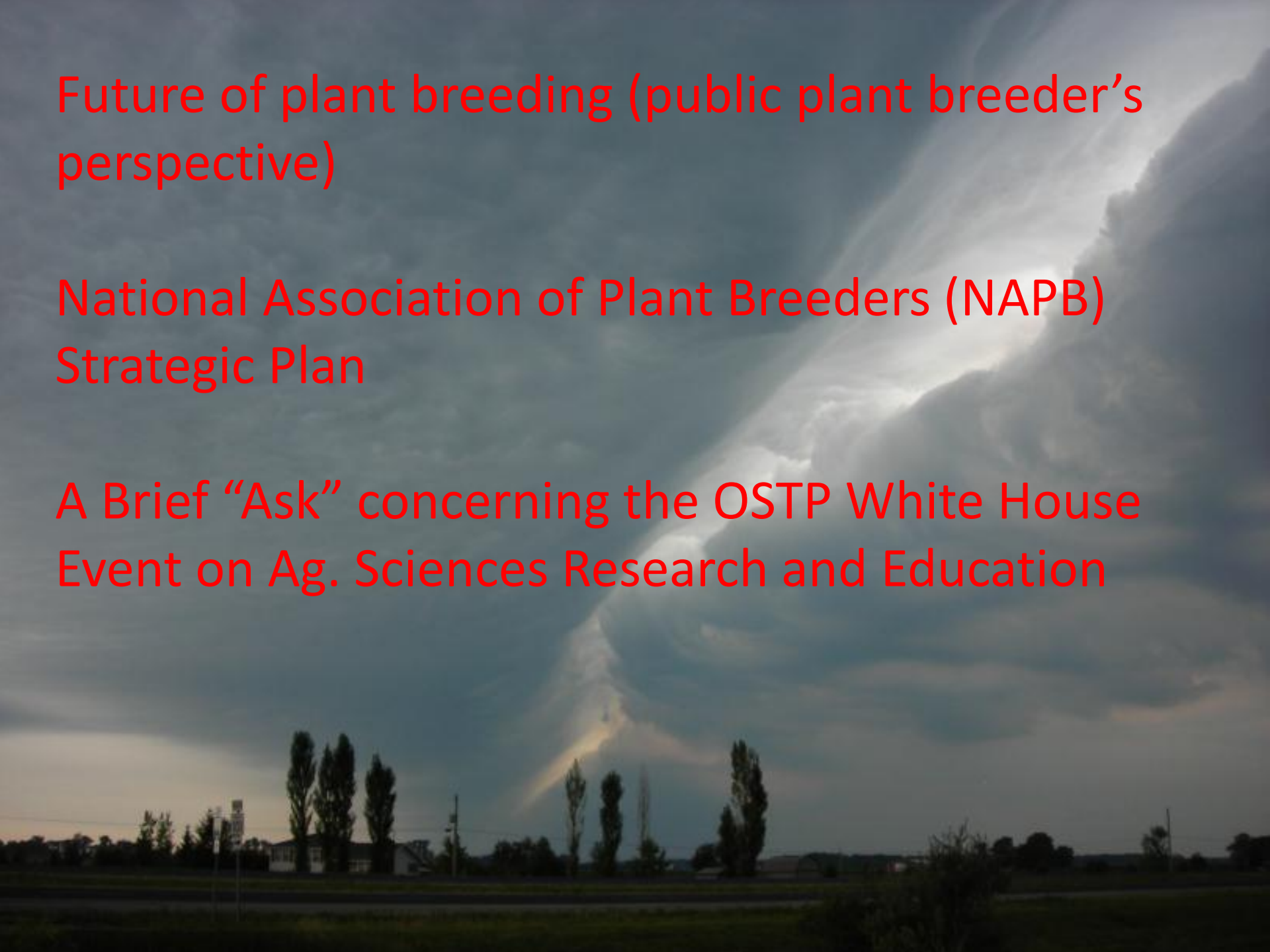
So many genomes, so little time: the future of plant breeding

(apologies to Webb Miller, Nature Biotechnology 18:148 - 149 (2000))

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

National Association of Plant Breeders
NAPB
Improving Plants to Improve Lives


Future of plant breeding (public plant breeder's perspective)
National Association of Plant Breeders (NAPB) Strategic Plan
A Brief "Ask" concerning the OSTP White House Event on Ag. Sciences Research and Education

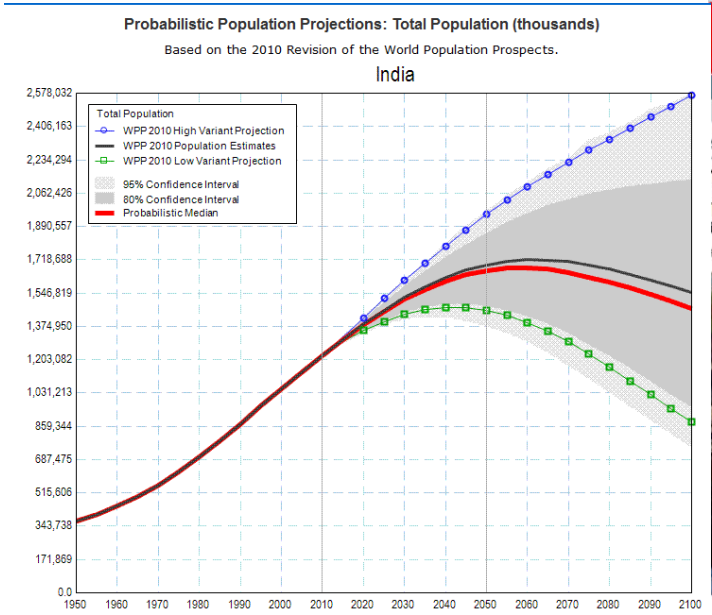
Shameless promotion of plant breeding

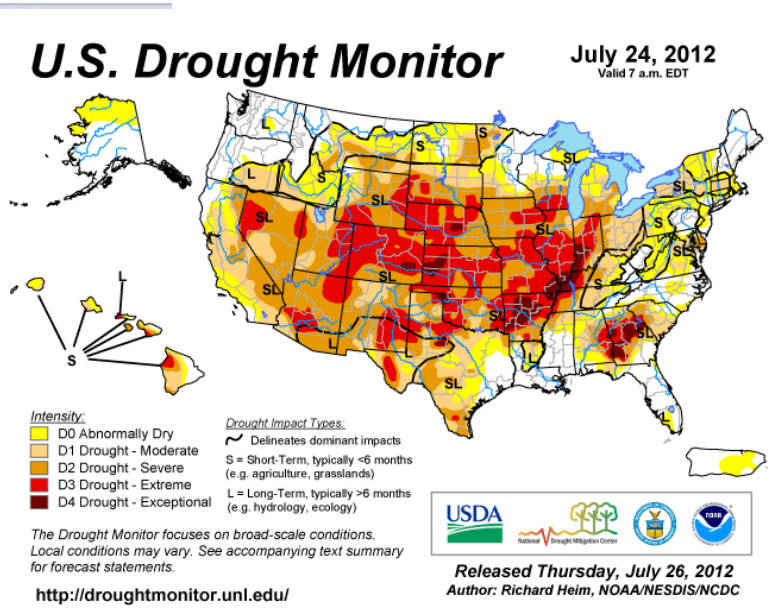
Not because other disciplines in the Ag. Sciences are less important but because:

- Translational potential for investment in genomics
- Serves as a key node in multi-disciplinary teams
- Record of solving problems
- Ability to mitigate risk (diversity of crops and diversity within crops)
- Position in University IP portfolios
- Projected needs in domestic Ag. Science hires

Examples from OSU research

The issue: How do we harness the power of science and education to develop and produce high quality crops that contribute to sustainable agricultural production and human health in the face of population growth and climate instability?





http://esa.un.org/unpd/ppp/index.htm

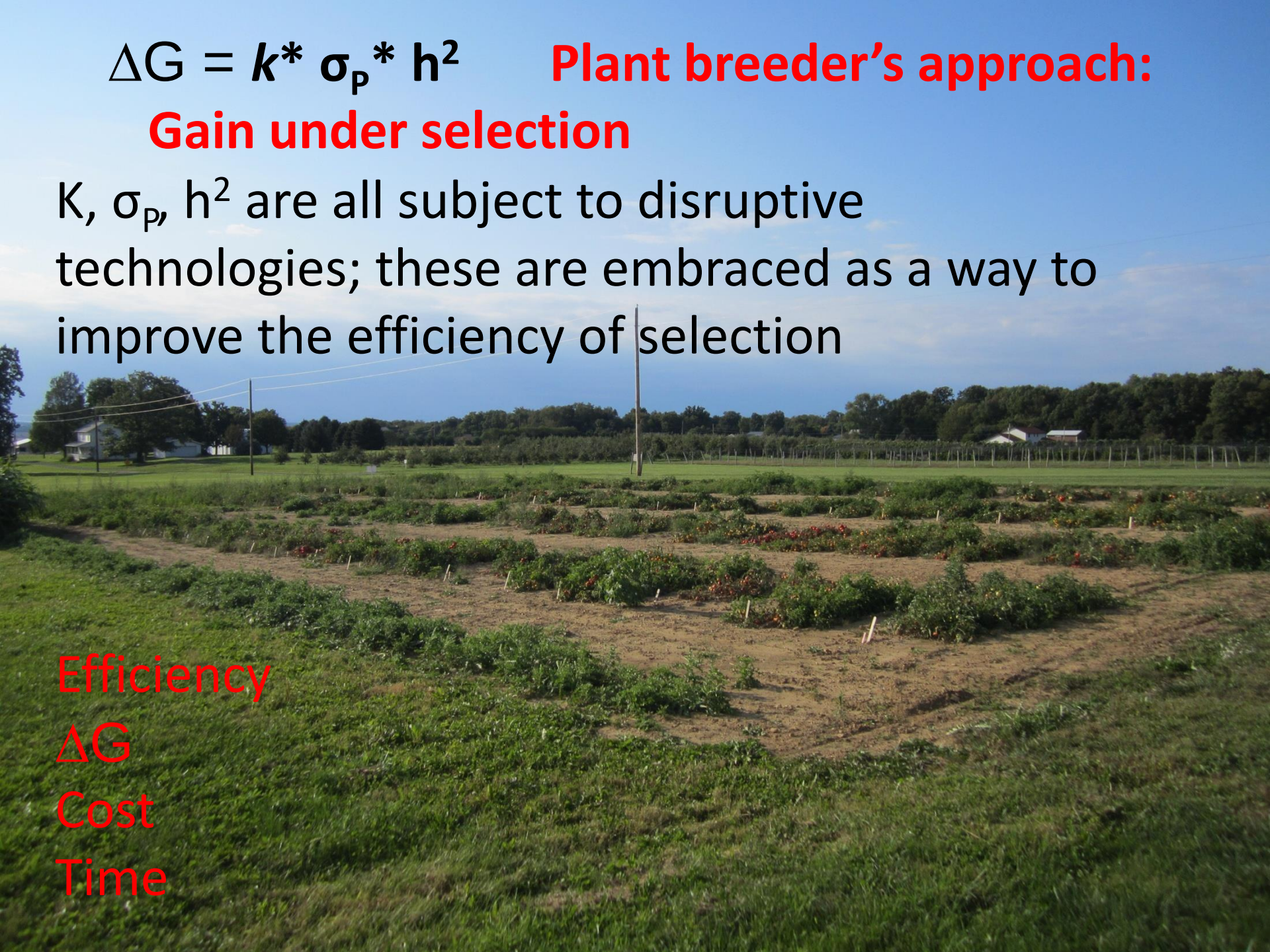
Bayesian Probabilistic Population Projections for 2045 = median: 9.0 billion; 95% interval: 7.8-10.3 billion

