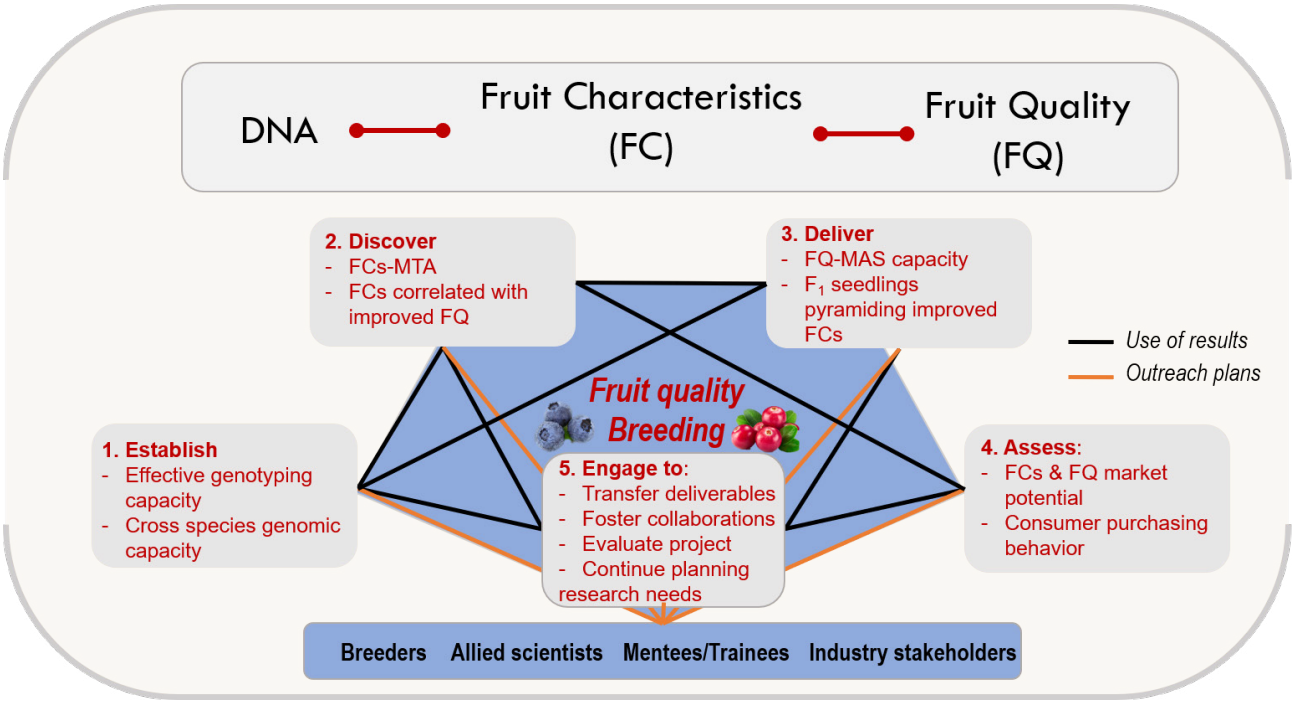
Improving Fruit Quality

Annual Project Report and Plan

Annual Meeting V | May 14–16, 2024 | Gainesville, FL | 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.



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

Agenda

Time	May 14 (No Zoom Available)
2:00-4:00	Registration at Blueberry Breeding Building
3:00-5:00	Breeding Tools/Demonstration
6:00	Dinner (Room 1308, Fifield Hall)

Wednesday, May 15, and Thursday, May 16, 2023 Hybrid Zoom Link

https://ufl.zoom.us/j/93520029509?pwd=QVptazVCWGRoWXd4M2FCOXRpblFYZz09

Meeting ID: 935 2002 9509

Passcode: 535048

15-May

Time zone	Breakfast	Session 1-2	Session 3	Lunch	Session 4-5	Session 6-7	Final discussion
PT (-3)	5:00 AM	5:30 AM	8:00 AM	9:00 AM	10:00 AM	12:00 PM	1:45 – 2:15 PM
CT (-1)	7:00 AM	7:30 AM	10:00 AM	11:00 AM	12:00 PM	2:00 PM	3:45 – 4:15 PM
ET	8:00 AM	8:30 AM	11:00 AM	12:00 AM	1:00 PM	3:00 PM	4:45 – 5:15 PM
IT (+6)	2:00 PM	2:30 PM	5:00 PM	6:00 PM	7:00 PM	9:00 PM	10:45 – 11:15 PM
NZ (+17)	1:00 AM	1:30 AM	4:00 AM	5:00AM	6:00AM	8:00AM	9:45 – 10:15 AM

16-May

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

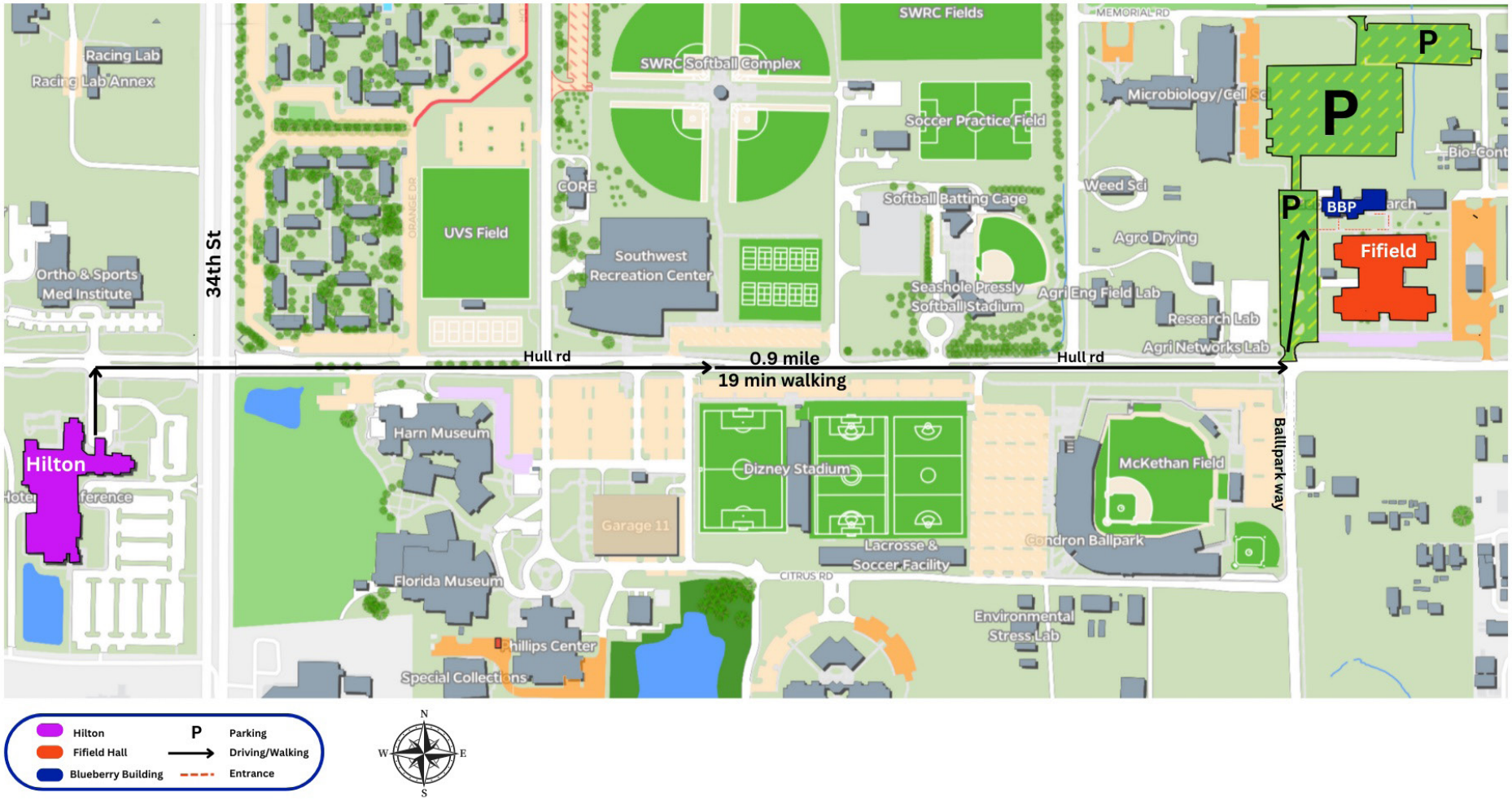
Agenda

Advisory Board Meeting | Wednesday, May 15, and Thursday, May 16, 2023 | Hybrid

Time (EST)	May 15
7:45	Pickup at the Hotel (Hilton)
8:00-8:30	Breakfast (Room 1308, Fifield Hall)
8:30-9:45	Session 1. Welcome, Introduction, and Obj. 1 Genomics and Genotyping Updates • Munoz, Patricio and Iorizzo, Massimo - Intro annual meeting • Edger, Patrick - *Vaccinium* Pangenome • Chagné David - A New Blueberry Genome • Bassil, Nahla - Vaccinium Genotyping • Group Recap Status and Next Steps Feedback/Discussion
9:45-10:45	Session 2. Obj. 2 Blueberry FC Genetric Discovery Updates • Iorizzo, Massimo - Genetics Chem.-Non-Volatile • Munoz, Patricio and Ferrao, Felipe - Genetics Texture and Chem.-Volatiles • Group Recap Status and Next Steps Feedback/Discussion
10:45-11:00	Coffee Break
11:00-12:00	Session 3. Obj. 2 Blueberry Fruit Quality (Shelf Life, Bruising, Sensory) Updates • Iorizzo, Massimo - Post-Harvest and Texturs Sensory Studies • Giongo, Lara - Acoustic Method for Texture Analysis • Perkins-Veazie, Penelope & Li, Charlie – Cell Wall and Bruising • Group Recap Status and Next Steps Feedback/Discussion
12:00-1:00	Lunch (Room 1308, Fifield Hall)
1:00-2:00	Session 4. Obj. 2 Cranberry FC Genetic Discovery Updates • Zalapa, Juan and Jenyne, Loarca, - Genetics of Texture, Appearance and Anthocyanin • Sideli, Gina - Genetics Organic Acids • Group Recap Status and Next Steps Feedback/Discussion
2:00-3:00	Session 5. Obj. 3 DNA Markers and Breeding Updates • Munoz, Patricio - Blueberry DNA Assay Development, Status and Next Steps • Polashock, Jim - Cranberry DNA Assay Development, Status and Next Steps Feedback/Discussion
3:00-4:00	Session 6. Obj. 4 Blueberry and Cranberry Socio-Economic Updates • Canales, Elizabeth - Willingness to Pay Study in Blueberry

Agenda

Time	May 15 (Continued)
4:00-4:45	Session 7. Obj 5. Extension Updates • Main, Dorrie - GDV • Atucha, Amaya - VacCAP and Other Extension Activities • Coe, Michael - Project Evaluation Feddback/Discussion
4:45-5:15	Adjourn • Final Discussion Planning Year 5-6 Activities
6:30	Dinner and Social Event at First Magnitude Brewing Company 1220 SE Veitch St, Gainesville, FL 32601
	May 16
7:45	Pickup at the Hotel (Hilton)
8:00-8:30	Breakfast (Room 1308, Fifield Hall)
8:30-9:30	Session 1. Planning VacCAP1-2 Project Activities
9:30-10:45	Session 2. Break Up Groups Session 1
10:45-11:00	**Coffee Break**
11:00-12:00	Session 3. Break Up Groups Seassion 2
12:00-1:00	**Lunch**
1:00-3:00	Seassion 4. Planning VacCAP1-2 Project Activities
3:00-4:00	Session 5. Adjourn


Racing Lab
Racing Lab Annex
34th St
Ortho & Sports Med Institute
UVS Field
CORE
SWRC Fields
SWRC Softball Complex
Soccer Practice Field
Softball Batting Cage
Southwest Recreation Center
Seashole Pressly Softball Stadium
MEMORIAL RD
Microbiology/Cell
Weed Sci
Agro Drying
Agri Eng Field Lab
Research Lab
Agri Networks Lab
P
BBP
Fifield
Hull rd
0.9 mile
19 min walking
Hull rd
Hilton
Harn Museum
Garage 11
Florida Museum
Phillips Center
Special Collections
Dizney Stadium
Lacrosse & Soccer Facility
CITRUS RD
McKethan Field
Condron Ballpark
Ballpark way
Environmental Stress Lab
Hilton
Fifield Hall
Blueberry Building
P
Parking
Driving/Walking
Entrance
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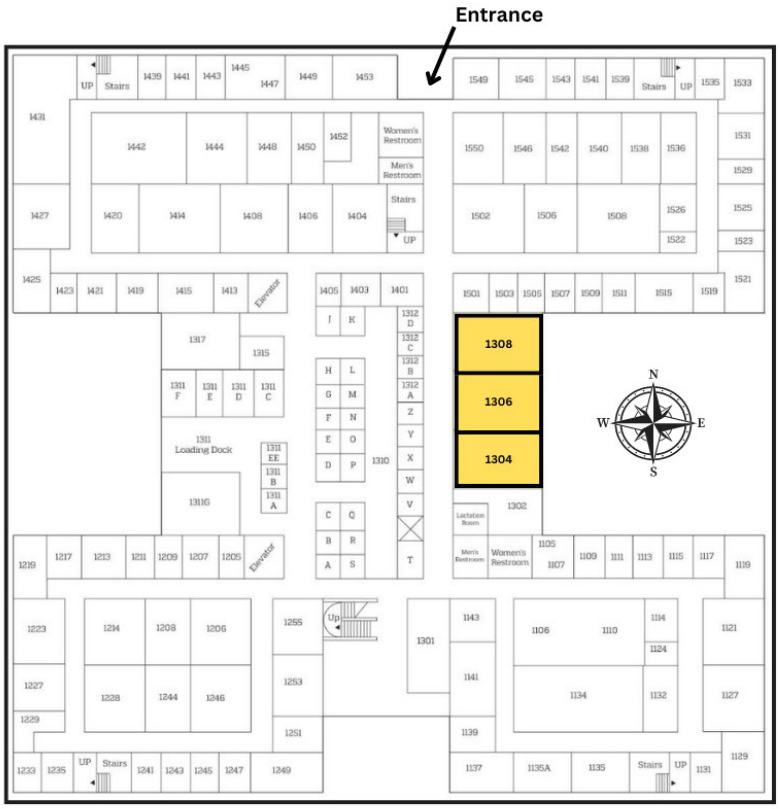

