Welcome to the Breeding for Organic Production Systems Webinar

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Today's Presenter: Dr. Jim Myers

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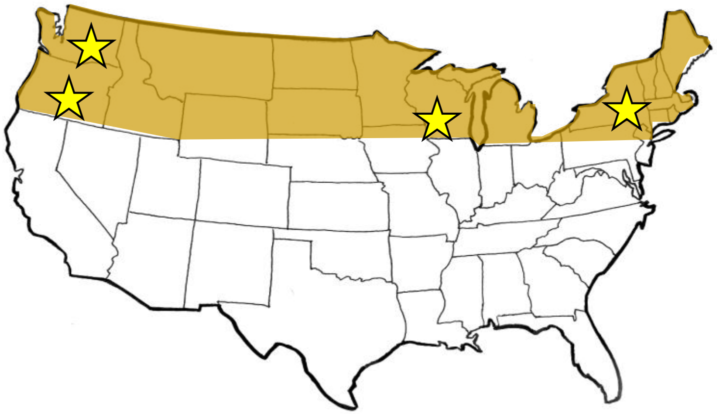
How to Breed for Organic Production Systems

James R. Myers
Department of Horticulture
Oregon State University

eOrganic/PBGWorks Webinar, October 2011

Wintergreen Farm, Veneta, OR

Northern Organic Improvement Collaborative (NOVIC)



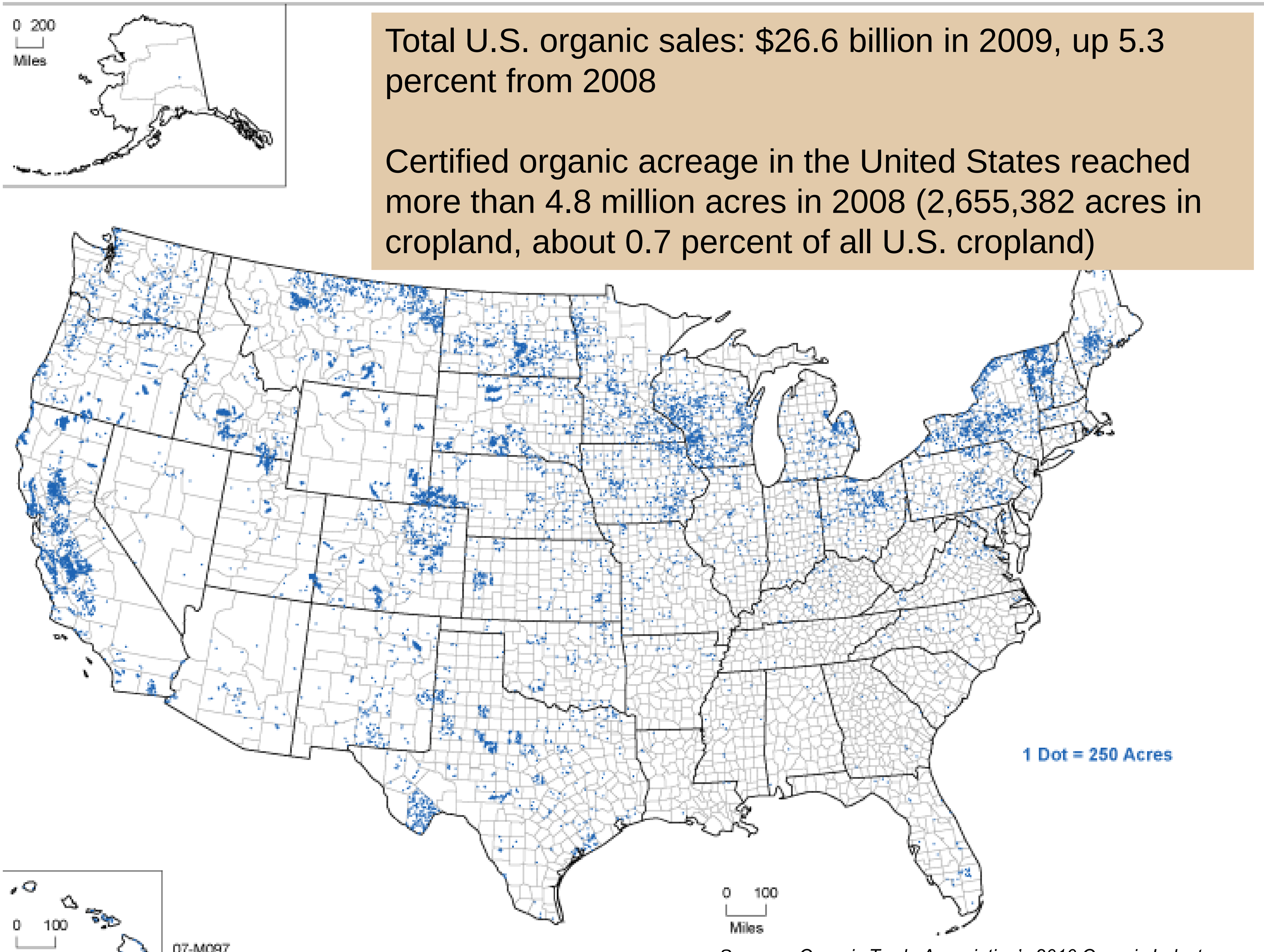
Plant Breeders:

- 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)



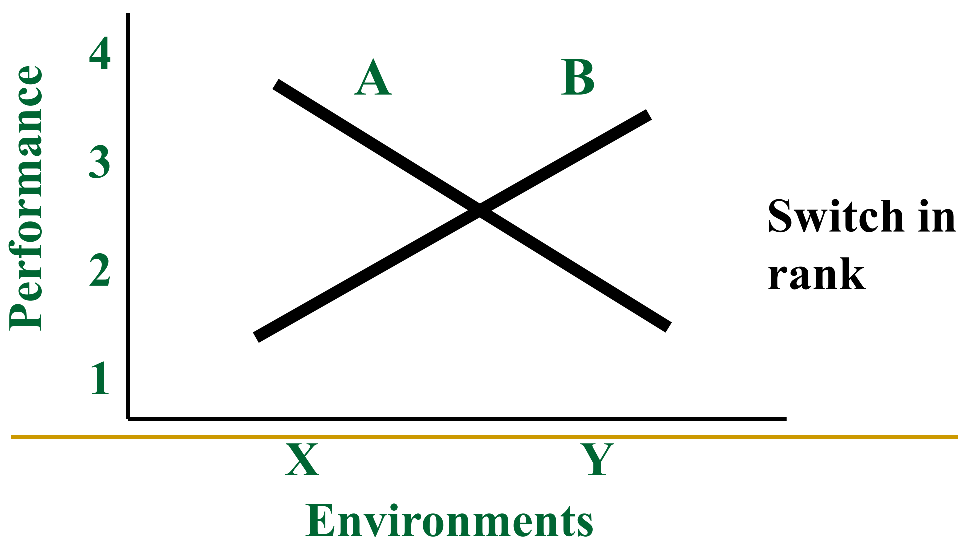
Sources: *Organic Trade Association's 2010 Organic Industry Survey* ; **www.ers.usda.gov/data/organic**

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

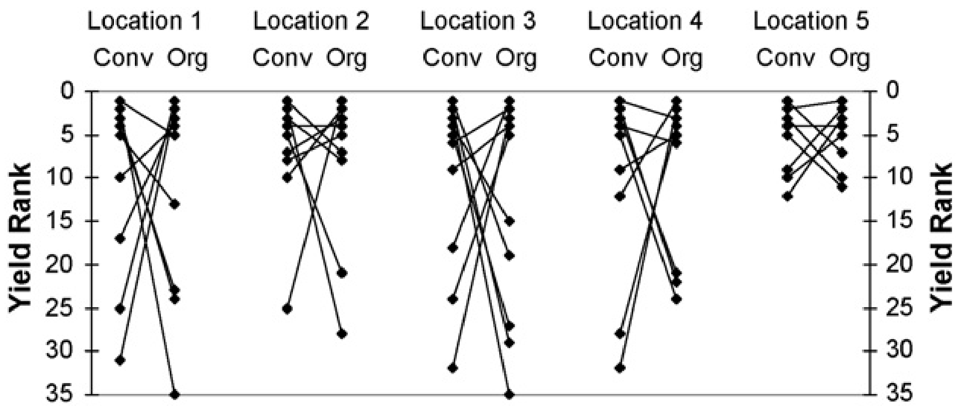
Questions in designing breeding program for organic systems