Response includes expertise in getting water off of fields and getting water on to fields. “It took a while to learn how to do that…”

$\Delta G = k^* \sigma_P^* h^2$ **Plant breeder's approach:**

Gain under selection

K, σ_P, h^2 are all subject to disruptive technologies; these are embraced as a way to improve the efficiency of selection



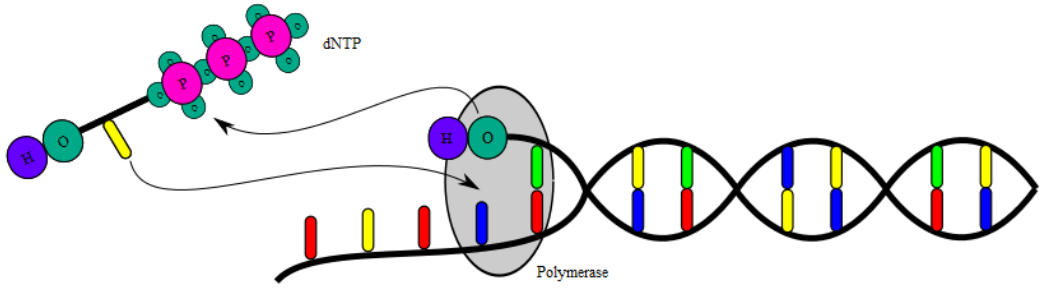
Efficiency
ΔG
Cost
Time

So many genomes…

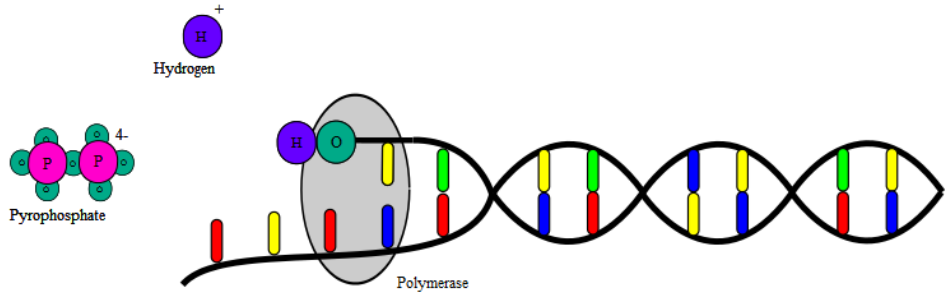
Disruptive technologies: sequencing by synthesis and parallel detection of hydrogen or pyrophosphate

1) Discovery of new alleles

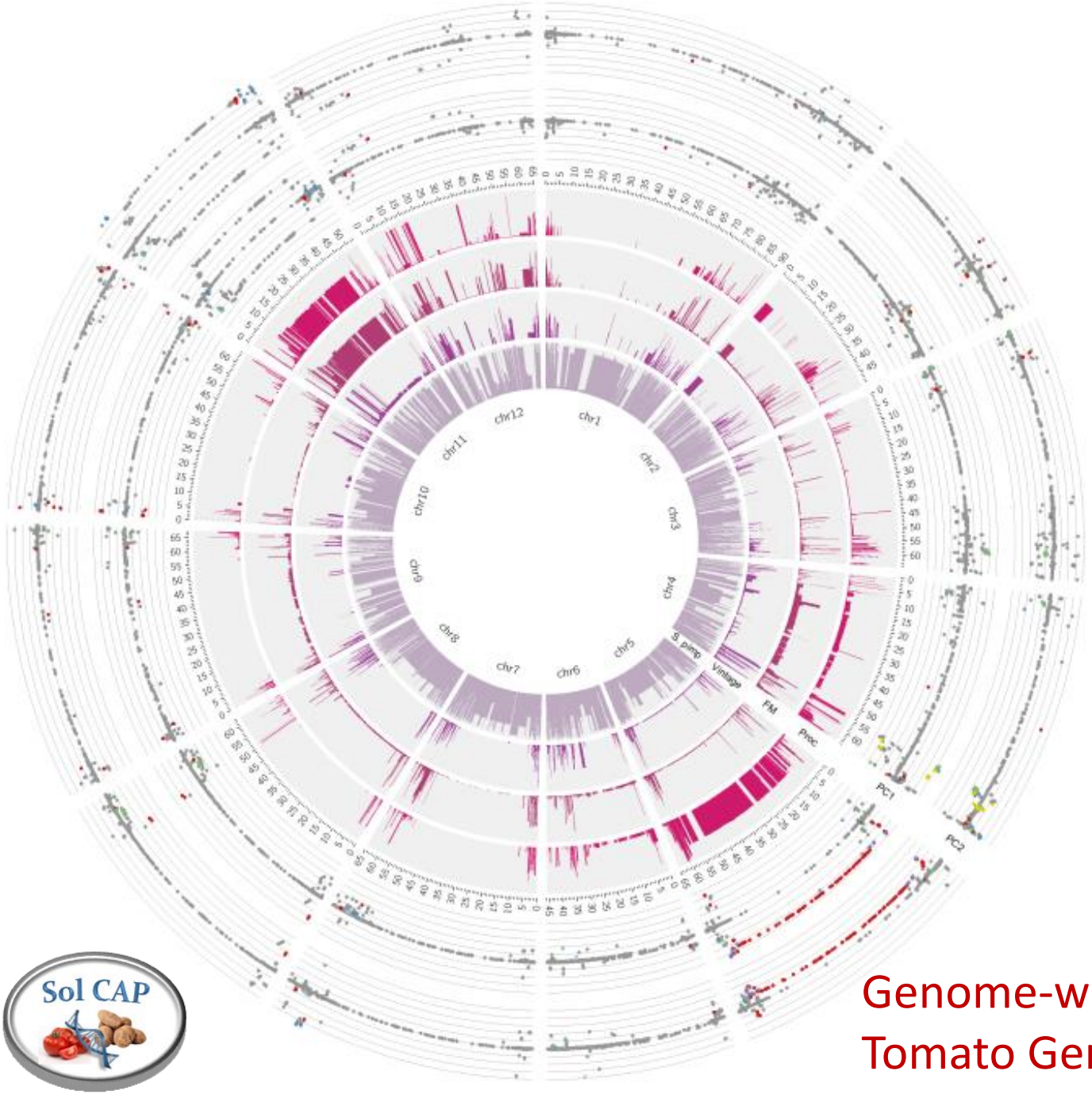
2) Predict performance based on genotype



Polymerase integrates a nucleotide.



Hydrogen and pyrophosphate are released.



