Welcome to the Breeding for Organic Production Systems Webinar

Brought to you by:
eOrganic and Plant Breeding & Genomics

Today’s Presenter: Dr. Jim Myers
Presentation Available at:
http://www.extension.org/pages/60431

Co-Hosts: Alice Formiga & Heather Merk
Sign up for eOrganic News: http://eorganic.info
Sign up for PBG News: http://pbgworks.org
Please fill out the survey evaluation! (You will be contacted via email)

Watch past webinars and sign up for future webinars!

eOrganic - http://www.extension.org/pages/25242
PBG - http://www.extension.org/pages/60426
How to Breed for Organic Production Systems

James R. Myers
Department of Horticulture
Oregon State University

eOrganic/PBGWorks Webinar, October 2011

Wintergreen Farm, Veneta, OR
Northern Organic Improvement Collaborative (NOVIC)

Plant Breeders:
- Michael Mazourek (Cornell)
- Bill Tracy (UW-Madison)
- Jim Myers (OSU)
- John Navazio (Organic Seed Alliance/WSU)

- Broccoli
- Carrot
- Edible Podded Pea
- Sweet Corn
- Winter Squash
Total U.S. organic sales: $26.6 billion in 2009, up 5.3 percent from 2008

Certified organic acreage in the United States reached more than 4.8 million acres in 2008 (2,655,382 acres in cropland, about 0.7 percent of all U.S. cropland)

Is there a need to breed within organic systems? Growers say:

- Organic production system environment is different from a conventional production system
- Varietal adaptation to environment, is paramount to obtaining the best varietal performance
- Contemporary varieties bred in and for conventional production systems may be less-than-optimally-adapted to organic systems
Questions in designing breeding program for organic systems

- Is genotype x production system interaction significant?
  - Is it cross-over interaction?
- Is genotypic correlation high?
Selected studies comparing organic vs. conventional performance

- **Wheat**: no genotypic correlation among 35 lines in 4 of 5 paired org-conv. environments for yield, but correlated in all environments for test weight (Murphy et al., 2007)

- **Maize**: genotypic correlations high for dry matter content, maturity, & disease resistance, but moderate for yield (>4000 hybrids evaluated) (Burger et al., 2008; 2012)

```
<table>
<thead>
<tr>
<th>Location 1</th>
<th>Location 2</th>
<th>Location 3</th>
<th>Location 4</th>
<th>Location 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv Org</td>
<td>Conv Org</td>
<td>Conv Org</td>
<td>Conv Org</td>
<td>Conv Org</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>r&lt;sub&gt;G&lt;/sub&gt;</th>
<th>r&lt;sub&gt;D&lt;/sub&gt;</th>
<th>r&lt;sub&gt;G&lt;/sub&gt;</th>
<th>r&lt;sub&gt;D&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>r&lt;sub&gt;p&lt;/sub&gt;</td>
<td>r&lt;sub&gt;g&lt;/sub&gt;</td>
<td>r&lt;sub&gt;p&lt;/sub&gt;</td>
<td>r&lt;sub&gt;g&lt;/sub&gt;</td>
</tr>
<tr>
<td>Mean r</td>
<td>0.37**</td>
<td>0.54**</td>
<td>0.91**</td>
</tr>
</tbody>
</table>
```
Organic – Conventional comparison trials

- Not all studies find GxS effects – (less likely to find differences when organic is based on “input substitution” or is new)
- For certain traits, breeding and evaluating in organic systems is essential to identifying varieties optimally adapted to those systems
- Not all traits show GxS, or have high genotypic correlations, so a separate breeding program may not justified
- Not many studies of this type; organic community says there are more urgent research needs than comparison trials
What is organic?

- “Organic agricultural systems which, while managed, must use natural processes and biological self-regulatory mechanisms to succeed.” (Dawson & Goldringer, 2012)

- Growers seek to minimize off farm inputs

- “Organic production system”
  - Many different production systems
  - Are there common factors across organic?
# Main differences in conventional, sustainable and organic farming systems

