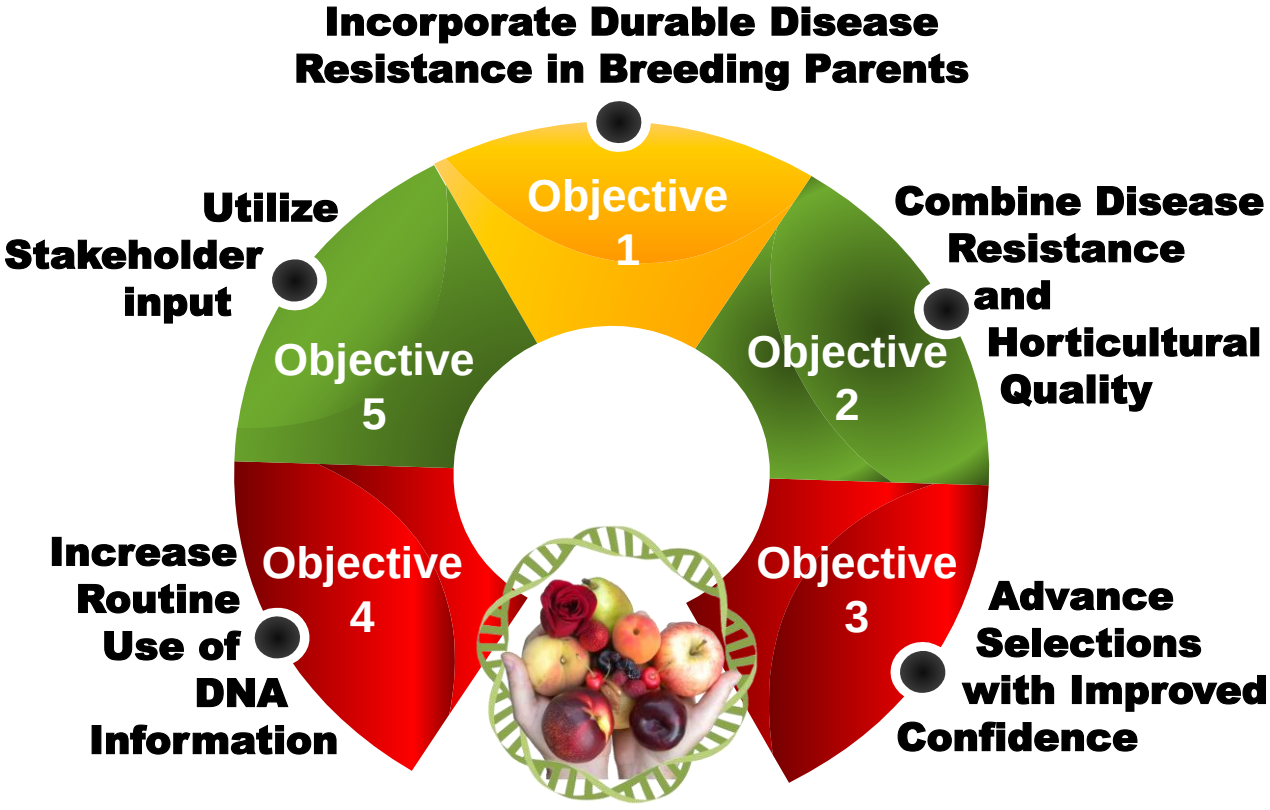
RosBREED Combining Disease Resistance with Horticultural Quality in New Rosaceous Cultivars

RosBREED
Annual Project Report

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Dedicated to the genetic improvement of U.S. rosaceous crops
www.rosbreed.org

RosBREED Advisory Panel
Annual Meeting
January 7, 2016
San Diego, CA



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RosBREED Combining Disease Resistance with Horticultural Quality in New Rosaceous Cultivars

Agenda

Thu, Jan 7, 2016
Marina Ballroom
Hilton San Diego Airport, 1960 Harbor Island Dr., San Diego, Calif.

Start	End	Audience/ group	Presenter/ moderator	Title
7:30	8:00	Continental breakfast		
8:00	8:30	All	Amy Iezzoni	Introductions and Agenda
8:30	9:00	All	Amy Iezzoni	Project overview
9:00	9:20	All	Team Leaders	Obj. 1: Incorporate durable disease resistance into breeding parents
9:20	9:40	All	Team Leaders	Obj. 2: Combine disease resistance and horticultural quality
9:40	10:00	All	Team Leaders	Obj. 3: Advance selections with improved confidence
10:00	10:30	Break		
10:30	11:00	All	Team Leaders	Obj. 4: Increase routine use of DNA information in rosaceous crop breeding
11:00	11:30	All	Team Leaders	Obj. 5: Utilize stakeholder input
11:30	11:45	All	Amy Iezzoni	Budget
11:45	12:00	All	Amy Iezzoni	Charge for afternoon break-out groups
12:00	1:15	Lunch		
1:15	1:30	All	Cameron Peace	Additional discussion questions & re-cap of Year 1 breeder survey
1:30	2:45	Break-out groups by crop	Group 1	Pome Fruits (Marina Ballroom)
			Group 2	Stone Fruits (Spinnaker Room)
			Group 3	Berries and Rose (Port Room)
2:45	3:15	Break		
3:15	4:00	All	Break-out group moderators	Report-outs & discussion – next steps/action items
4:00	5:00	All	Cameron Peace	Round table
5:00	Dinner on your own or in working groups			

Team Leaders

Project Director Amy Iezzoni Michigan State University iezzoni@msu.edu 517.353.0391	**Statistical Genetics** Vance Whitaker University of Florida vwhitaker@ufl.edu
Stone Fruit Breeding Ksenija Gasic Clemson University kgasic@clemson.edu	**DNA Testing** Nahla Bassil USDA-ARS National Clonal Germplasm nahla.bassil@ars.usda.gov
Pome Fruit Breeding James Luby University of Minnesota lubyx001@umn.edu	**Socio-Economics** Chengyan Yue University of Minnesota yuechy@umn.edu
Berry Breeding Chad Finn USDA-ARS, Corvallis, OR chad.finn@ars.usda.gov	**Co–PD, DNA-Informed Breeding** Cameron Peace Washington State University cpeace@wsu.edu
Rose Breeding Stan Hokanson University of Minnesota hokan017@umn.edu	**Extension** Mercy Olmstead University of Florida mercy1@ufl.edu
Pathology Jay Norelli USDA-ARS, Kearneysville, WV Jay.Norelli@ars.usda.gov	**Extension Evaluation** Michael Coe Cedar Lake Research Group, Portland, OR michael@cedarlakeresearch.com
Data Management Dorrie Main Washington State University dorrie@wsu.edu	**Stakeholder** Jim McFerson WA Tree Fruit Research Commission mcferson@treefruitresearch.com

RosBREED Team Members	
Richard Bell (USDA-ARS) richard.bell@ars.usda.gov	James Hancock (Michigan State Univ.) hancock@msu.edu
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Marco Bink (Wageningen Univ. & Research Centre, Netherlands marco.bink@wur.nl	Craig Hardner (Univ. of Queensland, Australia) c.hardner@uq.edu.au
Susan Brown (Cornell Univ.) skb3@cornell.edu	Kelly Ivors (Cal. Poly. State) kivors@calpoly.edu
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Breeder Collaborators	
Patrick Moore (Washington State Univ.) moorepp@wsu.edu	William Shane (Michigan State Univ.) shane@msu.edu

RosBREED Project Assistants	
Audrey Sebolt (Michigan State Univ.) grantzau@msu.edu 517.353.0432	Joan Schneider (Michigan State Univ.) schnei37@msu.edu 517.353.0360

International Partners and Nature of Partnership

1. **Centro di Ricerca per la Frutticoltura, Rome, Italy:** Ignazio Verde provides expertise in peach genomics, genetics, and QTL discovery.

2. **Department of Plant Breeding and Genetics, East Malling Research, East Malling, UK:** Richard Harrison provides expertise in strawberry genetics and genomics. Felicidad Fernandez provides expertise in cherry and pear breeding and genetics.

3. **INRA – Breeding & Genetics teams:** The INRA breeding teams provide parallel expertise in apple, peach, strawberry and cherry breeding and genetics.

   a. Unité de Génétique et Amélioration des Fruits et Légumes (UGAFL), INRA CR Beauouze, France INRA – Angers: Francois Laurens and team member Charles-Eric Durel provide expertise in apple breeding and genetics and collaborate by using common SNP markers. Linkages are formed with the molecular genetics laboratory of Pauline Lasserre.

   b. Unité de Recherche des Espèces Fruitières (UREF), INRA CR, Villenave d'Ornon, France INRA – Bordeaux: Béatrice Denoyes-Rothan provides expertise in strawberry breeding and genetics and collaborates by placing the RosBREED SNP markers on the INRA octoploid strawberry map. Elisabeth Dirlewanger provides expertise in *Prunus* genetics and comparative mapping in the Rosaceae. José Quero-Garcia provides expertise in sweet cherry breeding and genetics and we are collaborating by using common SNP markers.

   c. Unité de Génétique et Horticulture (GENHORT), INRA CR, Avignon, France INRA – Avignon: Benedicte Quilot-Turion provides expertise in peach molecular genetics and collaborates by using common SNP markers. Linkages are formed with the peach breeding team of Thierry Pascal and Patrick Lambert.

