Blueberry Public and VacCAP Genotypic and Phenotypic Resources: An Update

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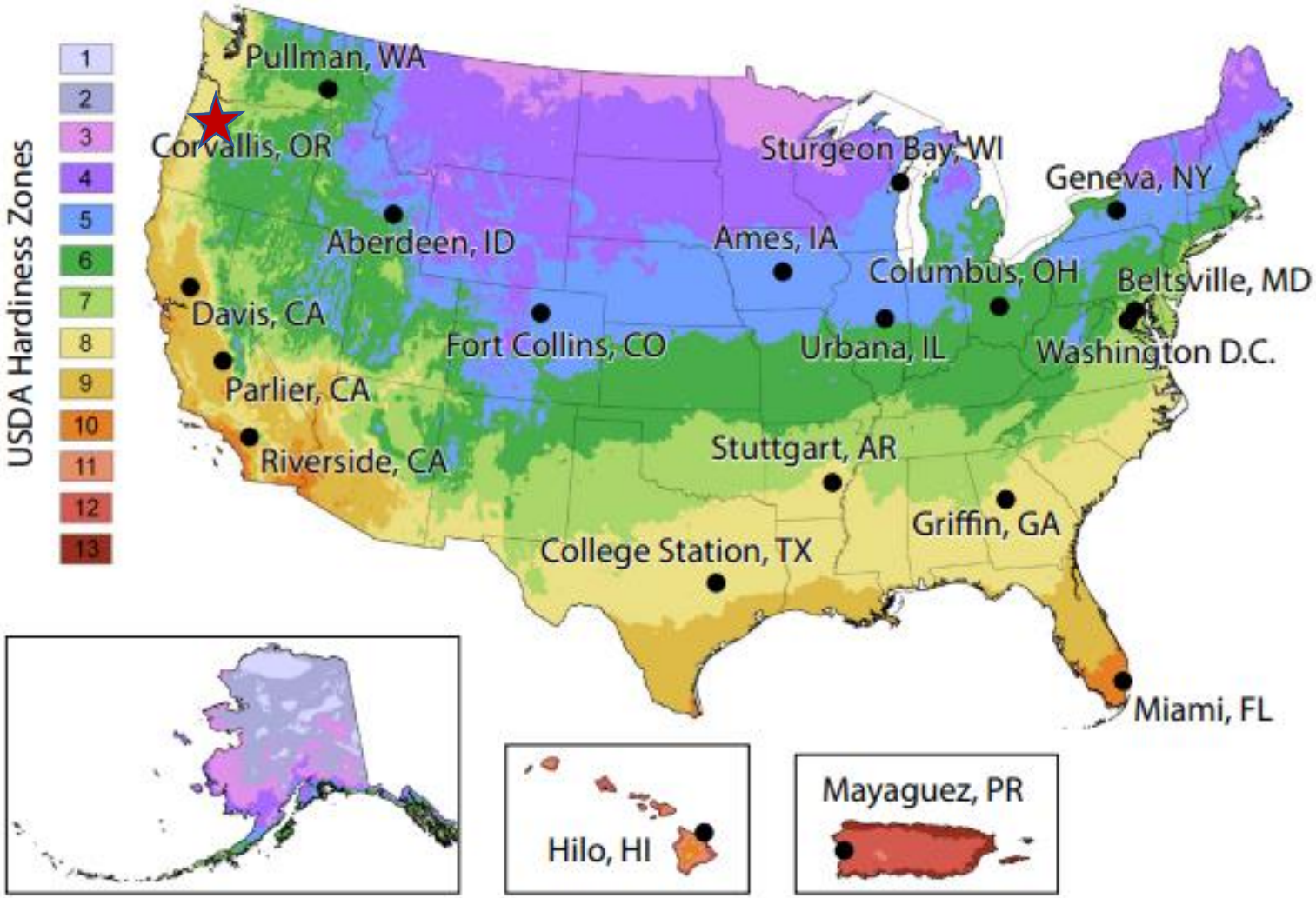
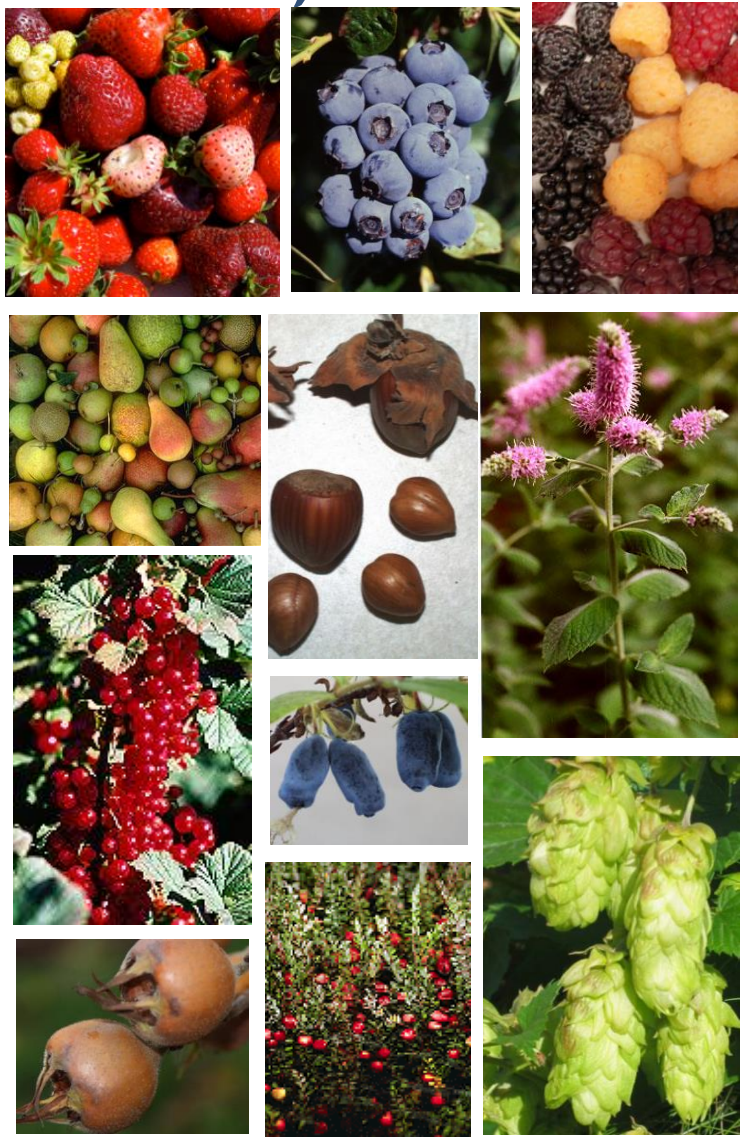
Curator, *Vaccinium, Fragaria, Rubus, Lonicera*
USDA-ARS, National Clonal Germplasm Repository, Corvallis, OR, USA

The U.S. National Plant Germplasm System (NPGS)



Temperate Fruits & Nuts, Corvallis



Vaccinium Genetic Resources

Screenhouses/Greenhouses
374 cultivars
554 relatives

Field: 267 cultivars

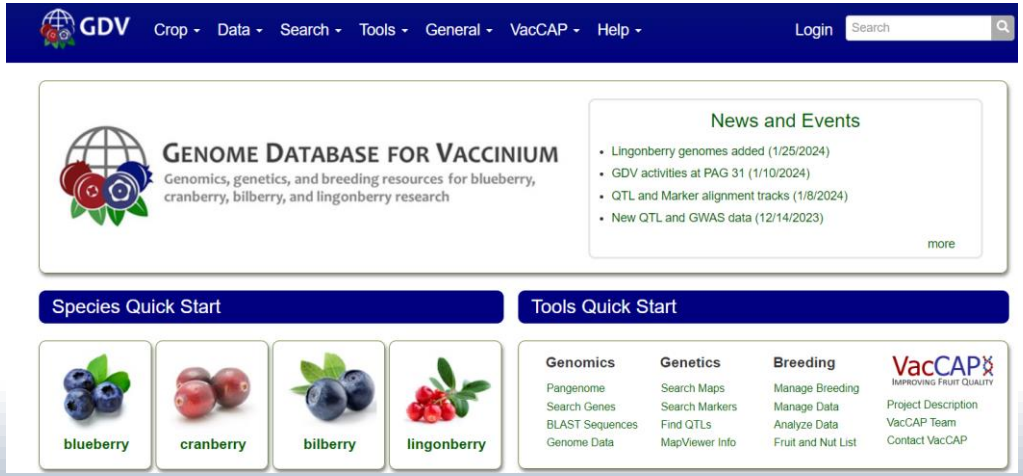
NCGR Mission

BREEDING Insight

VacCAP
IMPROVING FRUIT QUALITY

Acquire
Maintain
Evaluate/Characterize
Distribute
Document

BREEDING INSIGHT ONRAMP



Breeding Insight (BI) is a joint USDA Agricultural Research Service (ARS), Cornell University, Ithaca, New York, initiative

- Launched in 2018 to develop tools, technologies, and methods to enable the routine use of genomic selection in USDA specialty breeding programs.

- 'We integrate phenomics (trait analysis), genomics (genotypic data), data management, and software tools to help breeders increase the rate of genetic gain and create more healthy, nutritious, and sustainable specialty crops and animals.'

https://breedinginsight.org/

- **Blueberry Crop Ontology**
- **DArTag 3K genotyping panel**

Blueberry Crop Ontology

- **Standardized list of phenotypic variables** used by the crop community as a combination of:
  - Trait
  - Method
  - Scale

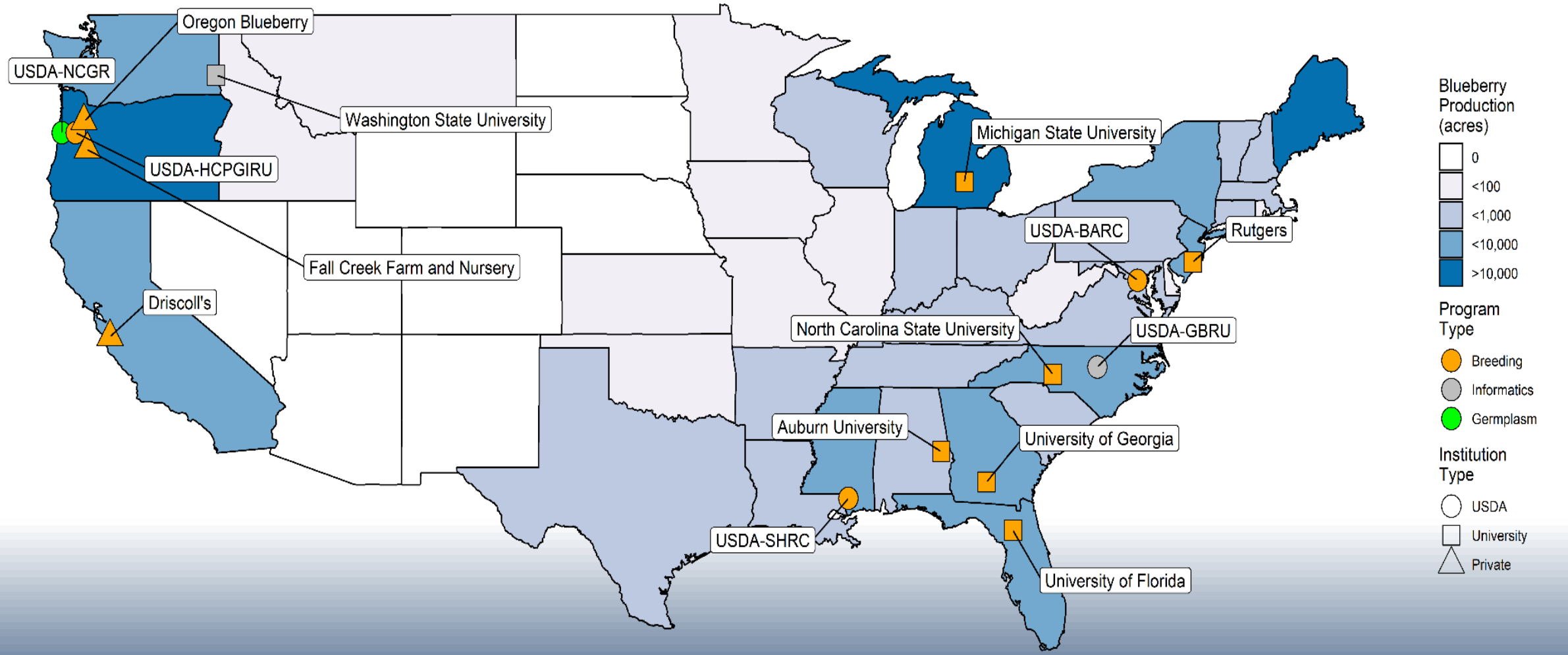
- **Supports digital capture** allowing:
  - Standardization of Breeding databases [*e.g.*, BreedBase, Breeding Information Management System (BIMS)]
  - Aggregation of trait data across locations and projects
  - Mobile data collection on tablets with Field Book or other phenotyping apps