<table>
<thead>
<tr>
<th>Category</th>
<th>Conventional</th>
<th>Sustainable, low-input</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity</td>
<td>Not a specific issue</td>
<td>Encourages natural predators</td>
<td>Biodiversity is product of and tool. Utilizes landscape &amp; varietal diversity</td>
</tr>
<tr>
<td>Fertilisation</td>
<td>High input of mineral fertilizers; maximum crop growth</td>
<td>Reduced &amp; precision fertilisation, green manures; optimal growth w/ reduced leaching</td>
<td>Organic fertilisers; slow release of nutrients; optimum growth w/ long-term soil building &amp; high biological activity</td>
</tr>
<tr>
<td>Crop protection</td>
<td>Synthetic-chemical crop protectants</td>
<td>IPM approach</td>
<td>Certified organically approved inputs only</td>
</tr>
<tr>
<td>Weed management</td>
<td>Herbicides</td>
<td>Reduced herbicide use &amp; cultivation</td>
<td>Mechanical weeding, flaming, field management (rotation, mulching, stale seedbed, &amp; crop competition)</td>
</tr>
<tr>
<td>Seed treatment</td>
<td>Chemical</td>
<td>Chemical and physical</td>
<td>Physical (hot water or steam) and organic additives</td>
</tr>
<tr>
<td>Tillage</td>
<td>Increasing use of no-till</td>
<td>Application of minimum or no-till</td>
<td>Reliance on tillage</td>
</tr>
</tbody>
</table>
Major differences between organic & conventional

Organic system

- Natural Biota
- Soil
- Fertility
- Climate
- Crop (species, cultivar)
- Pests
- Weeds
- Livestock
- Mechanization
- Labor
Comparison of traits that possibly differ for conventional vs. organic

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Above ground traits</strong></td>
<td></td>
</tr>
<tr>
<td>Performs well at high population density</td>
<td>Optimal performance at lower densities</td>
</tr>
<tr>
<td>Increased harvest index</td>
<td>Lower harvest index than conventional</td>
</tr>
<tr>
<td>Erect architecture and leaves, shortened plant stature</td>
<td>Taller plants, spreading canopy to be productive in low input situations</td>
</tr>
<tr>
<td>Weed competitiveness unknown</td>
<td>Weeds limited by competition (plant height, spreading architecture), plants tolerate cultivation, allelopathy</td>
</tr>
<tr>
<td>Pest and disease resistance to specific complex of organisms; need for resistance to diseases of monoculture systems</td>
<td>Pathogen and pest complex differ; induced resistance important; secondary plant compounds important for pathogen and pest defense; greater reliance on genetic resistance</td>
</tr>
</tbody>
</table>
Comparison of traits that possibly differ for conventional vs. organic

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rhizosphere traits</strong></td>
<td></td>
</tr>
<tr>
<td>Root architecture unknown</td>
<td>Exploratory root architecture; able to penetrate to lower soil horizons</td>
</tr>
<tr>
<td>Adapted to nutrients in readily available form</td>
<td>Adapted to nutrients from mineralization - not readily available; need for nutrient use efficiency; responsive to mycorrhiza</td>
</tr>
<tr>
<td><strong>Legume specific traits</strong></td>
<td></td>
</tr>
<tr>
<td>Nitrogen production by rhizobia of lesser importance</td>
<td>Rhizobia more important; discrimination against ineffective rhizobia important for N acquisition</td>
</tr>
<tr>
<td><strong>Harvest and marketing traits</strong></td>
<td></td>
</tr>
<tr>
<td>Improved harvest efficiency</td>
<td>Incorporate traits that improve working conditions</td>
</tr>
<tr>
<td><strong>“Ecological” traits</strong></td>
<td></td>
</tr>
<tr>
<td>Genetically and phenotypically uniform</td>
<td>Allow genetic and phenotypic diversity</td>
</tr>
</tbody>
</table>
Organic matter and soil pathogens

- Soil microbial populations higher and more diverse in soils supplemented with organic matter
- High organic matter may be pathogen suppressive
  - Exact mechanism unknown
    - Niche replacement
    - Antagonists
    - Induced resistance (SAR & ISR)
- Are there plant rhizosphere traits that favor beneficial microbial communities?
- Are there genetic differences in induced resistance responsiveness?
NOP regulations impacting breeding activities

- National Organic Program established in the U.S. in 2002
  - Requirement for certified organic seed
  - Allowable breeding technologies
Requirement for organic seed

“…The producer must use organically grown seeds…except…non-organically produced, untreated seeds and planting stock may be used to produce an organic crop when an equivalent organically produced variety is not commercially available” (§ 205.204).
A problem & an opportunity

- Farmers have only limited choices for varieties available as certified organic seed
- Seed companies find little demand for organically produced seed and will not produce it until there is a sufficient market to justify production
- Certification inspectors have increased scrutiny of seed purchases, and require more justification for use of non-certified varieties
Need for varieties where seed can be produced organically

- Variety trials to identify those adapted to organic systems (seed production as well as commercial production)
- Develop cultural methods for organic seed production
- Breed in and for adaptation to organic systems
Breeding techniques in organic plant breeding