4. **Institut für Pflanzengenetik, Leibniz University Hannover, Germany:** Thomas Debener provides expertise in rose genetics and genomics including access to a large collection of unpublished ESTs.

5. **Istituto Agraraio San Michele, Biology Department, Trento, Italy:** Riccardo Velasco provides expertise in genomics and will support RosBREED through the sharing of refinements in the apple genome sequence.

6. **Institut de Recerca i Tecnologia Agroalimentàries (IRTA), Cabrils, Spain:** Pere Arús provides expertise in peach genetics and genomics. Amparo Monfort provides expertise in strawberry genetics and genomics as part of the international strawberry SNP consortium.

7. **Instituto de Investigación y Formación Agraria y Pesquera, Málaga, Spain:** Iraida Amaya provides expertise in strawberry genetics, genomics, germplasm and breeding.

8. **Plant & Food Research, Palmerston North, New Zealand:** Sue Gardiner provides expertise in apple and pear genetics and marker-assisted breeding. David Chagné provides expertise in apple and pear genetics, including genome-wide selection.

9. **University of Chile, Santiago, Chile:** Herman Silva and Lee Meisel provide expertise in Rosaceae functional genomics and metabolomics through the sharing of peach, sweet cherry, and strawberry sequence data.

Professional Interests of RosBREED Advisory Panel Members

RosBREED has three Advisory Panels, representing industry, scientific, and extension interests. Panel members broadly represent the diversity of Rosaceae by crop, region, and professional expertise.

RosBREED Industry Advisory Panel

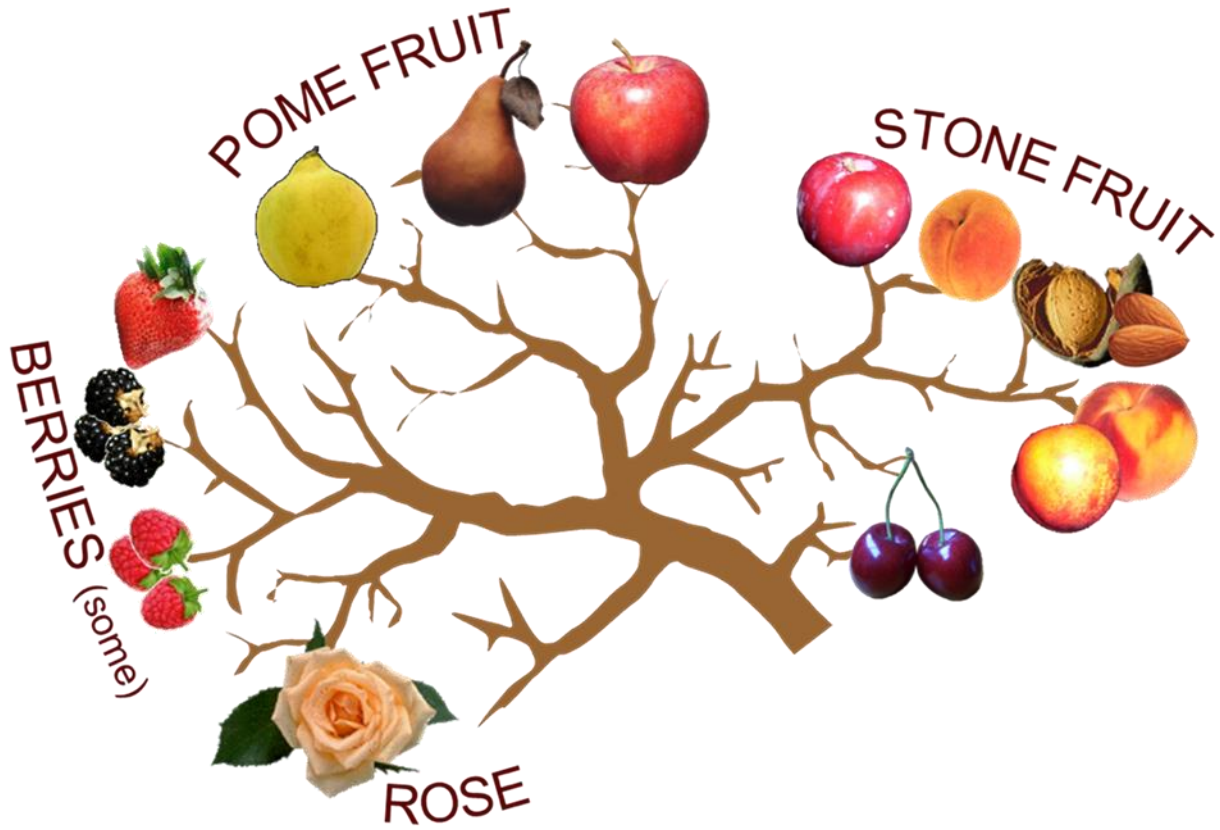
- **Jim Allen:** President
  New York Apple Association, Fishers, NY (www.nyapplecountry.com)
  Board of Trustees, US Apple Association (www.usapple.org)
- **Jen Baugher:** Marketing Associate
  Adams County Nursery, Aspers, PA (www.acnursery.com)
- **Chris Britton:** Partner
  Britton Konynenburg Partners, Modesto CA (www.brittonkonynenburg.com/)
  ex-President Board of Trustees, US Apple Association (www.usapple.org)
- **Chalmers Carr III:** CEO
  Titan Peach Farms, Inc., Ridge Spring, SC (www.titanfarms.com)
  Board of Directors, South Carolina Peach Council (www.scpeach.org)
- **Robert Curtis:** Senior Director, Agricultural Affairs
  Almond Board of California, Modesto, CA (www.Almonds.com)
- **Bill Dodd:** President
  Ohio Fruit Growers Marketing Association, Newcomerstown, OH
  (www.ohioapples.com/ohio_apples_fgma.htm)
  ex-President Board of Trustees, US Apple Association
- **Carlos Fear:** Director of Consumer Lab and Molecular Genetics
  Driscoll's Strawberry Associates, Watsonville, CA (www.driscolls.com)
- **Bob Gix:** Horticulturist
  Blue Star Growers, Cashmere, WA
  Co-Chair, Fresh Pear Research Subcommittee, Pears USA (www.usapears.com)
- **Bruce Grim:** Director
  Washington Marketing Associations, Wenatchee, WA (www.themarketingassociations.org)
  ex-President, Board of Trustees, US Apple Association
- **Philip Korson:** President
  Cherry Marketing Inst., Inc., Lansing, MI (www.choosecherries.com)
- **Dan Legard:** Director
  Research and Education, California Strawberry Commission, Watsonville, CA
  (www.calstrawberry.com)
- **John Lott:** President
  Bear Mountain Orchards, Inc., Aspers, PA
- **Chris Pellett:** Co-owner
  Newflora LLC, Central Point, OR (www.newflora.com)

RosBREED Scientific Advisory Panel

- **Pere Arús:** Head, Plant Genetics Dept., Institut de Recerca i Tecnologia Agroalimentàries (IRTA), Cabrils, Spain
  Research areas: molecular tools for plant genetics; comparative genomics and application of molecular markers in Rosaceae breeding. (www.irta.cat/ca-ES/Persones/Pagines/105.aspx)
- **Joe Arvai:** Max McGraw Professor of Sustainable Enterprise and Director, Erb Institute, University of Michigan, Ann Arbor, MI
  Research areas: Behavioral decision research and decision support systems (www.snre.umich.edu/profile/joseph_Arvai)
- **Frederick Bliss:** Professor Emeritus, Univ. of California, Davis and Sr. Director, R&D Special Projects, Seminis Vegetable Seeds, Woodland, CA
  Research areas: genomics, genetics, and breeding of fruit and vegetable crops; research administrator in public and private sectors; commercialization of breeding products
- **Robin Buell:** Professor, Dept. of Plant Biology, Michigan State Univ., East Lansing, MI
  Research areas: genomic aspects of plant biology and plant pathogens; high throughput sequencing, functional genomics, comparative genomics, and bioinformatics (www.plantbiology.msu.edu/faculty/faculty-research/robin-buell/)
- **Lailiang Cheng:** Professor, Professor, Dept. of Horticulture, Cornell Univ., Ithaca, NY
  Research areas: plant nutrition, fruit physiology, molecular, cellular, and whole plant response to abiotic stress in apple, cherry, grape; undergraduate and graduate education (http://hort.cals.cornell.edu/people/lailiang-cheng)
- **Susan Gardiner:** Principal Scientist, The Horticultural and Food Research Inst. of New Zealand (Plant & Food Research [PFR])
  Research areas: leads Gene Mapping Team integrated with PFR breeders in several Rosaceae crops, including, apple, apple rootstock, pear, peach/nectarine and apricot
- **Kim Hummer:** Supervisory Research Horticulturist, National Clonal Germplasm Repository, Corvallis, OR
  Research areas: conservation of fruit, nut, and specialty crop genetic resources; ploidy in strawberry species. She also actively studies genetics of a wide range of crops.
- **Dan Kluepfel**: Professor, Dept. of Plant Pathology, UC Davis, CA
  Research areas: research focuses on bacterial diseases of almonds and walnuts, specifically crown gall disease. (http://plantpathology.ucdavis.edu/?story=1033)
- **Brad Rickard:** Assoc. Professor, Dept. of Agricultural Sciences, Cornell Univ., Ithaca, NY
  Research areas: economic implications of policies, innovation, and industry-led initiatives applied to agricultural and food markets (http://dyson.cornell.edu/people/profiles/rickard.php)
- **Carolyn Ross:** Assoc. Professor, Dept. of Food Science, Wash. State Univ., Pullman, WA
  Research areas: sensory analysis and consumer preferences of fruit and fruit products, including fresh and processed apple, pear, and cherry and wine (http://sfs.wsu.edu/personnel/faculty-staff/ross-c/)
- **Phil Simon:** Research Geneticist, USDA-ARS and Professor, Dept. of Horticulture, Univ. of Wisconsin-Madison, Madison, WI
  Research areas: vegetable breeding and genetics; biochemistry of culinary and nutritive factors, terpenoids, and sugars in carrots and garlic. (www.ars.usda.gov/pandp/people/people.htm?personid=5186)
- **Chang-Lin Xiao**: Supervisory Research Plant Pathologist. USDA-ARS, Parlier CA
  Research areas: biology, epidemiology, and management of diseases of fruit crops with an emphasis on postharvest diseases.
  (www.ars.usda.gov/pandp/people/people.htm?personid=47587)