Fifield Hall Map

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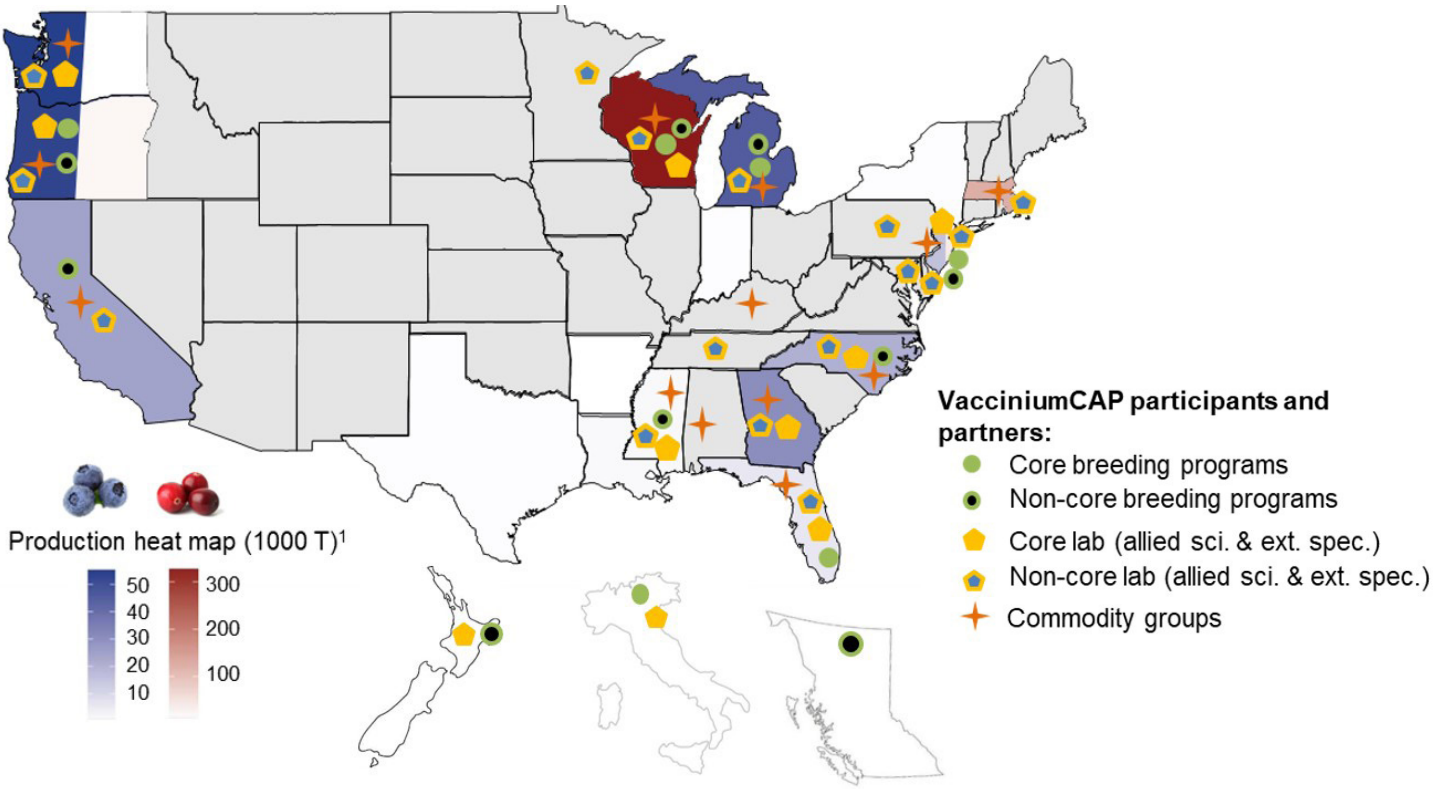
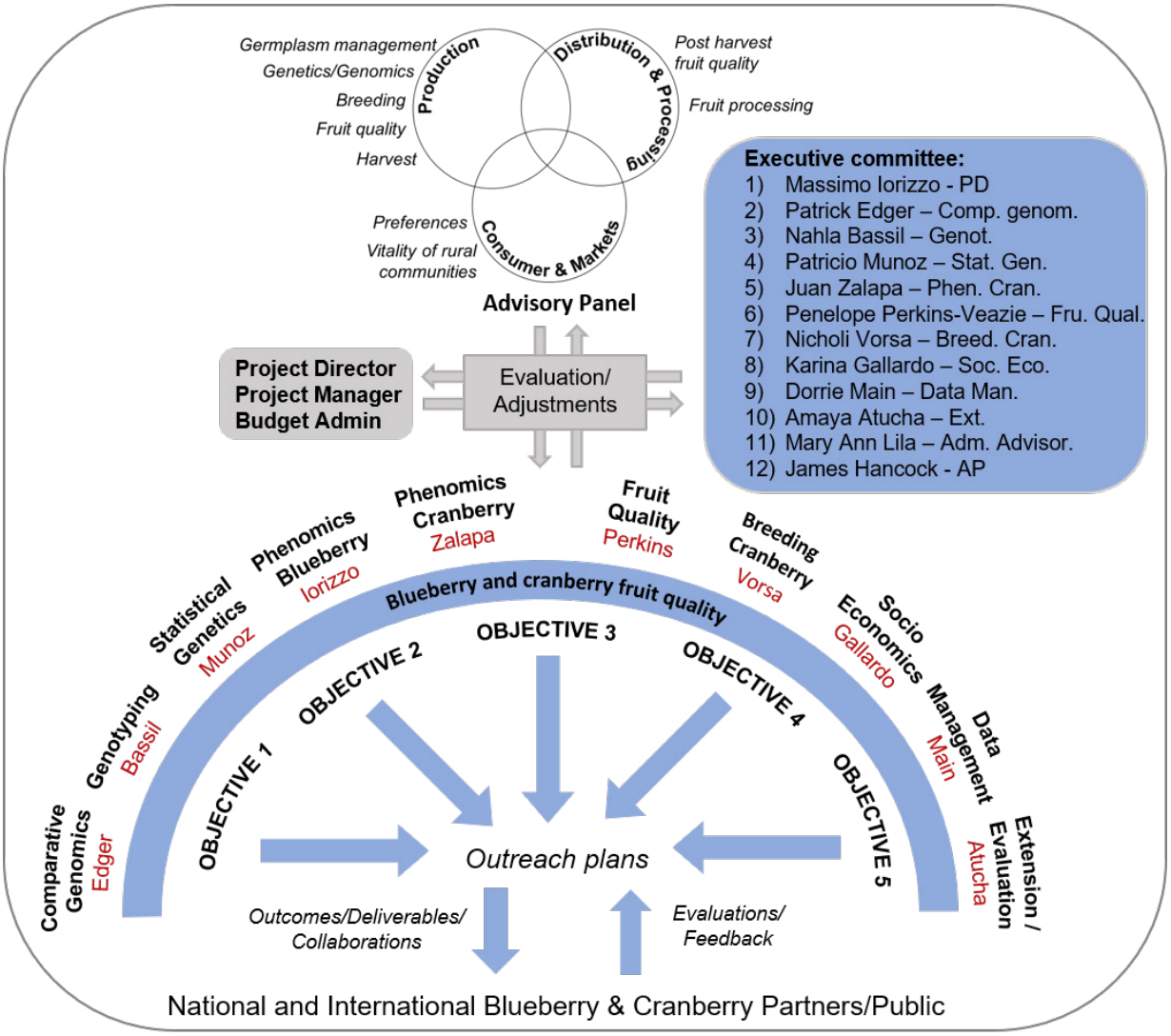
VacCAP PIs and Partners



- 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
- Gina Sideli, Co-PI, Rutgers University
- 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

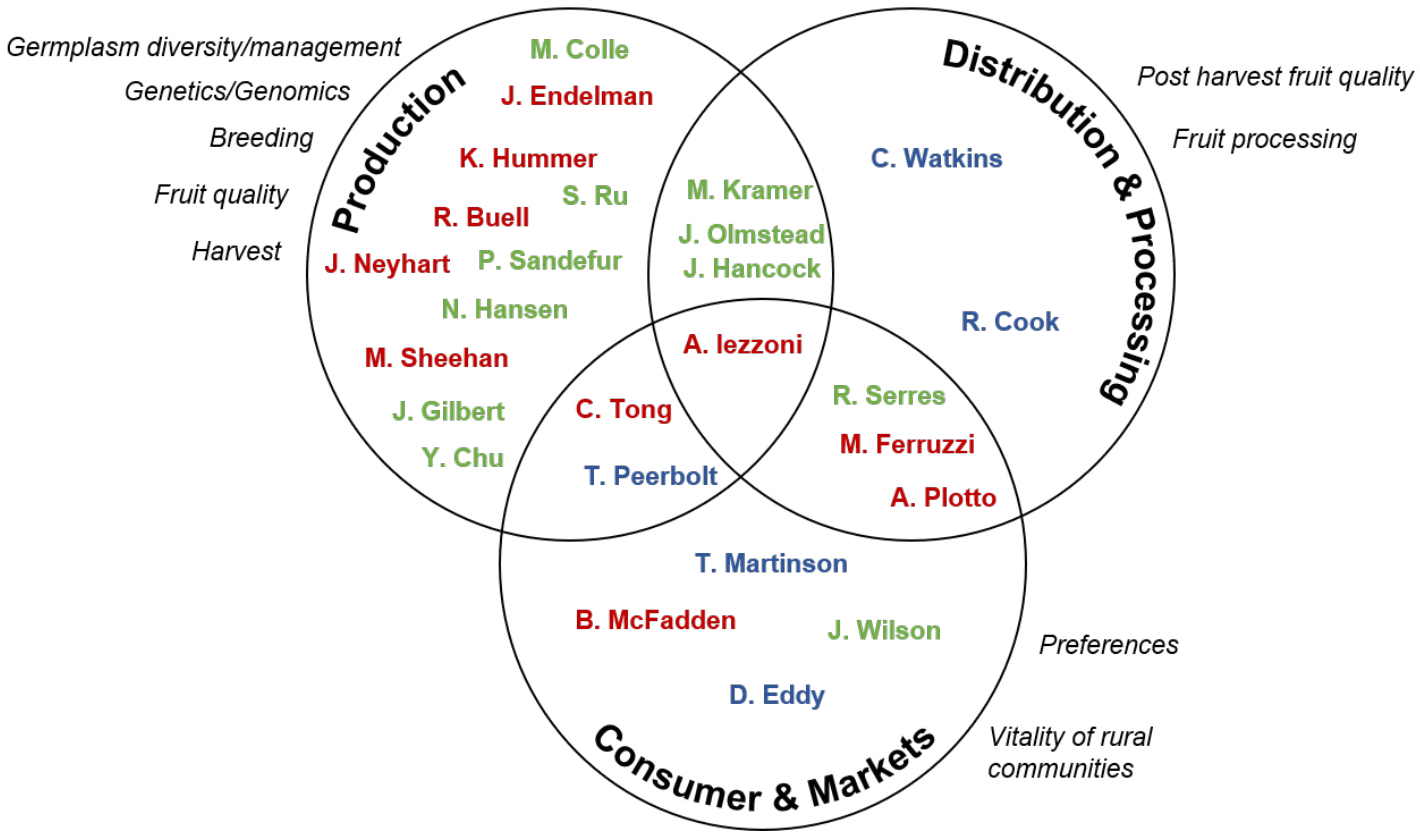
- James Hancock, Berry Blue LLC
- Nicole Hansen, Cranberry Grower
- Matt Kramer, Fall Creek Farm and Nursery
- James Olmstead, Driscoll's, Inc.
- Jessica Gilbert, Driscoll's, Inc.
- Mandie Driskill, Fall Creek Farm and Nursery
- Marivi Colle, Berry Blue LLC
- Rod Serres, Ocean Spray Cranberries, Inc.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

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

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
- Sushan Ru, Auburn University
- Ye Chu, The University of Georgia



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 search approach to develop standard phenotyping methods and DNA assisted selection 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 demand, and consumer preferences.

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

Delivery. VacCAP project will deliver:

- New genomes and genetic maps
- Cost effective genotyping platforms for marker trait association studies
- Standardized phenotyping methods to evaluate texture, appearance and chemical composition
- DNA markers and QTL regions associated with FCs
- DNA assays to use for marker assisted selection
- FCs benchmarks to select for improved quality
- Online platforms and communication material/activities to transfer project deliverables and outcomes

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:

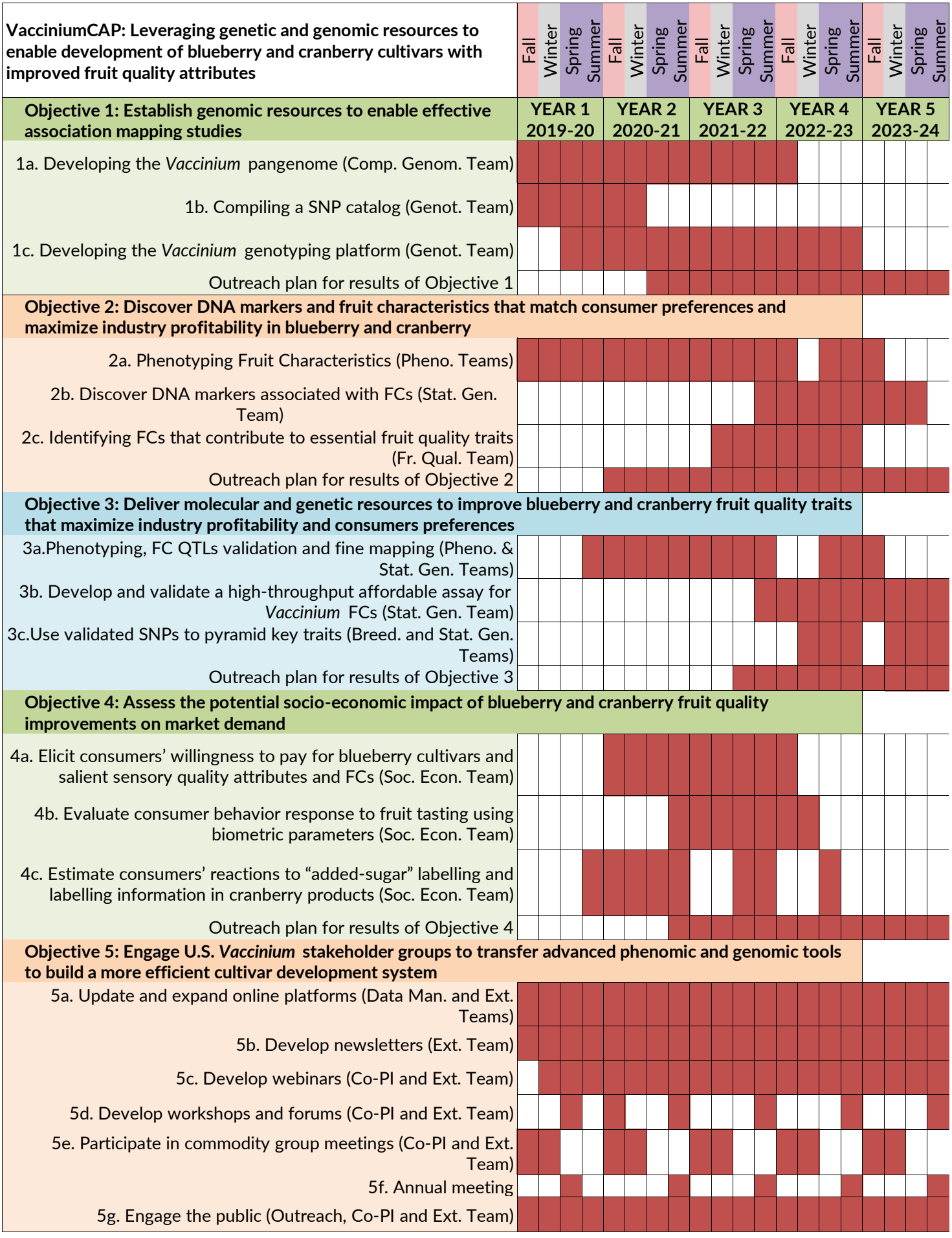
- MS/PhD students and post-docs are trained in plant breeding, genetics, fruit phenotyping, postharvest physiology, socio-economics, sensory analysis and extension practices, to become the next generation of breeders, scientists, and agriculture liaisons