- 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)



	r Grain Yield		r DMC (%)	
	r_p	r_g	r_p	r_g
Mean r	0.37**	0.54**	0.91**	0.94**

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

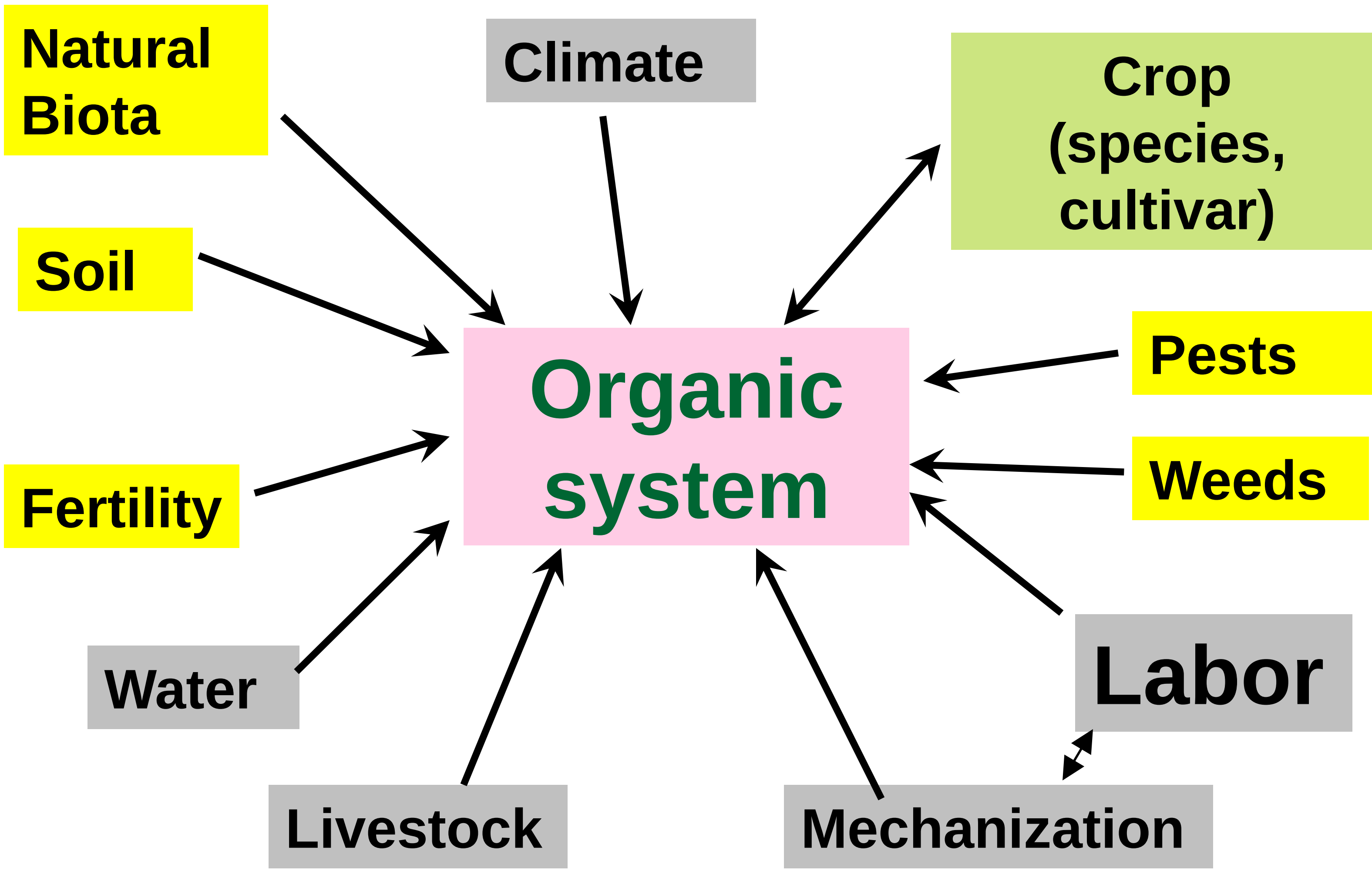
What is organic?