RosBREED Extension Advisory Panel

- **David Eddy**: Editor, American/Western Fruit Grower, MeisterMedia, Willoughby OH
  Professional interests: Ag journalism, print and electronic communication
  (www.growingproduce.com/author/david-eddy/)
- **Peter Hirst:** Professor, Dept. of Horticulture, Purdue Univ., West Lafayette, IN
  Professional interests: tree fruit production systems and physiology, physiological genetics of flowering and fruit development in Rosaceae; state Extension specialist; undergraduate and graduate education
  (https://ag.purdue.edu/hla/Pages/Profile.aspx?strAlias=hirst&intDirDeptID=16)
- **David Karp:** Associate, Agricultural Experiment Station, UC Riverside, Riverside, CA
  Professional interests; freelance food journalist and photographer
- **Ron Perry:** Professor, Dept. of Horticulture, Michigan State Univ., East Lansing, MI
  Professional interests: extension and research in cherry and apple orchard systems
  (http://www.hrt.msu.edu/ronald-perry/pg7)
- **Clark Seavert**: Professor & Director of the NW Agribusiness Executive Seminar Department of Agricultural & Resource Economics, Oregon State Univ., Corvallis, OR
  Professional interests: assessment and advancement of technologies that increase profitability and feasibility in commercial agriculture, with the aim of aligning business model innovation strategies to existing and future technologies.
  (http://arec.oregonstate.edu/seavert)
- **Chris Watkins:** Professor, Dept. of Horticulture, Cornell Univ., Assoc. Director for Cornell Cooperative Extension, Ithaca, NY
  Professional interests; postharvest physiology and management of apple, pear, peach, and cherry; state-wide agricultural extension activities
  (http://hort.cals.cornell.edu/people/christopher-watkins)



RosBREED

Combining Disease Resistance with Horticultural Quality in New Rosaceous Cultivars

What is RosBREED?

RosBREED is a multi-state, multi-institution project dedicated to the genetic improvement of U.S. rosaceous crops by targeted applications of genomics knowledge and tools to accelerate and increase the efficiency of breeding programs.

This Coordinated Agricultural Project is funded through the USDA-NIFA Specialty Crop Research Initiative by a combination of federal and matching funds, grant 2014-51181-22378.

What stakeholder and consumer needs does RosBREED address?

The perfect cultivar of apple, cherry, peach, strawberry, rose, and other rosaceous crops, one which consistently exceeds consumer expectations with satisfying appearance, aroma, flavor, shelf life, and texture AND also meets industry needs for durable disease resistances and productivity, remains elusive.

Yet, such rosaceous cultivars are possible. The components exist – but they must be combined.

What is our vision?

Combining horticultural quality, durable disease resistances, and productivity into new cultivars can be achieved through the coordinated application and implementation of new scientific advances.

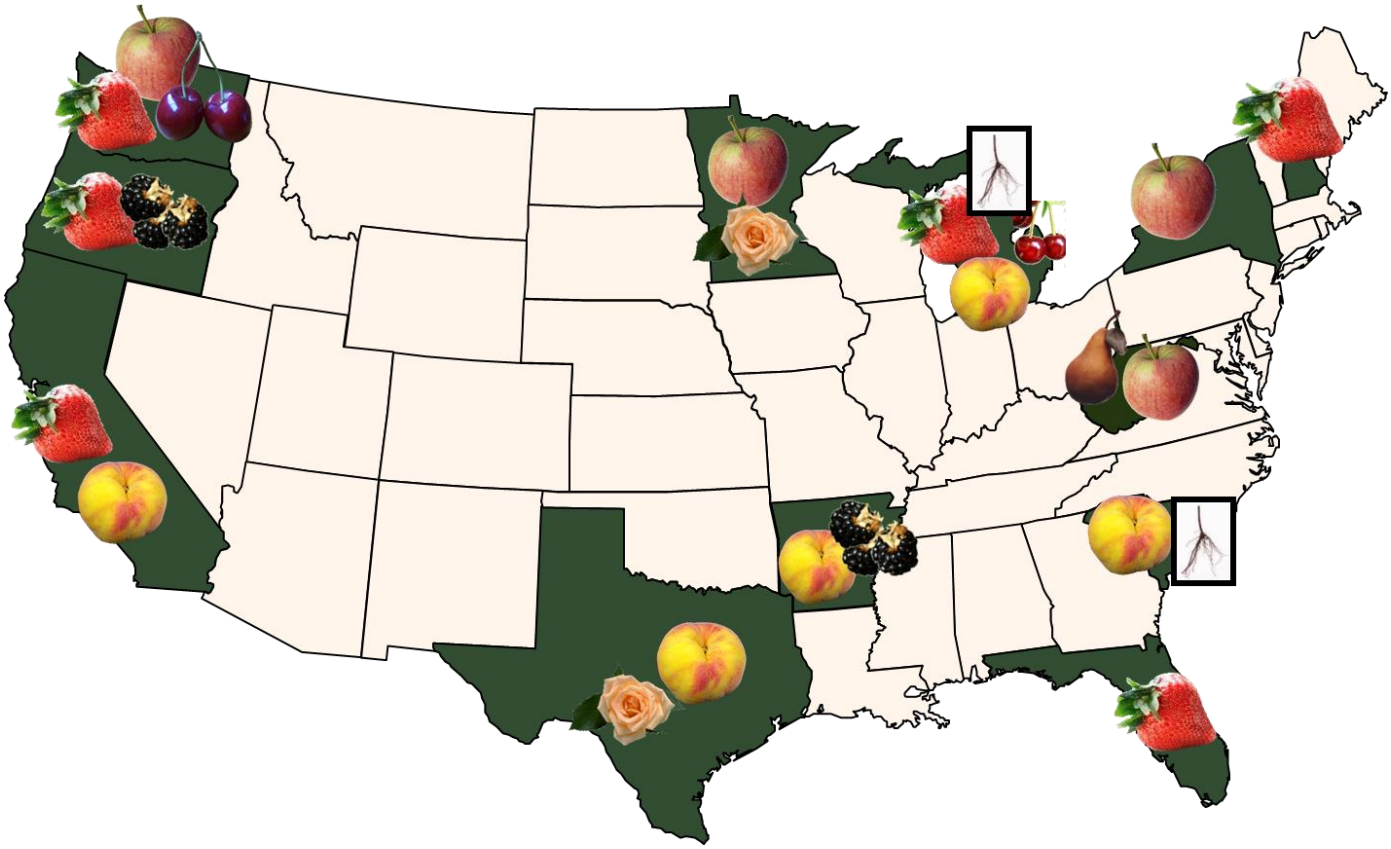
What does success look like?