MAF

- Processing
- Fresh Market
- Vintage
- S. pimpinellifolium

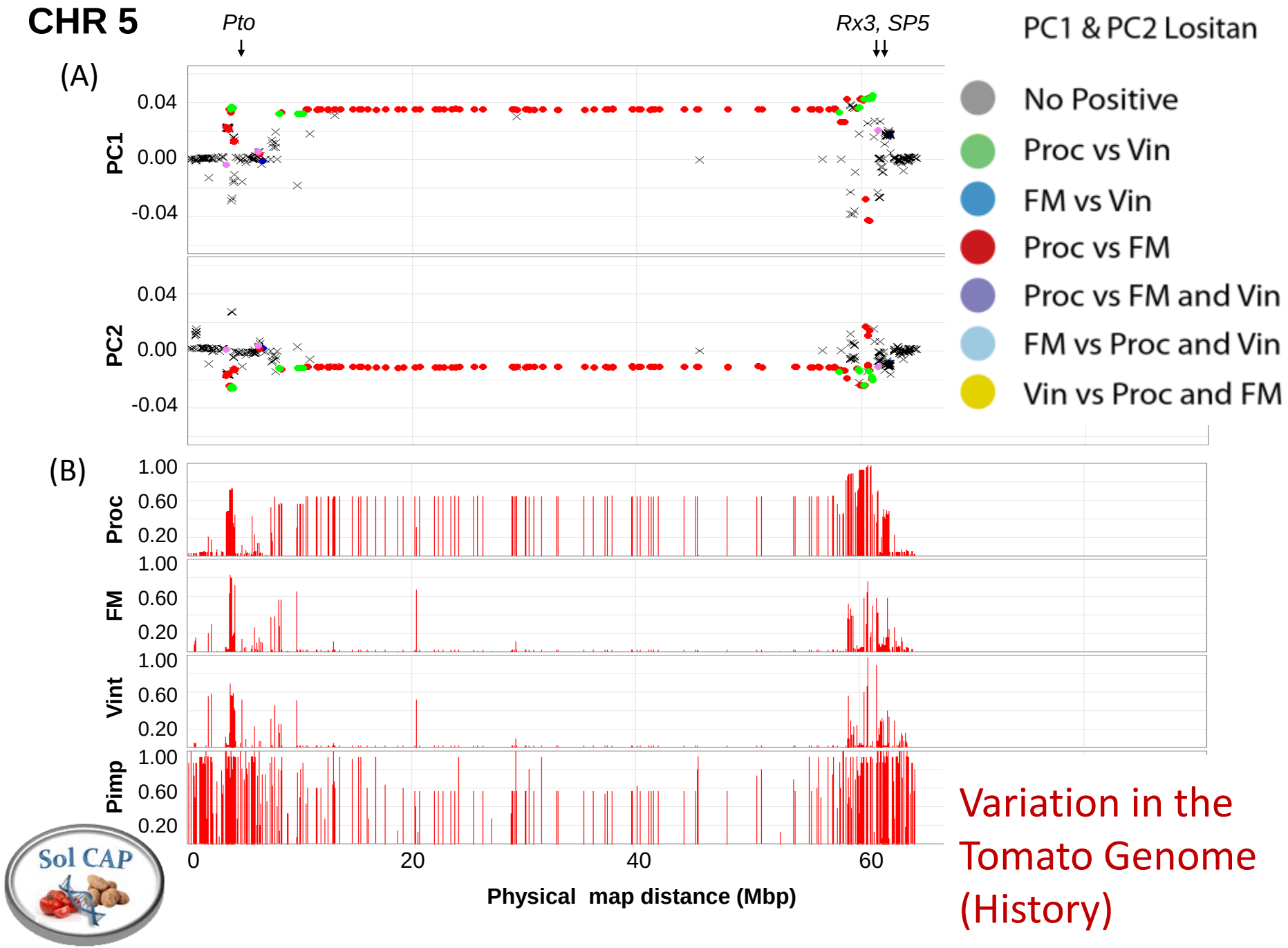
Loci under selection

PC1 & PC2 Lositan

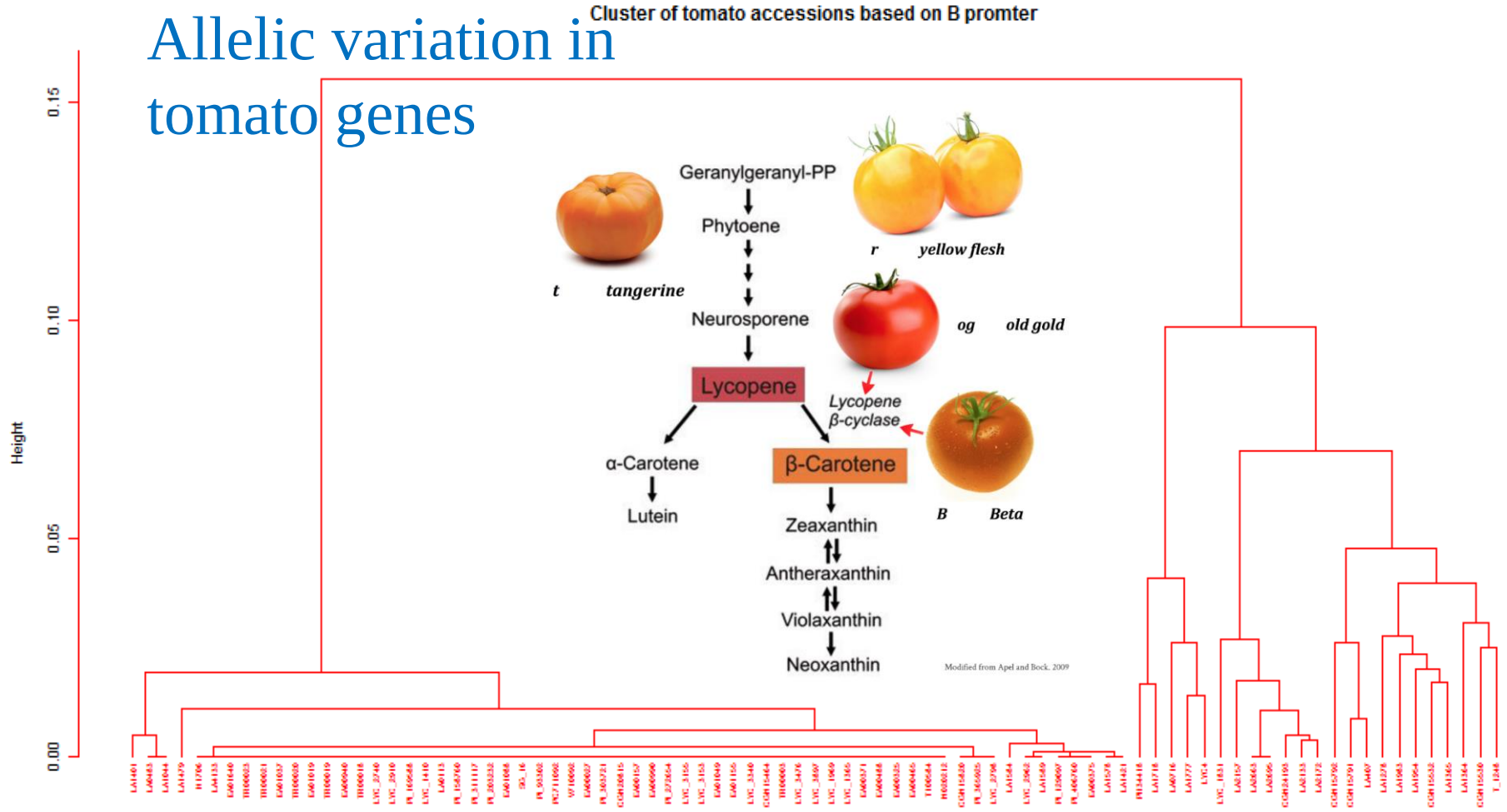
- No Positive
- Proc vs Vin
- FM vs Vin
- Proc vs FM
- Proc vs FM and Vin
- FM vs Proc and Vin
- Vin vs Proc and FM

Sol CAP

Genome-wide variation in the Tomato Genome (History)

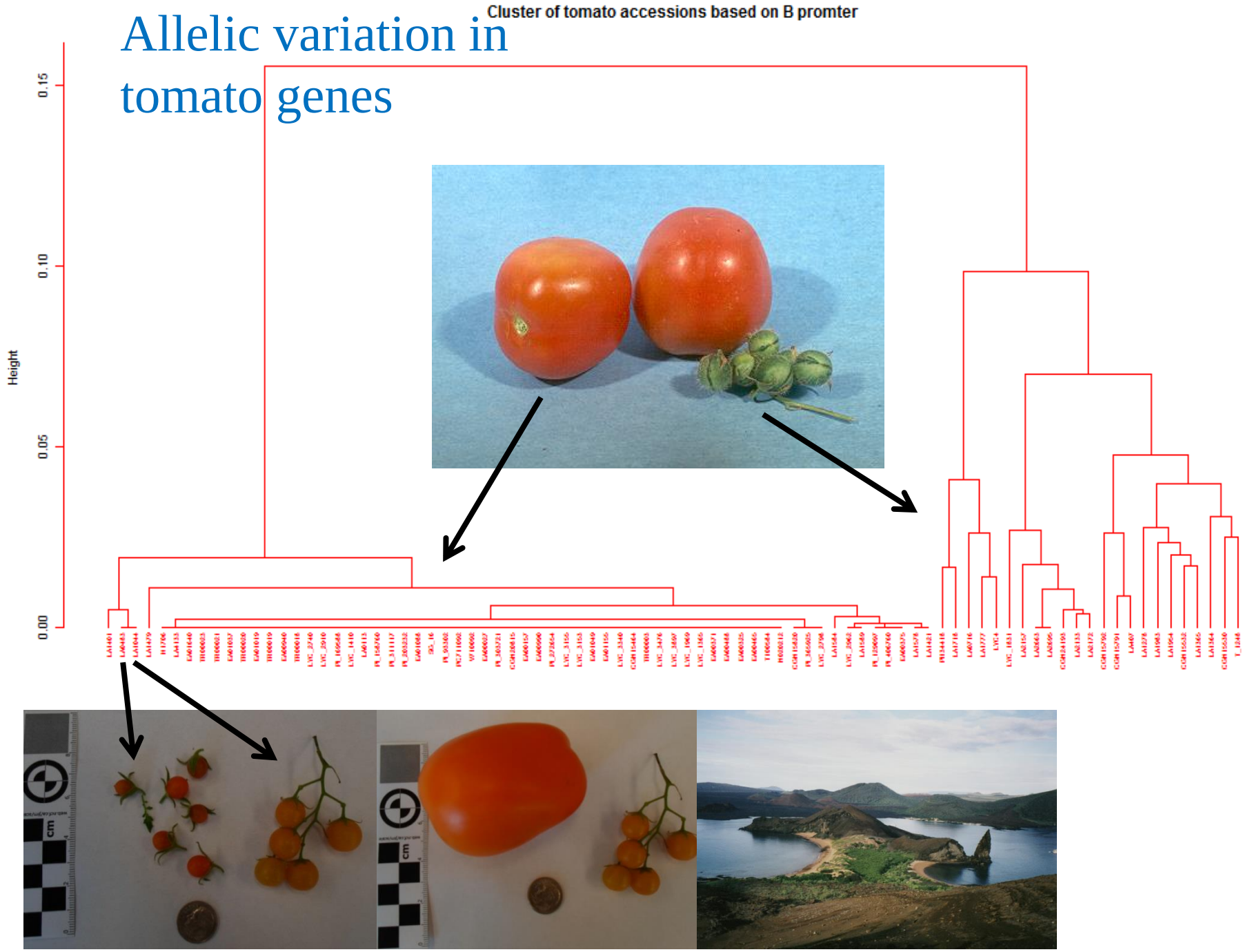

CHR 5
Pto
Rx3, SP5
(A)
PC1
PC2
0.04
0.00
-0.04
PC1 & PC2 Lositan
No Positive
Proc vs Vin
FM vs Vin
Proc vs FM
Proc vs FM and Vin
FM vs Proc and Vin
Vin vs Proc and FM
(B)
Proc
FM
Vint
Pimp
1.00
0.60
0.20
0
20
40
60
Physical map distance (Mbp)
Sol CAP
Variation in the Tomato Genome (History)