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

Timeline

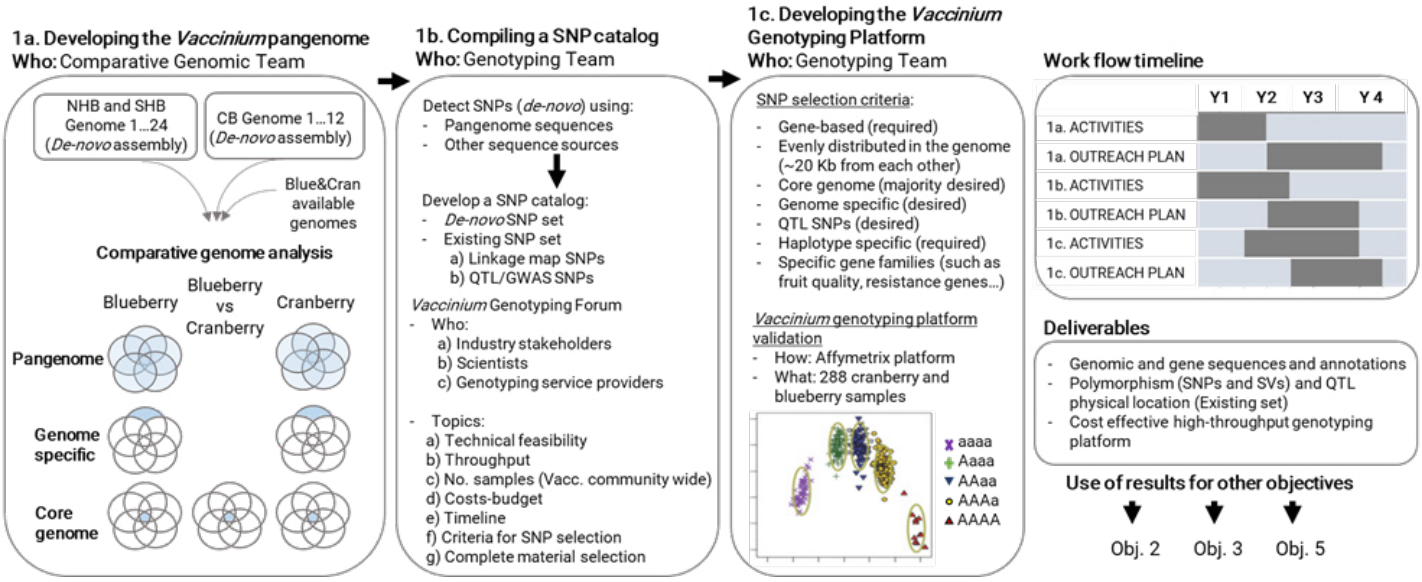
Cranberry Harvest Season Blueberry Harvest Season



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 4 Progress Summary

Obj. 1. Establish genomic resources to enable effective association mapping studies in blueberry and cranberry	
Contributed by: Edger, Bassil, Chagne',	
Presented by: Edger, Bassil, Chagne'	
1a. Developing the Vaccinium pangenome [Comparative Genomic Team]	To whom*
Completed construction of the pan-genome. Finalized and released annotations of blueberry and cranberry cultivars and a pangenome graph (Table 1). Initiated efforts for identification of dispensable genes that have fruit specific expression patterns. Also initiated annotation of genes involved in terpene biosynthesis.	Statistical Genetic Team, Breeder and Geneticist Partners
Development of new genomes and genetic resources for genetic and comparative analysis. A haplotype resolved assembly of a HortbluePetitexNui progeny (tetraploids) was developed (Table 1). The assembly is resolving a complex locus linked to a QTL for anthocyanin content on chromosome 2.	
Impact. 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; provided a solid framework to design genotyping platforms that best represents the blueberry and cranberry diversity; enabled comparative studies within the *Ericaceae* and across other plant families.	
1b. Compiling SNP catalog [Genotyping Team]	To whom
Compiled SNP catalog. Completed	Statistical Genetic Team, Breeder and Geneticist Partners
1c. Developing genotyping platform [Genotyping Team]	To whom
Advanced development of the Vaccinium Genotyping platform. Completed validation of the 22K blueberry and 17K cranberry genotyping platforms. Results confirmed that the platforms are highly informative across cultivated and wild blueberry and cranberry germplasm. Continued coordination of samples submission from members of the genotyping consortium, and secured a new discounted price for submissions in year 5. The consortium include 15 members representing public and publish breeding programs, from U.S., France, New Zealand, Canada and Italy and have genotyped 14,137 samples across 23 projects >24 experiments.	Breeding, Statistical Genetic Teams, Breeder and Geneticist Partners
Impact 1b-c. A cost effective genotyping platform that is useful to the *Vaccinium* scientific community worldwide is expanding 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 (2019-2020) and COVID-19 operational restrictions during 2020-2022, delayed the development of genotyping platforms (Obj. 1). As a result, delivery of the genotypic data for genetic studies expected in Y4 was delayed and will be completed in Years 5-6.	
Addressing challenges and recommendations. A one-year no cost-extension was already approved by the USDA and we are requesting a second year no cost extension to complete activities that were delayed. 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 1-4

Resource	Lab	Status	Citation	Data release status
Genomes				
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.	Completed**	Yocca et al., 2024	Raw data released on NCBI, raw and assembled data released on GDV
Cranberry pangenome	Edger P.	Completed**		Raw data released on NCBI
Nui x Hortblue Petite	Chagne D.	Work in progress**	-	-
Linkage maps				
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-Y3)
** completed/initiated during this reporting cycle (Y4)

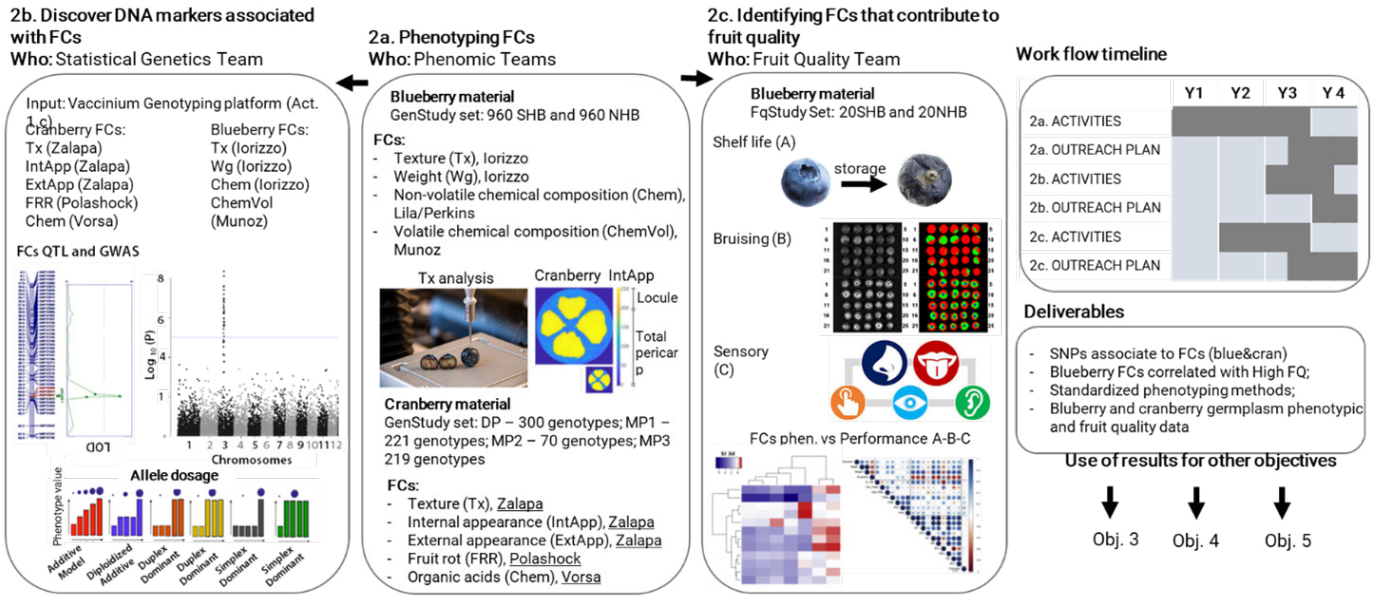
Obj. 1 - VacCAP Plan for Year 5-6

Obj. 1. Establish genomic resources to enable effective association mapping studies in blueberry and cranberry
1a. Developing the *Vaccinium* pangenome [Comparative Genomic Team]
Finalize identification of dispensable genes that have fruit specific expression patterns in the *Vaccinium* pangenome to identify cultivar-specific genes associated with fruit quality
Finalize annotation of the new tetraploid genome (HortbluePetitexNui)
Communicate outcomes through publications and presentations
1b-c. Developing genotyping platform [Genotyping Team]
Finalize data analysis of cranberry testing data
Continue coordination of sample submission for genotyping from the VacCAP genotyping consortium
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.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J. Zalapa


M. Lila


C. Li


C. Sims


G. Sideli


P. Munoz


P. Perkins-Veazie


L. Giongo


N. Vorsa


C. Luby

Obj. 2 Blueberry – VacCAP: Year 4 Progress Summary

Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in blueberry.	
Contributed by: Perkins-Veazie, Lila, Giongo, Iorizzo, Munoz, Bassil, Li, Espley, Chagne	
Presented by: Iorizzo, Ferrao/Munoz, Giongo, Perkins-Veazie, Li	
2a. Phenotyping fruit characteristics (FCs) [Phenomic Teams]	**To whom***
Finalize phenotyping protocols, equipment needs and settings. 1) Continued testing an acoustic system to evaluate fruit texture; 2) Continued to improve a web application to evaluate bruising rate.	Fruit Quality, Statistical Genetic and Breeding Teams and Partners
Phenotype FCs. 1) evaluated organic acids (by HPLC) in the NHB and SHB GenStudy sets (N=2,000)(Table 2). 2) evaluated pH, Fructose, glucose, citric acid and Malic acid in the NHB GenStudy set (N=800) using the Discrete analyzer (Table 2).	Statistical Genetic and Breeding Teams
Impact. 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 evaluated one parameters. This allowed us to better understand which texture parameters and/or other FCs contribute to fruit firmness and shelf life, and if it is genetically inherited. The NIR method used to measure sugars enabled large scale genetic studies for sugar content and profile which would be not feasible using HPLC data. Use of HPLC was needed to asses organic acids since the relationship between pH and OA was not always strong in the large diversity panels. 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**
Perform Genetic analyses (Table 3). Blueberry: performed QTL analysis for volatiles, anthocyanin content and composition, organic acids, TA, pH, sugars and texture. Major effect QTLs were identified for anthocyanin type (acylated and glycosylated), 33 volatiles, citric acid, malic acid, quinic acid, shikimic acid, pH, and TA. QTL for pH and TA were very strong in one biparental population but not stable and major effect QTLs were identified in the NHB and SHB GenStudy sets. No QTLs or very low effect QTLs were identified for sugars and texture, respectively. Except for volatiles and organic acids evaluated in the NHB and SHB Diversity Panels that were not tested for multiple years all major QTLs were stables across multiple years. Efforts to identify candidate genes underlying major QTLs were initiated. Tested and validated a modified VIGS method to validate the function of candidate genes in blueberry fruits. Results indicated that the system is able to silence target genes in the whole fruit (vs portion of a fruit). Ongoing work include multiple genetic studies for chemistry and texture traits (Table 4)	
Impact. FCs-DNA marker associations are being identified and preliminary results indicated that we expect to detect more significant associations. Preliminary results indicates that volatiles, organic acids, phytochemicals (e.g. anthocyanin, chlorogenic acids) are controlled by few genes with major effect and develop DNA markers for these traits is feasible. In contrast traits like texture, sugars are complex and strategies like genomic and phenomic selection should be used for these traits. This outcome provides the fundamental knowledge to understand the genetic inheritance and architecture of FC the position, number of QTLs (as proxy for genes) involved in controlling FCs, and validation of some key FC-QTLs will be used for marker assisted selection.	

2c. Identifying FCs that contribute to essential fruit quality traits [Fruit Quality Team]	To whom
Perform FQ analysis - shelf life: Completed a study to asses shelf-life at the scale resembling NHB and SHB breeding populations. The results highlighted that post-storage changes are positively correlated with initial texture. The low storage temperature for SHB best explained a notable lower rate of changes for all parameters. Correlation analysis indicated that three main texture components representing the Young Modulus parameters (YMs), 'Distance to Maximum Force' (DFM) and 'Mean Internal Firmness' (MIF) contributed to blueberry texture. YMs and DFM likely represent textural characteristics of the external fruit structural components. Also, texture parameters YMs and DFM explained most of the phenotypic changes observed between harvest and post-storage, suggesting that changes during storage largely occurs in the more external layers of the berry. Changes for parameters correlated to size were highly predictable, while most of the texture parameters had a low to moderate predictability. The contribution of fruit chemistry parameters to predict texture and appearance traits at harvest and post-storage was very limited or not significant. The rate of water loss and appearance of wrinkles was higher in small size berries and was not affected by the size of the stem scar. Parameters to select for berries with better post-storage texture and appearance were identified.	Breeding, Fruit Quality and Other industry partners
Sensory texture vs mechanicam texture (Table 5). Completed a study to asses the relationship between sensorial texture and mechanical texture and predictability of sensorial texture. The results indicated that the firmness perception of blueberries could be mainly evaluated using the sensory descriptors, springiness, hardness, and snap/crisp. Among the instrumental parameters, maximum force (FM; a flat probe parameter) and gumminess (a TPA parameter) had the strongest correlations with these three sensory descriptors. Other descriptors, such as force to grind, juiciness, dissolvability, amount of particles, mealiness, and residual skin, improved the resolution to identify the overall textural variation among cultivars. For most of the descriptors, predictive models were able to effectively discern cultivars with the highest or lowest scores when multiple instrumental parameters were used for prediction. The prediction accuracy was much lower for some descriptors when relying on only one or a few parameters.	Breeding, Fruit Quality and Other industry partners
Perform FQ analysis bruising: A third year of bruise testing was done utilizing 50-60 cultivars of SHB, NHB, and RE and comparing mechanical texture variables to bruise ratios YM 20% burst strain was the mechanical parameter best correlated to bruise ratios. Blueberry cultivars with lower YM 20% BS values generally had higher bruise ratios (higher bruised area). Firmer cultivars (higher YM 20% BS) were less consistently correlated to lower bruise ratios.	Breeding, Fruit Quality and Other industry partners
Impact. FCs subcomponents that positively correlate with extended shelf life, consumer preferences and reduced internal bruising, contribute 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 select for improved quality.	
Challenges & Changes. Due to personal turnover and delay in obtaining genotypic data for the NHB and SHB GenStudy set, GWAS for organic acids and other chemistry parameters was delayed.	

* To whom results are transferred during the project

Table 2. 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 (N=160)	New methods reference
				2020	2021	2022	2021	2022	2020-21-22	2021-22	2019-2020	
FC Traits												
Texture and Appearance FC												
Texture (TxNp) Needle probe	T0* and T1*	4 mechanical parameters	TA.XTPlus***	Completed	Completed	Completed	Completed	Completed	Completed	Completed	NP	Giongo et al. 2022, *PBT 183, 111696*; Iorizzo et al. 2021, ISHS presentation
Texture (TxPp) Penetration probe		24 mechanical parameters	TA.XTPlus***									
Texture (TxPp) Double compression probe		23 mechanical parameters	TA.XTPlus***									
Weight (Wg) (Size**)		Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***									
Scar (ScD)		Diameter (ScD)	Digital caliper***									
Chemical composition												
Non-Volatile chemical composition (Chem)	T0	Titratable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	Completed	Completed	Completed	NP	Completed	Completed	Perkins et al. 2021, Acta Hort.
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC						NP		NP	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC and LC-MS	NP	Completed	NP	Completed	NP	NP		NP	
		Organic acids (Ac): malic, citric. Sugars: Fructose, Glucose. pH	Discrete method	NP	NP	Completed	NP	NP	NP	NP	NP	Babiker et al. 2023. HortScience, 58(7), 750-755
Volatile chemical composition (ChemVol)		Volatile organic composition (>60 volatile compounds)	GC-MS	NP	Completed	NP	Completed	NP	NP	NP	NP	
Shelf life indicators												
Wrinkle/Shrivel (Shr)	T0 and T1	Scale 0-3, and % yes/no	Visual***	Completed	Completed	Completed	Completed	Completed	Completed	Completed	NP	Giongo et al. 2022, *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)		% 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.

Table 3. Summary of FC QTL studies completed in blueberry.