- Design of breeding programs is similar
- Some biotechnology techniques cannot be used
  - Genetic engineering
  - Somatic hybridization (?)
- Organic breeding is compatible with use of molecular markers, genomics and bioinformatics
The U.S. NOP excludes methods under § 205.2 “Terms defined”: “A variety of methods used to genetically modify organisms or influence their growth and development by means that are not possible under natural conditions or processes and are not considered compatible with organic production. Such methods include cell fusion, microencapsulation and macroencapsulation, and recombinant DNA technology (including gene deletion, gene doubling, introducing a foreign gene, and changing the positions of genes when achieved by recombinant DNA technology). Such methods do not include the use of traditional breeding, conjugation, fermentation, hybridization, in vitro fertilization, or tissue culture.” (bold emphasis added)
A philosophical approach to farming


- Ethics and Ecology: maintain integrity of organisms in farming system

- Four levels of integrity:
  - Integrity of life - living organisms must have autonomy, be self-ordering
  - Plant specific integrity – retain ability to adapt to and interact with natural environment
  - Genotypic integrity – species specific genome
  - Phenotypic integrity – physical and chemical characteristics of individual plants are in balance with environment

NOVIC Participatory Broccoli Breeding
Jim Myers, Johnathan Spero, Julie Pulich
Rationale for OP Broccoli

- Some organic farmers & seed companies would like to save seed
- Need for an OP with contemporary quality and production traits
- Overall objectives:
  - Develop broadly-adapted open-pollinated broccoli cultivars
  - Develop a broccoli adapted to organic growing conditions
  - Engage grower’s knowledge through participatory plant-breeding since formal breeders have little knowledge of the genetics of organic traits
Historical perspective on broccoli

- Older (heirloom) Open Pollinated (OP) cultivars developed in production systems similar to organic systems
- Contemporary cultivars are nearly all $F_1$ hybrids developed in conventional systems
- OPs lack improved quality traits found in contemporary cultivars
**Parents**: Arcadia, Decathlon, Excelsior, Shogun, San Miguel, Barbados & 17 OSU inbreds

Random mated *without* selection 1997-2000

- Conventional production system
- One environment (Corvallis)
Broccoli – population origin

- Random mated with selection (head size, vigor, freedom from downy mildew, and heat tolerance) 2001-present
- Farmer participatory component added
  - (Farmer Cooperative Genome Project; Organic Seed Partnership)
- Grown in transition ground @ Corvallis 2004-2009, certified organic ground 2010-2011
- All farmer production under organic conditions
Broccoli – Farmers’ objectives

- Vigorous, growth under organic growing conditions
- Medium size nonsegmented heads (3-4 in. dia.) with tight, refined beads
- Even maturity
- Good flavor and attractive color
Farmer Participatory process in population improvement

- 500 - 1000 seeds sent to each grower (plot size 250 – 500 plants)
  - Plant, select (save best 25%), allow random mating and harvest seed
- Portion of harvested seed returned to OSU
- Seed mixed and redistributed
- Three cycles of selection in OSP
- Scheme is similar to convergent-divergent selection program used in maize (Lonnquist et al. 1979)
Guidelines to farmers:

- Keep plants in regularly spaced blocks to maintain interplant competition
- Avoid selecting border plants
- Select from all portions of the plot
- Keep at least 50 plants to minimize inbreeding
- Keep other *Brassica oleracea* crops (Brussels sprouts, cabbage, kohlrabi, kale, collards, cauliflower) from flowering within 1500 feet of the production site
Farmer participation – no. locations that produced seed

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Growers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2</td>
</tr>
<tr>
<td>2002</td>
<td>4</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>1</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
</tr>
</tbody>
</table>
Farmer participatory program – *pop’n improvement (2001-2007)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Cycle</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summers Yr. 1 - 3</td>
<td>0</td>
<td>Allow parents to random mate – do 3X</td>
</tr>
<tr>
<td>Summer/Fall Yr. 4</td>
<td>1</td>
<td>Send seed to farmers at multiple locations, plant population, select, allow random mating, return seed to coordinator</td>
</tr>
<tr>
<td>Summer/Fall Yr. 5</td>
<td>2</td>
<td>Seed coordinator blends seed from locations; repeat process</td>
</tr>
<tr>
<td>Summer/Fall Yr. 6</td>
<td>3</td>
<td>Seed coordinator blends seed from locations; repeat process</td>
</tr>
</tbody>
</table>
Farmer participatory program varietal development (2008-2013)

<table>
<thead>
<tr>
<th>Year</th>
<th>Generation</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summers Yr. 1</td>
<td>1</td>
<td>Plant OP population, select single plants</td>
</tr>
<tr>
<td>Summer/Fall Yr. 2</td>
<td>2</td>
<td>Plant SP rows, select among rows for uniformity</td>
</tr>
<tr>
<td>Summer/Fall Yr. 3</td>
<td>3</td>
<td>Repeat process</td>
</tr>
<tr>
<td>Summer/Fall Yr. 4</td>
<td>4</td>
<td>Repeat process</td>
</tr>
<tr>
<td>Summer/Fall Yr. 5 – 7</td>
<td>5 – 7</td>
<td>Test in replicated trials, develop varietal description</td>
</tr>
</tbody>
</table>
Participatory sweet corn breeding in Minnesota
Martin Diffley, Gardens of Eagan & Dr. Bill Tracy, University of Wisconsin