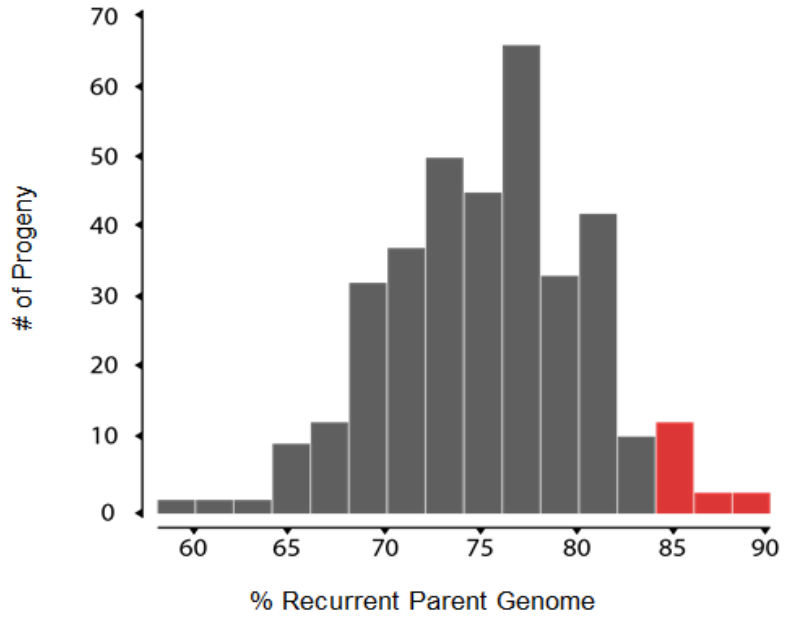
Allelic variation in tomato genes

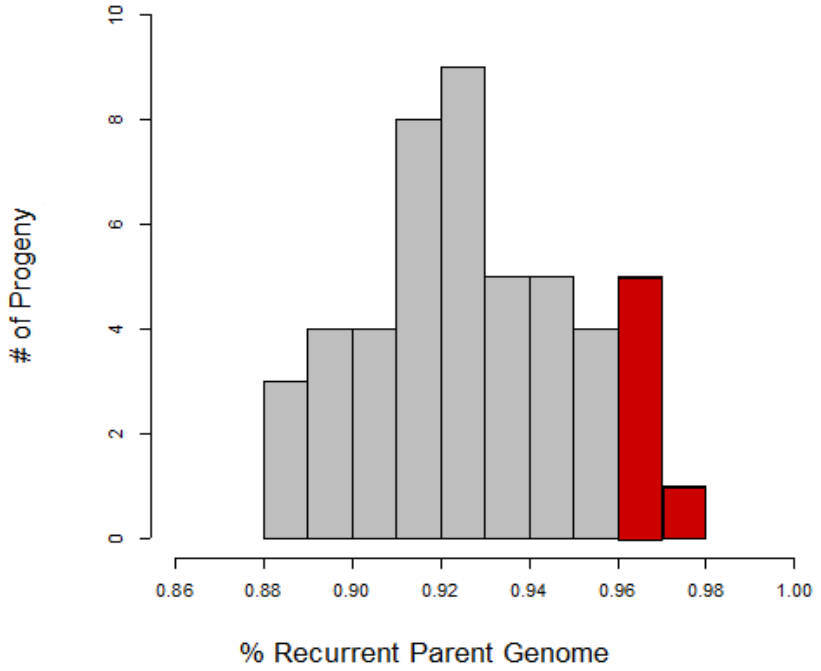


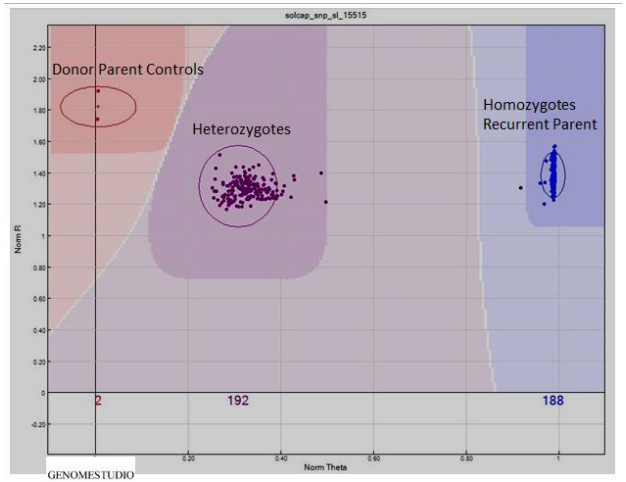
- Variation in tomato genes (future)
- 30 or more alleles within structural genes
- 30 or more alleles within 5’ untranslated regions

Allelic variation in tomato genes





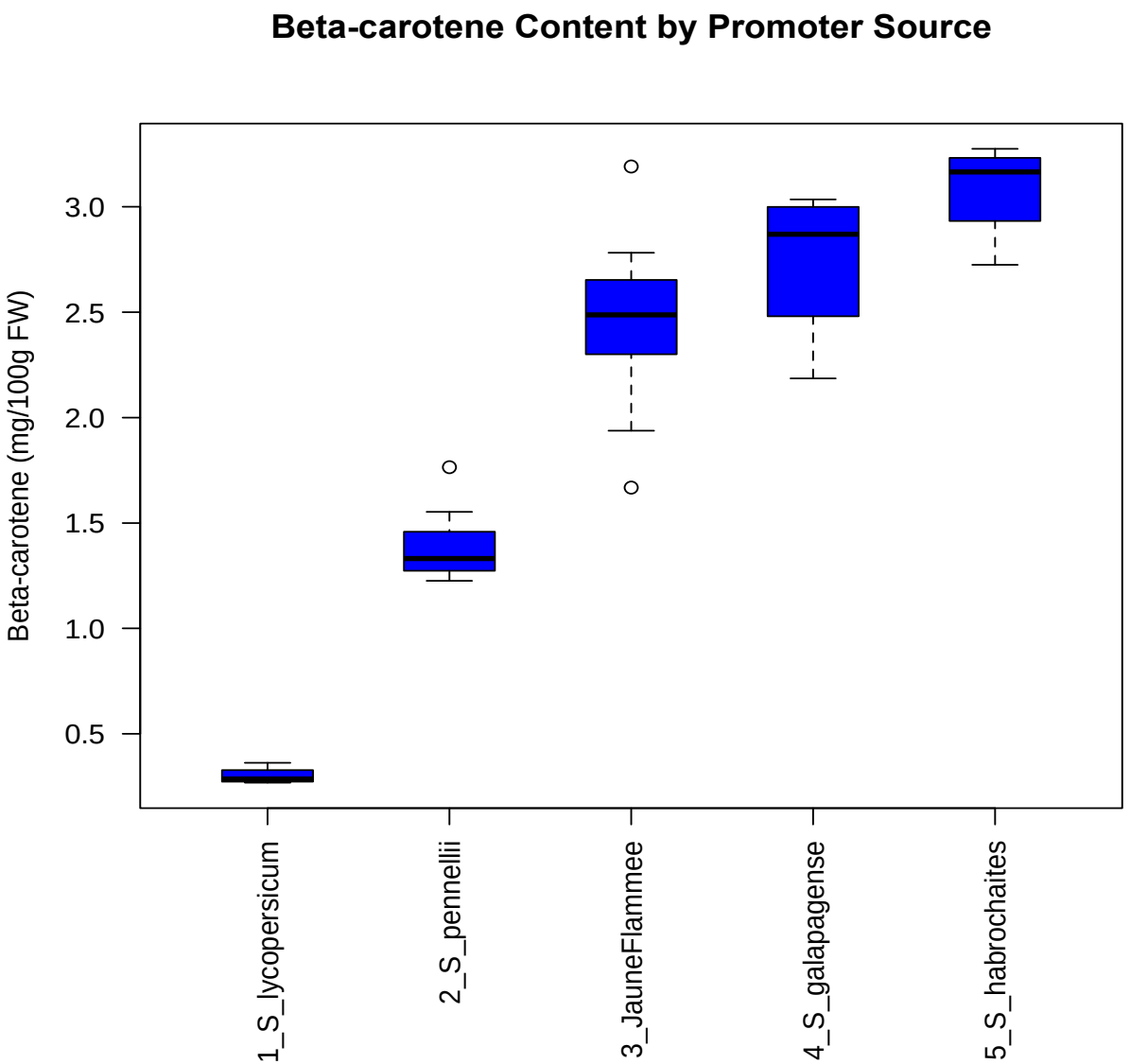




SolCAP team (sequence resources); HCS Greenhouses; OARDC branch farms; FST Pilot Plant; Schwartz lab at OSU; Clinton lab at OSU; Illumina; LGC Genomics;

illumina® LGC Genomics incorporating KBioscience

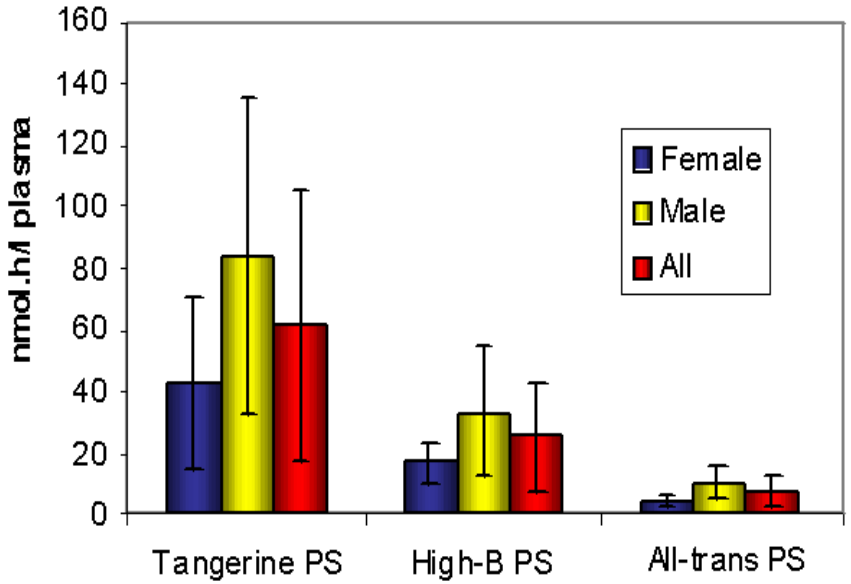
Sol CAP



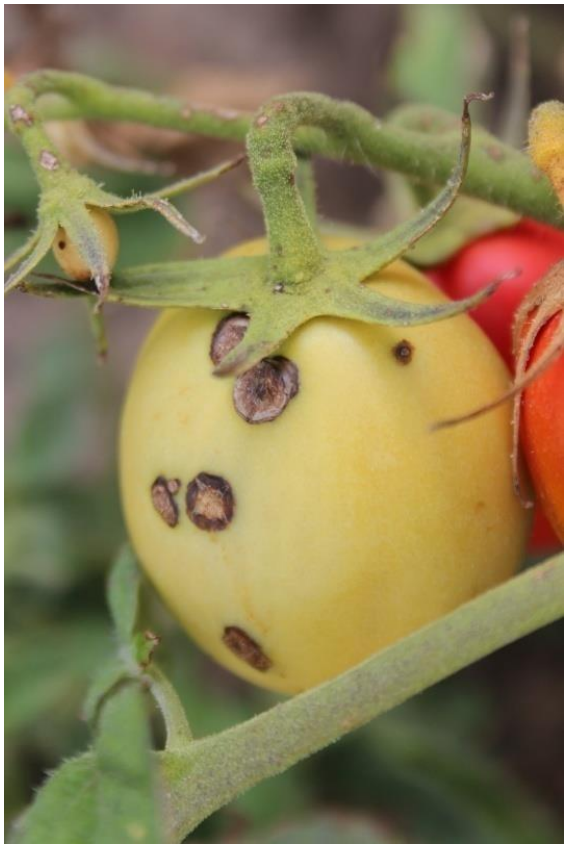
Conclusion:

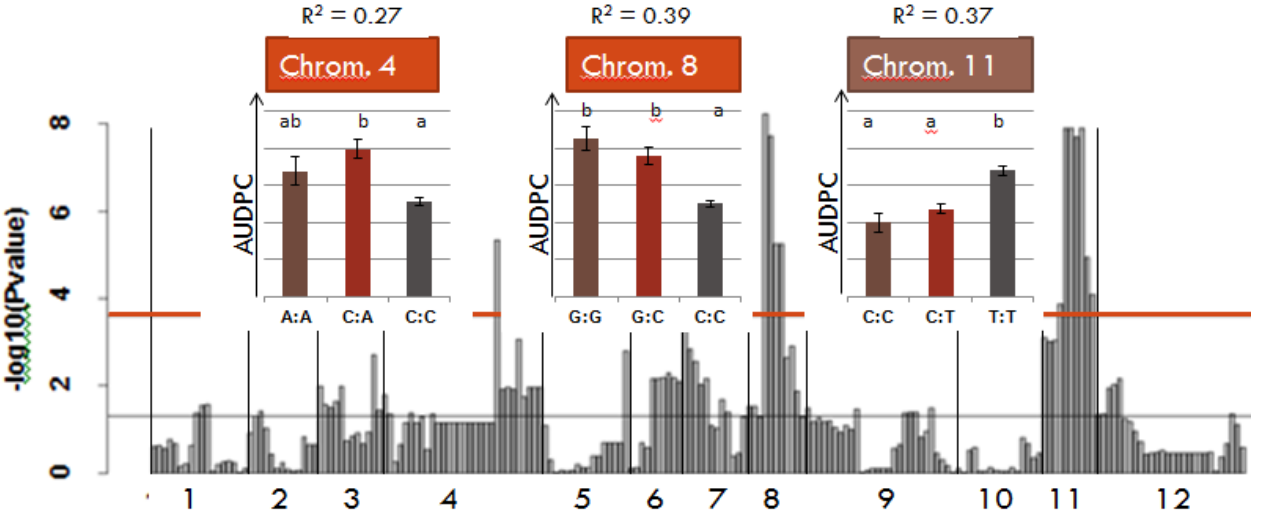
Within the context of a MS, new alleles can be identified, bred into cultivated background, and evaluated for function.

Result: 1) Plant genetic resources with novel high beta-carotene alleles to study carotenoid availability and efficacy in animal and human trials; 2) Association of putative causal SNPs with phenotype.



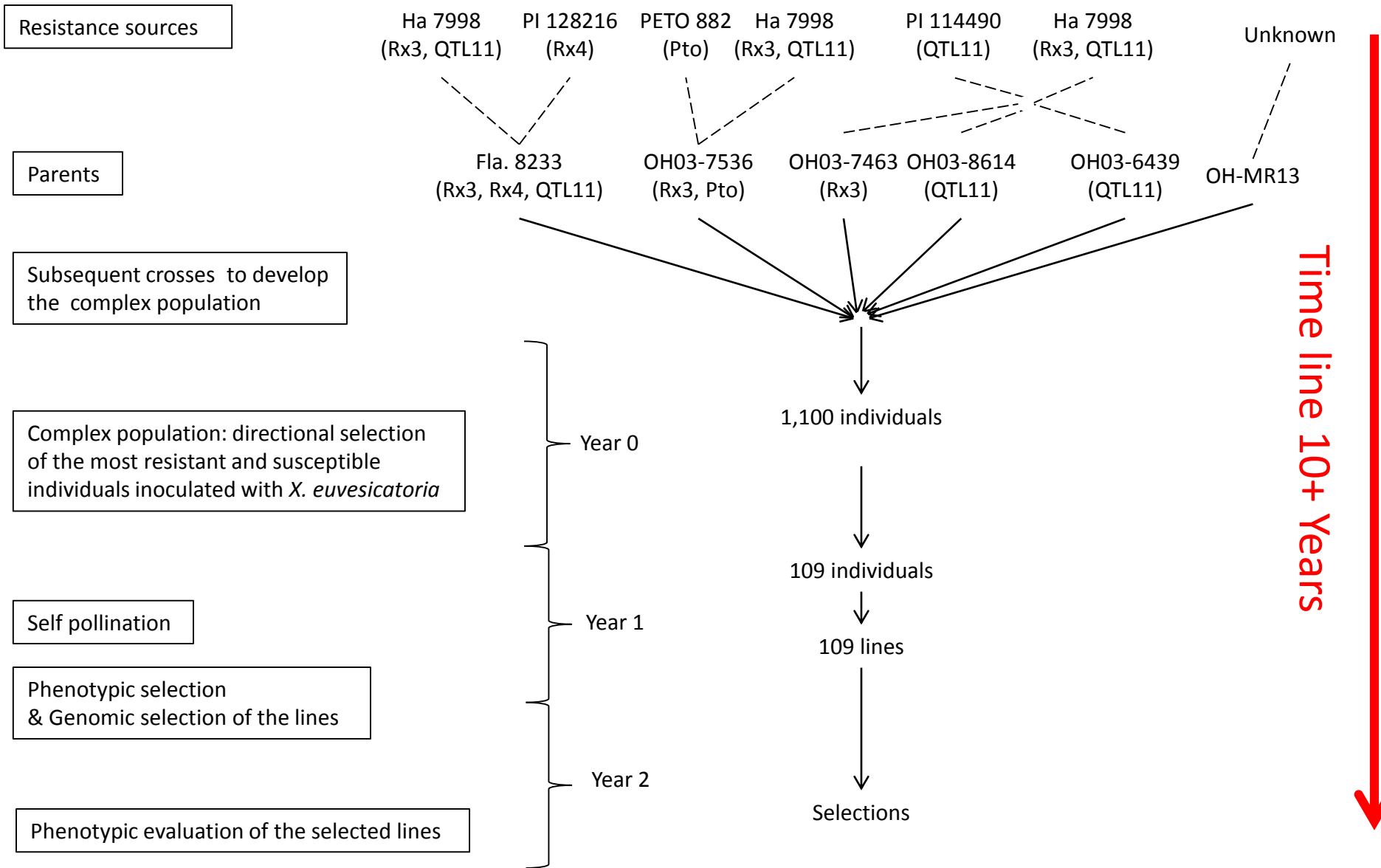
Disease Resistance (Emerging disease "Black Spot" *Xanthomonas gardneri*, 2009): Predicting performance – an empirical validation of genomic selection models