FC	Material	FC sub-component	# QTL	# Stable QTL/Years	Reference
Chem	NxHB* (N=128)	Anthocyanin types	165	3/2 Yrs	Montanari et al., 2022, Front. Plant Sci. 13:965397. doi: 10.3389/fpls.2022.965397
Chem	DSxJ* (N=190)	Anthocyanin types (acylation and glucosylation)	172	4/3 Yrs	Mengist et al. 2022, Front. Plant Sci. 13:964656. doi: 10.3389/fpls.2022.964656
		Total Anthocyanin content	5	1/3 Yrs	
		Chlorogenic acid	3	1/3 Yrs	
		pH	2	1/2 Yrs	
		TA	4	1/3 Yrs	
		SSC	2		
Chem	RxA** (N=287)	pH	10	1/5 Yrs	Mengist et al. 2021, Hort Research 8, 169 (2021). https://doi.org/10.1038/s41438-021-00605-z Oh et al. manuscript in progress
		TA	7	1/5 Yrs; 1/3 Yrs	
		SSC	6	2/3 Yrs	
		Total Organic Acid	3	1/2 Yrs	
		Citric	3	1/2 Yrs	
		Quinic	2	1/2 Yrs	
		Shikimic acid	2	1/2 Yrs	
Appearance		Wg/Size	10	1/3 Yrs; 2/2 Yrs	
		Wg loss	3	-	
		He	2	-	
Texture		F1mm	4	1/2 Yrs	
		FM	2	-	
		SFM	1	-	
		AFM	1	-	
		LDFM	1	-	
		MIF	1	1/2 Yrs	
		AIF	2	-	
		NIP	2	-	
		FLD	4	-	
		AFLD	6	1/2 Trs	
		YM10_PDCond			
		YM20_BuStr			
		YM80_BuStr			
		YM100_BuStr			
		YM1.2			
Chem	BNJ16-4	Chlorogenic acid	2	1/2 Yrs	Herniter et al., Plants, 12(6), 1346 https://doi.org/10.3390/plants12061346
		Acetyl-caffeoylquinic acid iso 1	2	1/2 Yrs	
		Acetyl-caffeoylquinic acid iso 2	2	1/2 Yrs	
		Caffeoylarbutin	5	2/2 Yrs	
Disease resistance/Appearance	DxL (N=323)	Anthracnose fruit rot resistance	3	-	MacKenzie et al., Hort Research, 10(10), uhad169. https://doi.org/10.1093/hr/uhad169
Chem	DP NHB (N=153)	Anthocyanin types (acylation and glucosylation)	25	2/3 Yrs	Manuscript in progress
Texture	DP NHB and SHB GenStudy set (N=2000)	F1mm	4	-	Ferrao et al. manuscript in progress
		FM	2	-	
		SFM	3	-	
		AFM	2	-	
		LDFM	1	-	
		MIF	5	-	
		AIF	5	-	
		NIP	3	-	
		FLD	7	-	
		AFLD	2	-	
		DFM	2	-	
		BuStr	1	-	
		YM10_PDCond	11	-	
		YM20_BuStr	10	-	
		YM80_BuStr	11	-	
		YM100_BuStr	8	-	
		YM1.2	10	-	

* completed during this reporting cycle (Y3)

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

Table 4. Summary of ongoing FC QTL studies in blueberry.

FC	Material	FC sub-component	Status
Chem	DxB (N=160)	pH TA SSC	Ongoing Giongo (DxB) team
Appearance	DSxJ (N=190) And DxB (N=160)	Wg/Size	Ongoing Bassil (DSxJ) and Giongo (DxB) teams
		Wg loss He	
Texture T0 and T6		F1mm, FM, SFM, AFM, LDFM, MIF, AIF, NIP, FLD, AFLD, YM10_PDCond, YM20_BuStr, YM80_BuStr, YM100_BuStr, YM1.2	
Chem-Non volatiles T0	DP NHB and SHB GenStudy set (N=2000)	pH TA SSC Total Organic Acid Citric Quinic Shikimic acid Malic	Ongoing, Iorizzo, Munoz teams
Chem-volatiles Appearance - T0 and T6		>33 volatiles Wg/Size Wg loss He	
Texture T0 and T6		F1mm, FM, SFM, AFM, LDFM, MIF, AIF, NIP, FLD, AFLD, YM10_PDCond, YM20_BuStr, YM80_BuStr, YM100_BuStr, YM1.2	

Table 5. 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	2023	
FC Traits							
Texture and Appearance FC							
Texture (TxNp) penetration needle probe	T0 and T4*	4 mechanical parameters	TA.XTPlus***	Completed		NP	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***		Completed	Completed	
Texture (TxPp) Double compression probe	T0 and T2, T4, T6*	23 mechanical parameters	TA.XTPlus***				
Weight (Wg) (Size**)	T0 and T2, T4, T6*	Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***	Completed		Completed	
Scar (ScD)		Diameter (ScD)	Digital caliper***			NP	
Chemical composition							
Non-Volatile chemical composition (Chem)	T0 and T2, T4, T6*	Titratable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	NP	Perkins et al. 2021, Acta Hort.
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Completed	NP	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC and LC-MS	Completed	Completed	NP	
Shelf life indicators							
Wrinkle/Shrivel (Shr)	T0 and T2, T4, T6*	Scale 0-3, and % yes/no	Visual***	Completed	Completed	NP	Giongo et al. 2021, *PBT 183, 111696*; Iorizzo et al. 2021, Proceeding of XII ISHS Int Vac Symp
Leakage (Lk)		% yes/no	Visual***			NP	
Mold		% yes/no	Visual***			NP	
Mold color		Visual	Visual***			NP	
Stem scar Tear (ScTr)		% yes/no	Visual***			NP	
Wet stem scar (WSc)		% yes/no	Visual***			NP	
Weight loss (WgLo)		Avg. 10-12 berry weight (T0-T1)	High Precision Mettler Scale***			NP	
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			NP	
Bruising	T0	Bruising rate	Image analysis	Completed	Completed	NP	Ni et al. 2022, CEA 201, 107200.
Sensorial texture	T1	Nine sensorial descriptors	Trained panel	NP	NP	Completed	Oh. et al. manuscript in preparation

* T0= 12-24 hours post-harvest; T1= one week 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 5-6

Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in blueberry.
2a. Phenotyping fruit characteristics [Phenomics Team]
Complete analysis of year 1-4 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.*
Prepare manuscripts for dissemination of results.
2b. Discover DNA markers associated with FCs [Statistical Genetic Team]
Continue QTL mapping in biparental populations and GWAS in GenStudy .
Prepare manuscripts for dissemination of results.
2c. Identifying FCs that contribute to essential fruit quality traits [Fruit Quality Team, Penelope Perkins Lead]
Complete analysis of phenotypic data collected for FqStudy sets to identify FCs that contribute to reduced bruising and sensorial texture
Prepare manuscripts for dissemination of results.
Excepted challenges. None at this time.

Obj. 2 Cranberry – VacCAP: Year 4 Progress Summary

Obj. 2. Discover DNA markers and fruit characteristics that improve fruit quality in cranberry.	
Contributed by: Zalapa, Polashock, Sideli, Cicalese, Loarca	
Presented by: Sideli, Loarca, Polashock	
2a. Phenotyping fruit characteristics (FCs) [Phenomic Teams]	**To whom***
Finalize phenotyping protocols, equipment needs and settings. 1) Tested a new method to evaluate internal structure; 2) developed a trait ontology; 3) Developed software 'CARP' (Cranberry Assessment for Rot Prediction) to phenotype FRR. 4) Initiated development of a Hyperspectral Agricultural Research Vehicle for field phenotyping. 5) developed software for cranberry fruit quality phenotyping (CranCV).	Fruit Quality, Breeding, Statistical Genetic and Breeding Teams and Partners
Phenotype FCs (Table 6). Evaluated yield, vigor and fruit shape, size, internal and externa appearance, Tacy, fruit weight, color, yield, % fruit rot, total anthocyanin, brix and TA, organic acids, multiple morphological, phenological traits (e.g. number of fruit per upright branch) and texture on self-pollinated plants (N=847), diversity panels (Rutgers. N=312, and Wisconsin, N=350), MP1 (N=172), MP2 (N=71) and MP3 (N=211), MP4 (N=141) and MP5 (N=68).	Statistical Genetic and Breeding Teams
Expected Impact. 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**
Collect material, extract DNA from GenStudy set. Completed genotyping	Breeding and Genotyping Teams, Breeders and geneticist partners
Perform Genetic analysis (Table 7). completed three genetic studies for fruit rot resistance (FRR), epicuticular wax (ECW), size and shape related traits, chemistry (Tacy, TA, Brix), uprights and Yield traits. Highlights from these studies were: QTL for ECW overlap with QTLs for FRR, stable QTLs for Tacy and traits related to size and shape related were identified. Preliminary results from other genetic studies identified QTLs for TA, Benzoic acid and Malic acid, ECW and texture parameters.	
Expected impact. 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.	
Challenges & Changes. Delay in the delivery of genotypic data delayed some of the genetic studies.	
Addressing challenges and recommendations. 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.	

* To whom results are transferred during the project

Table 6. Summary of cranberry phenotyping activities completed or ongoing for the GenStudy 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_NJ (N=293)		New methods reference
			2019	2020	2019	2020	2019	2020	2021	2022	2019	2020	2021	2023-2024	2019	2020	2021	2023-2024	2022	2023-2024	
FC Traits																					
Texture and Appearance FC																					
Texture (TxCp) compression probe	31 mechanical parameters	TA.XTPlus***	Done	Done	Done	Done	Done	Done	NP*	NP*	NP*	NP*	NP*		NP*	NP*			Done		Lopez-Moreno et al., 2023. Horticulturae. 9(4). Article 479.
External Appearance (ExtApp)	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																			Lopez-Moreno et al., 2024. Submitted to Journal of Textural Studies
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							Done												
Fruit wax		Visual rating	NP*	NP*	NP*	NP*	NP*	NP*	NP	Done	Done	Done			Done	Done			NP		
Fruit Shape		Visual rating	NP	NP	NP	NP	NP	NP	NP	NP		NP			Done	Done			NP		
Chemical composition																					
Non-Volatile chemical composition (Chem)	Total Anthocaynin	Spectrophotometric	NP**	NP**	NP**	NP**	Done	Done	Done	NP									NP**		
	Organic acids: quinic, citric, and malic	HPLC	NP	NP	NP	NP		Done	Done	NP		Done	Done			Done	Done		Done		
	Brix	Refractometer	NP**	NP**	Done	Done	Done	Done	Done	NP									NP**		
	TA	Titration	NP**	NP**	Done	Done	Done	Done	Done	NP		Done	Done			Done	Done		NP**		
Fruit Rot Resistance (FRR)	% of rotted fruit/sq ft	Precision scale	Done	Done	Done	Done	Done	Done	Done	NP											
Yield (total Wg)	Total Wg/sq. ft.	Precision scale	NP**	NP**	Done	Done	Done	Done	Done	NP											
Leaf disease		Visual rating					Done		Done	Done	**NP**	**NP**	**NP**	Ongoing	NP	NP	NP	Ongoing	NP**	Ongoing	
Bloom time	% of open & past flw/total flw in 10 uprights	Count	NP	NP	NP	NP	NP		NP	Done											
fruit set	#fruit per 10 uprights	Count								Done											

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 7. Summary of FC QTL studies completed in cranberry.

Crop	FC	Material	FC sub-component	# QTL	# Stable QTL/Years	Reference
Cranberry						
	Fruit Weight	DP_NJ (N=293)*	Avg Fruit Weight	6	NA	Diaz-Garcia et al., 2021. Front Plant Sci.;11:607770. https://doi.org/10.3389/fpls.2020.607770
	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. https://doi.org/10.1007/s11295-020-01482-8
		CM100* (N=33)	Low Malic acid (mala) < 2.5 mg/g	1	1 / 2 Yrs	
	Fruit rot Resistance	MP1 N=172; MP2 N=71; MP3** N=200	Fruit rot	1	1 / 2 Yrs	Maule et al. (submitted); Knowles et al. 2024. (in prep)
	TA		Titratable Acidity	1	1 / 2 Yrs	
	TACY		total anthocyanins	3	1 / 2 Yrs	
	brix		soluble solids	1	1 / 2 Yrs	
	Epicuticular Wax	MP4*** (N=141)	Epicuticular Wax	1	1	Erndwein et al., 2023 BMC Plant Biology; 23:181.https://doi.org/10.1186/s12870-023-04207-w
	Fruit rot resistance		Fruit rot	2	2	Kawash et al., 2024 Phytopathology; https://doi.org/10.1094/PHYTO-12-23-0477-R
	% of open & past flw/total flw in 10 uprights	MP1*** N=172	Fruit size and yield	13	8	Maule et al., Submitted
				36	17	

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

** completed during previous reporting cycle (Y3)

***completed during this reporting cycle (Y4)

Table 5. 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	2023	
FC Traits							
Texture and Appearance FC							
Texture (TxNp) penetration needle probe	T0 and T4*	4 mechanical parameters	TA.XTPlus***	Completed		NP	
Texture (TxPp) penetration flat probe	T0 and T2, T4, T6*	14 mechanical parameters	TA.XTPlus***		Completed	Completed	Giongo et al. 2021, *PBT 183, 111696*; Iorizzo et al. 2021, ISHS presentation
Texture (TxPp) Double compression probe	T0 and T2, T4, T6*	23 mechanical parameters	TA.XTPlus***				
Weight (Wg) (Size**)	T0 and T2, T4, T6*	Avg. individual berry weight and avg. 10-12 berry weight	High Precision Mettler Scale***	Completed		Completed	
Scar (ScD)		Diameter (ScD)	Digital caliper***			NP	
Chemical composition							
Non-Volatile chemical composition (Chem)	T0 and T2, T4, T6*	Titratable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	NP	Perkins et al. 2021, Acta Hort.
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC	Completed	Completed	NP	
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC and LC-MS	Completed	Completed	NP	
Shelf life indicators							
Wrinkle/Shrivel (Shr)	T0 and T2, T4, T6*	Scale 0-3, and % yes/no	Visual***	Completed	Completed	NP	Giongo et al. 2021, *PBT 183, 111696*; Iorizzo et al. 2021, Proceeding of XII ISHS Int Vac Symp
Leakage (Lk)		% yes/no	Visual***			NP	
Mold		% yes/no	Visual***			NP	
Mold color		Visual	Visual***			NP	
Stem scar Tear (ScTr)		% yes/no	Visual***			NP	
Wet stem scar (WSc)		% yes/no	Visual***			NP	
Weight loss (WgLo)		Avg. 10-12 berry weight (T0-T1)	High Precision Mettler Scale***			NP	
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			NP	
Bruising	T0	Bruising rate	Image analysis	Completed	Completed	NP	Ni et al. 2022, CEA 201, 107200.
Sensorial texture	T1	Nine sensorial descriptors	Trained panel	NP	NP	Completed	Oh. et al. manuscript in preparation

* T0= 12-24 hours post-harvest; T1= one week 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

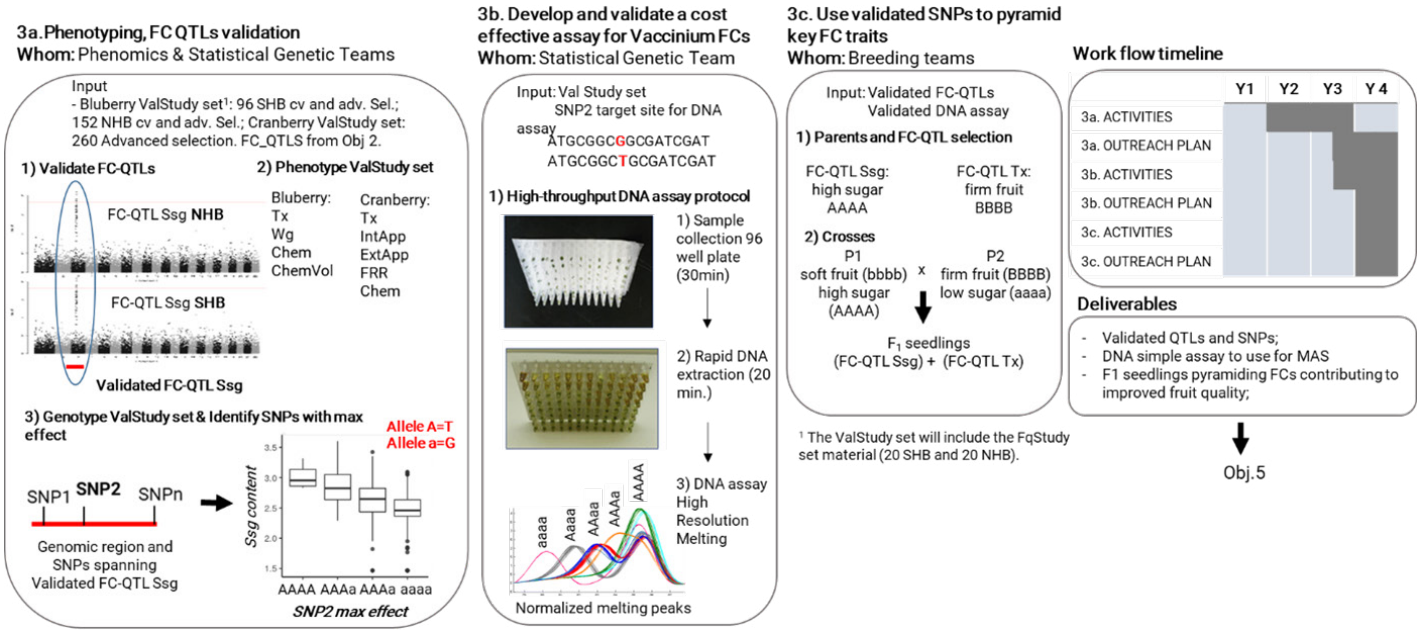
Obj. 2 Cranberry – VacCAP: Plan for Year 5-6

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 and fruit rot resistance: continue testing improved methods for harvesting small plots and image analysis to assess FC and fruit rot.
Complete data analysis for data collected during year 1-4
Prepare manuscripts for dissemination of results.
2b. Discover DNA markers associated with FCs [Statistical Genetic Team]
Perform QTL mapping analysis for data collected in year 1-4 (Table 8).
Prepare manuscripts for dissemination of results.
Expected challenges.