- Consumers are satisfied, repeat customers
- Rosaceous crop industries are more profitable and sustainable
- Plant breeding programs are more efficient and effective

RosBREED

Combining Disease Resistance with Horticultural Quality in New Rosaceous Cultivars

Targeted Crops, Breeders, & Diseases



Apple: Scab, Blue mold, Fire blight
- Washington State Univ. (Kate Evans)
- Univ. of Minnesota (James Luby)
- Cornell Univ. (Susan Brown)
- USDA-ARS Kearneysville (Jay Norelli)

Peach (scion & rootstock): Bacterial spot, Brown rot, *Armillaria* root rot
- Clemson Univ. (Ksenija Gasic)
- Univ. of Arkansas (John Clark)
- Texas A&M (David Byrne)
- Univ. of California Davis (Tom Gradziel)
- Michigan State Univ. (William Shane)

Pear: Fire blight
- USDA-ARS Kearneysville (Richard Bell)

Sweet cherry: Powdery mildew
- Washington State Univ. (Nnadozie Oraguzie)

Tart cherry (scion & rootstock): Cherry leaf spot, *Armillaria* root rot
- Michigan State Univ. (Amy Iezzoni)

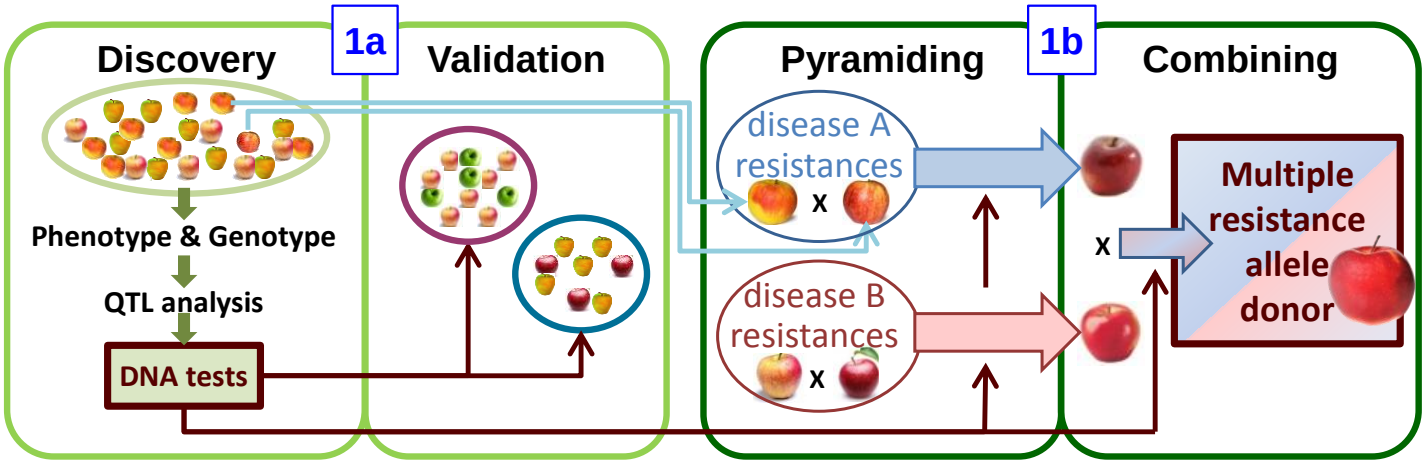
Rose: Black spot
- Univ. of Minnesota (Stan Hokanson)
- Texas A&M Univ. (Dave Byrne)

Strawberry: Root and Crown rots, Bacterial angular leaf spot
- Michigan State Univ. (James Hancock)
- USDA-ARS Corvallis (Chad Finn)
- Univ. of Florida (Vance Whitaker)
- Univ. of New Hampshire (Tom Davis)
- Washington State Univ. (Pat Moore)

Blackberry: Fruit sweetness. This is the overwhelming need as there is not a major disease threat
- Univ. of Arkansas (John Clark)
- USDA-ARS Corvallis (Chad Finn)

OBJECTIVE 1
Incorporate Durable Disease Resistance in Breeding Parents

U.S. Rosaceae breeders, collaborating with pathologists, will identify and incorporate disease resistance alleles into breeding parents. Use of these parents will enable new disease resistant cultivars to be developed more rapidly, as these parents will donate multiple resistance alleles to their progeny.



Methods Overview: Participating teams of U.S. Rosaceae breeders and pathologists will:

1a Identify and validate alleles for disease resistance by QTL analysis

1b Incorporate these by marker-assisted introgression into breeding parents, which we call "multiple resistance allele donors". These multiple resistance allele donors, with pyramided resistance alleles from multiple sources for one disease and/or combined resistance alleles for multiple diseases, will be made available to breeders U.S.-wide.

Timeline: **1a** was initiated in Year 1 and will be completed at the end of Year 3. **1b** started in Year 1 for apple and will begin for all other crops in Year 4, with resistance alleles pyramided or combined from at least two sources accomplished by Year 5.

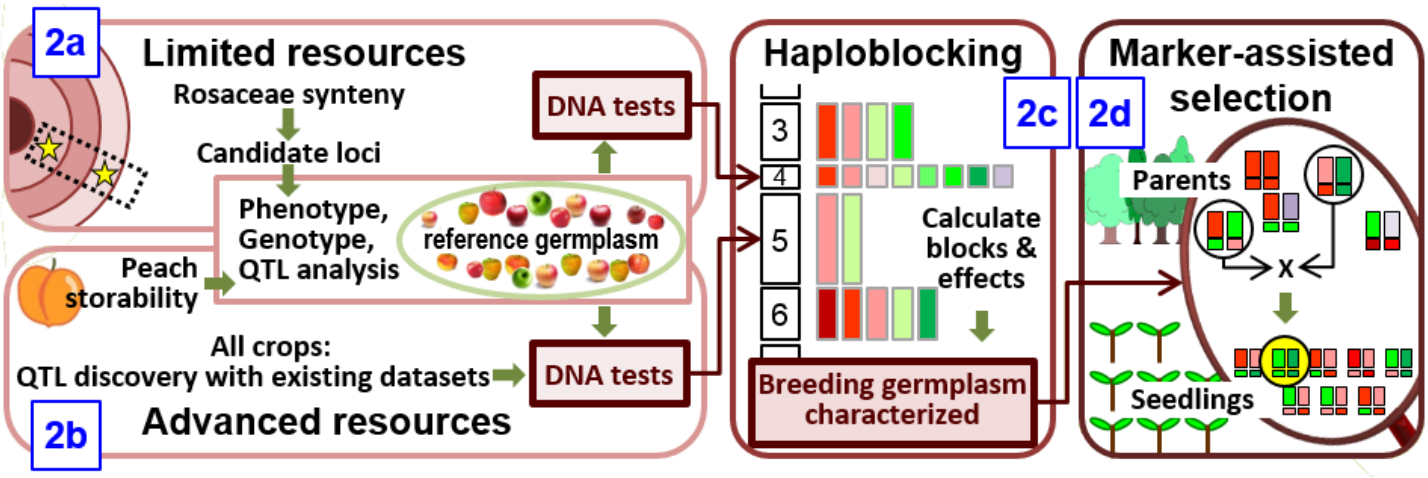
Jay Norelli

Guido Schnabel

Kelly Ivors

OBJECTIVE 2
Combine Disease Resistance and Horticultural Quality

Development of cultivars that combine excellent horticultural quality and disease resistance will be enabled with knowledge of desirable alleles and their locations in the genome.



Methods Overview: New large-effect fruit quality alleles will be discovered by:

2a Leveraging syntenic genomic locations of QTLs, and

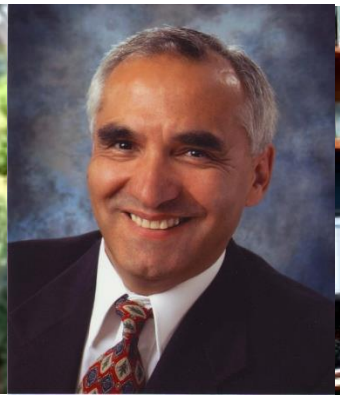
2b Using a genome-wide pedigree-based analytical approach.

2c Alleles within regions contributing to desired phenotypes will be identified by haplotype blocking to expand selection decisions from individual loci and traits to many linked loci and traits.

2d Marker-assisted parent and seedling selection will combine disease resistance with superior horticultural quality in the next generation of breeding families.

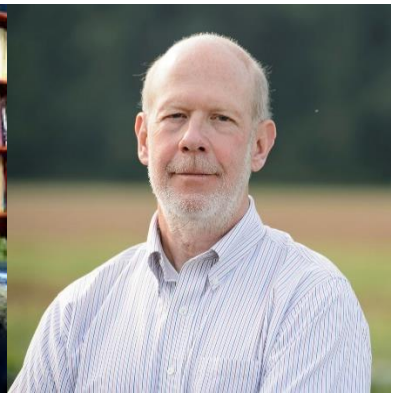
Timeline: **2a–2c** was initiated in Year 1, with completion in Year 3. **2d** will be accomplished in Years 1-5 (apple, peach, strawberry, cherry) or Years 4-5 (rose, blackberry, pear).