- "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

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

Major differences between organic & conventional



Comparison of traits that possibly differ for conventional vs. organic

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

Comparison of traits that possibly differ for conventional vs. organic

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

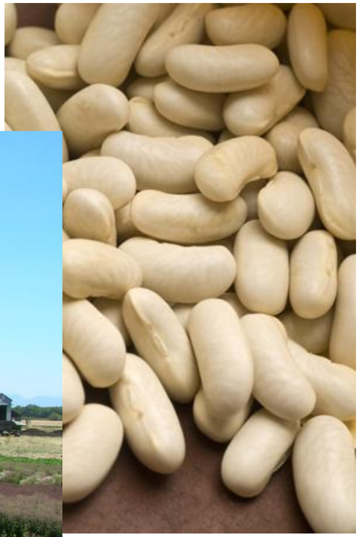
Organic matter and soil pathogens

- 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

U.S. NOP addresses some uses of biotechnology

- 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

- Organic farming based on: Principle of Health, Ecology, Fairness & Care (IFOAM, 2005)
- 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

Lammerts van Bueren et al., Crop Sci. 43:1922–1929 (2003)

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

Broccoli – population origin

- **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

Year	No. of Growers
2001	2
2002	4
2003	2
2004	2
2005	1
2006	3
2007	6

Farmer participatory program – *pop'n improvement (2001-2007)*

Year	Cycle	Activity
Summers Yr. 1 - 3	0	Allow parents to random mate – do 3X
Summer/Fall Yr. 4	1	Send seed to farmers at multiple locations, plant population, select, allow random mating, return seed to coordinator
Summer/Fall Yr. 5	2	Seed coordinator blends seed from locations; repeat process
Summer/Fall Yr. 6	3	Seed coordinator blends seed from locations; repeat process

Farmer participatory program *varietal development (2008-2013)*

Year	Generation	Activity
Summers Yr. 1	1	Plant OP population, select single plants
Summer/Fall Yr. 2	2	Plant SP rows, select among rows for uniformity
Summer/Fall Yr. 3	3	Repeat process
Summer/Fall Yr. 4	4	Repeat process
Summer/Fall Yr. 5 – 7	5 – 7	Test in replicated trials, develop varietal description