- CO (created in 2008 by the CGIAR)

Blueberry Crop Ontology

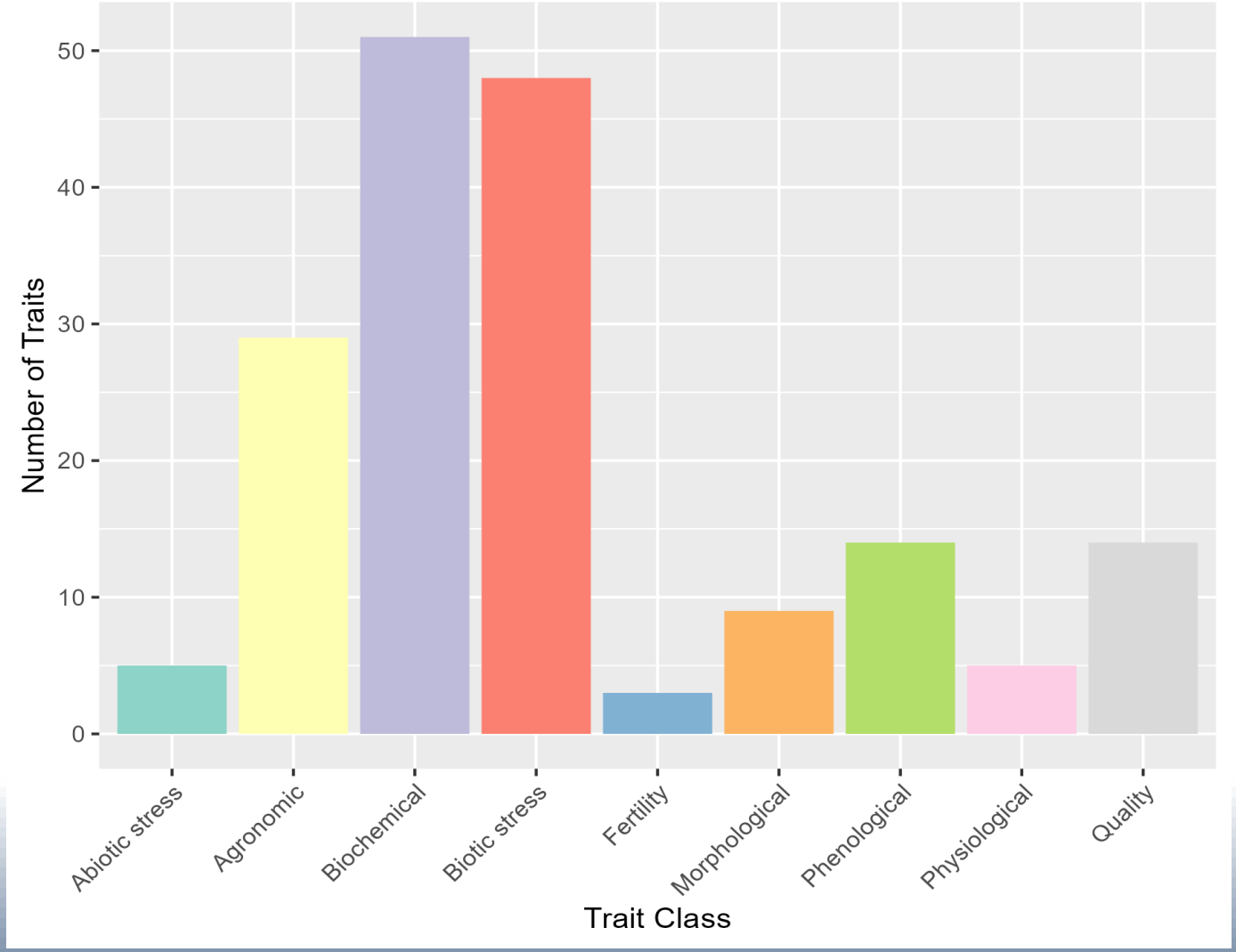
Map of US continental blueberry production in acres, overlayed with survey respondents

Data for blueberry acreage from USDA NASS 2017 Census of Agriculture



Hislop et al 2024

178 Unique Ontology Entries



Now 183 entries

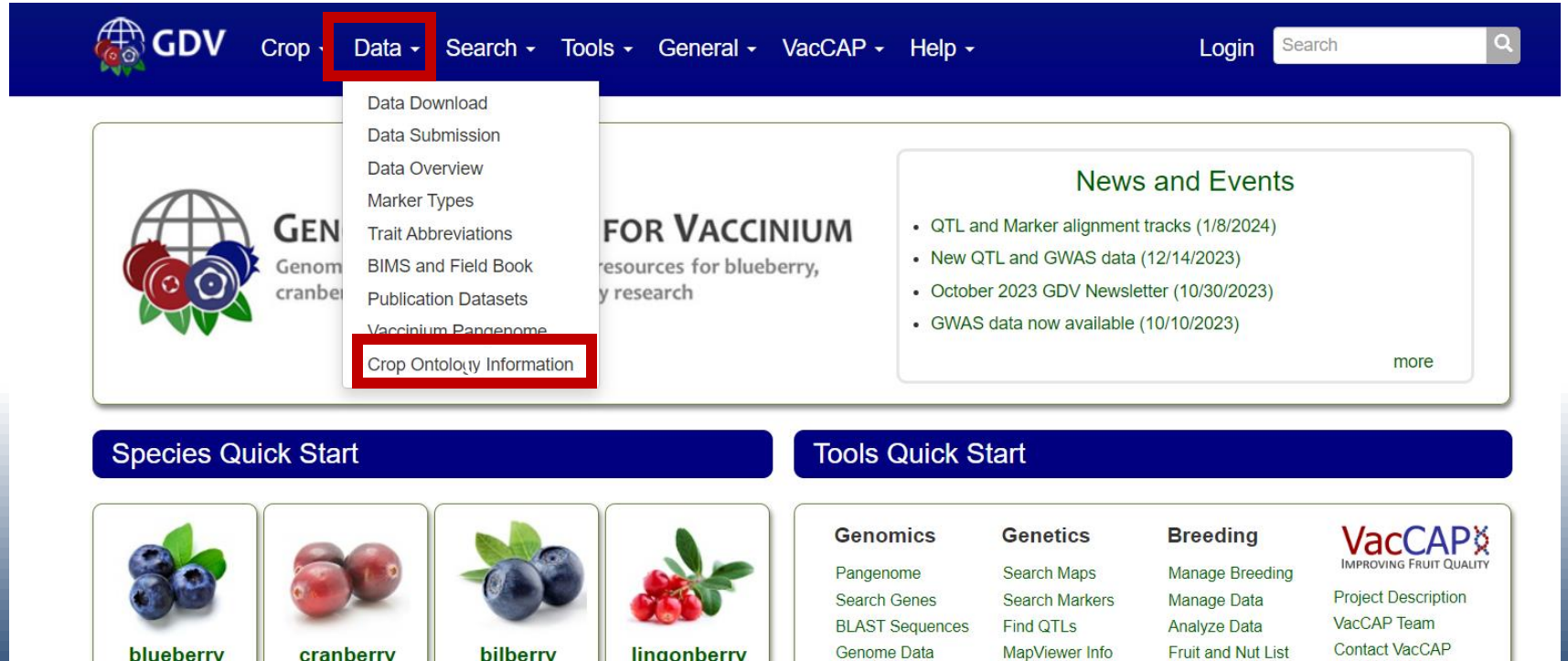
Hislop et al. 2024

Blueberry CO on GDV

Information page: https://www.vaccinium.org/crop_ontology

'The Blueberry Crop Ontology was a collaborative effort between the USDA, Breeding Insight, and GDV. Information about the phenotypic traits measured by U.S. blueberry breeders was collated to form the crop ontology. The ontology is being used on Breeding Insight and is available as Trait Descriptors in GDV and public traits to be imported into private breeding programs in BIMS.
The most current version of the Blueberry Crop Ontology can be viewed and downloaded from the Crop Ontology website. To request changes or additional trait descriptors, please fill out this form on Planteome. The Blueberry Crop Ontology can also be found on Github and requests can also be submitted there.'

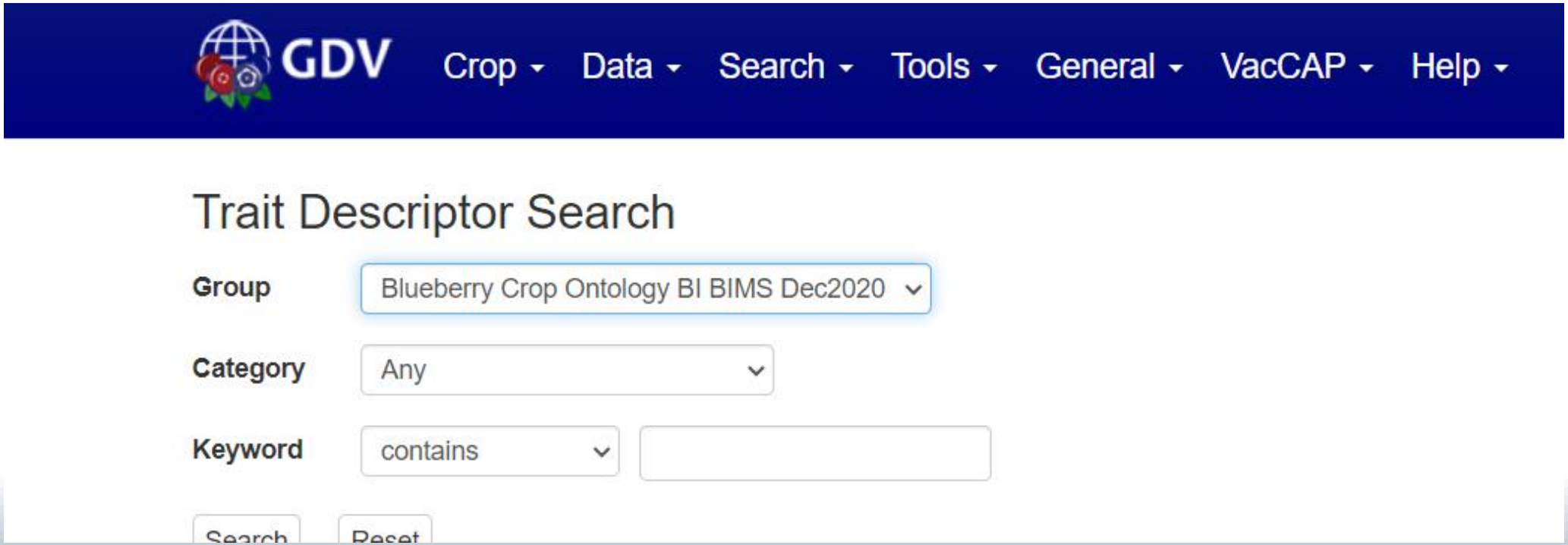
Data menu



Blueberry CO on GDV

- Uploaded as a trait descriptor dataset and can be searched
  https://www.vaccinium.org/search/trait_descriptor

- As phenotype data is being collected, measurements are linked to the Blueberry CO



https://cropontology.org/ CO_371

Crop Ontology
for agricultural data

About | Guidelines | Site Help | Governance | API | CoP Tools | Contact

Curators

Nahla Bassil, USDA-ARS

Amanda Huls

Contributors: Lillian M. Hislop, Claire H. Luby, Jenyne Loarca, Jodi Humann, Kim Hummer, Nahla Bassil, Dongyan Zhao, Moira Sheehan, Alexandra M. Casa,

cropontology.org

Blueberry

Created on Thursday 16th of November, 2023. 08:26:01

178 variables

Blueberry (Vaccinium) ontology defines crop traits and variables to support the standardization of phenotypic data collection for blueberry breeding programs in the USA. The ontology provides a description of agronomic, biochemical, morphological, phenological, physiological, quality, abiotic and biotic stress traits with their methods and scales used for each trait.

