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

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

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

Efficiency

\(\Delta G\)

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.
Loci under selection
PC1 & PC2 Lositan

Genome-wide variation in the Tomato Genome (History)
CHR 5

(A)

PC1 vs 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)

Variation in the Tomato Genome (History)

Physical map distance (Mbp)
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;
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.

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

Resistance sources

Parents

Subsequent crosses to develop the complex population

Complex population: directional selection of the most resistant and susceptible individuals inoculated with *X. euvesicatoria*

Self pollination

Phenotypic selection & Genomic selection of the lines

Phenotypic evaluation of the selected lines

Year 0

1,100 individuals

Year 1

109 individuals

Year 2

109 lines

Selections

Time line 10+ Years
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

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)
Justifying Continued Investment:
Plant Varieties account for 20% of Land-Grant IP portfolios and 92% of royalty income; there are abundant jobs for graduates.

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
NAPB, PBCC
Strategic Planning
History

2006: NAPB Hatched

2007: The Public outreach arm of the PBCC was named the National Association of Plant Breeders (NAPB) Committee (SSC080 also known as PBCC)

2008: NAPB needs to fly

2009: Independent NAPB was created

2010: Two organizations began holding joint annual meetings

2011: NAPB begins developing organizational and governance policy

2012: Strategic Planning began

2013: NAPB Hatched
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
Joint strategic plan

NAPB strategic plan

Renewal of SSC-80

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

This is the official website of the National Association of Plant Breeders. The National Association of Plant Breeders (NAPB), was begun as an initiative of the Plant Breeding Coordinating Committee (PBCC) which began in 2005. The PBCC (official committee SCC 080) is a forum for leadership, regarding issues, problems, and opportunities of long-term strategic importance to the contribution of plant breeding to national goals. The NAPB is the outreach group that represents plant breeders in federal, state, commercial and non-government organizations.

Through this site we strive to inform our members of events and opportunities, and educate the public on what plant breeding is and what plant breeders do.

Our Mission

The National Association of Plant Breeders strengthens plant breeding to promote food security, quality of life, and a sustainable future.

Six objectives (https://www.plantbreeding.org/about-us/goals-and-objectives)
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<tr>
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<th>Six Goals of NAPB</th>
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<tbody>
<tr>
<td>1</td>
<td>Support for plant breeding: Increase support for plant breeding among decision makers in the public and private sectors</td>
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<td>2</td>
<td>Public plant breeding capacity: Increase public and private support for cultivar development and germplasm improvement in public institutions</td>
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<td>3</td>
<td>Education of plant breeding professionals: Strengthen education for plant breeding professionals at all levels of experience</td>
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<td>4</td>
<td>Public awareness: Increase public awareness of plant breeding and what it contributes to the public good</td>
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<td>5</td>
<td>Membership: Strengthen and increase value provided to the membership</td>
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<td>6</td>
<td>Organization: Strengthen the NAPB organization</td>
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## Strategic Plan Goal 3

<table>
<thead>
<tr>
<th>Goal</th>
<th>Objectives - 5-year</th>
<th>Objectives - 10 to 15-year</th>
<th>Possible Measures</th>
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| **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.  
  - 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 and support training of plant breeders. | • 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 breeders. | • 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 opportunities 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?
FACT SHEET: New Commitments in Support of the President’s Nation of Makers Initiative
• 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.
Click here to view this months featured barley success story

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/R8ibH & ow.ly/R8ibI & ow.ly/R8ibJ