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

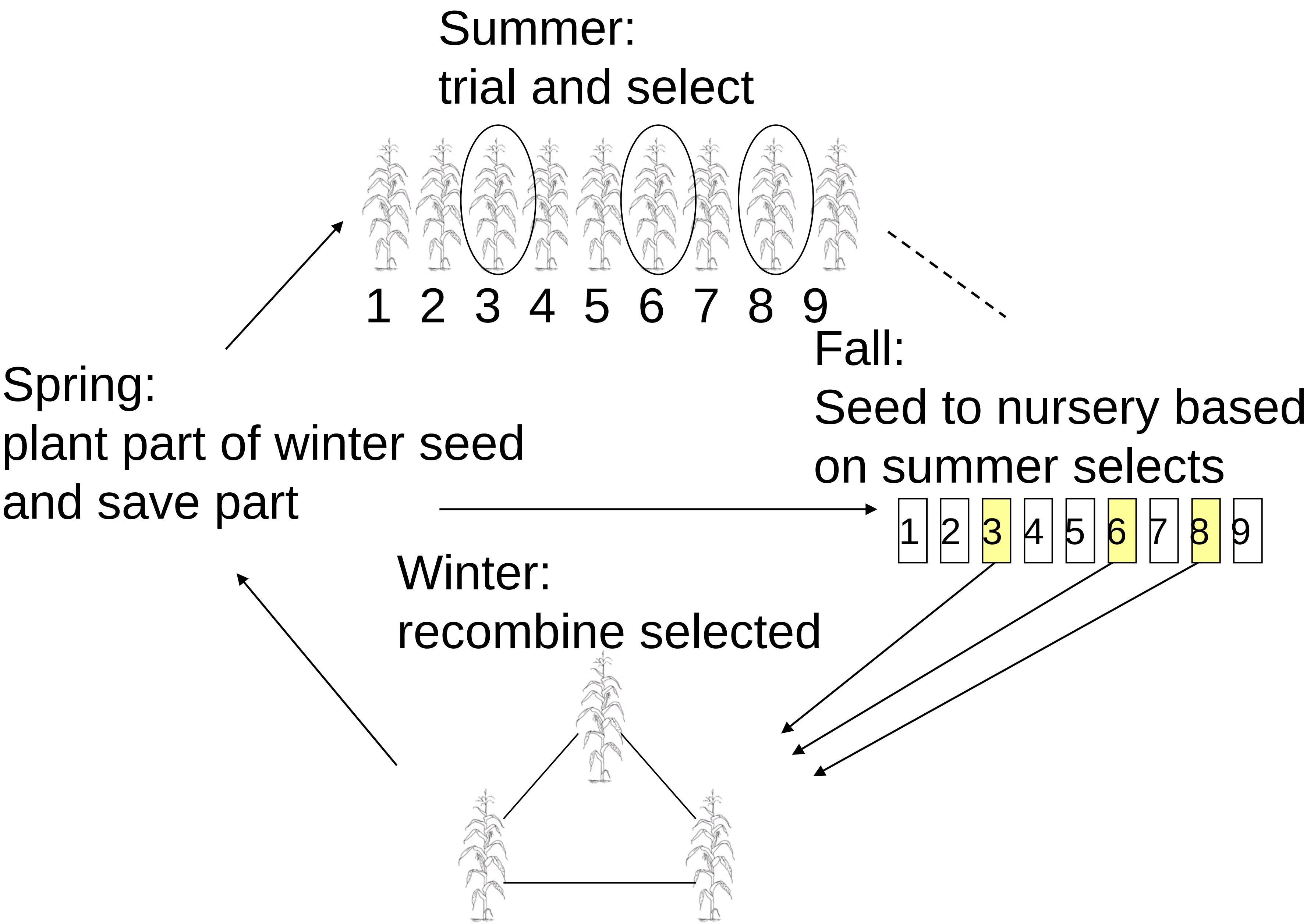
Courtesy J. Zystro, OSA

1st selection: Early vigor

Courtesy J. Zystro, OSA

2nd Selection: Diseases and pests, quality

Courtesy J. Zystro, OSA



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

Courtesy John Navazio, OSA

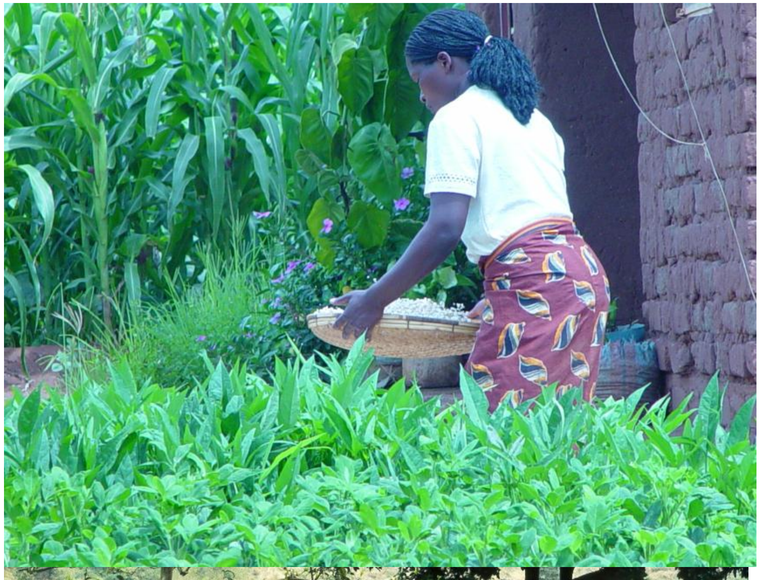
‘Darkstar’ zucchini useful in other regions