Dorrie Main



Carlos Crisosto

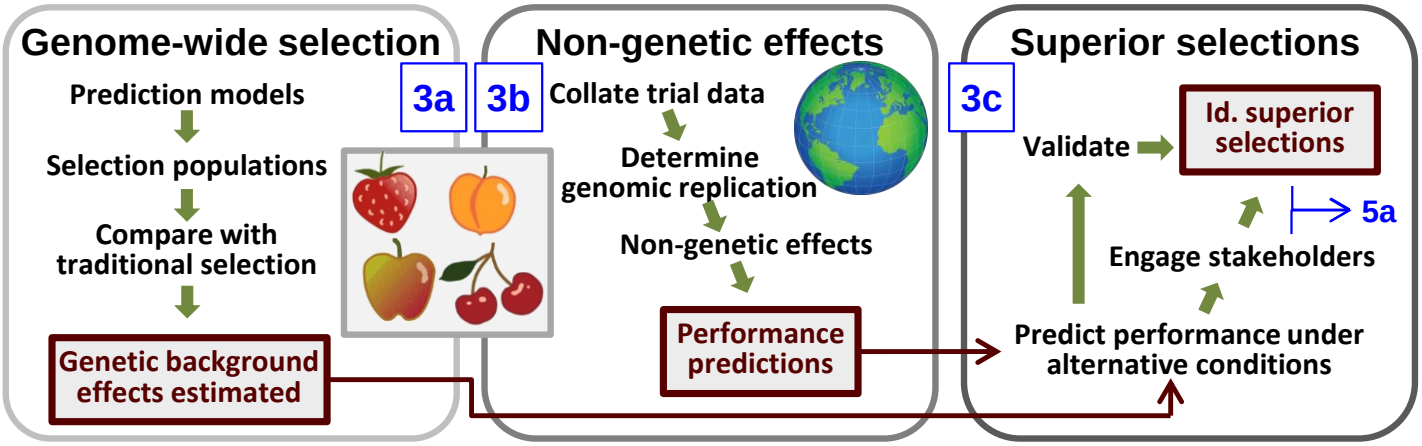
Amy Lawton-Rauh



Stephen Kresovich

OBJECTIVE 3
Advance Selections with Improved Confidence

New selections will be advanced toward commercial release with improved confidence due to more accurate predictions of fruit quality performance, which includes estimates of non-genetic factors (e.g., cultural practices, climate) and alleles at small-effect loci across the entire genome.



Methods Overview: Influences of genetic background and non-genetic factors will be identified using new statistical approaches to improve accuracy of predictions of genetic potential based on large-effect horticultural quality and disease resistance QTLs in apple, peach, sweet cherry, and strawberry breeding germplasm.

3a Genome-wide prediction models will calculate relative effects of genetic background (cumulative effects of individually small-effect alleles) using existing high-resolution phenotypic and genotypic datasets.

3b Genomic relationship matrices using dense SNP arrays will be used to merge RosBREED datasets with trials in the U.S. and other countries. Effects of non-genetic factors (e.g., management, climate, G × E) will be evaluated to improve prediction accuracy of genetic potential among and within these factors.

3c In case studies, performance stability of elite selections under alternative growing conditions will be predicted using **3a** and **3b** results, validated, and used to streamline selection advancement and engage stakeholders in the latter stages of their breeding programs.

Timeline: **3a** and **3b** was initiated in Year 1 with data compilation and analysis completed in Year 4. **3c** will be conducted in Year 4.

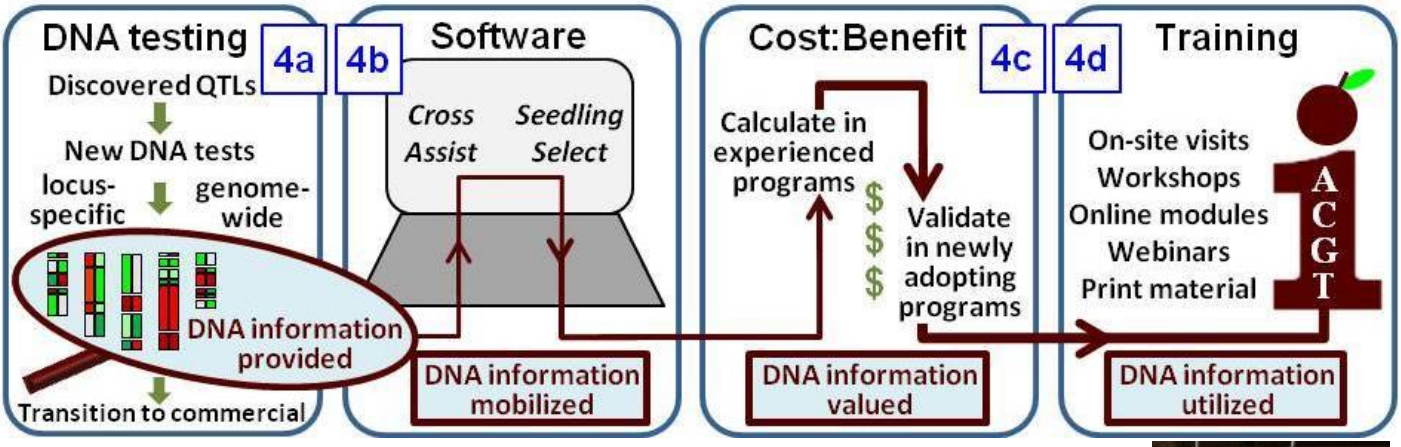
Vance Whitaker

Rex Bernardo

Craig Hardner

OBJECTIVE 4
Increase Routine Use of DNA Information

The development of cost-effective and accessible DNA diagnostic tools will enable DNA-informed breeding to be widely adopted by rosaceous crop breeders, leading to increased breeding efficiency.



Methods Overview:

4a Cutting-edge DNA diagnostic tools will be developed and crop-specific DNA testing services will be made available.

4b DNA Information will be integrated into enhanced decision-support software.

4c Cost-benefit analyses will be conducted to identify tangible dollar values for DNA-informed breeding applications.

4d Breeders and allied scientists will receive technical training in use of DNA information in breeding.

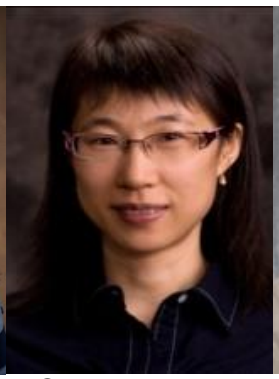
Timeline: **4a** was initiated in Year 1 and tool development will continue until the end of Year 5. **4b** software enhancement was be completed in Year 1; information integration will be started in Year 1 and will end in Year 5; routine DNA testing will transition to commercial service providers after Year 3. **4c** cost: benefit analyses began in Year 1 and new adoption case studies will begin in Year 2; all will be completed in Year 4. **4d** technical training will be ongoing for all five years.


Nahla Bassil


Chris Saski


Cameron Peace


Mercy Olmstead

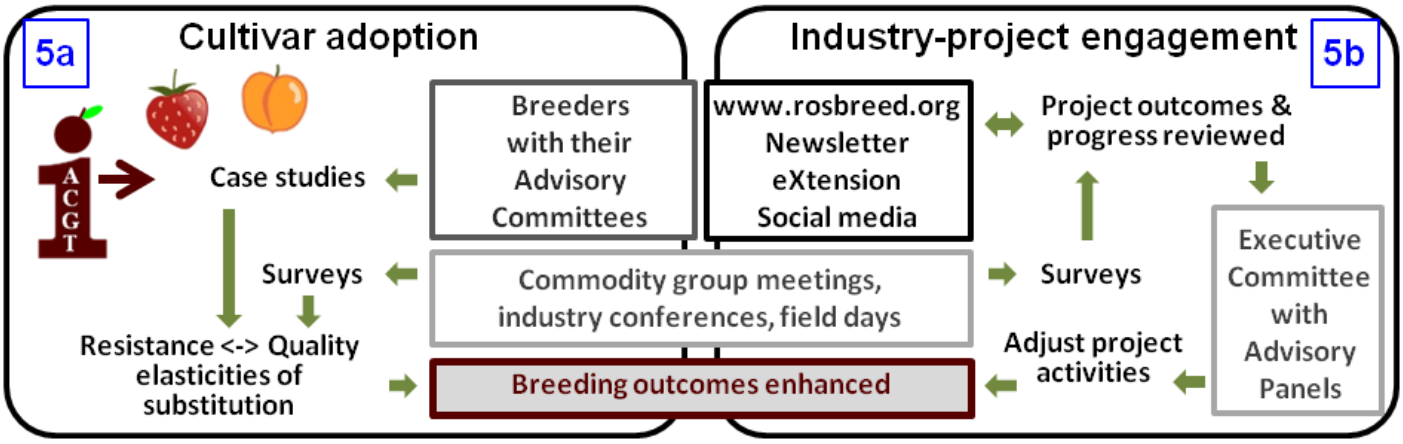

Chengyan Yue


Vicki McCracken


Karina Gallardo

OBJECTIVE 5
Utilize Stakeholder Input

The impact of new cultivars will be maximized with stakeholder input into cultivar trait priorities and improved predictability of commercial performance. Due to the geographic and crop diversity within RosBREED, stakeholder input and recommendations will be specific for individual crop breeding programs.