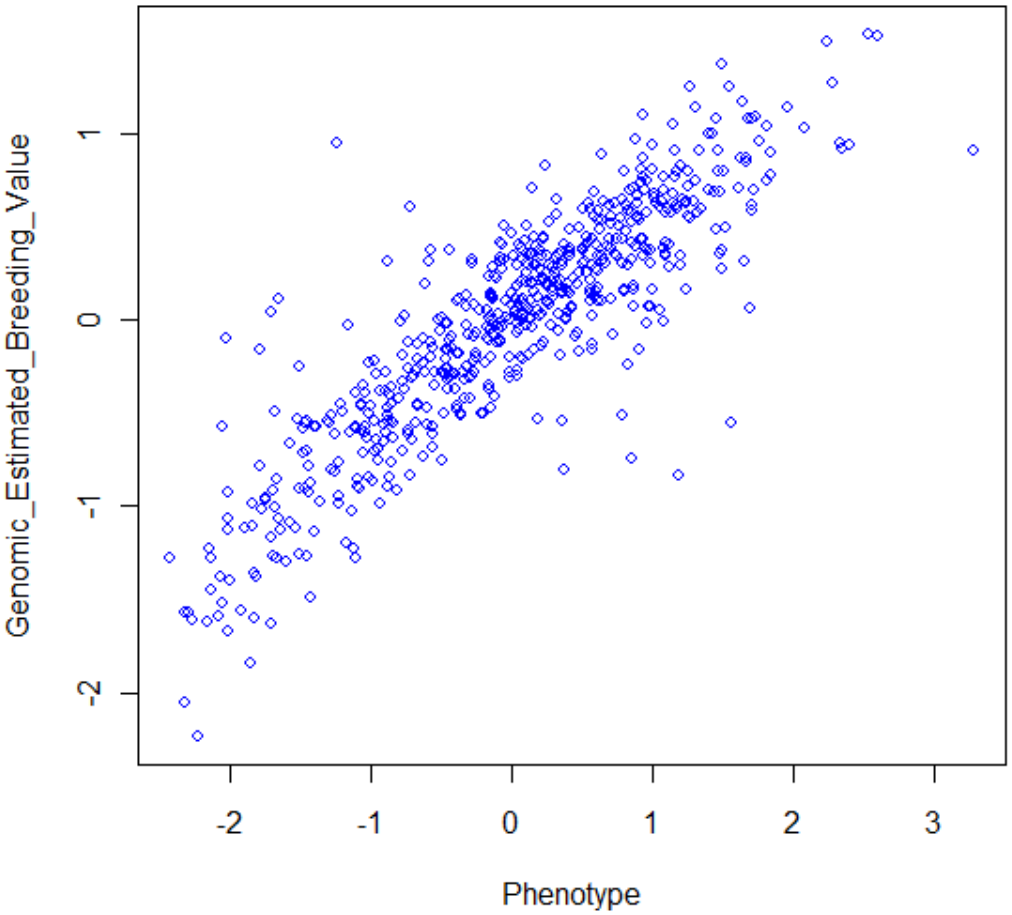


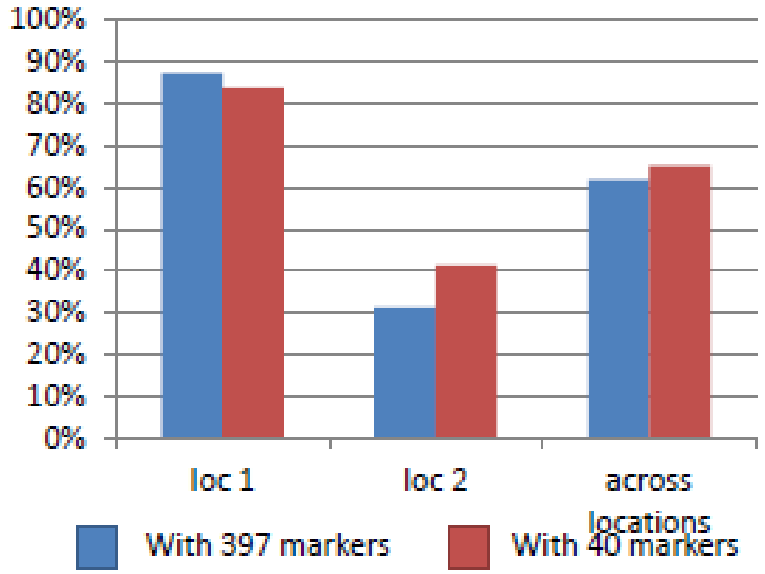
SolCAP team (sequence resources); HCS Greenhouses; OARDC branch farms; Miller lab at OSU; Scott group at UFL; Illumina; LGC Genomics;

Population and workflow



Disruptive Technologies: Computational power, open source software, statistical innovations. When coupled to highly efficient genotyping = power to predict progeny performance (Genomic Selection)





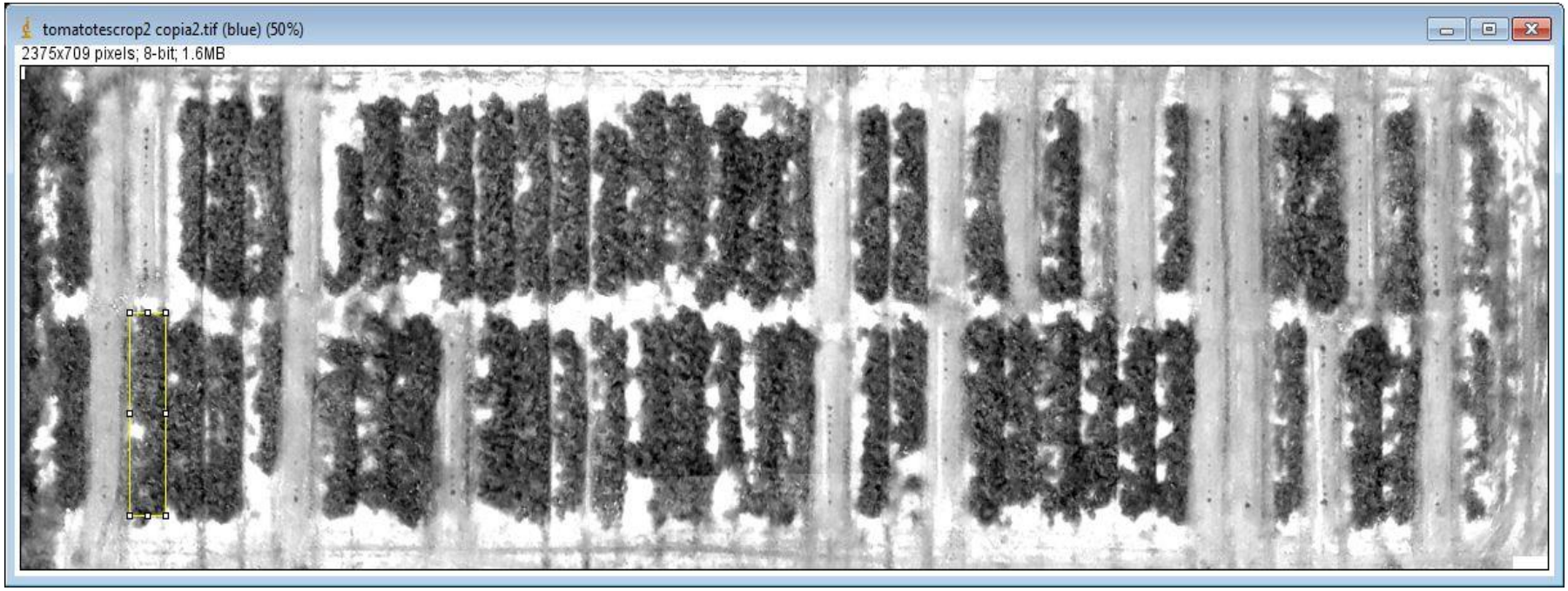
Result: 1) Plant genetic resources to address a problem (inbred parents and hybrids evaluated at commercial scale); 2) Accurate knowledge of genome position for effective alleles; 3) Models for off-season selection.

Other Disruptive Technologies:

Biological (Doubled haploids and Genome Editing)

Engineering (biological assessment through remote sensing and image analysis)

IP (open source seeds initiative)



The Future of Plant Breeding

OHIO STATE

The Future of Plant Breeding

Look hard at what needs to be done “in house” and what can be outsourced (core service providers)

We do less wet-lab work despite increasing sequencing and genotyping 100x

Computational (bioinformatic and statistical genetics) demands have increased.

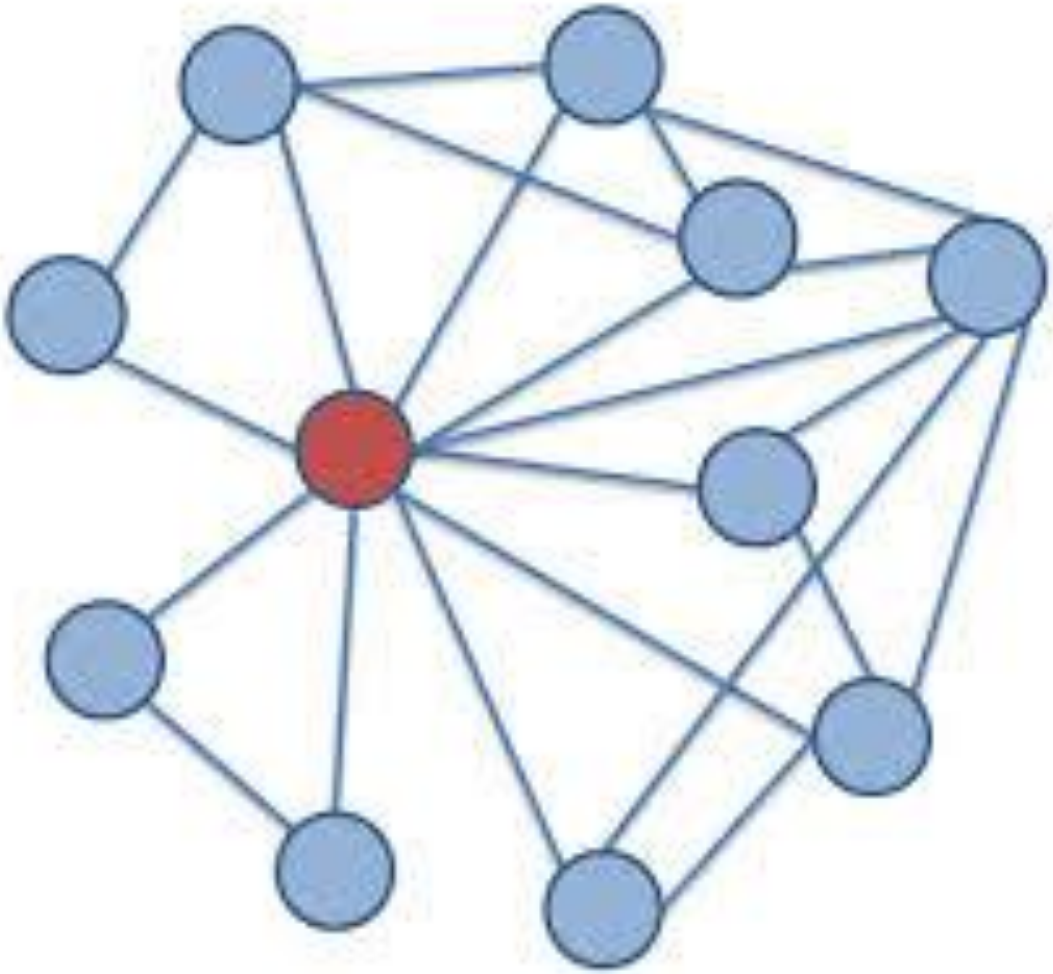
Our core strength – field and greenhouse capacity is more important than ever (> biological assessment capacity 80%)