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 4 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***
Phenotype ValStudy Set. Blueberry. Completed evaluation of FCs and shelf life indicators on the NHB ValStudy set and 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). **Cranberry**: 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.	Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.
Develop list of target existing FC-QTL. Blueberry: Anchored stable QTL identified across three mapping populations to the blueberry genome. Three QTL regions associated with pH/TA, chlorogenic acid, anthocyanin acylation and anthocyanin glycosylation are being considered as validated, as they were detected across multiple genetic backgrounds. Also 29 QTLs for 20 volatiles for NHB and SHB GenStudy sets were identified. Efforts to identify candidate genes and possible polymorphisms to target for DNA assay development were initiated. Some QTL regions were used to design DNA assays to test their prediction ability, and thus, their potential for Marker Assisted Selection. **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. Three QTLs for yield, one for TAcy, and one for fruit rot resistance overlap with those identified in previous studies and will be evaluated further.	
3b. Develop and validate a high-throughput affordable assay for Vaccinium FCs [Statistical Genetic Team]	**To whom**
Finalize selection and protocol for simple DNA assay. Blueberry: KASP assays targeting SNPs associated with eucalyptol content were tested. Preliminary results indicated a mid-level prediction accuracy. Efforts to use haplotype information to increase prediction accuracy were initiated. 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. **Cranberry**: validated a DNA assay using PACE technology targeting SNPs associated with epicuticular wax and FRR. The marker for epicuticular wax is very sensitive at distinguishing homozygous alleles (Table 10) but not able to distinguish the heterozygous alleles. Initiated marker development for other QTLs using KASP assay. Initiated efforts to test KASP assays targeting SNP for organic acids (Table 10) in different germplasm.	Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.
3c. Pyramid key traits using validated SNPs and phenotypic data [Breeding Teams]	**To whom**
Leverage FC and FQ phenotypic data for advancing breeding selections. Blueberry and cranberry: continued making selections for genotypes with good performance for FC and propagated selections for trialing. Crosses of superior individuals were also performed and will be germinated in the fall of 2023 and spring 2024.	Genotyping and Breeding teams, Vaccinium Breeders, and Geneticist Partners.
Expected impact 3a-c. 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.	
Challenges & changes. 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-Y4 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.	

* 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		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	Titratable 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	Completed	NP	Completed	NP
Volatile chemical composition (ChemVol)		Volatile organic composition (>60 volatile compounds)	GC-MS	NP****	Completed	NP	Completed	NP
Shelf life indicators								
Wrinkle/Shrivel (Shr)	T0 and T1	Scale 0-3, and % yes/no	Visual***	Completed	Completed	Completed	Completed	Completed
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 https://doi.org/10.1007/s11295-020-01432-4
		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. https://doi.org/10.1007/s11295-020-01482-8
		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. BMC Plant Biology, 23, 181 (2023). https://doi.org/10.1186/s12870-023-04207-w

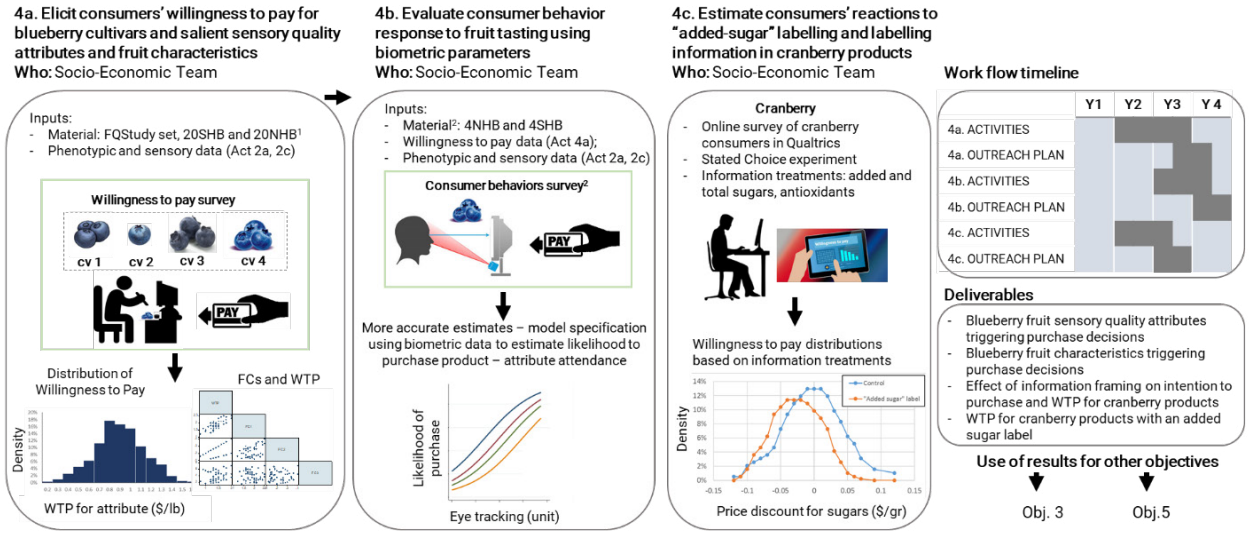
Obj. 3 – VacCAP: Plan for Year 5-6

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]
Continue efforts to validate QTLs across populations
3b. Develop and validate a high-throughput affordable assay for Vaccinium FCs [Statistical Genetic Team]
Continue testing protocols for simple DNA assay on a set of existing FC-QTLs
Analyze DNA assay data
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.
Communicate outcomes through presentations.
3c. Pyramid key traits using validated SNPs and phenotypic data [Breeding Teams]
Validate performance of genotypes selected during year 1-4 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.



[1] The willingness to pay survey will be carried in conjunction with sensory panel survey.
[2] For the consumer behaviors study 4 SHB and 4 NHB were selected form the set of cultivars used for the FQStudy set (used in Act 2c and 4a).

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 4 Progress Summary

<table>
<tr><td colspan="2">Obj. 4 Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand.</td></tr>
<tr><td colspan="2">Contributed by: Gallardo, Canales, Sims,</td></tr>
<tr><td colspan="2">Presented by: Gallardo, Ma, Canales</td></tr>
<tr><td>4a-b. Elicit consumers' willingness to pay for blueberry cultivars and salient sensory quality attributes and fruit characteristics [Socio Economic Team]</td><td>To whom*</td></tr>
<tr><td>Completed phenotyping blueberry sensory set. Finalized evaluation of pH, TA, TSS, sugars and volatiles on blueberry cultivars used for willingness to pay (WTP) study. Phenotipic, sensory and WTP data for 42 NHB and 40 SHB collected from two years, two locations were integrated and analysis of the data to identify salient sensory attributes and fruit characteristics is ongoing.</td><td rowspan="2">Breeding, Fruit Quality and Statistical Genetic teams, Blueberry industry partners, Distributors</td></tr>
<tr><td>Completed a study assessing consumer preference for labels associated with blueberry sensory quality (Sweety, Crunchy, Stay Fresh). Results indicated that "Stay Fresh" is the wording on the label of packaged blueberries that resulted in the lowest own price elasticity. This imply that the label "Stay Fresh" (a phrase that signals longer shelf life and freshness) could favor potential demand increase as compared to "Sweety" or "Crunchy" labels. Initiated distribution of a breeding priority survey. The outcomes of these studies are informing breeders and producers about possible strategies to reduce the negative impact of the added sugar labels on cranberry consumption and trigger purchase decisions and repeated purchases for blueberry.</td></tr>
<tr><td colspan="2">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. Information about blueberry quality traits preferred by consumers will be useful for breeders and growers in identifying quality traits with higher consumer acceptance and potential market performance, and for distributors in developing marketing strategies based on preferred quality traits.</td></tr>
<tr><td>4c. Estimate consumers' reactions to "added-sugar" labelling and labelling information in cranberry products [Socio Economics Team]</td><td>To whom</td></tr>
<tr><td>Finalized a study assessing WTP for cranberry products from fruit developed using CRISPR technology. The results indicated that consumers are in general averse to the use of alternative breeding methods such as CRISPR in cranberry production. However, the discount for added sugars in cranberry products is larger than the discount for CRISPR, implying that consumers may be more receptive of breeding methods such as CRISPR if its use results in products with reduced sugar content.</td><td rowspan="2">Breeding and Statistical Genetics teams, Cranberry industry partners (nurseries, processors, growers, commodity group organizations)</td></tr>
<tr><td>Finalized a study assessing WTP for cranberry products based on added sugars content and sweetening method (regular sugar or juice concentrate from other fruits). The results indicated that consumers apply significant discounts for increases in added sugars reported on the label that vary based on the information provided to consumers about the health benefits associated with cranberries and/or recommendations to limit added sugars.</td></tr>
<tr><td colspan="2">Expected Impact. 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.</td></tr>
<tr><td colspan="2">Challenges & Changes: 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 new study described in 4a-b (consumer preference for labels associated with sensory quality).</td></tr>
</table>

* 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	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	
Scar (ScD)		Diameter (ScD)	Digital caliper***				
Chemical composition							
Non-Volatile chemical composition (Chem)		Titratable acidity (TA), pH, Soluble Solid Content (SSC)	Digital refractometers and pH meter	Completed	Completed	Completed	Completed
		Sugars (SSg): fructose, glucose, sucrose	NIR & HPLC		Completed	Completed	Completed
		Organic acids (Ac): malic, citric, quinic, shikimic	HPLC	Completed	Completed	Completed	Completed
Volatile chemical composition (ChemVol)		Volatile organic composition (>60 volatile compounds)	GC-MS	Completed	Completed	Completed	Completed

* 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

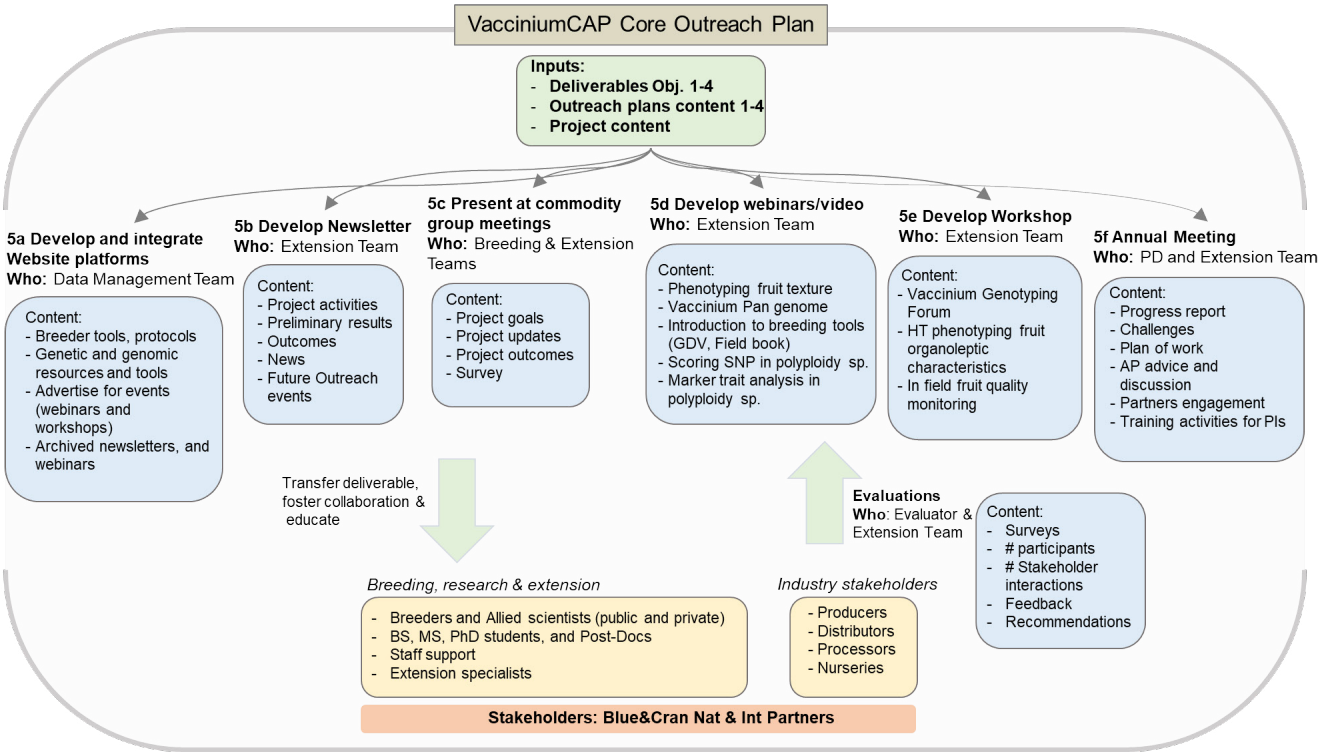
Obj. 4 – VacCAP: Plan for Year 5-6

Obj. 4 Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand.
4a-b. Elicit consumers' willingness to pay for blueberry cultivars and salient sensory quality attributes and fruit characteristics [Socio Economic Team]
Finalize the analyses of the blueberry sensory and willingness-to-pay data collected in year 3
Communicate outcomes through manuscript and presentations.
4b. Evaluate grower and consumer behavior response to fruit quality attibutes [Socio Economics Team]
Summarize results of blueberry and cranberry breeding priorities
4c. Estimate consumers' reactions to "added-sugar" labelling and labelling information in cranberry products [Socio Economic Team]
Communicate outcomes through presentations. All manuscripts were accepted and published.
Expected challenges: None at this time

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 4 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 YR4: - created specific categorized content for user groups such as breeders and stakeholders and using icons to organize information on these pages. - Development of VacTraits and VacCAP for all deliverables - Updated webinar videos, newsletters and publications/presentations - Website stats summary (September 1, 2023–August 31, 2024): 9,251 pageviews; 2,698 users; 3,320 sessions (1.23 sessions per users).	VacCAP core labs and the Vaccinium genomics, genetics and breeding research community
Genome Database for Vaccinium (GDV) data updates: During year 4 of the project twenty-two new blueberry and ten new cranberry genomes from the Vaccinium Pangenome Project (https://www.vaccinium.org/bio_data/2703087) and the Vaccinium darrowii Camp genome were added to GDV. The gene, mRNA, and functional annotation information for all the genomes were added to the database and the genomes were added to the BLAST and JBrowse genome tools. The V. darrowii genome and the three best blueberry (Duke, Earlie Blue, Elliot) and cranberry genomes (Budd's Blues, Garwood Bell, Native Budd's Blues) from the pangenome project were added to the PathwayCyc and Synteny Viewer genome tools. GDV also hosts the structural graphs from the Vaccinium Pangenome Project (https://www.vaccinium.org/node/1251207). GDV was accessed by 5,722 users from 84 countries, with 11,842 visits and 129,418 pages served (Google Analytics).	
GDV tools updates. Improvements and upgrades were done to the tools deployed on GDV. The Breeding Information Management System (BIMS), used to manage private breeding program data, now imports images from the Field Book App and supports BrAPI v1 and v2 Field Book calls. We added the ability to load GWAS data to the database, and search and view GWAS data in the MegaSearch and MapViewer Tools. And also added an ortholog/paralog search to MegaSearch and orthologs are also displayed on the gene/mRNA feature pages. The genotype search was also added. We have also added the ability to load gene annotation information to the database for use in the coming year. Crosslinks between germplasm records and the Fruit and Nut database are now available as well. In addition to making all MainLab modules compatible with PHP8, the following modules were released: TripalMap v2.0, ChadoSearch v2.7, and Tripal MegaSearch v1.4.	
5.b. Develop material for newsletters and other social media [Extension Team]	**To whom**
Develop and release newsletters: Three VacCAP newsletters and four GDV newsletters were issued during year 4. Newsletters are achieved on the VacCAP ad GDV websites and are delivered by email to our stakeholders (breeders, researchers, extension specialists, and industry stakeholders, as well as project participants). Newsletter stats: 347 subscribers get the newsletter directly by email, with an opening rate of >48% (compared to an average of 45% among similar email campaigns).	VacCAP core labs, partners, stakeholders, general public
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 2023–August 2024): 379 followers; 7,118 (average 593/month) profile visits. YouTube stats: 1,215 video views, 104.7 hours of watch-time.	