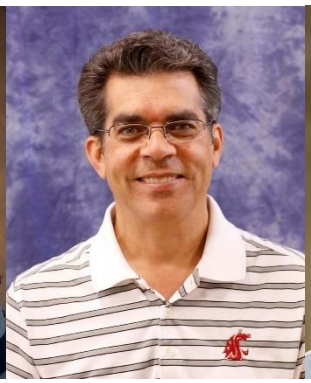
Methods Overview:

5a Stakeholder decisions on new cultivar adoption will be systematically investigated in two breeding programs.

5b Stakeholders are being engaged in project outcomes, evaluation, and adjustments.

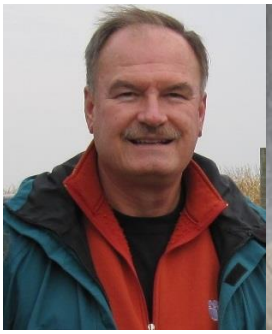
Timeline: **5a** will be initiated in Year 2, with surveys conducted in Years 3 and 4. **5b** stakeholder activities will follow an annual timeline for all five years and supplemented with extension activities.


Mercy Olmstead


Des Layne

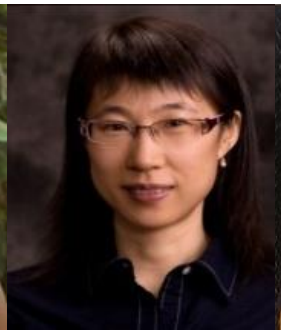

Vance Whitaker


Lisa Wasko DeVetter


Greg Reighard


Vicki McCracken


Karina Gallardo


Chengyan Yue


Ksenija Gasic

Table 1: Objective 1 – Deliverables for Year 1 (green) and Challenges (blue)

Objective	Sub-Objective	What	To Whom	Impact
1 Incorporate Durable Disease Resistance in Breeding Parents	**1a.** Disease resistance allele discovery and validation	Standardized disease phenotyping protocols including the most appropriate pathogen strain(s) – established	Crop Breeding Teams and Pathology Team	These plant materials and their phenotypic and genotypic data is resulting in discovery of loci associated with disease resistance and enable development of DNA tests for breeding application
		Strawberry root and crown rot plant materials from MSU, USDA-Corvallis, U of NH established at Cal Poly; disease phenotyping – initiated	Strawberry pathologists and strawberry breeders	
		Disease phenotypic data for ~ 7500 plant materials for 2015 season – completed [apple scab 918, fire blight 890, blue mold 183, pear fire blight 300, cherry leaf spot 100, powdery mildew 600, peach bacterial spot 830, brown rot 500, rose black spot 1600, strawberry bacterial leaf spot 320, anthracnose crown rot 625, *Phytophthora* crown rot 680]	Crop Breeding Teams and Pathology Team	
		Genotypic data of a subset of those populations phenotyped for disease resistance – initiated [apple scab, fire blight, blue mold, strawberry bacterial leaf spot, anthracnose crown rot, *Phytophthora* crown rot]	Crop Breeding Teams and DNA Testing Team	
		RosBREED and Plant and Food Research collaborative effort to validate DNA tests for fire blight resistance in pear and 'Splendour' apple - initiated	Pathology Team and DNA-Informed Breeding Team	
		DNA tests – in development [apple - blue mold (*BM3*), fire blight (several); sweet cherry - powdery mildew (*Pl-w*); *strawberry* - *Pc*1 locus for *P. cactorum* resistance]	Pathology Team, DNA-Informed Breeding Team, DNA Testing Team	
	1b. Pyramid and combine disease resistance alleles	Progeny from crosses created to pyramid disease resistance alleles – obtained [strawberry - pyramiding alleles for anthracnose crown rot and *Phytophthora* crown rot, and combining with bacterial angular leaf spot][apple - 2015 crosses combining 'Honeycrisp', 'Wildung', and Vf scab and fire blight resistance sources]	Crop Breeding Teams	These progenies will provide individuals that breeders can use as parents to develop cultivars with more durable disease resistance due to the presence of resistance from multiple loci

Objective	Challenge	Plan for Tackling
1 Incorporate Durable Disease Resistance in Breeding Parents	Crown and root rot resistance is not identified in the strawberry germplasm chosen for screening	Screen germplasm of different ancestry than that previously examined
	Some genetic resistances may be due to many small-effect alleles across multiple loci and therefore difficult to individually detect and introgress	Search for other sources of resistance or use other DNA-informed breeding approaches such as genome-wide selection (Obj. 3a)

Table 1 cont.: Objective 1 – Year 2 Planned Deliverables

Objective	Sub-Objective	What	To Whom	Impact
1 Incorporate Durable Disease Resistance in Breeding Parents	1a. Disease resistance allele discovery and validation	Standardized disease phenotypic data of plant materials for 2016 season – obtained	Crop Breeding Teams and Pathology Team	These plant materials and their phenotypic and genotypic data will continue to lead to discovery of loci associated with disease resistance and enable development of DNA tests for breeding application
		Genome scan data of those populations phenotyped for disease resistance – obtained	Crop Breeding Teams and DNA Testing Team	
		QTL discovery for those diseases/donor sources where phenotyping and genotyping have been completed – ongoing	Crop Breeding Teams and Crop Post-Docs	
	1b. Pyramid and combine disease resistance alleles	Progeny from crosses created to pyramid disease resistance alleles – obtained	Crop Breeding Teams and Crop Post-Docs	These progenies will provide individuals that breeders can use as parents to develop cultivars with more durable disease resistance due to the presence of resistance from multiple loci
		Pyramided populations genotyped with disease-resistance DNA tests to advance resistant individuals – initiated		

Table 2: Objective 2 – Deliverables for Year 1

Objective	Sub-Objective	What	To Whom	Impact
2 Combine Disease Resistance and Horticultural Quality	**2a.** Horticultural quality allele discovery and validation – RosMAP	RosMAP online tool – completed	Crop Breeding and DNA Testing Teams	This resource provided a shortcut to locate loci controlling sweetness in blackberry and pear by leveraging knowledge of common ancestral origin across rosaceous genera.
		Three syntenic regions with fruit quality alleles – identified	Data Management Team	
		Germplasm sets of blackberry and pear – pedigrees confirmed	DNA Testing Team	
		Phenotyping of fruit (Brix, TA, and pH) from blackberries populations in Ore. and Ark – completed	Berry and Pome Fruit Breeding Teams	
	2b. Horticultural quality allele discovery and validation – advanced resources	Standardized peach postharvest fruit quality phenotyping protocol and at-location training – developed and conducted	Peach breeders	Rosaceae breeders will have many new available DNA tests for valuable traits. Peach breeders will benefit from DNA tests for post-harvest traits. Strawberry breeders will have knowledge of which strawberry accessions to advance based on knowledge of horticultural traits and root and crown rot resistance
		Advanced Peach Crop Reference Set – established, parentage confirmed, phenotyped in 2015 season	Peach breeders	
		Phenotypic data on soluble solids content (peach) and day neutrality (strawberry) in plant materials targeted for root and crown rot resistance screening – obtained	Strawberry breeders	
		Pedigree-Based Analysis software support – provided	Crop Breeding Teams	
		Valuable alleles from "RosBREED 1" data sets – identification in progress using Pedigree-Based Analysis software	DNA-Informed Breeding Team	
	2c. Compile locus specific DNA information	Genotyping-by-Sequencing data of important individuals – compiled	Breeding and Statistical Genetics Teams	Knowledge of DNA sequence and genome-wide SNP genotypes will allow the characterization of alleles present in the diverse range of germplasm used in breeding at a resolution that breeders can easily manage
		Haploblocking analyses using existing high-resolution data (SNP array, Genotyping-by-Sequencing) – initiated	DNA-Informed Breeding and DNA Testing Teams	
		Pilot haploblocking study using the G2 trait rich region in sweet cherry – in progress	Statistical Genetics Teams	
	2d. Conduct marker-assisted selection for combined traits	Marker-assisted parent selection in apple, peach, cherry, and strawberry breeding programs – conducted	Crop Breeding Teams	Breeders will benefit from DNA information for parent and cross selection. Information on marker-assisted parent selection used will provide insights into those DNA tests that are considered high priority and will provide success stories to share widely to the breeding and stakeholder community
		Use of marker-assisted parent selection – tracked	Demonstration Breeders and Extension Team	

Table 2 cont.: Objective 2 – Challenges (blue) & Year 2 Planned Deliverables (purple)

Objective	Challenge	Plan for Tackling
2 Combine Disease Resistance and Horticultural Quality	For the RosMAP candidate gene approach, influencing loci in one or more crops may not have genetic variation in the target crop	Use a linkage mapping approach to identify trait loci