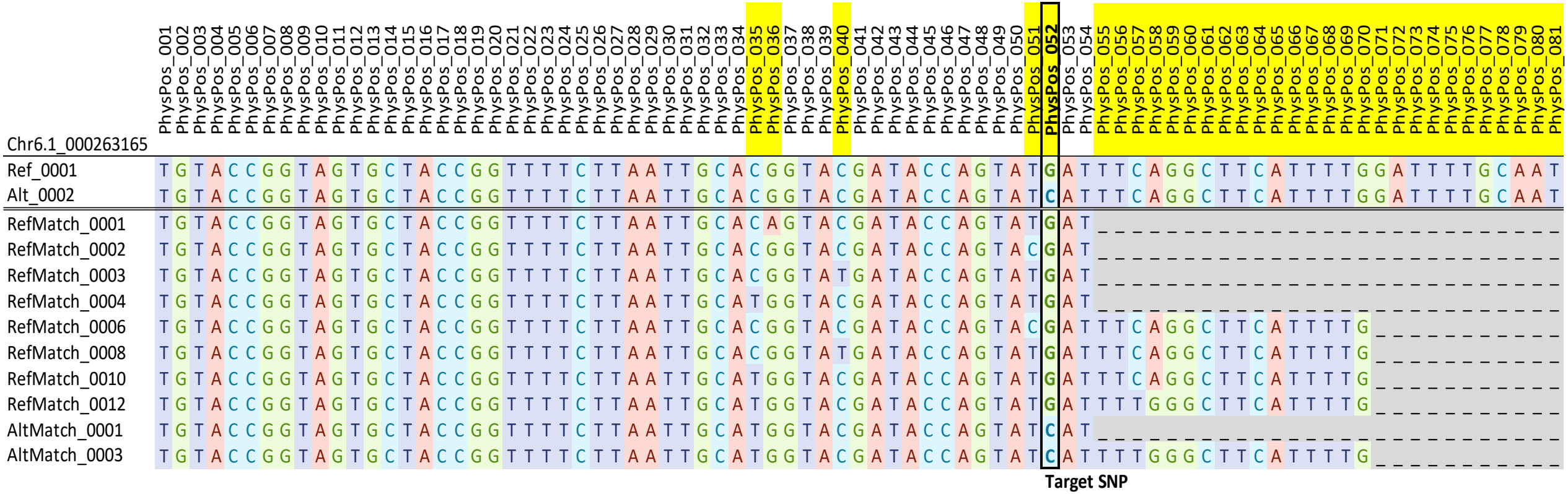
Trait

Download Trait File

Ontology explorer

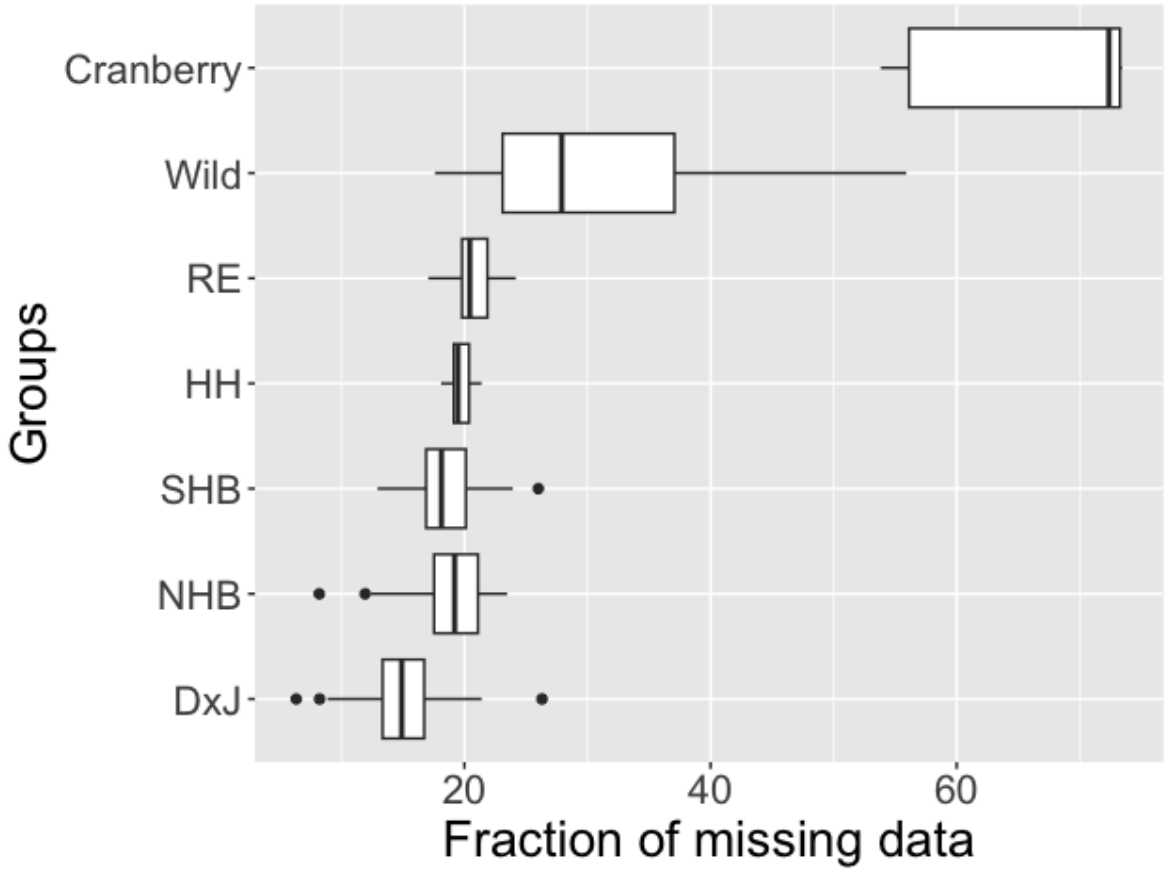
Blueberry ontology can be downloaded from the Ontology.org: https://cropontology.org/term/CO_371:ROOT