5.c. Develop webinars [Extension Team]	To whom
Deliver webinars: delivered four webinars (see VacCAP pub and presentations for titles and link), attended by 148 live participants.	VacCAP core labs, breeding and genetic partners
5d. Protocols and methodology training videos [Extension Team]	**To whom**
Develop video training. Seven 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 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 13 presentations at grower association meetings and field days across U.S. states. Developed handouts flyer that summarized the objectives of the VacCAP project.	Blueberry and cranberry growers, processors, distributors, nurseries and breeding partners
Initiated reassessment of the blueberry and cranberry breeding priorities. Two survey to re-asses the blueberry and cranberry breeding priorities were developed and used to initiate distribution at commodity group meetings.	
5f. Annual meeting [Extension Team]	**To whom**
Facilitate annual meetings targeting project participants, AP members, and national and international partners: An annual report that summarized Year 4 activities and plans for Year 5-6 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 5-6 activities. The annual report was posted on the VacCAP web site at https://www.vacciniumcap.org/annualreport.	Team members, AP members, USDA program officers
External Evaluation [Extension Evaluator]	**To whom**
Coordinate the design and implementation of surveys for webinar, workshop and meeting participants and assist with annual report forms for project participants: 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.	Team members, AP members, USDA program officers, extension audiences
Manage, analyze, interpret and report project evaluation feedback, recommendations, and related data: 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. More than 80% reported that each webinar "greatly" or "moderately" improved their understanding of the topics (82% to 100%) and almost all would recommend the webinars to others (93% to 100%). Over 21,000 (11,842 GDV+ 9,251 VacCAP) users/viewers and 347 newsletter subscribers from >99 countries accessed 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.	Team members, AP members, USDA program officers, extension audiences

Expected impact. 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.
Challenges & changes. None at this time
Addressing challenges and recommendations. We will continue to develop training videos for new methodologies developed by the team.

Obj. 5 – VacCAP: Plan for Year 5-6

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. Update the GDV modules to be compatible with Drupal 10 and Tripal 4.

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

Release additional VacCAP newsletter editions: During Year 5 we will issue 3 editions of our VacCAP Newsletter that will be distributed to our stakeholders and partners. These newsletters will feature highlights from each Objectives. 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 5.

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]

New webinars are planned for Year 5: Blueberry cell wall analysis (Marlee Trandel-Hayse); Predicting blueberry texture and shelf life (Massimo Iorizzo, Heeduk Oh, Lara Giongo); Organic acids and texture genetic study (Heeduk Oh); 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 5, 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]

Continue to deliver presentations at commodity group meetings to update stakeholders on project progress. Finalize analysis of breeding priorities survey data.

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]

Continue to engage and educate the general public about the project outcomes and impacts.

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 5.

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 5.

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.

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Journal Article

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- 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
- Trandel-Hayse M, Oh H, Iorizzo M, Johanningsmeier S and Perkins-Veazie P. 2023. Blueberry cell wall composition helps to explain fruit firmness phenotypes. ACS Food Science and Technology. https://doi.org/10.1021/acsfoodscitech.3c00284
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- Main D. 2023. Hands-on Training for Effective Use, Data Contribution, and Options for Long Term Sustainability of Specialty Crop Community Databases. ASHS 2023 Annual Conference, July 31-August 4, Orlando, FL.
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VacCAP Team Publications and Presentations

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Also check out our new website 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 with the subject line "VacCAP Newsletter Contribution"

VacCAP
IMPROVING FRUIT QUALITY

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

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IMPROVING FRUIT QUALITY

USDA-NIFA Annual Report

Year 4

United States Department of Agriculture

Progress Report

Title:	**VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes**

Sponsoring Agency	NIFA	**Project Status**	ACTIVE
Funding Source	Non Formula	**Reporting Frequency**	Annual
Accession No.	1020223	**Grants.gov No.**	
		Award No.	2019-51181-30015
Project No.	NC09879	**Proposal No.**	2019-03177
Project Start Date	09/01/2019	**Project End Date**	08/31/2024
Reporting Period Start Date	09/01/2022	**Reporting Period End Date**	08/31/2023
Submitted By		**Date Submitted to NIFA**	

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

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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

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. A haplotype resolved assembly of a HortbluePetitexNui progeny (tetraploids) was developed. The assembly is resolving a complex locus linked to a QTL for anthocyanin content on chromosome 2. Finalized and released annotations of blueberry and cranberry cultivars and a pangenome graph. Initiated efforts for identification of dispensable genes that have fruit specific expression patterns. Advanced development of the Vaccinium Genotyping platform. Completed validation of the 22K blueberry and 17K cranberry genotyping platforms. Results confirmed that the platforms are highly informative across cultivated and wild blueberry and cranberry germplasms. Continued coordination of samples submission from member of the genotyping consortium, and secured a new discounted price for submissions in year 5. The consortium include 13 members representing public and publish breeding programs, from U.S., France, New Zealand, Canada and Italy and have genotyped 10,300 samples. Overall, these activities are expanding use of molecular tools in blueberry and cranberry breeding and research programs and facilitating genetic discoveries.
Obj. 2. Advanced phenotyping methods. Blueberry: 1) Evaluated relationship between acoustic system and mechanical texture analysis; 2) Continued to improve a web application to evaluate bruising rate. Cranberry: 1) Tested a new method to evaluate internal structure; 2) developed a trait ontology; 3) Developed software 'CARP' (Cranberry Assessment for Rot Prediction) to phenotype FRR. 4) Initiated development of a Hyperspectral Agricultural Research Vehicle for field phenotyping. Phenotyped genetic study sets (GenStudy). Blueberry: evaluated pH, TA, sugars, organic acids (by HPLC) in the NHB and SHB GenStudy sets (N=2,000). Cranberry: evaluated yield, vigor and fruit shape, size, internal and externa appearance, Tacy, fruit weight, color, yield, % fruit rot, total anthocyanin, brix and TA, organic acids, multiple morphological, phenological traits (e.g. number of fruit per upright branch) and texture on self-pollinated plants (N=847), diversity panels (Rutgers. N=312, and Wisconsin, N=350), MP4 (N=141), MP5 (N=68) and MP6. Advanced FC genetic studies. Blueberry: completed QTL analysis for volatiles, anthocyanin content and composition, organic acids, TA, pH, sugars and texture. Major effect QTLs were identified for anthocyanin (acylated and glycosylated), 33 volatiles, citric acid, malic acid, quinic acid, shikimic acid, pH, and TA. No QTLs or very low effect QTLs were identified for sugars and texture, respectively. Except for volatiles that were not tested for multiple years all major QTLs were stables across multiple years. Efforts to identify candidate genes underlying major QTLs were initiated. Cranberry: completed three genetic studies for fruit rot resistance (FRR), epicuticular wax (ECW), size and shape related traits, chemistry (Tacy, TA, Brix), uprights and Yield traits. Highlights from these studies were: QTL for ECW overlap with QTLs for FRR, stable QTLs for Tacy and traits related to size and shape related were identified. Preliminary results from other genetic studies identified QTLs for TA, Benzoic acid and Malic acid, ECW and texture parameters. Fruit quality (FQ) studies. 1) completed one study to identify FCs that contribute to extended shelf-life. The study identified berry size and some mechanical texture parameters as traits that could be used to select for improved texture and appearance at harvest and post-storage. 2) Performed a new experiment to evaluate the relationship between sensorial texture and mechanical texture. 3) Completed evaluation of bruising rate.
Obj.3. Phenotyped germplasm for FC-QTL validation. Blueberry: phenotyped FCs (pH, TA, Sugars, TSS) on NHB (N=132), and SHB (N=101) ValStudy sets. Advanced validation of FC-QTLs. Blueberry: seven QTL regions associated with volatiles and chlorogenic acid, were considered validated since they were detected across multiple genetic backgrounds. Efforts to identify candidate genes and possible polymorphisms to target for DNA assay development were initiated. Advanced simple DNA assay design. Blueberry: KASP assays targeting SNPs associated with eucalyptol content were tested. Preliminary results indicated a mid-level prediction accuracy. Efforts to use haplotype information to increase prediction accuracy were initiated. Cranberry: validated a DNA assay using PACE technology targeting SNPs associated with epicuticular wax and FRR. The marker is highly sensitive. Initiated marker development for other QTLs. Leveraged FC phenotypic data for breeding selection. Blueberry and cranberry: continued making selections for genotypes with good performance for FC and propagated selections for trialing. Crosses of superior individuals were also performed and will be germinated in the fall of 2023 and spring 2024.
Obj. 4. Completed phenotyping blueberry sensory set. Finalized evaluation of pH, TA, TSS, sugars and volatiles on blueberry cultivars used for willingness to pay (WTP) study. Phenotipic, sensory and WTP data for 42 NHB and 40 SHB collected from two years, two locations was integrated and mining of the data to identify salient sensory attributes and fruit characteristics is

ongoing. Finalized a study assessing WTP for cranberry products from fruit developed using CRISPR technology. The results indicated that consumers are in general averse to the use of alternative breeding methods such as CRISPR in cranberry production. However, the discount for added sugars in cranberry products is larger than the discount for CRISPR, implying that consumers may be more receptive of breeding methods such as CRISPR if its use results in products with reduced sugar content. Completed a study assessing consumer preference for labels associated with blueberry sensory quality (Sweety, Crunchy, Stay Fresh). Results indicated that "Stay Fresh" is the wording on the label of packaged blueberries that resulted in the lowest own price elasticity. This imply that the label "Stay Fresh" (a phrase that signals longer shelf life and freshness) could favor potential demand increase as compared to "Sweety" or "Crunchy." labels. Initiated distribution of a breeding priority survey. The outcomes of these studies are informing breeders and producers about possible strategies to reduce the negative impact of the added sugar labels on cranberry consumption and trigger purchase decisions and repeated purchases for blueberry.

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) seven newsletters; 2) seven instructional videos; 3) one VacCAP traits information sheets; 4) four webinar videos. Maintained the VacCAP Twitter account that has 379 followers and had 1,375 impressions/month in Y4. Webinars: delivered four webinars, attended by 148 participants. Provided project updates at 13 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, and education/extension specialists. More than 80 percent reported that each webinar "greatly" or "moderately" improved their understanding of the topics (82% to 100% across four webinars) and almost all would recommend the webinars to others (93% to 100%). Feedback and recommendations gained from Y3 were integrated into Y4 activities, and feedback received in Y4 is being considered in planning future activities. Over 21,000 (11,842 GDV+ 9,251 VacCAP) users/viewers and 347 newsletter subscribers from >99 countries accessed VacCAP and GDV. 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 6 post-doctoral researchers, 13 professionals and technicians, along with 18 graduate students and undergraduate students fully or partially funded by the project across all the VacCAP team programs. These trainees 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.

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 17 peer reviewed publications and 50 posters and oral presentations at regional, national and international conferences (including the American Society of Horticultural Science, Plant & Animal Genome conferences, National Association of Plant breeding annual meeting). The information was also disseminated to the broader Vaccinium community (producers, processors and distributors) through 16 oral presentations at commodity group meetings, 13 VacCAP/GDV newsletter and blog articles, and two articles in trade magazines. Four 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 21 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, breeding, 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 identification of dispensable genes that have fruit specific expression patterns in the Vaccinium pan-genome to identify cultivar-specific genes associated with fruit quality

- Finalize data analysis of cranberry testing data
- Continue coordination of samples submission for genotyping from the VacCAP genotyping consortium
- Prepare new manuscripts and complete manuscripts under re-revision for dissemination of results

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

- Complete analysis of phenotypic data collected for FqStudy sets to identify FCs that contribute to reduced bruising and sensorial texture
- Complete genotyping cranberry diversity panel (Rutgers DP)
- Initiate efforts for functional characterization of candidate genes controlling FCs
- Continue QTL mapping in biparental populations and GWAS in GenStudy sets
- Prepare new manuscripts and complete manuscripts that are under re-revision 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 1-4 from the ValStudy sets
- Analyze blueberry DNA assay data (KASP) and evaluate possible use of haplotype on prediction accuracy;
- Continue testing 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 1-4 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
- Prepare new manuscripts for dissemination of results

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
- Complete re-assessment of industry breeding priorities
- Prepare new manuscripts and complete manuscripts under re-revision for dissemination of results

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: engage core and non-core labs to transfer method used to evaluate fruit quality traits
- 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 annual meeting (in-person and Zoom accessible, Geinesville, Florida)
- Continue to engage and educate the general public about the project outcomes and impacts through outreach activates our website, newsletter, and social media
- Project evaluation: continue project evaluation activity to improve stakeholder engagement, communication, and effectiveness of extension activities.
- Initiate development of impact statements.

Participants

Accession No. 1020223 **Project No. NC09879**

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	6.4	5.5	6.5	3.5	21.9
Professional	6	0	0	1	7
Technical	5.9	3.5	0	1.3	10.700000000000001
Administrative	0.1	0	0	0	0.1
Other	0.3	0	0	0	0.3
Computed Total	18.7	9.0	6.5	5.8	40.000000000000001

Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
9	7	6	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

Mengist MF, MH Grace, T Mackey, B Munoz, B Pucker, NV Bassil, C Luby, M Ferruzzi, MA Lila and M Iorizzo. (2022). Dissecting the genetic basis of bioactive metabolites and fruit quality traits in blueberries (Vaccinium corymbosum L). Frontier in Plant Science, 13:964656.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Herniter IA, Kim Y, Wang Y, Havill JS, Johnson-Cicalese J, Muehlbauer GJ, Iorizzo M and Vorsa N. (2023). Trait mapping of phenolic acids in interspecific (Vaccinium corymbosum var. caesariense x V. darrowii) diploid blueberry population. Plants, 12:1346.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Erndwein L, Kawash J, Knowles S, Vorsa N and Polashock J. (2023). Cranberry fruit epicuticular wax benefits and identification of a wax-associated molecular marker. BMC Plant Biol. 23(1):181.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Albert NW, Iorizzo M, Mengist MF, Montanari S, Zalapa J, Maule A, Edger PP, Yocca AE, Platts AE, Pucker B and Espley RV. (2023) Vaccinium as a comparative system for understanding of complex flavonoid accumulation profiles and regulation in fruit. Plant Physiology, 192(3), 1696–1710.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Nguyen HM, Putterill J, Dare AP, Plunkett BJ, Cooney J, Peng Y, Souleyre EJF, Albert NW, Espley RV and Günther CS. Two genes, ANS and UFGT2, from Vaccinium spp. are key steps for modulating anthocyanin production. Frontiers in Plant Science, 14 (2023): 1082246.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Jacobs M, Thompson S, Platts AE, Body MJA, Kelsey A, Saad A, Abeli P, Teresi, A Schilmiller SJ, Beaudry R, Feldmann MJ, Knapp SJ, Song G, Miles T and Edger PP (2023) Uncovering genetic and metabolite markers associated with resistance against anthracnose fruit rot in northern highbush blueberry, Horticulture Research, uhad169.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Torres-Meraz MA, de La Torre F, Berro I, Loarca J, Mura J, Ikeda S, Atucha A, Giongo L, Iorizzo M and Zalapa J. (2023) A Survey of Key Methods, Traits, Parameters, and Conditions for Measuring Texture in Cranberry (Vaccinium macrocarpon Ait.). Horticulturae. Apr 11; 9(4):479.