Objective	Sub-Objective	What	To Whom	Impact
2 Combine Disease Resistance and Horticultural Quality	2a. Horticultural quality allele discovery and validation – RosMAP	Germplasm sets of blackberry and pear phenotyped for 2016 season - completed	Blackberry and pear breeding teams	This case study for the RosMAP candidate gene approach will seek to identify loci controlling soluble solids content in blackberry and pear
		Candidate loci for sweetness for pear and blackberry - tested	DNA Testing Team	
	2b. Horticultural quality allele discovery and validation – advanced resources	Advanced Peach Crop Reference Set phenotyped for 2016 season – completed	Peach breeders	Rosaceae breeders will have many new available DNA tests for valuable traits. Peach breeders will benefit from DNA tests for post-harvest traits. Reliable phenotypic dataset for important strawberry traits will support discovery of robust trait loci
		Advance Peach Crop Reference Set genotyped (genome scan, SNP array) – completed	DNA Testing Team, Crop Post-Docs	
		Phenotypic data on soluble solids content and day neutrality in plant materials targeted for root and crown rot resistance screening – obtained	Strawberry breeders	
		Pedigree-Based Analysis software instruction – provided	Crop Breeding Teams	
		Valuable alleles from "RosBREED 1" data sets – identified using Pedigree-Based Analysis software	DNA-Informed Breeding Team, Crop Post-Docs	
	2c. Compile locus specific DNA information	Haploblock construction and characterization – completed	DNA-Informed Breeding and DNA Testing Teams	Knowledge of DNA sequence and genome-wide SNP genotypes will allow the confirmation of alleles present in the diverse range of germplasm used in breeding
	2d. Conduct marker-assisted selection for combined traits	Marker-assisted parent selection and marker-assisted seedling selection genotyping provided for apple, peach, cherry, and strawberry breeding programs – conducted	Crop Breeding Teams	Breeders will benefit from DNA information for parent and cross selection. Information on marker-assisted parent selection used will provide insights into those DNA tests that are considered high priority and will provide success stories to share widely to the breeding and stakeholder community
		Use of marker-assisted parent selection and marker-assisted seedling selection – tracked	Demonstration Breeders and Extension Team	

Table 3: Objective 3 - Deliverables for Year 1 (green) and Challenges (blue)

Objective	Sub-Objective	What	To Whom	Impact
3 Advance Selections with Improved Confidence	**3a.** Add genetic background effects	Pedigree, phenotypic, and genome-scan data for genome-wide selection training populations – compiled and error-checked	Apple, peach, sweet cherry, and strawberry breeders and Statistical Genetics Team	Progeny will be selected and advanced with improved confidence based on knowledge of significant and non-significant loci influencing trait variation
		Selection populations genotyped for major loci – initiated	Apple, peach, sweet cherry, and strawberry breeders and DNA Testing Team	
		Genome-wide predictions – initiated	Statistical Genetics Team	
		Major locus genotyping – complete in apple	DNA Testing Team	
		Software to handle genomic selection predictions (including including effects of heterozygotes; polyploidy) – written	Statistical Genetics Team	
		Genome-wide predictions – initiated	Statistical Genetics Team	
	3b. Add non-genetic effects	Data sets for genotype x environment x management – compiled	Apple, peach, sweet cherry, and strawberry breeders and Statistical Genetics Team	Progeny will be selected and advanced with improved confidence based on knowledge of the influence of non-genetic factors compared to genetic factors, including the effects of climates/locales and management practices
		Data uploaded on Genome Database Rosaceae – in progress	Data Management Team	
		Genome-scan data to fill data gaps – initiated	DNA Testing and Statistical Genetics Teams	

Objective	Challenge	Plan for Tackling
3 Advance Selections with Improved Confidence	**3a.** Accuracy of genome-wide predictions can not be determined as it is affected by linkage disequilibrium, trait heritability, training population size, and training and selection population similarity	Testing the genome-wide selection strategy in four crops, with multiple cycles possible in strawberry, will allow for empirical validation over a range of breeding situations

Table 3 cont.: Objective 3 – Year 2 Planned Deliverables

Objective	Sub-Objective	What	To Whom	Impact
3 Advance Selections with Improved Confidence	3a. Add genetic background effects	Selection populations of peach and sweet cherry genotyped for significant trait loci – completed	Apple, peach, sweet cherry, and strawberry breeders and DNA Testing Team	Progeny will be selected and advanced with improved confidence based on knowledge of significant and non-significant loci influencing trait variation
		Selection populations phenotyped for 2016 season – completed	Apple, peach, sweet cherry, and strawberry breeders	
		Genome-wide predictions – in progress	Statistical Genetics Team	
	3b. Add non-genetic effects	Genome-scan data to fill data gaps – completed	DNA Testing and Statistical Genetics Teams	Progeny will be selected and advanced with improved confidence based on knowledge of the influence of non-genetic factors compared to genetic factors, including the effects of climates/locales and management practices
		Data sets for genotype x environment x management compiled – completed	Apple, peach, sweet cherry, and strawberry breeders and Statistical Genetics Team	
		Calculation of genetic and non-genetic sources of variation and their interactions – initiated	Statistical Genetics Team	

Table 4: Objective 4 Deliverables for Year 1 (green) and Challenges (blue)

Objective	Sub-Objective	What	To Whom	Impact
4 Increase Routine Use of DNA Information	**4a.** DNA testing	New DNA tests for discovered disease resistance and fruit quality trait loci – developed	Crop Breeding Teams and service providers for DNA testing	Demonstration breeders have access to DNA-based diagnostics services; lessons learned for commercial providers
		DNA-based diagnostics services for Obj. 1 and 2 – provided	Crop Breeding Teams	
	4b. Software support	*Cross Assist* and *Seedling Select* decision-support software for breeders – enhanced, DNA information added	Crop Breeding Teams and DNA-Informed Breeding Team	Software will serve breeders to make more informed decisions on parent and seedling selection; software will be useful tools for MAB technical training
	4c. Economics of DNA information use	Case studies of cost-benefit analysis of DNA information use in breeding (Univ. of Minn – apple, WSU - cherry) including cost categories and detailed costs within each – obtained	Socio-Economics Team and apple and cherry breeders	Knowledge of relative costs and benefits of various uses of DNA information in breeding and experiences of new adopters will increase impact of DNA information use in breeding
		Case studies of DNA informed breeding adoption (MSU - peach, WSU - strawberry) – initiated	Socio-Economic Team and peach and strawberry breeders	
	4d. Technical training in routine use of DNA information in breeding	Face-to-face *Prunus* breeder visits in California and southeastern U.S. – conducted	U.S. Rosaceae breeders	Rosaceae crop breeders benefit from use of DNA information to achieve greater efficiency, accuracy, and superior cultivar releases; knowledge of successes and limitations in DNA-informed breeding adoption identifies strategies and weaknesses to focus future efforts
		DNA test cards for strawberry and peach breeders with brochures – completed	Peach and Strawberry breeders	
		Online content for breeders – in progress	DNA-Informed Breeding and Extension Teams	
		Successful adoption of DNA-informed breeding by U.S. rosaceous crop breeders – quantified; Pitfalls and limitations – identified	External Evaluator	

Objective	Challenge	Plan for Tackling
4 Increase Routine Use of DNA Information	**4a.** Genome-scanning resolutions and technologies are constantly changing	Close collaborations with other international users and commercial service providers of genome-scanning and DNA-testing platforms will allow us to meet current and changing genotyping needs of the rosaceous crop community for affordable, accessible, and varied genotyping capability. Prepare each trait-locus DNA test for use on a range of genotyping platforms
	4a. Trait locus DNA testing platforms are varied and changing	
	4c. Cost:benefit analyses of case studies might not apply to other programs	Templates will be provided for breeders to calculate costs and benefits for their own program

Table 4 cont.: Objective 4 Year 2 Planned Deliverables

Objective	Sub-Objective	What	To Whom	Impact
4 Increase Routine Use of DNA Information	4a. DNA testing	DNA tests from Obj. 1 and 2 – developed	Crop Teams and DNA Testing Team	Demonstration breeders have access to sustained DNA-based diagnostics services; lessons learned for commercial providers
		DNA testing services transitioning to fee-based – initiated	Crop Teams and DNA Testing Team	
	4b. Software Support	Data to support DNA information use added to software – ongoing	DNA-Informed Breeding Team and DNA Testing Team	Software will serve breeders in making more informed decisions on parent and seedling selection; software will be useful tool for MAB technical training
	4c. Economics of DNA information use	Case studies of cost-benefit analysis of DNA information use in breeding (Univ. of Minn – apple, WSU - cherry) including cost categories and detailed costs within each – ongoing	Socio-Economics Team and apple and cherry breeders	Knowledge of relative costs and benefits of various uses of DNA information in breeding and experiences of new adopters will increase impact of DNA information use in breeding
		Case studies of DNA informed breeding adoption (MSU - peach, WSU - strawberry) – ongoing	Socio-Economics Team and peach and strawberry breeders	
	4d. Technical training in routine use of DNA information in breeding	Continued content development for breeder visits adjusted using Year 1 feedback – completed	DNA-Informed Breeding and Extension Teams	Rosaceae crop breeders benefit from use of DNA information to achieve greater efficiency, accuracy, and creativity culminating in superior cultivar release; knowledge of successes and limitations in DNA-informed breeding adoption identifies strategies and weaknesses to focus future efforts
		MAB Workshop – conducted	DNA-Informed Breeding and Extension Teams	
		Face-to-face breeder visits – conducted	DNA-Informed Breeding and Extension Teams	
		Successful adoption of DNA-informed breeding by U.S. rosaceous crop breeders – quantified; Pitfalls and limitations – identified	External Evaluator	