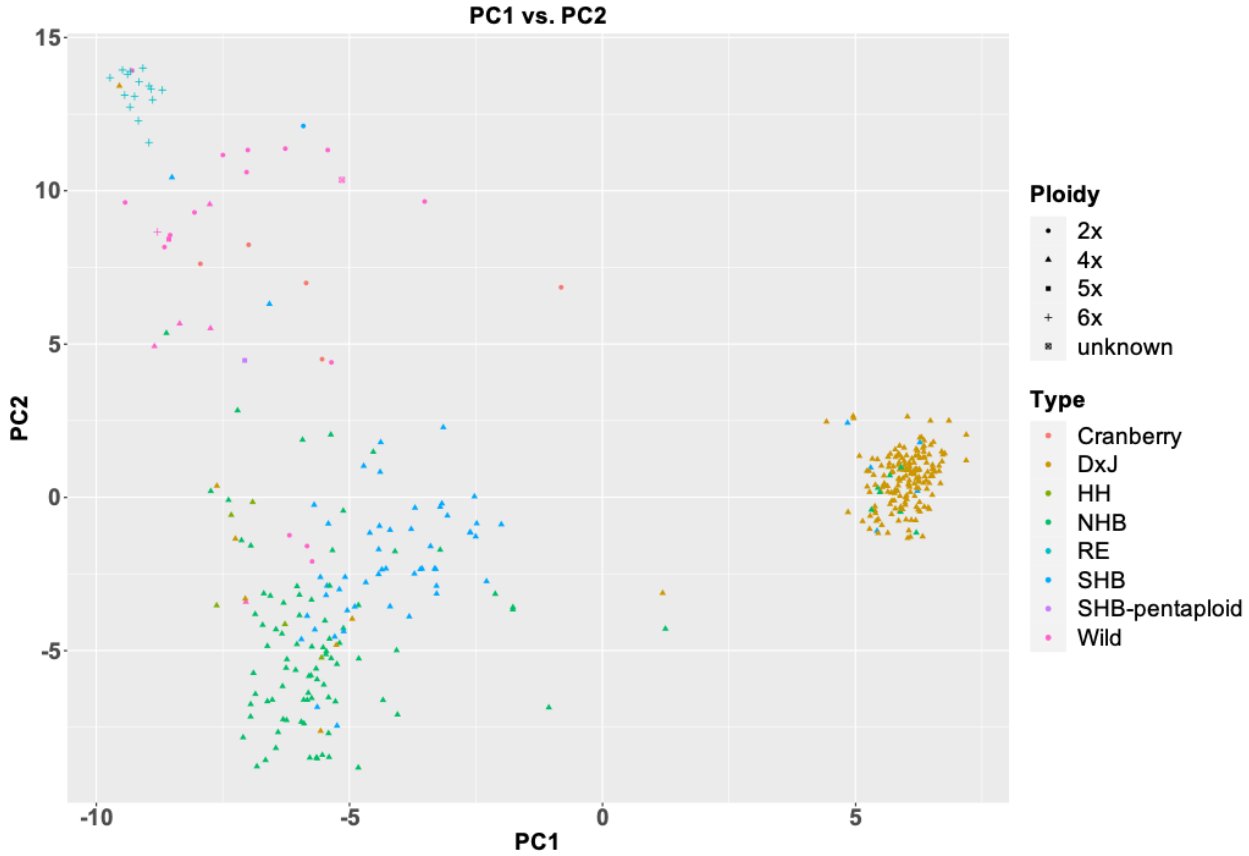
3K DArTag Genotyping Panel



Zhao et al. 2024

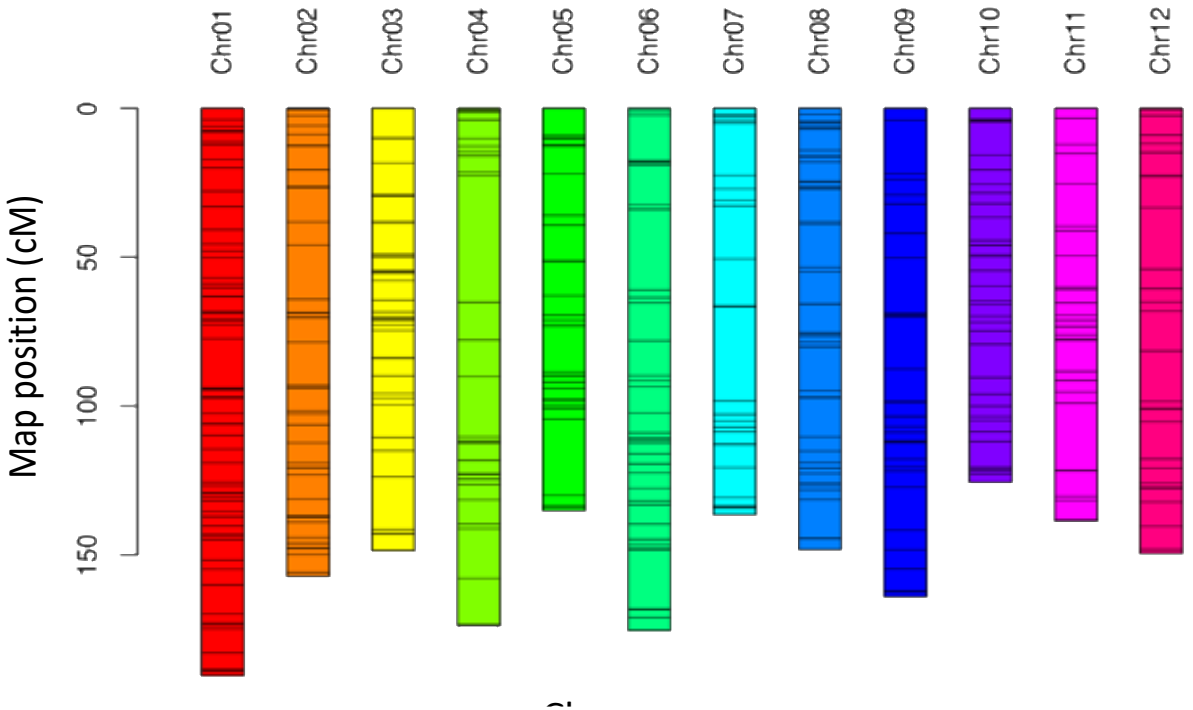
3K DArTag: 375 accessions

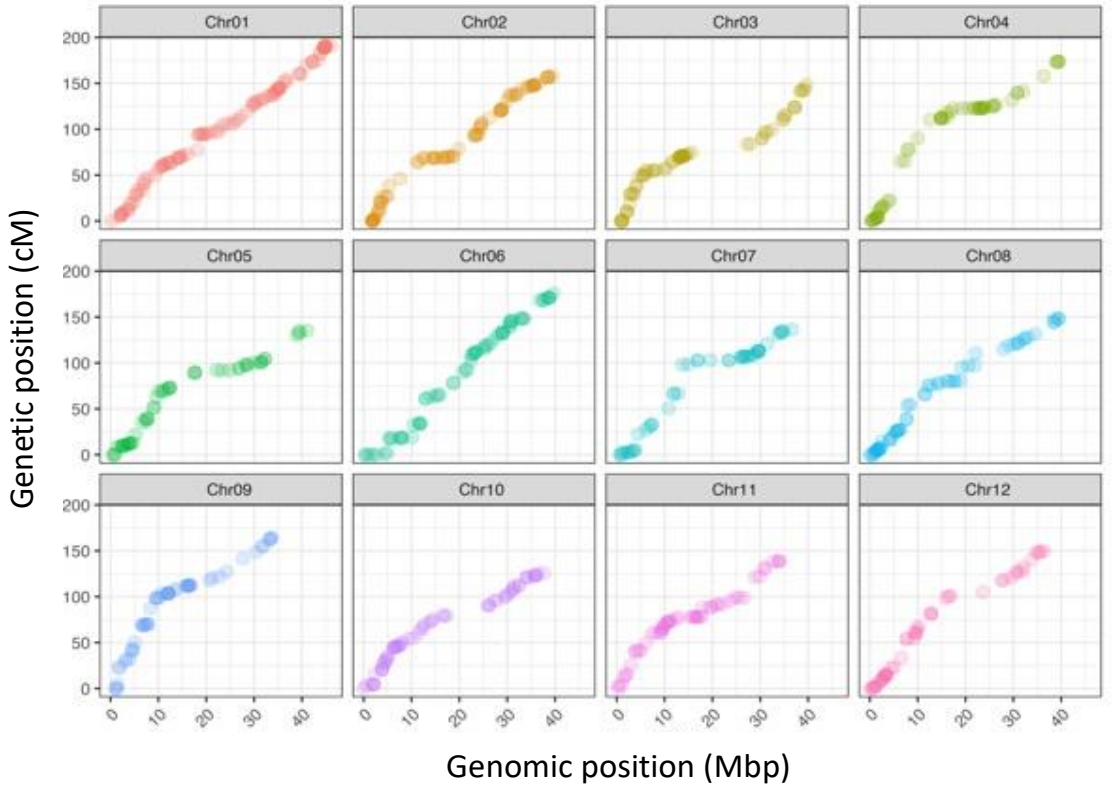




Zhao et al. 2024

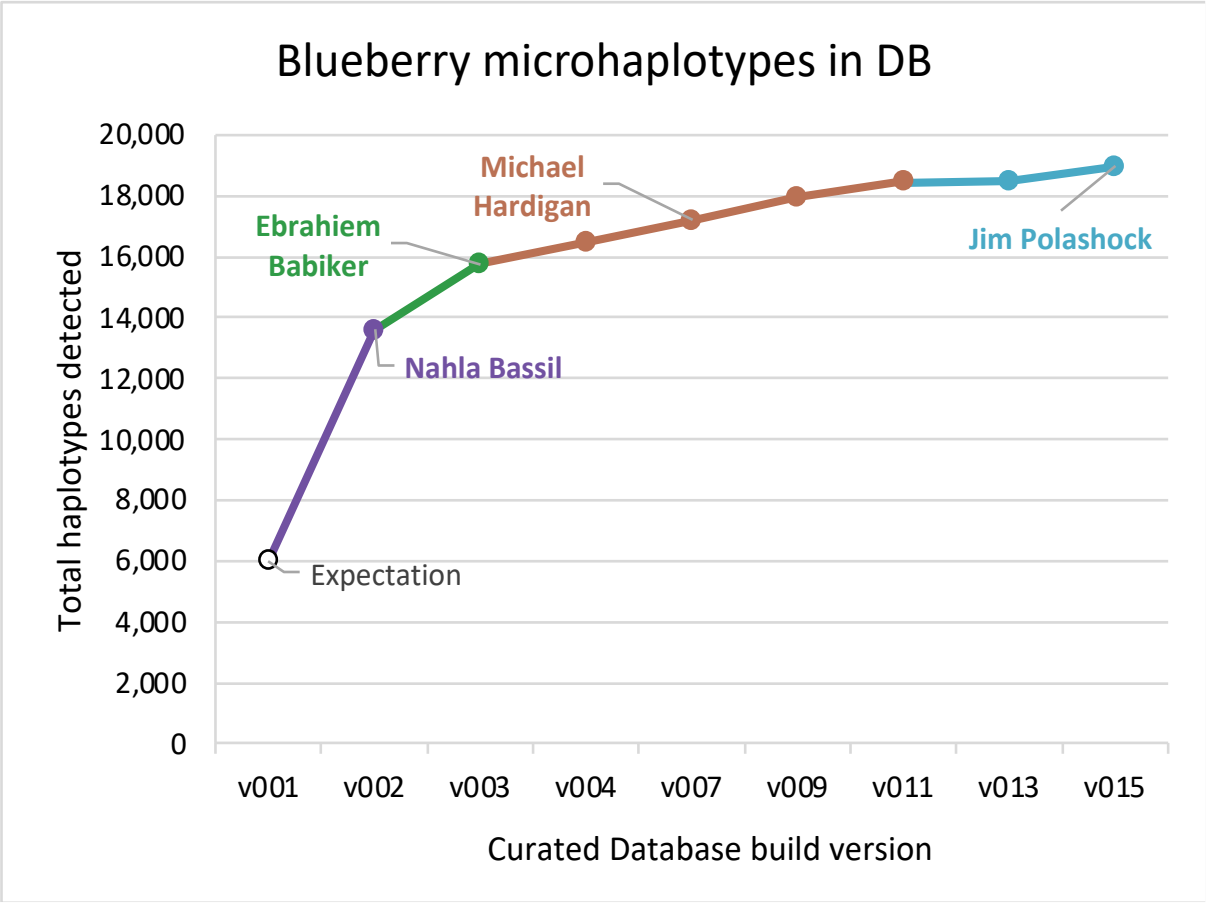
3K DArTag: Genetic Mapping in Draper x Jewel (175)