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	Accepted	2023	YES

Citation

Ma X, Gallardo RK, Canales E, Atucha A, Zalapa J and Iorizzo M. Would Consumers Accept CRISPR Fruit Crops if the Benefit Has Health Implications? An Application to Cranberry Products. Agricultural and Resource Economics Review.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Maule AF, Diaz-Garcia L, Loarca J, Lopez-Moreno H, Johnson-Cicalese J, Vorsa N, Iorizzo M, Neyhart J and Zalapa J. (2023) Of Buds and Bits: A QTL Study on Traditional Upright Traits and Modern Plot Phenotyping in Cranberry (Vaccinium macrocarpon Ait.). Frontiers in Plant Sciences – Plant Breeding.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Torres-Meraz M, Jarquin D, Lazar F, Loarca J, Maule A, Ikeda S, Giongo L, Grygleski E, Neyhart J, Iorizzo M and Zalapa J. (2023) Multiparametric fruit textural trait development for harvest and postharvest in representative cranberry (Vaccinium macrocarpom Ait.) cultivars differing in texture. Postharvest Biology and Technology.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Ferrão FLV, C Luby, M Pottorff, GIP Casorzo, M Fentie Mengist, T Mikey, MA Lila, L Giongo, N Bassil, P Perkins-Veazie, M Iorizzo and PR. Munoz. Inference of the genetic basis of fruit texture and chemical component in Northern and Southern Highbush blueberries. Scientia Horticulturea.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Trandel-Hayse M, Oh H, Iorizzo M, Johanningsmeier S and Perkins-Veazie P. Blueberry cell wall composition helps to explain fruit firmness phenotypes. ACS Food Science and Technology.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Oh H, Pottorff M, Giongo L, Mainland CM, Iorizzo M and Perkins-Veazie P.
Exploring shelf-life predictability of appearance traits and fruit texture in blueberry. Postharvest Biology and Technology

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Submitted	2023	YES

Citation

Yocca AE, Platts A, Alger E, Teresi S, Mengist MF, Benevenuto J, Ferrão LFV, Jacobs M, Babinski M, Magallanes-Lundback M, Bayer P, Golicz A, Humann JL, Main D, Espley RV, Chagné D, Albert NW, Montanari S, Vorsa N, Polashock J, Díaz-Garcia L, Zalapa J, Bassil NV, Munoz PR, Iorizzo M, Edger PP (2023) Blueberry and cranberry pangenomes as a resource for future genetic studies and breeding efforts. Horticulture Research

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Under Review	2023	YES

Citation

Ma X, Gallardo RK, Canales E, Atucha A, Zalapa J and Iorizzo M. Consumers' Discount for Added Sugars: An Application to Cranberry Products Under Different Nutrition-Related Information Treatments. Journal of the Agricultural and Applied Economics Association.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Under Review	2023	YES

Citation

Ma X, Gallardo RK, Canales E and Iorizzo M. Quality-Related Descriptors to Increase Fresh Blueberries Purchase - Evidence from a Basket-Based Choice Experiment. Journal of the Agricultural and Applied Economics Association.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Knowles S, Kawash J, Spain T, Erndwein L, Johnson-Cicalese J, Polashock J and Vorsa, N. Exploring fruit chemistry in a fruit rot resistance American cranberry mapping population and QTL discovery. North American Cranberry Research and Extension Workers Conference. Chatsworth, NJ. August 21-24, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Knowles S, Kawash J, Johnson-Cicalese J, Polashock J and Vorsa N. Relationships between fruit rot resistance and horticultural traits in American cranberry (Vaccinium macrocarpon Ait.). American Seed Trade Association Vegetable & Flower Seed Conference. Orlando, FL. January 27-31, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Prasad R, Duiven J, Fraser A, Smits C, Vorsa N and Johnson-Cicalese J. Performance of high-yield cranberry selections from the Rutgers breeding program in southwestern British Columbia. North American Cranberry Research and Extension Workers Conference. Chatsworth, NJ. August 21-24, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Knowles S, Herniter IA, Traband R, Bowman C, Wang X, Lo S, Wysocki K, Chitwood DH, Johnson-Cicalese J, Jia Z and Vorsa N. Unusual leaf and fruit morphology in a low titratable acidity cranberry population. North American Cranberry Research and Extension Workers Conference. Chatsworth, NJ. August 21-24, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Bassil et al. VacCAP Develops High Throughput Genotyping Platforms for Blueberry and Cranberry. 2023. Annual Conference of the American Society for Horticultural Science. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Clare et al. Assessment of the Flex-Seq Platform in Vaccinium. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Nahla Bassil, Mandie Driskill, Shaun Clare, Ping Zheng, David Chagne, Sara Montanari, Susan, Thompson, Richard Espley, Patricio Munoz, Juliana Benevenuto, Dongyan Zhao, Moira, Sheehan, Molla Mengist Fentie, Lisa J. Rowland, Hamid Ashrafi, Kalpalatha Melmaiee, Ebrahiem Babiker, James Olmstead, Jessica Gilbert, Joel Kniskern, Juan Zalapa, James, Polashock, Massimo Iorizzo and Patrick Edger. Leveraging Vaccinium genomic resources for genotyping in blueberry and cranberry. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Perkins-Veazie P., Massimo Iorizzo, Heeduk Oh, Farah Saeed and Changying Li. Fruit Bruising, Firmness, and Estimation of Cell Membrane Damage across Blueberry Genotypes. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Bassil N., Driskill M., Clare S., Ping Zheng, David Chagne, Sara Montanari, Susan, Thompson, Richard Espley, Patricio Munoz, Juliana Benevenuto, Dongyan Zhao, Moira, Sheehan, Molla Mengist Fentie, Lisa J. Rowland, Hamid Ashrafi, Kalpalatha Melmaiee, Ebrahiem Babiker, James Olmstead, Jessica Gilbert, Joel Kniskern, Juan Zalapa, James, Polashock, Massimo Iorizzo and Patrick Edger. VacCAP Develops High Throughput Genotyping Platforms for Blueberry and Cranberry. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Kawash J and Polashock J. 2023. Developing a new machine learning tool for improved genomic selection in non-model systems. Meeting: Mapping the Future of Agricultural Genome to Phenome Research in Kansas City, Missouri on June 15-16, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Erndwein L and Polashock J. 2023. Two-year survey of cranberry fruit rotting fungi detects azoxystrobin and thiophanatemethyl resistant Colletotrichum siamense. North American Cranberry Research and Extension Workers Conference in Absecon, New Jersey on August 21-24, 2023.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Kawash J, Dehzangi I, Mehedi Azim S and Polashock J. 2023. Hyperspectral imaging and the application of machine learning for rapid phenotyping of cranberry samples. North American Cranberry Research and Extension Workers Conference in Absecon, New Jersey on August 21-24, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Torres-Meraz MA, Devi Mura J, Ikeda S, Johnson-Cicalese J, Vorsa N, Iorizzo M, Neyhart J and Zalapa J. 2023. Phenomics of Processing Industry Fruit Quality Traits for Genetic Mapping in the American Cranberry (Vaccinium macrocarpon Ait ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Torres-Meraz MA, Mura JD, Ikeda S, Johnson-Cicalese J, Vorsa N, Iorizzo M, Neyhart J and Zalapa J. 2023. Unraveling the genetic bases of fruit quality in the American cranberry. NACREW. Absecon, New Jersey, August 22, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Loarca J, Mura JD, Ikeda S, Vorsa N, Iorizzo M, Johnson-Cicalese J, Neyhart J and Zalapa J. 2023. Fruit Quality phenotyping for breeding and genetic studies in cranberry. Alejandra Torres-Meraz, NACREW. Absecon, New Jersey, August 22, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Cheng CH, Jung S, Lee T, Buble K, Humann J, Zheng P., ... and Main D. 2023. Open-Source Solutions for Efficiently Building Community Databases for Crop Genomics, Genetics, and Breeding Research. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Main D. 2023. Hands-on Training for Effective Use, Data Contribution, and Options for Long Term Sustainability of Specialty Crop Community Databases. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Jung S, Lee T, Cheng CH, Gasic K, Humann J, Yu J and Main D. 2023. Breeding Information Management System (BIMS) for Crop Breeders. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Main D, Jung S, Lee T, Cheng CH, Zheng P, Gasic K, Humann J., … and Buble K. 2023. Hands-on Training for Effective Use, Data Contribution, and Options for Long Term Sustainability of Specialty Crop Community Databases. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Main D, Jung S, Lee T, Cheng CH, Zheng P, Gasic K, Humann J., … and Buble K. 2023. Resources for Fruit Breeding Research in Databases for Rosaceae, Vaccinium, and Citrus. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Humann J, Jung S, Jung S, Lee T, Cheng CH, Zheng P, Gasic K, … and Main D. 2023. Updates on Genomic Data and Tools in Rosaceae, Cotton, Citrus, Vaccinium, and Pulse Crop Databases. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Jung S, Jung S, Lee T, Cheng CH, Zheng P, Humann J, Gasic K, … and Main D. 2023. Updates on Genetics Data and Tools in Rosaceae, Cotton, Citrus, Vaccinium, and Pulse Crop Databases. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Bassil N, Jung S, Jung S, Lee T, Cheng CH, Zheng P, Gasic K, … and Main D. 2023.
Updates on Germplasm and Diversity Data and Tools in Rosaceae, Cotton, Citrus, Vaccinium, and Pulse Crop Databases. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Iorizzo M, Lila M, Perkins-Veazie P, Luby CH, Vorsa N, Edger P, Bassil NV, Munoz P, Zalapa JE, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock JJ, Sims C, Canales E, Devetter L, Coe M, Chagne D, Colonna A and Espley R. (2023) VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Acta Horticulturae. 1362:71-80.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Giongo, L., Ajelli, M., Pottorff, M., Coe, K., Perkins-Veazie, P., Bassil, N.V., Hummer, K.E., Farneti, B. and Iorizzo, M. 2023. Comparative study on texture: a key for blueberry quality breeding. Acta Horticulturae 1357, 107-114.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Perkins-Veazie, P., Ma, G., Pottorff, M., Lila, M.A. and Iorizzo, M. (2023). New tools for rapid fruit quality analysis in blueberry. Acta Horticulturae 1357, 193-198.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Iorizzo M., M.A. Lila, P. Perkins-Veazie, N. Vorsa, P. Edger, N. Bassil, P. Munoz, J. Zalapa, K.R. Gallardo, A. Atucha, D. Main, L. Giongo, C. Li, J. Polashock, C. Sims, E. Canales, L. M. Coe, D. Chagne, R. Espley and L. De Vetter. 2022. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. Proceedings of the ISHS International Symposium on Breeding and Effective Use of Biotechnology and Molecular Tools in Horticultural Crops. Acta Horticulturae 1362, 71-80

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Humann, J.L., Cheng, C.-H., Lee, T., Buble, K., Jung, S., Yu, J., Zheng, P., Hough, H., Crabb, J., Frank, M., Scott, K., Iorizzo, M. and Main, D. 2023. Using the Genome Database for Vaccinium for genetics, genomics, and breeding research. Acta Horticulturae 1357, 115-122

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Oh H, Mengist MF, Pottorff M, Giongo L, Perkins-Veazie P, Iorizzo M. Mapping QTLs for postharvest fruit texture and size characteristics in blueberry. Plant & Animal Genomics Conference (PAG) 30. January 13-18, 2023, San Diego, CA, USA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Oh H, Mengist MF, Pottorff M, Giongo L, Perkins-Veazie P, Iorizzo M. Identification of QTLs related to fruit texture at harvest and postharvest in blueberry. Tools for Polyploids Workshop 2023. January 11-12, 2023, San Diego, CA, USA. Poster

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Trandel-Hayse M.A., Oh H., Johanningsmeier S., Iorizzo M. and P. Perkins-Veazie. 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

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Perkins-Veazie P., Ma G., Oh H., Trandel-Hayse M.A., Bassil N., Luby C., Munoz P.R. and M. Iorizzo. 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.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

M. Iorizzo. Genetics, genomics, germplasm improvement to advance breeding of berries. 1st Latin American Congress of Berries, August 24-25, Chillán, Chile.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Molla Fentie Mengist, Marti Pottorff, Lara Giongo, Ted Mackey, Felipe Ferrao, Mary Ann Lila, Claire Luby, Nahla Bassil, Patricio R. Munoz, Penelope Perkins-Veazie and Massimo Iorizzo. Assessing Genetic Parameters and Predictability for Shelf Life Parameters in Blueberry. ASHS 2023 Annual Conference, July 31-August 4, 2023, Orlando, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Mengist M.F. , M.H. Grace, T. Mackey, B. Munoz, B. Pucker, N. Bassil, C. Luby, M. Ferruzzi, M.A. Lila and M. Iorizzo. Investigating the genetic basis of bioactive metabolites and fruit quality traits in blueberries (Vaccinium corymbosum L.). XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Iorizzo M. Exploring fruit/vegetable nutrigenomic properties as new target traits to improve phytochemicals and nutrients uptake/health outcomes. 7th Annual UF Plant Science Symposium, January 30-31, 2023, Gainesville, FL, US.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Iorizzo M. Vaccinium CAP status and updates: advancing genetic and genomic tools to improve fruit quality in blueberry and cranberry. Southeaest Regional Fruit & Vegetable Conference, January 6, 2023, Savannah, GA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

M. Iorizzo. Leveraging genetic and genomic tools to improve bioactive delivery/use from fruit and vegetables. CNR – ISPA, Italy. November 15, 2022.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Borges et al. 2023. Development of molecular markers for flavor improvement in autotetraploid blueberry. Polyploid across the tree of life, May 9-12, 2023, Palm Coast, FL, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Munoz P. 2023. Advancing Genomic Methods and Knowledge in Blueberry. Plant and Animal Genome. XXX Plant & Animal Genome, January 13-18, 2023, San Diego, California, USA.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Munoz P. Strategies applied to the selection and development of new blueberry varieties. In Te Puke, New Zealand, June 15, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Munoz P. Generating tools and resources for a more informed breeding process. Cornell University College of Agriculture and Life Sciences seminar series, October 02, 2022. Ithaca, NY

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Munoz P. Generating tools and resources for a more informed breeding process. Rutgers Fall graduate program seminar series. November 18, 2022. Newark, NJ

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Munoz P. Breeding Blueberry for Improving Eating Experience. Minnesota Plant Breeding Center Seminar Series, May 12, 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Munoz P. Strategies applied to the selection and development of new blueberry varieties. 1st Latin American Congress of Berries, August 24-25, Chillán, Chile.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Martensson K, Loarca J and Zalapa J. Analyzing cranberry fruit quality and internal structure. UW-Madison Undergraduate Research Symposium, December 12, 2022, Madison-WI.