Courtesy J. Zystro, OSA
Background:

• “Temptation” was choice for spring

• Fewer good seed sources

Martin’s needs:

• Cold germination
• Early vigor
• Good husk protection
• Disease resistance
• Eating quality

Courtesy J. Zystro, OSA
• 2 separate populations
  • Each from 4 hybrids
  • Recurrent selection

Spring 2008:

• ~100 rows planted / population

• Each row from one ear

• Some seed from each ear also saved

Courtesy J. Zystro, OSA
1\textsuperscript{st} selection: Early vigor

Courtesy J. Zystro, OSA
2nd Selection: Diseases and pests, quality

Courtesy J. Zystro, OSA
Summer: trial and select

Spring: plant part of winter seed and save part

Winter: recombine selected

Fall: Seed to nursery based on summer selects

Courtesy J. Zystro, OSA
Development of Darkstar Zucchini

Courtesy John Navazio, OSA
Eel River valley in N. California
Dryland but high water table

Courtesy John Navazio, OSA
Zucchini breeding goals:

- Dark green fruits (high lutein content)
- Cylindrical, ridged shape
- Vigorous plants productive in dry-farm conditions
- Open canopy
- Bush habit
- Spinelessness
- Productive
‘Darkstar’ zucchini useful in other regions

- Winter slot in Baja, MX (Jan. – Apr. or May)
- 40 to 50% of the acreage of one of the largest organic melon/squash/winter squash growers in Baja
- 60 year frost in Jan. only zucchini to survive and for the next 6 to 8 weeks
- Marketed through Whole Foods & other outlets
- Drought tolerant and “robust”

Courtesy John Navazio, OSA
Borrowing research tools from the international arena

Many similarities between smallholder farmers in developing countries and organic farmers in developed countries

- Diverse agroecological systems and environments
- Little reliance on chemical fertilizer, pesticides and herbicides
- Greater reliance on genetic solutions (resistance and stability)
Borrowing research tools from the international arena (NOVIC)

- Farmer Participatory Research
  - Farmer Participatory Trialing
  - Farmer Participatory Plant Breeding
- Mother-daughter trial design
Organic breeding programs in US

- Role for public sector plant breeders
  - A niche that can help stem the loss of public plant breeding positions & can train the next generation of plant breeders

- Private sector engaged in trialing & breeding for organic
  - Some are wholly committed to breeding w/in organic systems
  - Others have developed blended programs
<table>
<thead>
<tr>
<th>Funding Source</th>
<th>No. of projects</th>
<th>Total funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOP/OREI</td>
<td>6</td>
<td>$6,399,229</td>
</tr>
<tr>
<td>IOP/OREI, SARE, Other</td>
<td>1</td>
<td>$1,195,883</td>
</tr>
<tr>
<td>Non-Federal Funds</td>
<td>1</td>
<td>$273,439</td>
</tr>
<tr>
<td>Other Federal Funds</td>
<td>1</td>
<td>$24,690</td>
</tr>
<tr>
<td>SARE</td>
<td>3</td>
<td>$173,342</td>
</tr>
<tr>
<td>SARE, Other Federal Funds</td>
<td>1</td>
<td>$246,445</td>
</tr>
<tr>
<td>Other Non-Federal Funds</td>
<td>2</td>
<td>$261,633</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>30</strong></td>
<td><strong>$8,574,661</strong></td>
</tr>
</tbody>
</table>

State of Organic Seed, Organic Seed Alliance, 2010
Top Issues in breeding for organic

- Develop organic no till systems (weed control)
- Address the yield gap (particularly an issue in field crops)
- Investigate conventional-organic hybrid models for breeding programs
- Fundamental & applied studies on organic-specific traits (such as soil/rhizosphere – plant genotype interactions)
- Integrate genomics and bioinformatics with organic plant breeding problems
Part I (general)

- Nutrient mgmt & selection strategies
- Pest & disease mgmt & implications for OPB
- Breed for weed suppression
- Breeding for genetic diversity
- Centralized vs. decentralized PB
- Consequences of organic principles for OPB
- Laws & policies influencing OPB
Part II (crops)
- Wheat
- Maize
- Rice
- Soybean
- Faba bean
- Potato
- Tomato
- Vegetable Brassicas
- Onion