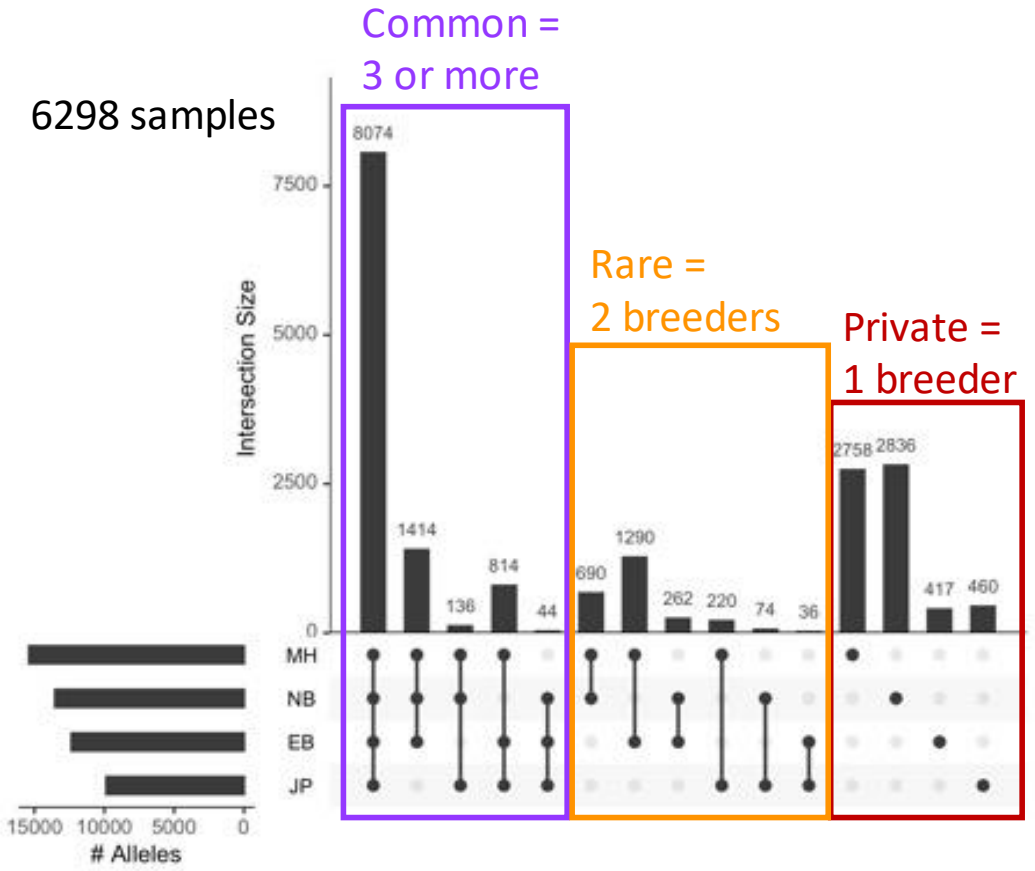




Zhao et al. 2024

Multiallelic Diversity is Sampled and Databased





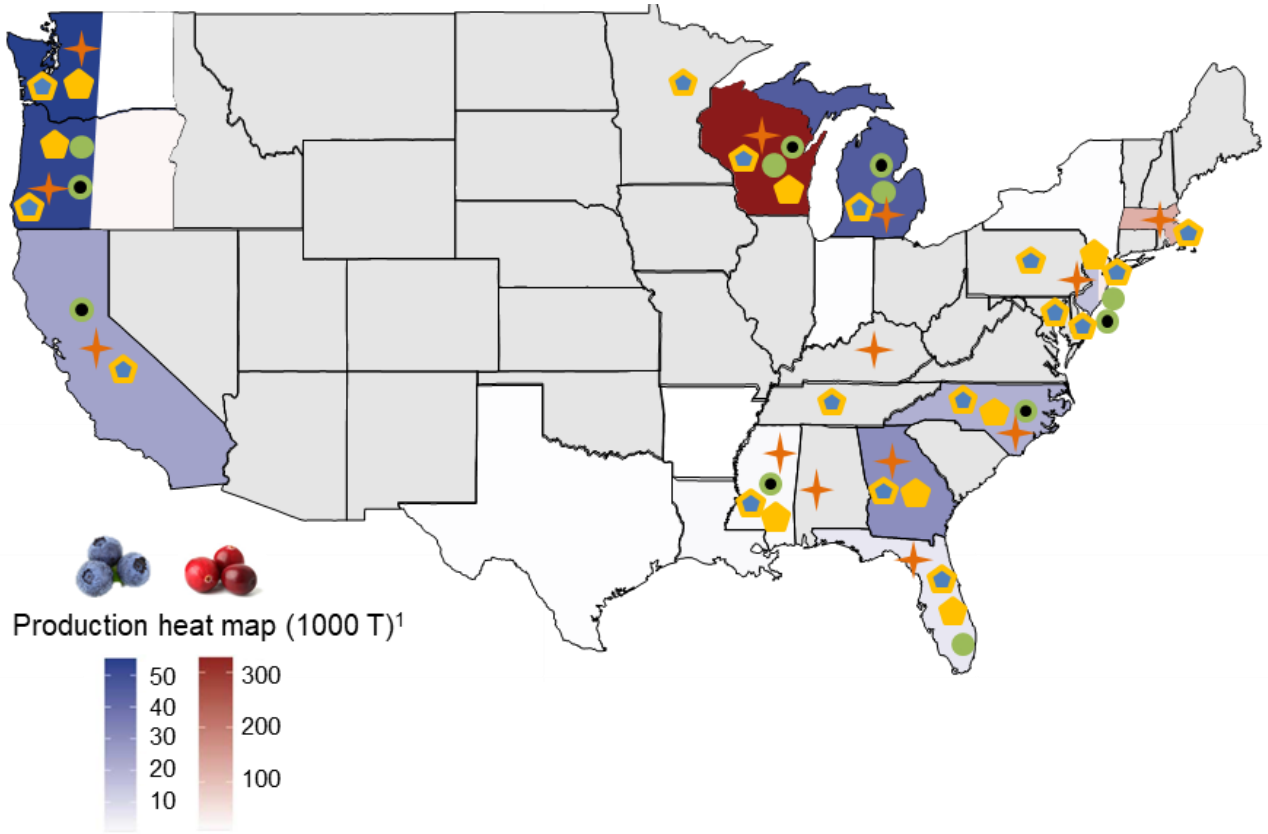
Distribution of common, rare, and private alleles by breeder.

Moira Sheehan, personal communication

VacCAP

Improving Fruit Quality

M. Iorizzo



2019-2023

$12.8 M

$6.4 M sponsor

$6.4 M match

VacciniumCAP participants and partners:

- Core breeding programs
- Non-core breeding programs
- Core lab (allied sci. & ext. spec.)
- Non-core lab (allied sci. & ext. spec.)
- Commodity groups

Team: >50 scientists, 25 institutions (US, Canada, New Zealand, Italy)

Iorizzo et al. 2023

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Iorizzo et al. 2023

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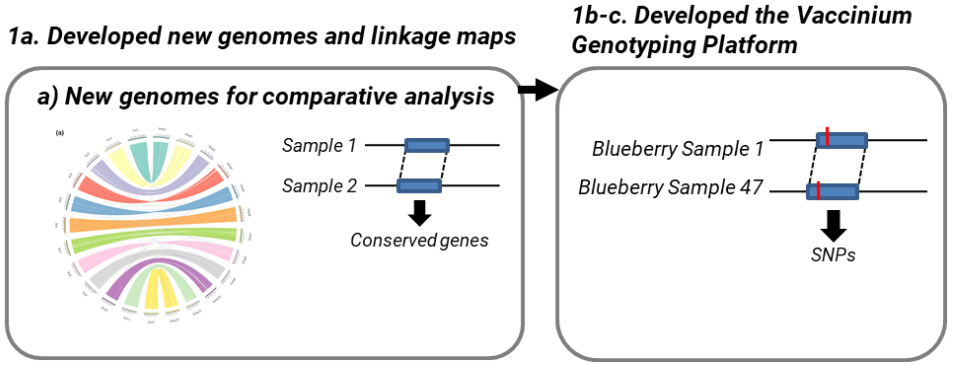
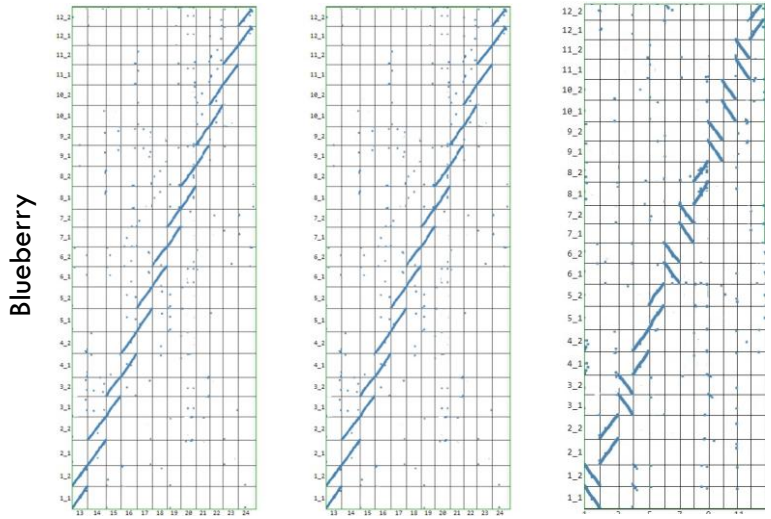
IMPROVING FRUIT QUALITY

VacCAP Obj. 1

Objective 1: Establish genomic and genotyping resources



- Released 6 new genomes



V. darrowii | *V. myrtillus* (bilberry) | *V. macrocarpon* (cranberry)

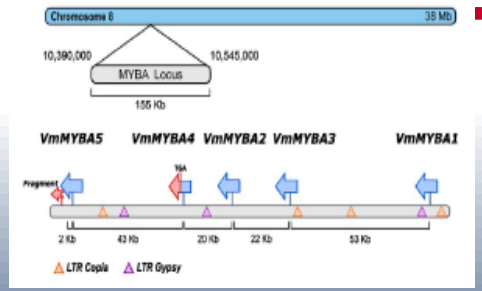
Research — New Phytologist

Autopolyploid inheritance and a heterozygous reciprocal translocation shape chromosome genetic behavior in tetraploid blueberry (*Vaccinium corymbosum*)

Molla F. Mengist[1]*, Hamed Bostan[1]*, Domenico De Paola[2], Scott J. Teresi[3], Adrian E. Platts[3], Gaetana Cremona[4], Xinpeng Qi[5], Ted Mackey[6], Nahla V. Bassil[7], Hamid Ashrafi[8], Lara Giongo[9], Rubina Jibran[10], David Chagné[10], Luca Bianco[9], Mary A. Lila[1], Lisa J. Rowland[5], Marina Iovene[4], Patrick P. Edger[3] and Massimo Iorizzo[1,8]

MYB TF

anthocyanin genes



frontiers in Plant Science — ORIGINAL RESEARCH
published: 10 February 2021
doi: 10.3389/fpls.2021.633310

Chromosome-Level Genome Assembly of the American Cranberry (*Vaccinium macrocarpon* Ait.) and Its Wild Relative *Vaccinium microcarpum*

Luis Diaz-Garcia[1*], Luis Fernando Garcia-Ortega[2], María González-Rodríguez[2], Luis Delaye[2], Massimo Iorizzo[3] and Juan Zalapa[4,5*]

- *Vaccinium* genomes are highly collinear

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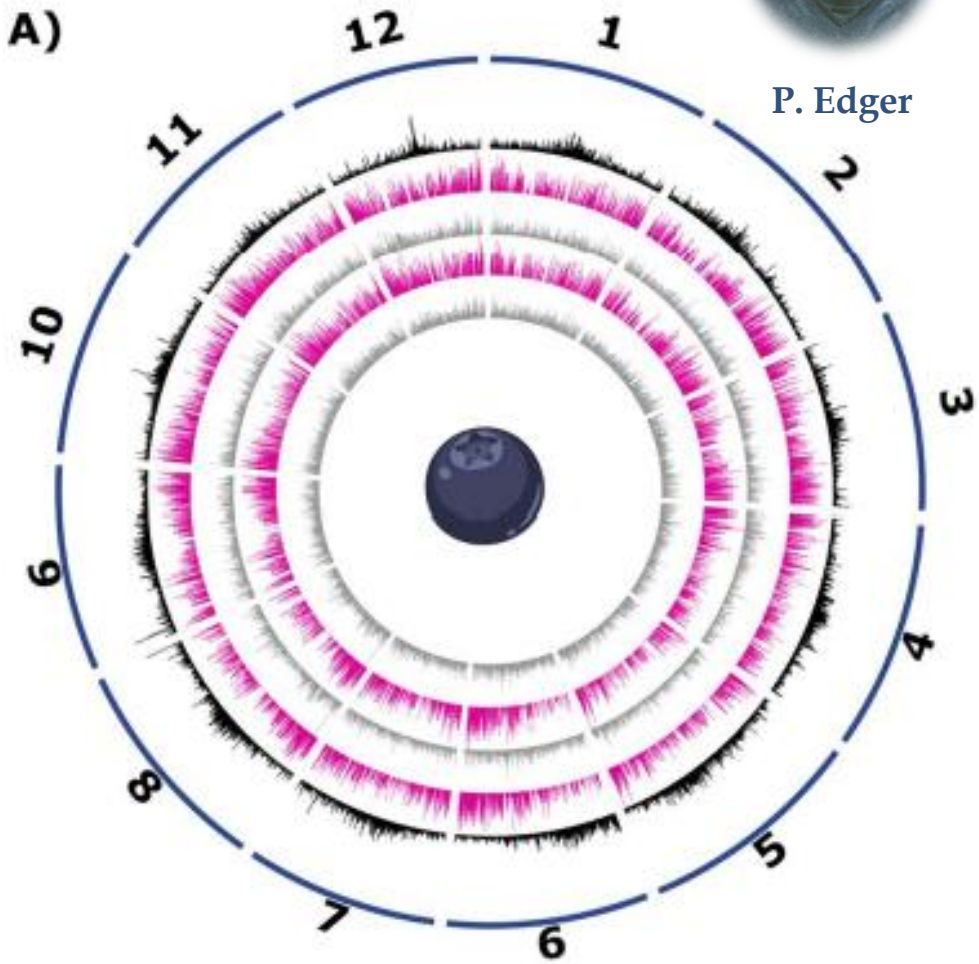
Blueberry Pangenome

P. Edger

Horticulture Research

Horticulture Research, 2023, 10: uhad202

https://doi.org/10.1093/hr/uhad202



Article

Blueberry and cranberry pangenomes as a resource for future genetic studies and breeding efforts

Alan E. Yocca[1,2,*], Adrian Platts[1,2], Elizabeth Alger[1], Scott Teresi[1,3], Molla F. Mengist[4], Juliana Benevenuto[5], Luis Felipe V. Ferrão[5], MacKenzie Jacobs[1,6], Michal Babinski[1], Maria Magallanes-Lundback[1], Philipp Bayer[7], Agnieszka Golicz[8], Jodi L. Humann[9], Dorrie Main[9], Richard V. Espley[10], David Chagné[11], Nick W. Albert[11], Sara Montanari[12], Nicholi Vorsa[13], James Polashock[13], Luis Díaz-Garcia[14], Juan Zalapa[14], Nahla V. Bassil[15], Patricio R. Munoz[5], Massimo Iorizzo[4,16] and Patrick P. Edger[1,3,17,*]