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Zalapa J and H Herline. Varietal trial bed expansion: building the future genetic structure of cranberry. Proceedings article in the 2023 summer cranberry meeting and Field Day, page 19-20.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Zalapa J. USDA-ARS Food Science and Fruit Quality Ad hoc committee research roundtable meeting. Madison WI. 3-29-2023.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Cranberry research at the Walnut Street greenhouse UW, CALS Leadership tour. UW-Madison. 5-22-2023

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Cranberry cultivar fruit quality and yield discussion with UMass-Amherst. Zoom meeting. 4-11-23.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Cranberry cultivar fruit quality and yield discussion with Wisconsin growers. Zoom meeting. 4-21-23.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Other	2023	YES

Citation

Giongo L. Blueberry breeding program at FEM: an integrated approach to innovate through new varieties for Northern and Southern Europe – MacFrut 2023 Rimini, Italy, May 3-5.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Giongo L. Quality evaluations and requirements at harvest and postharvest for new cultivars of highbush blueberry. 11th Blueberry Conference Warsaw, Poland, March 9-10, 2023

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2023	YES

Citation

Giongo L. Developments and impacts of fruit quality analyses in blueberry: a focus on texture and postharvest. International Blueberry School, 2nd May 2023, Ancona, Italy.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

Citation

De Vetter L. Breeding Efforts in Berry Crops Growing By Leaps and Bounds. Growing Produce, Dec 20, 2022. https://www.growingproduce.com/fruits/berries/breeding-efforts-in-berry-crops-growing-by-leaps-and-bounds/?utm_source=gp&utm_medium=twitter&utm_campaign=2212

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

Citation

Mirtillo, a caccia dei geni per renderlo migliore. Terra e Vita, n. 34-2022, November 11.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Luby C., Hislop L., M. Iorizzo, L. Giongo, A. Atucha, L. Wasko DeVetter and Russo J. Blueberry Shelf Life. April 18, 2023. https://www.vacciniumcap.org/sites/default/files/inline-files/VacTrait%20Shelf%20Life.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

DeVetter and Bassil. 2023. VacCAP: Improving Fruit Quality. Oregon State University Blueberry Field Day. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Lopez-Moreno H, Phillips M, Diaz-Garcia L, Torres-Meraz MA, de La Torre F, Berro I, Loarca J, Mura JD, Ikeda S, Atucha A, Giongo L, Iorizzo M, Zalapa JE. 2023. A survey of key methods, traits, parameters, and conditions for measuring texture in cranberry (Vaccinium macrocarpon Ait.). U Mass Cranberry Management Update. East Wareham, Mass., January 25, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

M. Iorizzo. VacCAP Project updates. North Carolina Blueberry Council – 57th Annual Open House and Trade Show, January 10, 2023, Fayeteville, NC, USA. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Polashock J and Sarowar S. Gene Functional Analysis in Cranberry. American Cranberry Growers Assoc. Winter Meeting, Bordentown, NJ, January 19, 2023. Presentations for Growers or Other Industry Stakeholders

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Johnson-Cicalese J, Vorsa N, Knowles S and Spain T. Update on Cranberry Breeding Projects. American Cranberry Growers Assoc. Winter Meeting, Bordentown, NJ, January 19, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Kawash J and Polashock J. 2023. Updating Approaches to Fruit Rot Resistance Research. American Cranberry Growers Assoc. Winter Meeting, Bordentown, NJ, January 19, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Erndwein L, Kawash J and Polashock J. Cranberry Fruit Epicuticular Wax Benefits and Identification of a Wax-Associated Molecular Marker. American Cranberry Growers Assoc. Winter Meeting, Bordentown, NJ, January 19, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Munoz P. Research update and new cultivars. Florida Blueberry Growers Association. October 20, 2022. Howdy on the hill, FL. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Mini clinic: Cranberry variety trail and VaCap traits showcase. Wisconsin Cranberry Growers Asscociation summer meeting. Black River Falls, WI, August 9, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Cranberry Research Round Table. Zalapa Lab Summary of activities, including VaCcap report to the Wisconsin growers. November 17, 2022. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Wisconsin Cranberry Board Research Report. Black River Falls, Wi, March 15, 2023. Presentations for Growers or Other Industry Stakeholders

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Zalapa J. Wisconsin State Cranberry Growers Association meeting. Black River Falls WI, July 6, 2023. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Giongo L. Blueberry breeding program at FEM: an integrated approach to innovate through new varieties for Northern and Southern Europe. May 21, 2023 Meeting with Spanish and Chilean growers. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Giongo L. Blueberry breeding program at FEM: an integrated approach to innovate through new varieties for Northern and Southern Europe. July 6, 2023 Meeting with Spanish growers. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Giongo L. Blueberry breeding program at FEM: an integrated approach to innovate through new varieties for Northern and Southern Europe. July 11, 2023 Meeting with Italian growers. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Giongo L. Blueberry breeding program at FEM: an integrated approach to innovate through new varieties for Northern and Southern Europe. July 13, 2023 Meeting with English growers. Presentations for Growers or Other Industry Stakeholders

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Atucha A, Russo J, DeVetter L and Iorizzo M. Understanding the W85 Blueberry Genome. VacCAP Newsletter Issue 6, March 2023. https://www.vacciniumcap.org/w85genome

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Atucha A, Russo J, DeVetter L and Iorizzo M. Exploring the New Frontier of Flavonoid Genetics in Blueberry. VacCAP Newsletter Issue 6, March 2023. https://www.vacciniumcap.org/frontierofflavonoidgenetics

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Atucha A, Russo J, DeVetter L, Lopez-Moreno H and Zalapa J. Survey Says: How the Zalapa Team Is Identifying the Best Methods for Measuring Texture Traits in Cranberry. VacCAP Newsletter Issue 7, June 2023. https://www.vacciniumcap.org/texturesurvey

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

DeVetter L. A Tribute to Bernadine Strik – Berry Goddess. VacCAP Newsletter Issue 7, June 2023. https://www.vacciniumcap.org/bernadinetribute

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Trandel-Hayse M. A Deeper Look Into Blueberry Cell Wall Composition and Fruit Firmness Phenotypes. VacCAP Newsletter Issue 8, August 2023. https://www.vacciniumcap.org/blueberrycellwallcomp

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Russo J. VacCAP for All: Cranberry Fruit Epicuticular Wax Benefits and Identification of a Wax-Associated Molecular Marker. VacCAP Newsletter Issue 8, August 2023. https://www.vacciniumcap.org/sites/default/files/inline-images/VacCAP%20for%20All%20Cranberry%20Wax.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

Citation

Humann JL and Main D. Genome database for Vaccinium newsletters, Issue 5, (October 2022). https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-Oct2022.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Humann JL and Main D. Genome database for Vaccinium newsletters, Issue 6, (January 2023). https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-Jan2023.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Humann JL and Main D. Genome database for Vaccinium newsletters, Issue 7, (April 2023). https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-Apr2023.pdf

Accession No. 1020223 **Project No. NC09879**

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Humann JL and Main D. Genome database for Vaccinium newsletters, Issue 8, (July 2023). https://www.vaccinium.org/sites/default/files/files/GDV%20Newsletter-Jul2023.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2022	YES

Citation

Trandel-Hayse M, Oh H, Iorizzo M, Johanningsmeier S, Perkins-Veazie P. 2022. Blueberry cell wall composition helps to explain fruit firmness phenotypes. Fla State Hort Soc, Scientific note

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	YES

Citation

Zalapa J., F. Lazar, F. De la Torre, H. Lopez-Moreno. 2023. The Importance of Genetics in Cranberry Production. College of Agricultural and Life Sciences Division of Extension Integrated Pest Management Program Nutrient and Pest Management Program. Wisconsin Fruit Program. Available Online: https://ipcm.wisc.edu/wp-content/uploads/sites/54/2023/04/UW_CranberryBacktoBasics.pdf

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2022	YES

Citation

Iorizzo M. Autopolyploid Inheritance & Heterozygous Reciprocal Translocation Shape Chromosome Genetic Behavior on December 16, 2022. Webinar presentation.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Bassil N. and S. Clare. Two New Flex-Seq-EX-L High Throughput Genotyping Platforms for Blueberry and Cranberry on January 26, 2023. Webinar presentation.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Polashock J. Wax On, Acid Off: Approaches to Cranberry Fruit Improvement on April 24, 2023. Webinar presentation.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2023	YES

Citation

Montanari S. Understanding the Genetic Control of Anthocyanin Content in Blueberry on May 25, 2023. Webinar presentation.

Other Products

Accession No. 1020223 **Project No. NC09879**

Product Type

Databases

Description

GDV data updates. 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 4 of the project twenty-two new blueberry and ten new cranberry genomes from the Vaccinium Pangenome Project (https://www.vaccinium.org/bio_data/2703087) and the Vaccinium darrowii Camp genome were added to GDV. The gene, mRNA, and functional annotation information for all the genomes were added to the database and the genomes were added to the BLAST and JBrowse genome tools. The V. darrowii genome and the three best blueberry (Duke, Earlie Blue, Elliot) and cranberry genomes (Budd's Blues, Garwood Bell, Native Budd's Blues) from the pangenome project were added to the PathwayCyc and Synteny Viewer genome tools. GDV also hosts the structural graphs from the Vaccinium Pangenome Project (https://www.vaccinium.org/node/1251207). For genetic data, we curated data from 5 manuscripts and added 5 genetic maps, 128,438 genetic markers, and 368 QTL. During year 4, GDV was accessed by 5,722 users from 84 countries, with 11,842 visits and 129,418 pages served (Google Analytics)

Product Type

Databases

Description

GDV tools updates. Improvements and upgrades were done to the tools deployed on GDV. The Breeding Information Management System (BIMS), used to manage private breeding program data, now imports images from the Field Book App and supports BrAPI v1 and v2 Field Book calls. We added the ability to load GWAS data to the database, and search and view GWAS data in the MegaSearch and MapViewer Tools. And also added an ortholog/paralog search to MegaSearch and orthologs are also displayed on the gene/mRNA feature pages. The genotype search was also added. We have also added the ability to load gene annotation information to the database for use in the coming year. Crosslinks between germplasm records and the Fruit and Nut database are now available as well. In addition to making all MainLab modules compatible with PHP8, the following modules were released: TripalMap v2.0, ChadoSearch v2.7, and Tripal MegaSearch v1.4. The lab is also working on updating the modules to be compatible with Drupal 10 and Tripal 4.

Product Type

Databases

Description

Vaccinium CAP project website (https://www.vacciniumcap.org).
- During year 4 we continued to refine design for optimal access to project information and update content with new webinars, VacCAP traits, short video, newsletters.
- Website stats summary (September 1, 2022–August 31, 2023)
o 9,251 pageviews
o Top 5 Pages Based on Views
? Home | VacCAP
? About | VacCAP
? Newsletters | VacCAP
? Team | VacCAP
? News | VacCAP
o 2,698 users
o Top 5 Counties Based on User Locations
? United States (1,700 users)
? China (225 users)
? Australia (71 users)
? Canada (66 users)
? India (41 users)
o 3,320 sessions (1.23 sessions per users)

Product Type

Other

Description

Social Media. A twitter account (@VacciniumCAP) was mantained 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 2022–August 2023)
o 379 followers
• YouTube (September 2022–August 2023)
o 1,215 video views
o 104.7 hours of watch time

Product Type

Audio or Video

Description

Webinars. The following four webinars were made available on VacCAP:
• Autopolyploid Inheritance & Heterozygous Reciprocal Translocation Shape Chromosome Genetic Behavior on December 16, 2022. Presenter: Dr. Massimo Iorizzo. 45 participants.
• Two New Flex-Seq-EX-L High Throughput Genotyping Platforms for Blueberry and Cranberry on January 26, 2023. Presenters: Dr. Nahla Bassil and Shaun Clare. 42 participants.
• Wax On, Acid Off: Approaches to Cranberry Fruit Improvement on April 24, 2023. Presenter: Dr. James Polashock. 29 participants.
• Understanding the Genetic Control of Anthocyanin Content in Blueberry on May 25, 2023. Presenter: Dr. Sara Montanari. 32 participants.
For videos see here: https://www.youtube.com/@vaccapproject2641

Product Type

Other

Description

Genotyping platform. Continued coordination of sample submission for the Vaccinium genotyping consortium. Three new partners submitted 2000 samples which total 10,300 samples. The platform is available for use through LGC.

Product Type

Other

Description

Blog. US Department of Agriculture dives into blueberry and cranberry genotyping. https://blog.biosearchtech.com/us-department-of-agriculture-dives-into-blueberry-and-cranberry-genotyping

Product Type

New Germplasm

Description

Cranberry. At the Rutgers program new breeding populations carrying fruit rot resistance and new germplasm have been added to the cranberry breeding program, and new field plots established. Developed new half sib-families based on phenotipic data collected from VacCAP. Material will be planted in 2024. At the USDA-Wisconsin program twenty lines were selected for yield and improved quality traits from the high density cranberry breeding nursery at the USDA-ARS cranberry breeding program in WI. Also, developed seed for eight half sib-families using #35 as a male Potter's Favorite, Stevens, Sundance, Pilgrim, HyRed, Ruby Star, WSU108, Ben Lear. Material will be planted in 2024.

Blueberry. At the UF program, a bi-parental population with contrasting volatile content was created for further molecular marker validation. Progenies were planted in the field in May 2023. From the GenStudy and ValStdy sets superior flavor individuals were selected based on the data generated with the VacCAP project. Using texture and acoustic data at the FAM program over 300 blueberry lines were selected and were moved into the next phase on the breeding program. At the USDA program 53 selections were made for quality traits and 16 selections were used to make new crosses.

Product Type

Protocols

Description

New methods and protocols to evaluate cranberry fruit Texture, External Appearance, Internal appearance were 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 and update the method to other core and non-core labs during Y5.

Product Type

Survey Instruments

Description

Distributed a survey to blueberry and cranberry growers across the United States to elicit the breeding priorities. Re-assessing breeding priorities will guide the direction of future research efforts.

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:
1. Humann JL and Main D. Learn how to start with a trait, find an associated GWAS, view the gene, and then find an ortholog! https://youtu.be/MRLqwEh68Gk?si=36AM4Q0zBd3aZnMa
2. Humann JL and Main D. Learn how to search and view traits and associated data. https://www.youtube.com/watch?v=nKo8c7s5pHc
3. Humann JL and Main D. Learn how to search and view GWAS data. https://www.youtube.com/watch?v=MRLqwEh68Gk
4. Humann JL and Main D. Learn how to view genomes linked to genetic maps. https://www.youtube.com/watch?v=ZHn-tIHKhfw
5. Humann JL and Main D. Learn how to search markers. https://www.youtube.com/watch?v=NrwYZB_ywsg
6. Humann JL and Main D. Learn how to overlay Omics Data in PathwayCyc https://youtu.be/qhSTmzBZCLQ?si=eJiZF0ZCozSMwjyO
7. Humann JL and Main D. Learn how to BLAST to mRNA details to JBrowse https://youtu.be/FBN9s4-a7BU?si=Hl8UMUrgfjAiPo8N

Product Type

Other

Description

Fostered collaborations: VacCAP activities fostered multiple collaborations. Zalapa lab has been working with Breeding Insight to transfer phenotyping methods into PlantCV a platform develop by BI. Collaboration with Breeding Insight also led to develop trait ontology for both blueberry and cranberry.

Changes/Problems

The delay of funding release from the USDA-NIFA during Year 1 and COVID-19 requirements during 2020-2022, delayed multiple activities and led the team to request a one-year no cost extension. A summary of affected activities and alternative

plans are summarized below:
Obj. 1. Development of genotyping platforms was delayed. As a result, delivery of the genotypic data for genetic studies expected in Y4 was delayed and will be completed in Year 5. Obj. 2. Delay in the delivery of genotypic data delayed 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) was used to during year 4 and analysis is planned to be completed during Year 5. Due to COVID-19, and the loss of a key PI due to illness evaluation and analysis of cranberry data at Rutgers was delayed. During year 4 evaluation of fruit texture and structure was completed, and data analysis will be performed during year 5. 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-Y4 in mapping populations, and from previous studies into the blueberry and cranberry physical maps. Efforts to perform functional characterization of candidate genes were also initiated. 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 new study to elicit the sensory quality attributes that would increase demand.