Table 5: Objective 5 Deliverables for Year 1 (green) and Challenges (blue)

Objective	Sub-Objective	What	To Whom	Impact
5 Utilize Stakeholder Input	**5a.** Cultivar adoption case studies	Case studies of strawberry and peach cultivar release – initiated	Socio-Economics Team and strawberry and peach breeders	Insight into decision-making received from peach and strawberry industry members about new elite selections will inform cultivar development and release strategies
	5b. Industry stakeholder engagement	Activities, outcomes, and impacts communicated at Year 1 Advisory Panel meeting – conducted	Advisory Panel members	Feedback received and needs addressed. Stakeholders value benefits of DNA-informed breeding. Stakeholders use DNA information made available with new cultivar releases to support their adoption decisions
		Outcomes and impacts communicated through electronic media and presentations at industry meetings – delivered	Industry stakeholders	
		Jargon-free material using breeding program specific language and a common project-wide format – developed and delivered	Crop Breeding Teams	
		Stakeholder input provided to breeders on DNA informed breeding – received	RosBREED Executive Committee	

Objective	Challenge	Plan for Tackling
5 Utilize Stakeholder Input	**5a.** Results of case studies may not be widely applicable	Document survey tools, economic models, and analytical methods for other programs to follow
	5a. Small sample sizes for case studies of cultivar adoption	Supplement case studies with clicker surveys of larger audiences at grower meetings
	5b. Industry stakeholder participation in communication and engagement opportunities may be low	Stakeholders will be offered repeated, varied opportunities to engage and contribute their feedback and recommendations
	5b. Content development of success stories, newsletter articles, and social media posts	A schedule of topics and proposed authors will be developed to ensure steady flow of information is delivered to stakeholders via various communication methods.

Table 5 cont.: Objective 5 Year 2 Planned Deliverables

Objective	Sub-Objective	What	To Whom	Impact
5 Utilize Stakeholder Input	5a. Cultivar adoption case studies	Case studies of strawberry and peach cultivar release – ongoing	Socio-Economics Team and strawberry and peach breeders	Insight into decision-making received from peach and strawberry industry members about new elite selections will inform cultivar development and release strategies
	5b. Industry stakeholder engagement	Activities, outcomes, and impacts communicated at Year 2 Advisory Panel meeting – conducted	Advisory Panel members	Feedback received and needs addressed. Stakeholders value benefits of DNA-informed breeding. Stakeholders use DNA information made available with new cultivar releases to support their adoption decisions
		Outcomes and impacts communicated through electronic media and presentations at industry meetings – delivered	Industry stakeholders	
		Jargon-free material using breeding program specific language and a common project-wide format – developed and delivered	Crop Breeding Teams	
		Stakeholder input provided to breeders on DNA informed breeding – received, summarized and items addressed	External Evaluator, RosBREED Executive Committee	

Implement "Marketing Plans" For Stakeholders
AP Member Recommendations Yr 1

Breeders

Product we are providing: DNA diagnostics

Marketing Plan: Undertake a user-friendly approach to interact with breeders:

- Provide a clear web-based breeder toolbox with easy to interpret on-line and hard copy content
- Provide a contact person who potential customers can contact for information and support
- Know the customer – provide one-on-one assistance as requested

Allied Scientists

Products we are providing: Genetic populations, DNA-based tools and new knowledge amenable for discovery research in pathology, physiology, food science, entomology, as well as clarified breeder needs

Marketing Plan: Present RosBREED project-wide outcomes at diverse scientific conferences to publicize successful examples of research enabled by RosBREED. Place numerous, timely research manuscripts in journals with appropriate audiences.

Industry

***Product we are providing*:** Increased breeding efficiency and effectiveness, emphasizing disease resistance and other high-priority industry needs

***Marketing Plan*:**

- Communicate success stories focused on industry priorities using clear, well-illustrated one page summaries (branded as "RosBRIEFs")
- Support breeder-industry partnerships through development of requested content
- Identify and highlight technical connections, continuity, and leveraged public/private funding enabled by RosBREED 1

Consumers

***Products we are providing*:** Cultivars with improved eating/aesthetic qualities

***Marketing Plan*:** Showcase superior phenotypes and provide clear examples of consumer-oriented selection criteria

RosBREED's Demonstration Breeders' Annual Report for Year 1 (9/1/2014 – 8/31/2015)
Progress in DNA-Informed Breeding
Summarized by Michael Coe, Cedar Lake Research Group LLC

Respondents: 15 breeders representing 20 rosaceous crop breeding programs (see page 11)

Breeder-Industry stakeholder engagement about DNA-informed breeding in Year 1

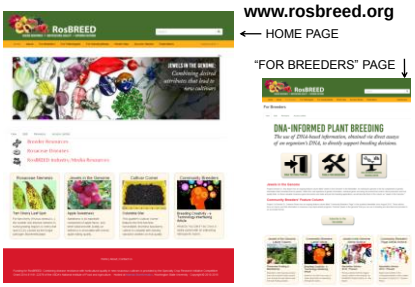
Status

- All RosBREED breeders engaged their regional stakeholders in formal or informal communications about DNA-informed breeding practices or opportunities. Formal presentations or publications for growers and other industry stakeholders were reported by 17 of the 20 programs. Sixteen of the 20 programs reported informal discussions with stakeholder groups or individuals, focused on DNA-informed breeding opportunities.
- Stakeholders have expressed interest and positive attitudes towards DNA-informed breeding and the RosBREED project. The project has obtained much input from stakeholders, but so far general requests for further information and communication have been received, rather than specific requests or recommendations.

Breeders' Recommendations

- Printed handouts, such as RosBRIEFs and DNA test cards, were seen as useful; more of these on additional topics would be appreciated, including how resistance or tolerance factors would be manifested in new cultivars (e.g., slower defoliation or no defoliation; no/fewer lesions or smaller/different lesions; reduced infection rates, etc).
- Slides and graphics for use in presentations would be helpful; for example, slides for use in explaining how DNA information is developed and used, and slides or materials focused on success stories.
- Outreach and engagement strategies may differ for specific crops or crop groups and this should be taken into account. Breeders working together with the RosBREED Extension Team to develop an outreach communications strategy for particular crop industries could be helpful.
- It is important not to oversell the current and potential impact of DNA information.

Addressing Breeders' Needs



RosBREED Breeders' Annual Report for Year 1 Cont.

Breeding program use of DNA information

Status

- Fifteen programs reported use of DNA information in the past year; five programs new to RosBREED had not begun using DNA tests for breeding applications, but were preparing to do so.
- Ten programs reported using DNA information for verifying or understanding germplasm identity, relatedness, or parentage; one other program reported being in the process of implementing this.
- Eleven of the 20 programs reported using DNA information for parent selection or planning crosses; two others reported being in the process of implementing this.
- Eight of the 20 programs reported using DNA information for seedling selection or culling; four others reported being in the process of implementing this.

Breeders' Recommendations

- Continued development of DNA tests (for trait loci of value)
- More information about sources of useful alleles
- Reducing costs of DNA testing and/or increased funding for program operations and personnel
- More personnel trained to perform essential activities for using DNA information
- Software tools and training for manipulating and analyzing genotypic and phenotypic information
- Assistance with interpretation of DNA testing results

Action items developed based on Demonstration Breeders' reports

- Develop complementary slides, brochures, handouts, and online materials which can be used separately or together, using similar style and content so as to reinforce each other and the RosBREED "brand"
- Identify and publicize crop-specific success stories about DNA-informed applications in the context of overall breeding program activities; do not oversell
- Identify and publicize non-crop-specific RosBREED 2 success stories, and success stories about students and technical staff members from RosBREED 1 – where they are now, how they were affected by RB experiences
- Continue outreach through the website, newsletter, events, conferences, interactions with stakeholders, etc.
- Respond to Demonstration Breeder recommendations and needs

Discussion Questions for Break-out Session

Question 1. ***Genomics Research***

What are the key emerging opportunities for DNA informed breeding that are arising from worldwide Rosaceae genomics research and how can RosBREED best facilitate their use in breeding programs?

Question 2. ***Breeding-Industry Interface***

What's new (or gaining in importance) in industry that breeders need to know about and that RosBREED can help address?

What's new (or gaining in importance) in breeding that industry should know about and how can RosBREED help address this?

Question 3. ***Project Outreach***

Are our stakeholder "marketing plans" (page 27) on target? Suggestions? Are the RosBREED communication tools being effectively employed?

- RosBREED web site
- Quarterly Newsletter
- RosBRIEFs
- eXtension
- Social media
- Annual RosBREED Advisory Panel meetings
- Commodity group meetings
- Individual breeding program interactions with their industries and other breeders (page 28-29)
- Others?