Yocca et al. 2023

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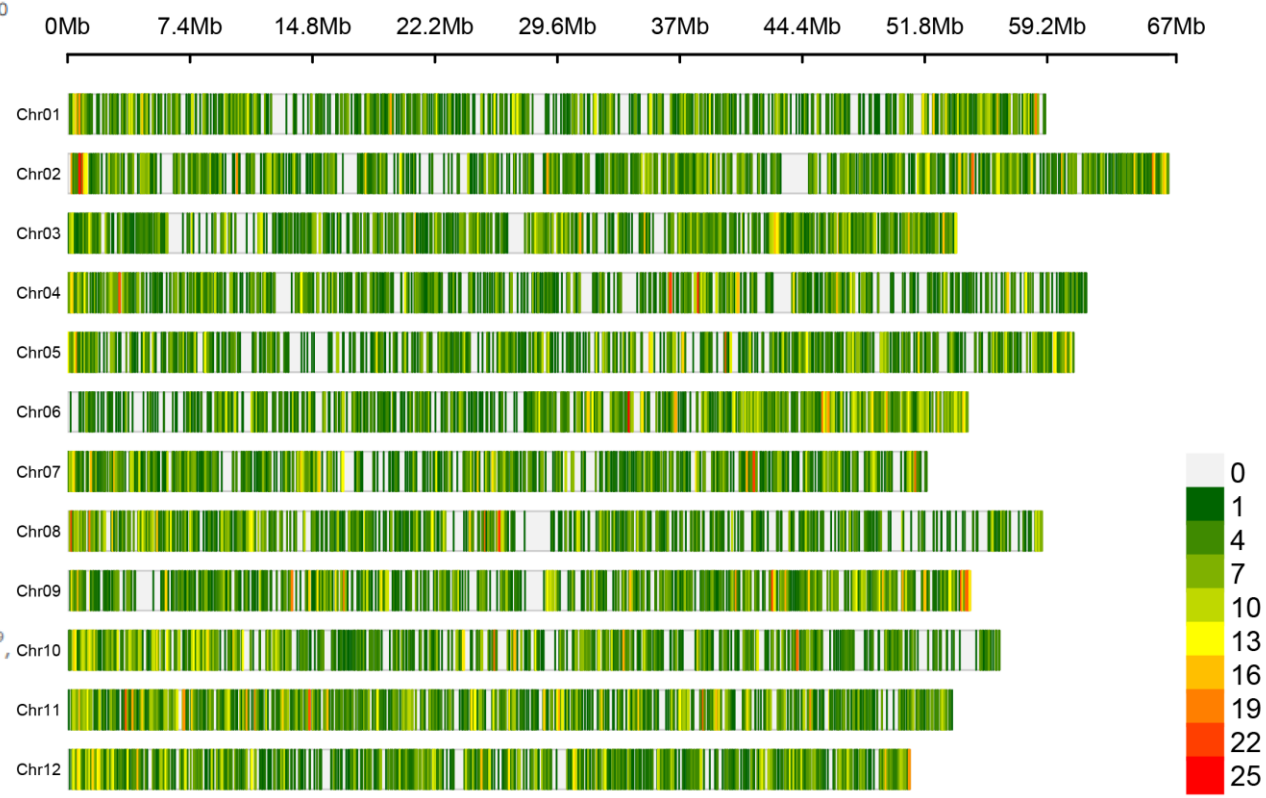
22K FlexSeq EX-L Genotyping Panel

frontiers | Frontiers in Horticulture

TYPE Original Research
PUBLISHED 15 January 2024
DOI 10.3389/fhort.2023.1339310

N. Bassil



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Clare SJ, Driskill M, Millar TR, Chagné D, Montanari S, Thomson S, Espley RV, Muñoz P, Benevenuto J, Zhao D, Sheehan MJ, Mengist MF, Rowland LJ, Ashrafi H,

Development of a targeted genotyping platform for reproducible results within tetraploid and hexaploid blueberry

Shaun J. Clare[1,2], Mandie Driskill[1,3], Timothy R. Millar[4,5], David Chagné[6], Sara Montanari[7], Susan Thomson[4], Richard V. Espley[8], Patricio Muñoz[9], Juliana Benevenuto[9], Dongyan Zhao[10], Moira J. Sheehan[10], Molla F. Mengist[11], Lisa J. Rowland[12], Hamid Ashrafi[13], Kalpalatha Melmaiee[14], Krishnanand P. Kulkarni[14], Ebrahiem Babiker[15], Dorrie Main[16], James W. Olmstead[17], Jessica L. Gilbert[17], Paul Havlak[17], Hsiaoyi Hung[17], Joel Kniskern[17], David Percival[18], Patrick Edger[19], Massimo Iorizzo[13,20] and Nahla V. Bassil[1*]

Clare et al. 2023

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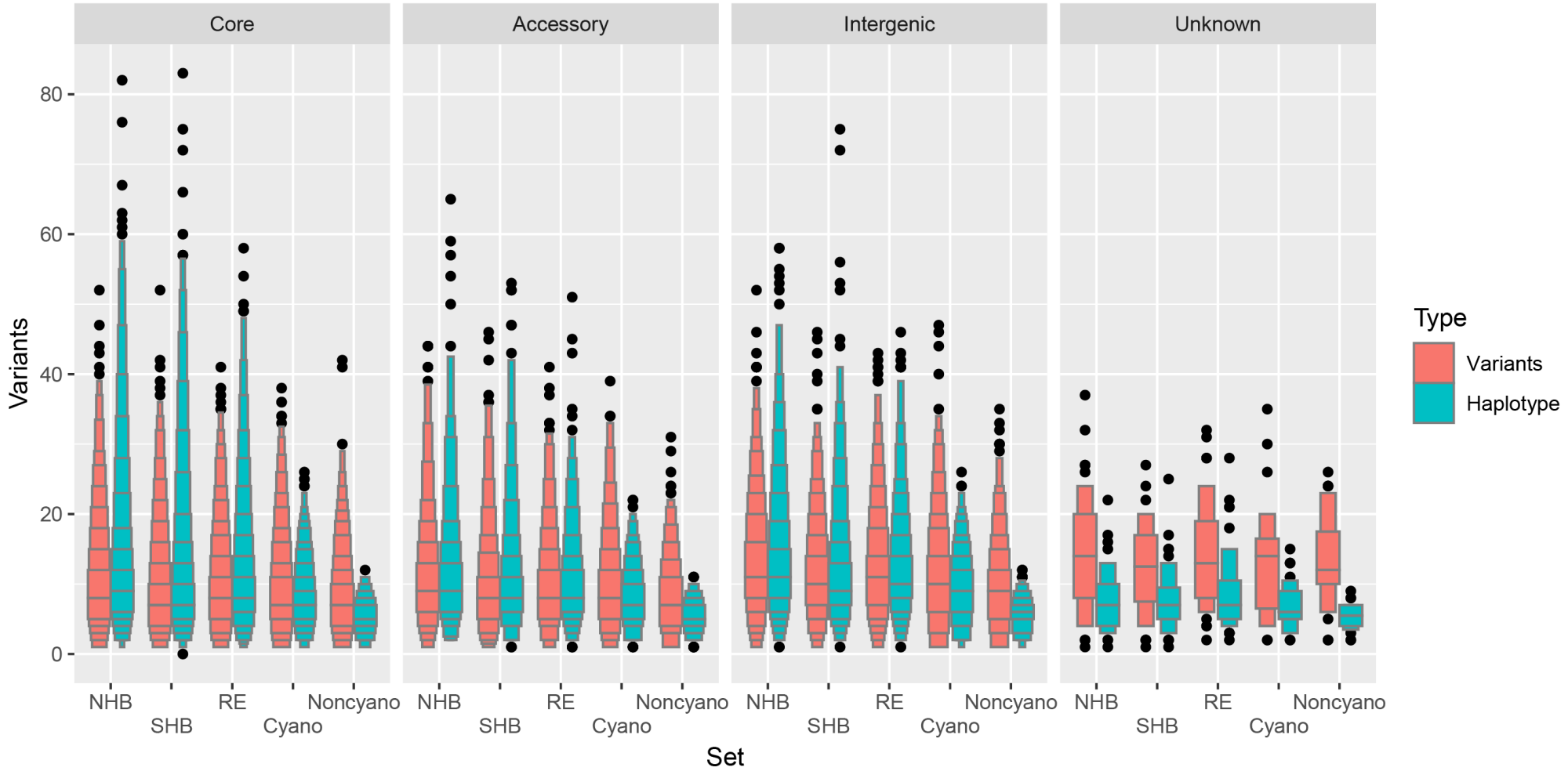
22K FlexSeq EX-L Genotyping Panel



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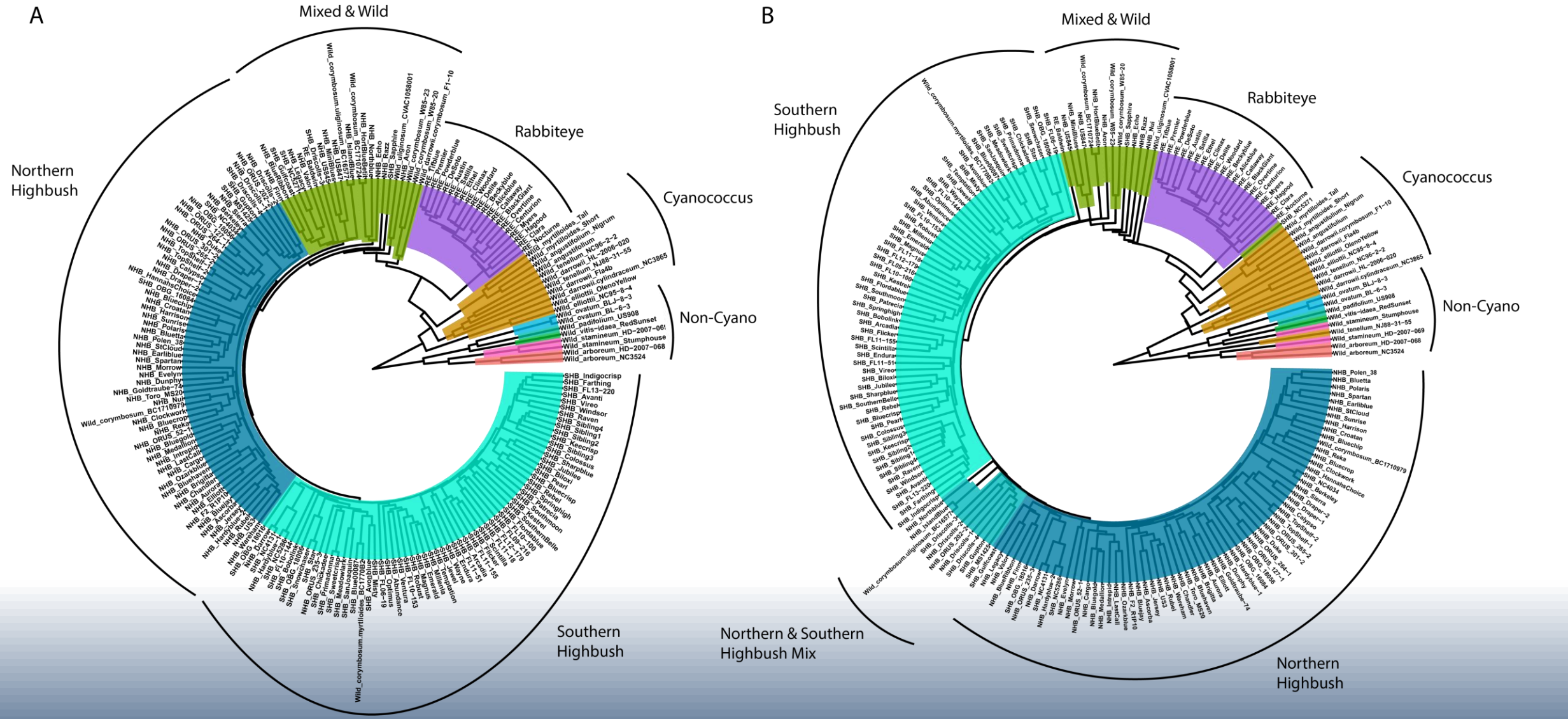
22K FlexSeq EX-L Genotyping Panel