The Future of Plant Breeding

"beyond mountains there are mountains“

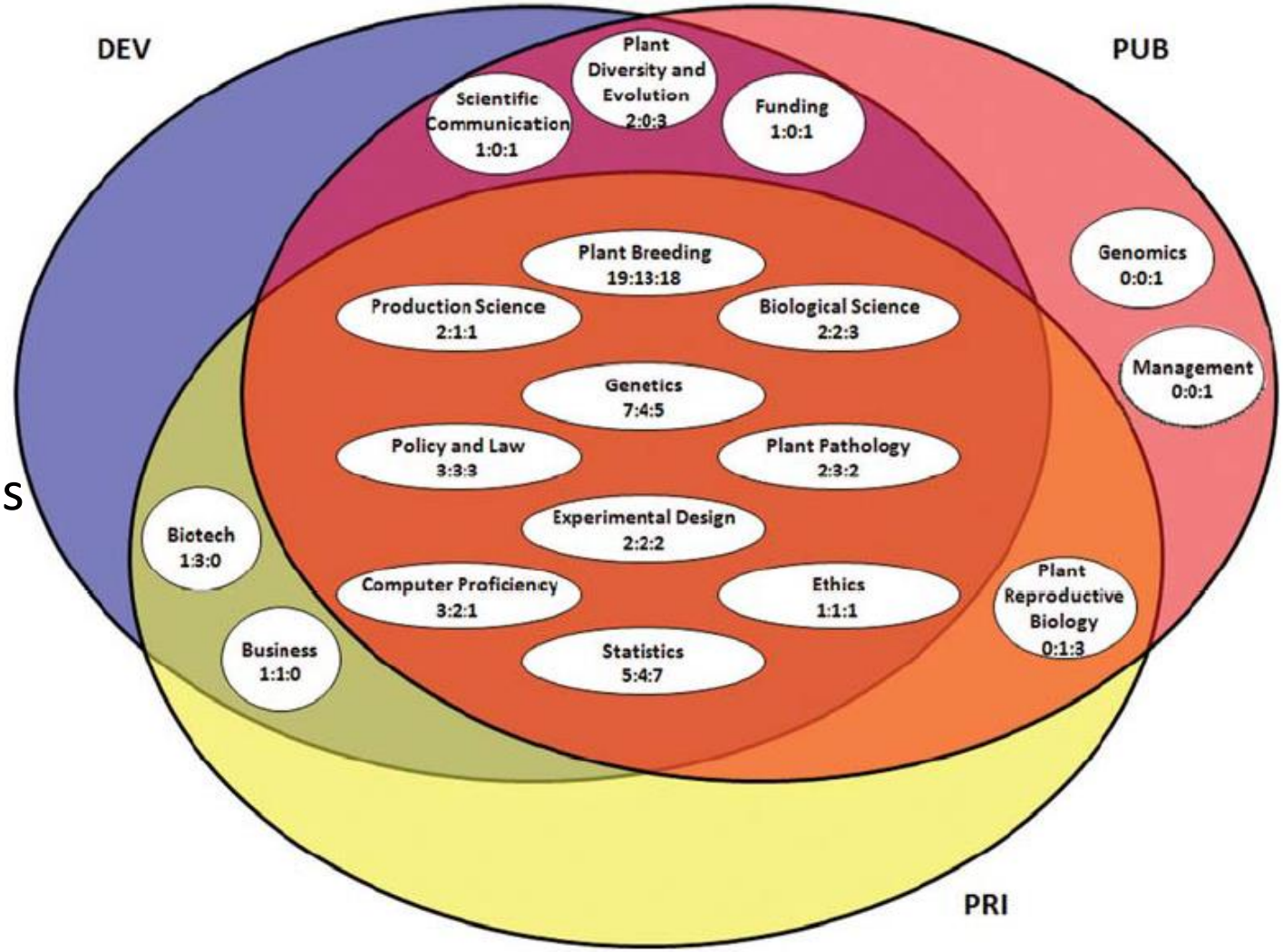
- Plant breeding requires:
  - development of multi-generation populations
  - evaluation under relevant conditions
  - a long-term endeavor

Educating the next generation of plant breeders



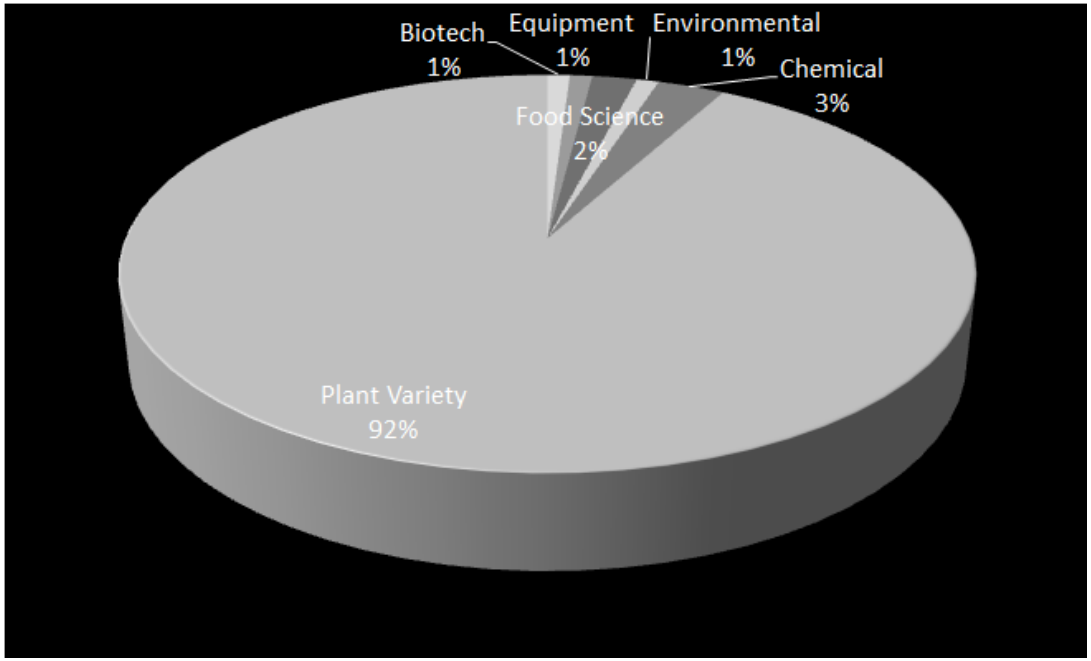
Plant breeding community has identified educational themes (Delphi study).

Several initiatives are moving forward (on-line courses, workshops, curriculum revisions)



Miller et al., 2011. Journal of Natural Resources & Life Sciences Education. Vol. 40 p. 82-90

Rapinski et al., 2011. Crop Science. vol. 51 p. 2325-2336



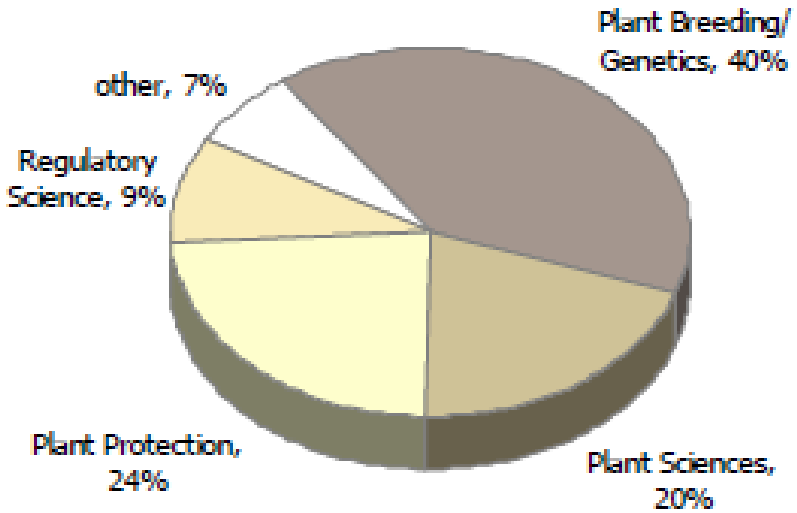
Justifying Continued Investment:

Plant Varieties account for 20% of Land-Grant IP portfolios and 92% of royalty income; there are abundant jobs for graduates

EXHIBIT 4

Domestic Ag Scientist Hires by Discipline

Percentage of FTEs



base: six largest responding CSAW companies

Distribution of Land-Grant University Intellectual Property portfolios (A) and Royalty Income (B). Source: UC Compilation of IP for top tier Ag. Universities; 2012 Peer Review Survey (University of Florida); Coalition for a Sustainable Agricultural Workforce (CSAW)

Take home messages:

- Reason for optimism for the future of plant breeding
- New technology is invigorating the field
- Abundant Sequence data allows exploration of new alleles
- High-throughput genotyping permits efficient (time and cost) prediction and selection
- Plant Breeding is a nucleating discipline within the plant sciences; solving real-world problems requires an alliance of disciplines.
- Driver of technology and innovation in the agricultural sciences
- Risk mitigation through increased diversity of crops and genetic diversity within a crop
- Demand for students is high
- Requires development of multi-generation populations
- Requires evaluation under relevant conditions
- A long-term endeavor

National Association of Plant Breeders

NAPB

Improving Plants to Improve Lives

Plant Breeding Coordinating Committee

NAPB, PBCC Strategic Planning

History

2006 2007 2008 2009 2010 2011 2012 2013 2014

Formation of the Plant Breeding Coordinating Committee (SSC080 also known as PBCC)

The PBCC sponsored the first national Plant Breeding Workshop in Raleigh, NC

Public outreach arm of the PBCC was named the National Association of Plant Breeders