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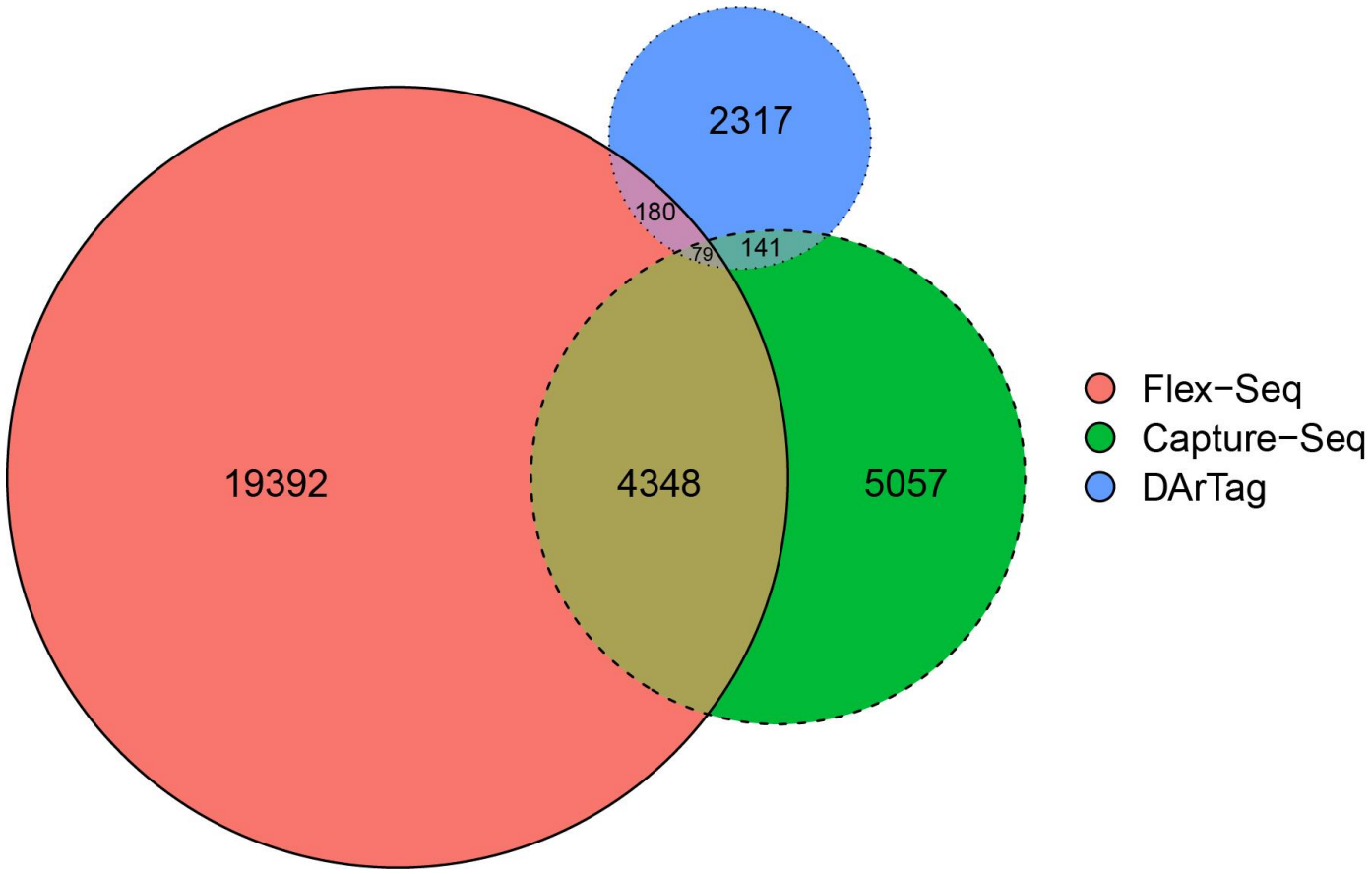
22K FlexSeq EX-L Genotyping Panel



DArTag: $15/sample
Flex-Seq 22K: $41.85/sample

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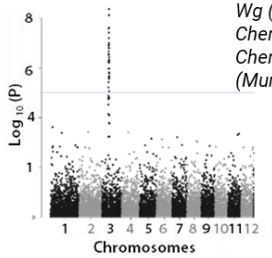
VacCAP Obj. 2

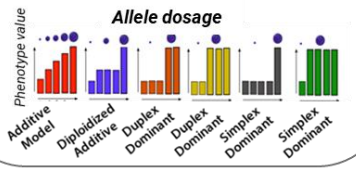
Discover DNA markers and fruit characteristics that maximize fruit quality

2b. Discover DNA markers associated with FCs
Who: Statistical Genetics Team

Input: Vaccinium Genotyping platform (Act. 1.c)

Blueberry FCs:
Tx (Iorizzo)
Wg (Iorizzo)
Chem (Iorizzo)
ChemVol (Munoz)



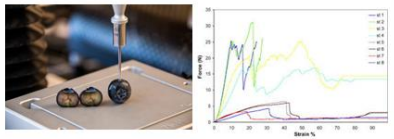


2a. Phenotyping FCs
Who: Phenomic Teams

Blueberry material
GenStudy set: 960 SHB and 960 NHB

FCs:
- Texture (Tx), Iorizzo
- Weight (Wg), Iorizzo
- Non-volatile chemical composition (Chem), Lila/Perkins
- Volatile chemical composition (ChemVol), Munoz

Tx analysis

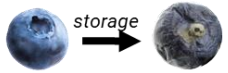


Fruit size

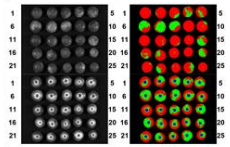
2c. Identifying FCs that contribute to fruit quality
Who: Fruit Quality Team

Blueberry material
FqStudy Set: 20SHB and 20NHB

Shelf life (A)

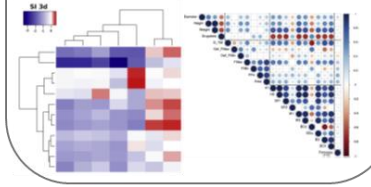


Bruising (B)

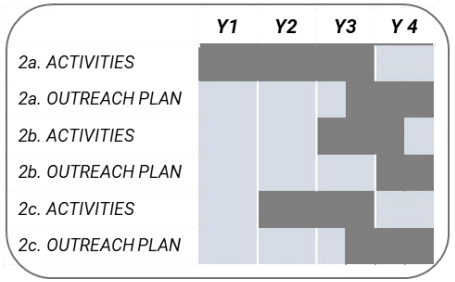


Sensory (C)

FCs phen. vs Performance A-B-C



Work flow timeline



Deliverables

- SNPs associate to FCs (blue&cran)
- Blueberry FCs correlated with High FQ;
- Standardized phenotyping methods;
- Bluberry and cranberry germplasm phenotypic and fruit quality data

Use of results for other objectives

Obj. 3 Obj. 4 Obj. 5

- Evaluated >2600 genotypes/plants over 3 years, 3 locations (OR, NC,FL) (>10,000 samples)
- Measured > 90 parameters, >80 chemicals
- Data is being analyzed
- Detected >300 new QTLs

M. Iorizzo P. Perkins-Veazie M.A. Lila P. Munoz C. Sims C. Li L. Giongo C. Luby N. Bassil

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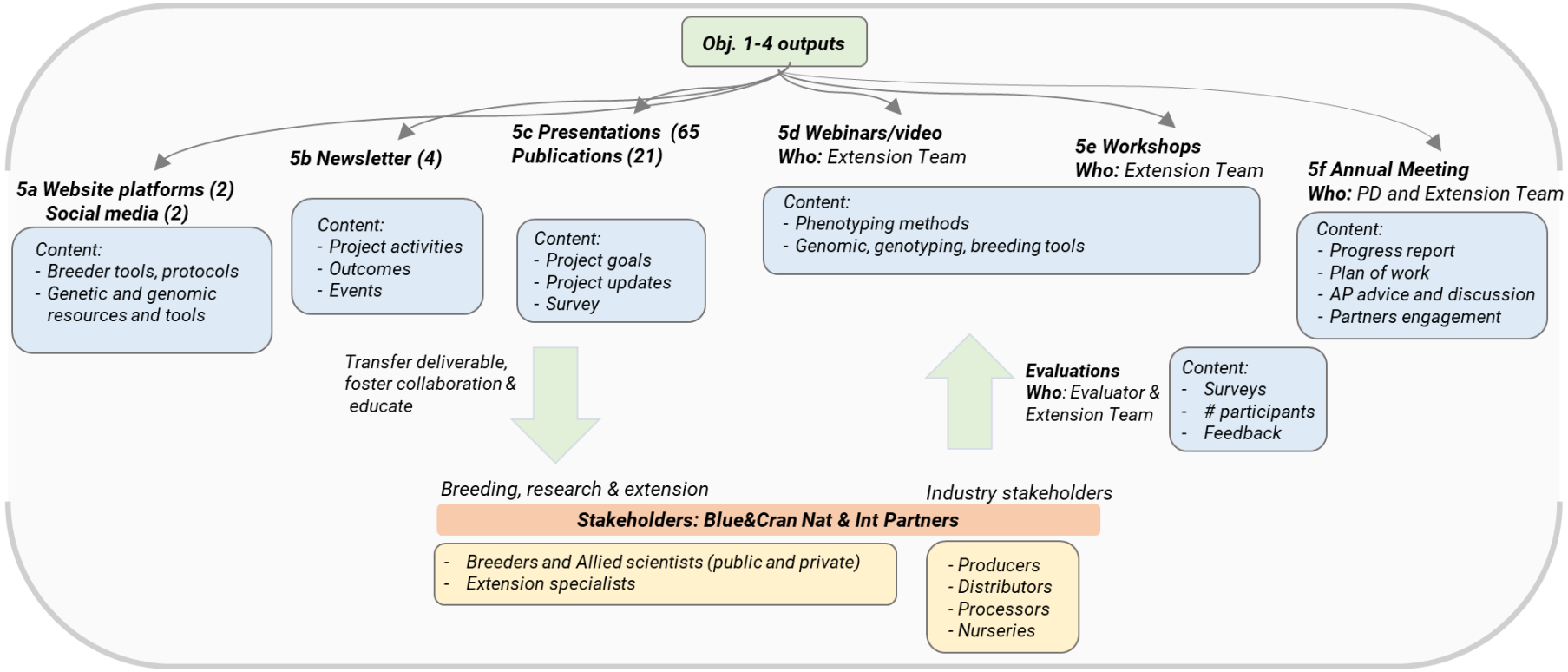
VacCAP Obj. 5

Engage U.S. *Vaccinium* breeders and stakeholder groups




A. Atucha


L. DeVetter


D. Main


M. Coe

Objective 5: Deliver molecular and genetic resources to improve blueberry and cranberry fruit quality

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Obj. 1-4 outputs

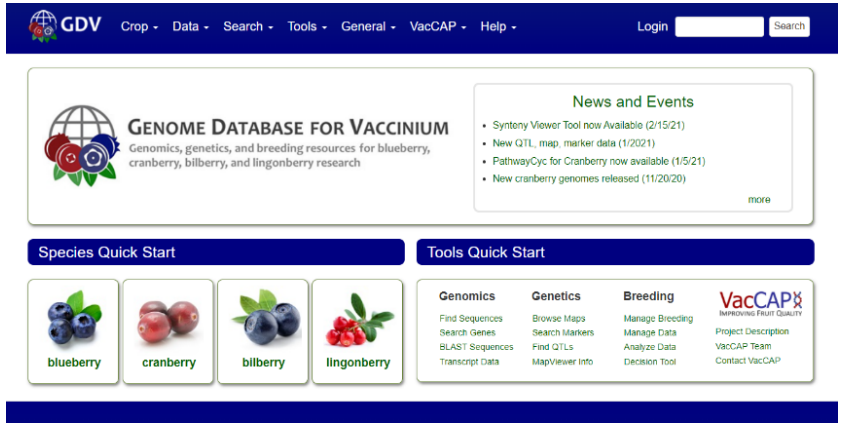
5a Website platforms (2)
Social media (2)

Content:
- *Breeder tools, protocols*
- *Genetic and genomic resources and tools*