PBCC Survey of breeders research priorities and needed infrastructure

Independent NAPB was created

Two organizations began holding joint annual meetings

NAPB begins developing organizational and governance policy

Strategic Planning Began

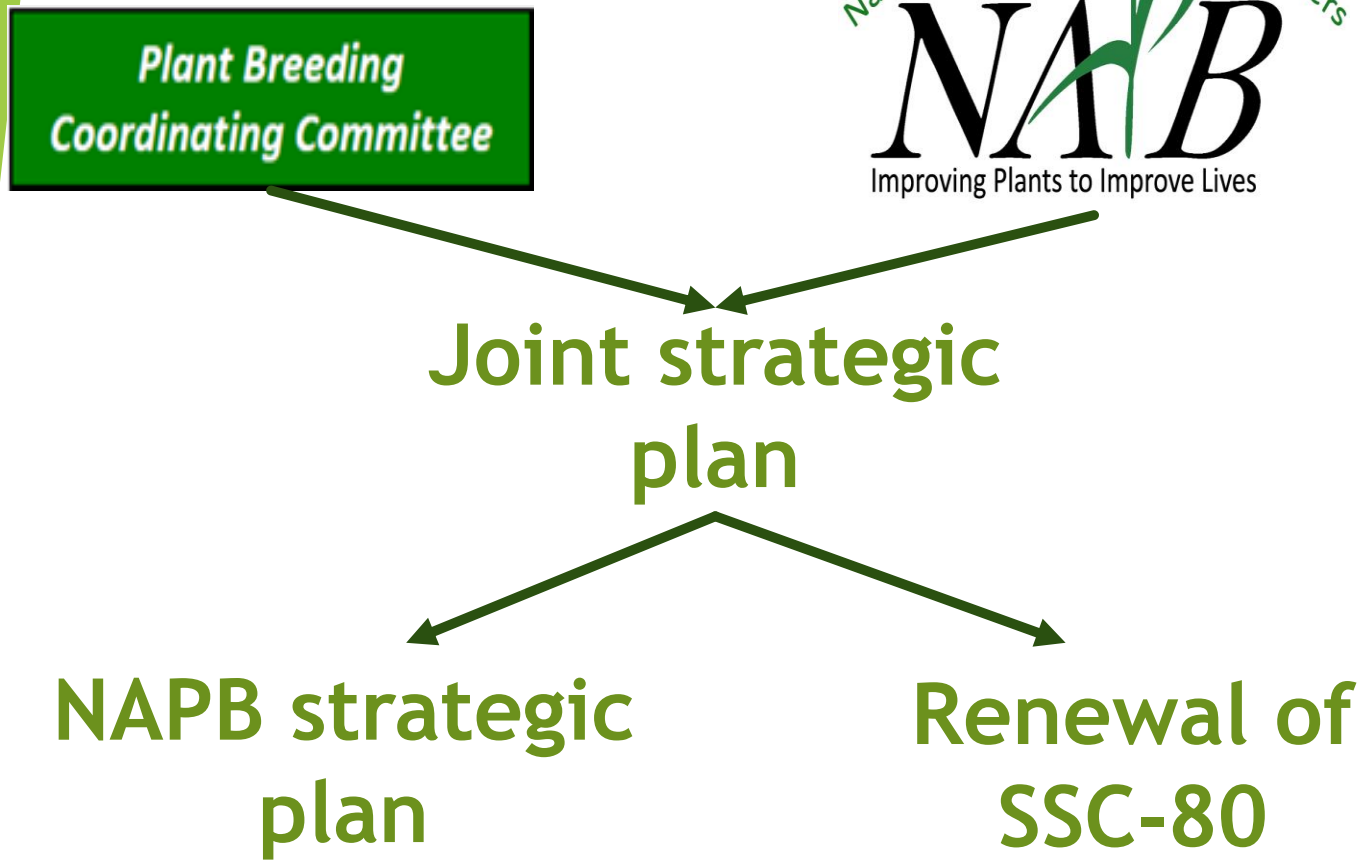
NAPB Idea

NAPB Hatched

NAPB needs to fly

Participants

- Ellen Cull- Consultant
- Minneapolis Meeting: Liz Lee, Patrick Byrne, Jamie Sherman, Duke Pauli, Barry Tillman, David Francis, David Stelly, Shelly Jansky, Seth Murray,, Allen Van Deynze, Shelby Ellison, Heather Merk, Donn Cummings, Don Jones, Wayne Smith, Eric Young, Ann Marie Thro, Phillip Simon, Bill Tracy, Mike Gore, Thomas Luebberstedt
- Distilling Group: Jamie Sherman, Donn Cummings, Mike Gore, David Francis, Barry Tillman



https://www.plantbreeding.org/about-us/

Distinctions

Structure and role well defined with distinct boundaries

Criteria	PBCC	NAPB
Organization type	Multistate Activity	Professional Society
Established by	State Agricultural Experiment Stations and USDA-NIFA	Members
Ownership	Land Grant University System	Independent
Membership	One official per SAES designated by Director; anyone else by request	Anyone by registering through the web site. Recently rolled out paid membership.
Primary activity	Coordinate activities to solve plant breeding problems of common interest	Scientific exchange Advocate for plant breeding Recognize achievements
Recommendations are made to	Land grant university and USDA leaders; state and federal agencies; Congress ONLY if asked	State or federal legislators; any other federal, state, or private entity
NIFA may request comments	Directly through the National Program Leader representative member	Only in open public forum widely announced in advance
Educational targets	Everyone	Everyone

Products and goals

Products of the process

- A strategic plan that outlines:
  - Missions and roles of PBCC and NAPB
  - Five-year goals
  - Major initiatives / areas of focus to accomplish the goals in the next five years
- An action plan that outlines:
  - Initial steps to implement the goals in the subsequent one to two years
  - Clarification of lead responsibility for the actions

www.plantbreeding.org

Six objectives (https://www.plantbreeding.org/about-us/goals-and-objectives)

Six Goals of NAPB

1) **Support for plant breeding:**
   Increase support for plant breeding among decision makers in the public and private sectors

2) **Public plant breeding capacity:**
   Increase public and private support for cultivar development and germplasm improvement in public institutions

3) **Education of plant breeding professionals:**
   Strengthen education for plant breeding professionals at all levels of experience

4) **Public awareness:**
   Increase public awareness of plant breeding and what it contributes to the public good

5) **Membership:**
   Strengthen and increase value provided to the membership

6) **Organization:**
   Strengthen the NAPB organization

Strategic Plan Goal 3

Goal	Objectives – 5-year	Objectives- 10 to 15-year	Possible Measures

Education of plant breeding professionals: Strengthen education for plant breeding professionals at all levels of experience	• Identify and disseminate best practices for plant breeding education to include experiential learning as well as improved curriculum with increased focus on graduating upper level students who are field-ready.
	• Explore and implement public-private collaborations to recruit and support training of plant breeders.
	  ○ Support for students – Expand public / private collaboration to provide support to plant breeding students for their training.
	  ○ Recruitment of students – Develop and begin implementing public-private partnership program for recruitment
		• Implement methods to encourage consistent, strong university curricula, possibly including: aggregating information on existing curricula, sharing curricula, developing curriculum standards, recommending strong curricula, and / or providing checklists of courses and content.
		• Continue to expand collaborations to recruit and support training of plant
			• Number of plant breeding students who graduate with masters and Ph.D.s field-ready – they know how to work in the field, are able to do the field work of plant breeding
			• Amount of financial support available to graduate students
			• Student access to information leading to

NAPB “ASKs” Federal:

Increase AFRI competitive grant funding (4x)

Increase ARS NPGS funding for germplasm evaluation through CGCs (4x; represents only a slight increase in real funding given static levels over 25 years)

Maintain/Increase Hatch (let us know how we can help)

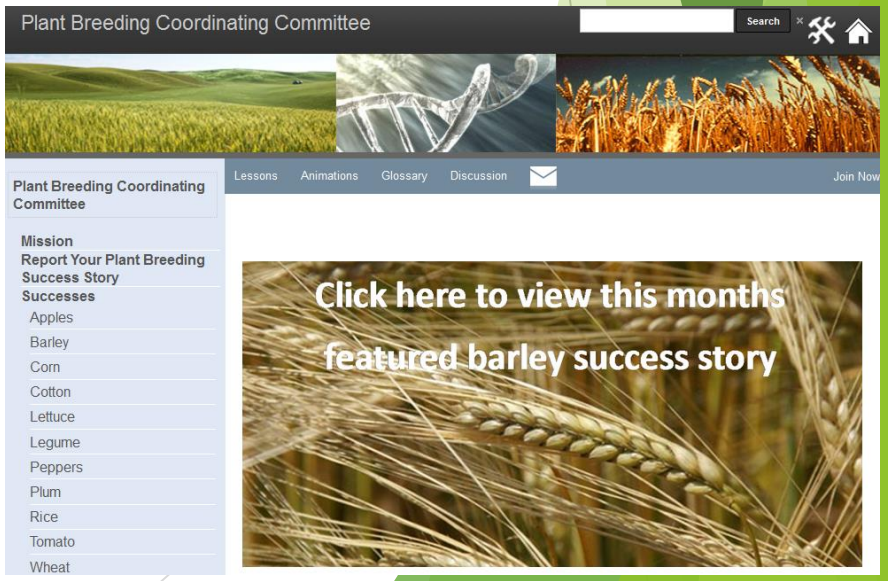
Work with us to develop a national plan based on eco-regions; commodity and specialty crops; emerging (both immediate and 10-year) issues. Goal is to **avoid planning by attrition.**

NAPB “ASKs” Land Grant Universities:

Maintain or even add faculty positions in plant sciences (NAPB recommendations parallel CSAW)

Participate in the Agricultural science research and education OSTP event (individually, regionally, as a whole)

How can we help you?



Example

The White House
Office of the Press Secretary

For Immediate Release June 12, 2015

FACT SHEET: New Commitments in Support of the President's Nation of Makers Initiative

SHARE THIS: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Joint letters and individual letters … committing to a response (see examples)

- More than 70 universities and colleges representing more than 1 million students, from Carnegie Mellon University to the University of Arizona, are doubling down on their efforts to expand Making on their campuses. These institutions, which include a diverse array of community colleges and public and private four-year universities of all sizes, in both **a joint letter and individual letters** to the President are each committing to expand their response to the President's call to action on making. For example:
  - *Bucknell* will open a central on-campus Bucknell MakerSpace, and host "maker jams" that will bring together students from engineering, arts, humanities and the social sciences.
  - *Case Western Reserve University* will open the first phase of a 50,000 square foot makerspace and innovation center – named think[box] – for students, while expanding cross-campus efforts to engage students and community members from different disciplines in making, such as involvement of its law school's intellectual property clinic.
  - *Cornell University's College of Engineering* will create a Makers' Projects website to connect all of the maker and maker-like activities across Cornell and are sponsoring the "Pitch your Prototype" and the Intel-Cornell Cup competitions.
  - *Lorain County Community College (LCCC)* will make its FabLab the forefront of its community-engagement strategy, and expand community access to its on-campus maker spaces.
  - *Santa Clara University* will expand its Maker Lab with new equipment and a larger workspace, incorporating the lab as a

Thank you for your time.

Plant Breeding Coordinating Committee

Search

Lessons Animations Glossary Discussion Join Now

Plant Breeding Coordinating Committee

Mission
Report Your Plant Breeding Success Story
Successes
- Apples
- Barley
- Corn
- Cotton
- Lettuce
- Legume
- Peppers
- Plum
- Rice
- Tomato
- Wheat

D M Francis @Ohio_Tomato · Aug 19
Share your plant breeding success stories:
passel.unl.edu/communities/pb…
Maybe we can get Joe interested @joesbigidea

Joe Palca @joesbigidea · Aug 20
@Ohio_Tomato Hey, I love plant breeding stories, esp. tomatoes ow.ly/R8lbH & ow.ly/R8lbI & ow.ly/R8lbJ

View summary