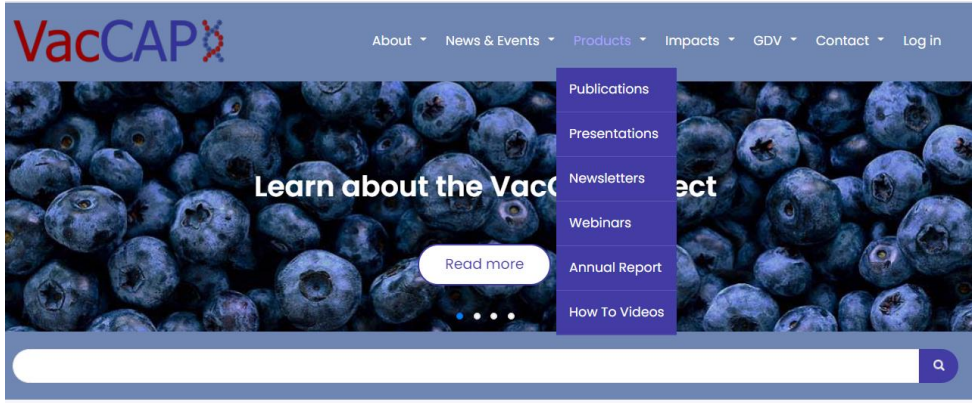
VacCAP
@VacciniumCAP

VacCAP
Project

Genomic and genetic resources



Extension resources



Transfer deliverable, foster collaboration & educate

Evaluations
***Who**: Evaluator & Extension Team*

Content:
- *Surveys*
- *# participants*
- *Feedback*

Breeding, research & extension

Industry stakeholders

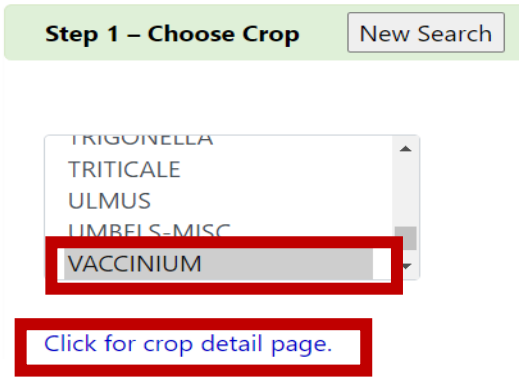
Stakeholders: Blue&Cran Nat & Int Partners

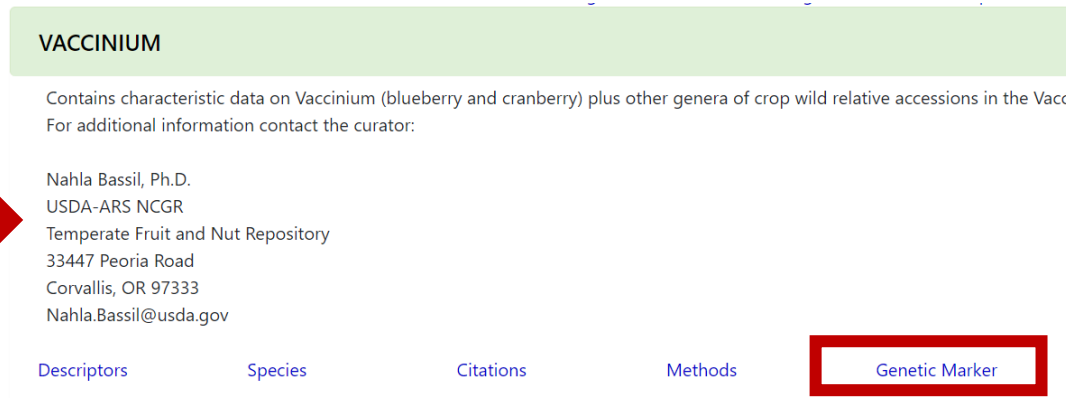
- *Breeders and Allied scientists (public and private)*
- *Extension specialists*

- *Producers*
- *Distributors*
- *Processors*
- *Nurseries*

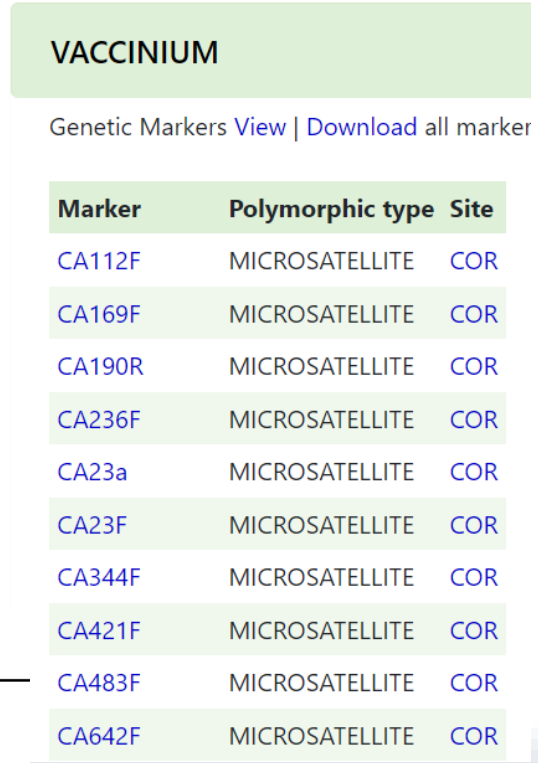
Vaccinium Genetic Resources: Phenotypic Data on GG

https://npgsweb.ars-grin.gov/gringlobal/descriptors





Data from 38 SSRs



Marker	Polymorphic type	Site
CA112F	MICROSATELLITE	COR
CA169F	MICROSATELLITE	COR
CA190R	MICROSATELLITE	COR
CA236F	MICROSATELLITE	COR
CA23a	MICROSATELLITE	COR
CA23F	MICROSATELLITE	COR
CA344F	MICROSATELLITE	COR
CA421F	MICROSATELLITE	COR
CA483F	MICROSATELLITE	COR
CA642F	MICROSATELLITE	COR

J. Amer. Soc. Hort. Sci. 131(5):674–686. 2006.

Genetic Diversity in the Highbush Blueberry Evaluated with Microsatellite Markers

Peter Boches, Nahla V. Bassil, and Lisa Rowland

Boches et al., 2006

Genet Resour Crop Evol (2020) 67:393–409
https://doi.org/10.1007/s10722-019-00873-8

RESEARCH ARTICLE

Microsatellite markers confirm identity of blueberry (*Vaccinium spp.*) plants in the USDA-ARS National Clonal Germplasm Repository collection

Nahla Bassil · Amira Bidani · April Nyberg · Kim Hummer · Lisa J. Rowland

Bassil et al., 2020

Vaccinium Genetic Resources: Phenotypic Data on GG

Descriptor	coded_name	Vac Madison 88	Vac Raleigh 90	Vac Corvall 90	Vac m core 1998	Vac coldhardy NJ 2006	Cytology 2012	Cytology 2012.6.30	10-SSR blueberry 2019	Stringer 2017	Tanaina Plantlore Dena'ina k'et'una	Sampson 2020 swd	Finn 2017 shock virus	Scheerens mineral soil	Gan pollen	Moyer 2002 antioxidant
Chemical Composition	Percent Soluble Solids											38				
	Total Anthocyanins															29
Disease	BlShV												35			
	PERCENTROT	21														
Morphological	BERRUPRGT	22														
	BLOOMCOLOR			21												
	CUPCOUNT	27														
	FLWRSUPRGT	22														
	FRTWEIGHT	27										38				
	LEAFCOLOR			120												
Phenological	FIRSTBLOOM			119												
	FULLBLOOM			44												
	FIRSTRIPE			143												
Cytological or Cellular	DNARATIO						30	86								
	PLOIDY						30	86								
	PLOIDYEQUA						30	86								
Physiology	Mineral soil adaptation index													32		
	Pollen germination rate														3	
Insect	LEAFHOPPER		16													
	Spotted-wing drosophila OSI									6						
	SWD adult mortality (%)											38				
	SWD larvae per fruit											38				
	SWD reproductive rate											38				
	SWD Resistance Index											38				
	SWD viable eggs per fruit											38				
Genetic Stock	CORE				369											
	TRUETOTYPE								45							
Production	FRUITSET	22														
	REPEATBLM	21														
	YIELDACRE	27														
General Info	Ethnic-Group										22					
Growth	GROWTHUP	22														
Environmental Stress	COLDHARDY					25										

Vaccinium Genetic Resources: Genotypic Data on GG (SSR)

Genetic stock descriptors

☐ VACCINIUM CORE SUBSET ☑ TRUE TO TYPE

Descriptor: TRUE TO TYPE (TRUETOTYPE)

Download list of accessions evaluated for this trait

Definition:	Confirmation of cultivar identity based on pedig
Crop:	VACCINIUM
Category:	Genetic stock descriptors
Status:	
Data Type:	Uppercase character descriptor
Maximum Length:	25
Original Data Type:	UPPER
Responsible Site:	Natl. Germplasm Repository - Corvallis (COR)

Studies or environments

- 2019 10-SSR Blueberry — 45 Accessions

Accession evaluated for TRUETOTYPE

acce	accession	method_name	plant_name	inventory	inventory_	inventory_ r
PI	554698	2019 10-SSR Blueberry	Tifblue	CVAC	233	0.001
PI	554699	2019 10-SSR Blueberry	Callaway	CVAC	234	0.001
PI	554700	2019 10-SSR Blueberry	Climax	CVAC	235	0.001
PI	554701	2019 10-SSR Blueberry	Southland	CVAC	236	0.001
PI	554705	2019 10-SSR Blueberry	Coastal	CVAC	240	0.001
PI	554706	2019 10-SSR Blueberry	Satilla	CVAC	241	0.001
PI	554708	2019 10-SSR Blueberry	Black Giant	CVAC	243	0.001
PI	554709	2019 10-SSR Blueberry	Homebell	CVAC	244	0.001
PI	554710	2019 10-SSR Blueberry	Myers	CVAC	246	0.001
PI	554715	2019 10-SSR Blueberry	Centurion	CVAC	291	0.001

Vaccinium Genetic Resources: Phenotypic and Genotypic Data To Add

Phenotypic

- Texture/Firmness (*VacCAP*)
- Chemical composition (*VacCAP*) *Mengist et al., 2020a, b*)
- Volatiles (*VacCAP*)
- Anthocyanin (*Ashrafi*)
- Monotropein (*Leisner et al., 2017*)
- Metabolites (*Mengist et al., 2020a, b*)
- ……

Genotypic

- CaptureSeq (*Iorizzo et al.*)
- Allegro (*Ashrafi et al.*)
- FlexSeq (*VacCAP*)
- 10-SSR (*Bassil et al.*)

…….

Enabling Genomics-Assisted Specialty Crop Breeding and Research through Advanced Database Resources *(Accession No: 1029319); PD, Dorrie Main; Jill Bushakra*

Take Home Message

- Increase in phenotypic data and cost-effective genotypic resources for blueberry (low, mid, and high density)
- Expanding knowledge on FC genetics and accurate phenotyping capacity for blueberry FCs
- Expanding collaborations across the *Vaccinium* community
- Expanding community-wide use of genetic and genomic resources to identify DNA markers and genes controlling important traits
- VacCAP: Establishing a solid interdisciplinary framework to link FCs, quality as well as socio-economics
- Expected: Advancing selection of new cultivars with improved FCs, FQ

Acknowledgements

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VacCAP
IMPROVING FRUIT QUALITY

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VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes. Award #2019-51181-30015

VacCAP
IMPROVING FRUIT QUALITY

Thank You Supporting Organizations













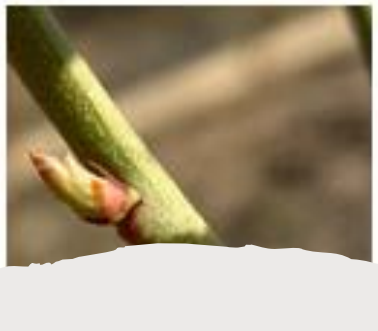

Thank you