- 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

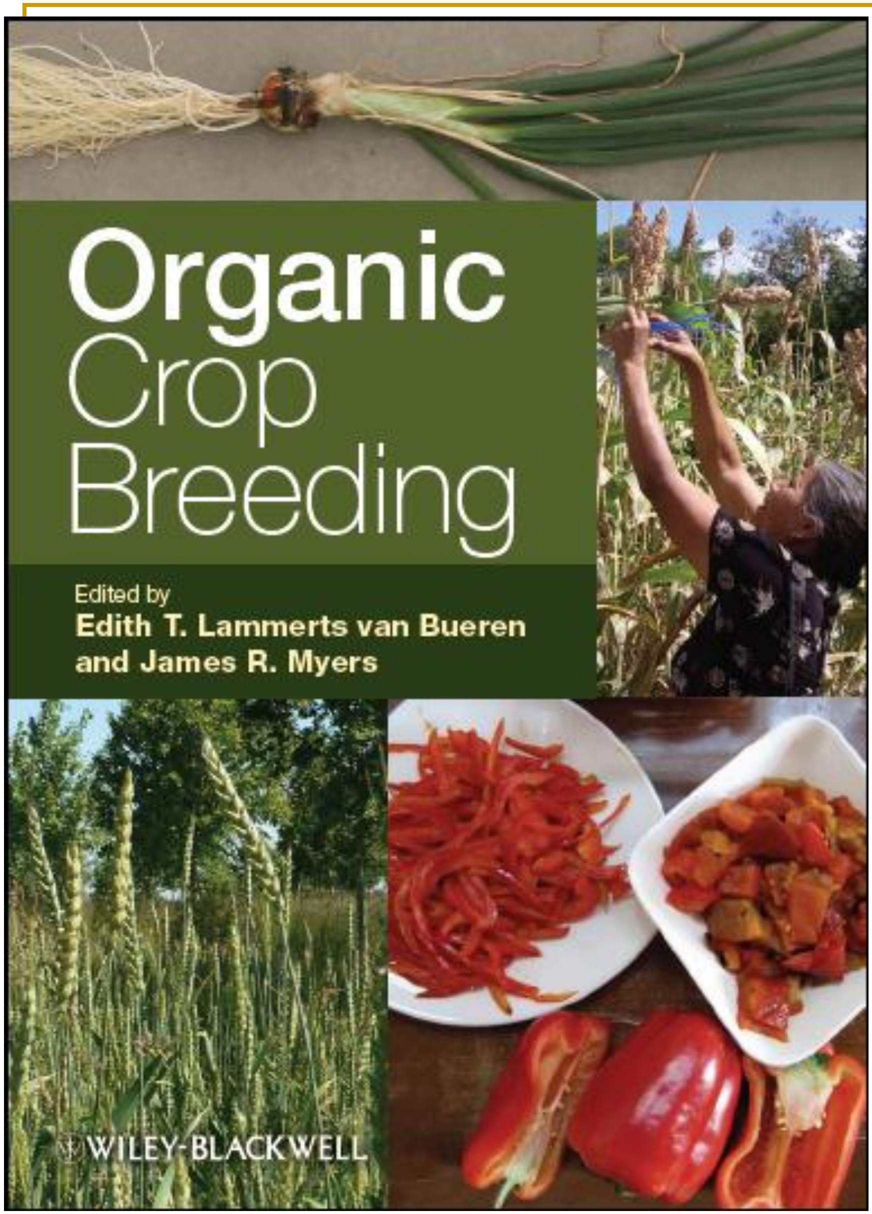
Funding for organic plant breeding (1996-2009)

Funding Source	No. of projects	Total funding
IOP/OREI	6	$6,399,229
IOP/OREI, SARE, Other Non-Federal Funds	1	$1,195,883
OFRF	16	$273,439
Other Federal Funds	1	$24,690
SARE	3	$173,342
SARE, Other Federal Funds, Other Non-Federal Funds	1	$246,445
SARE, Other Non-Federal Funds	2	$261,633
Grand Total	**30**	**$8,574,661**

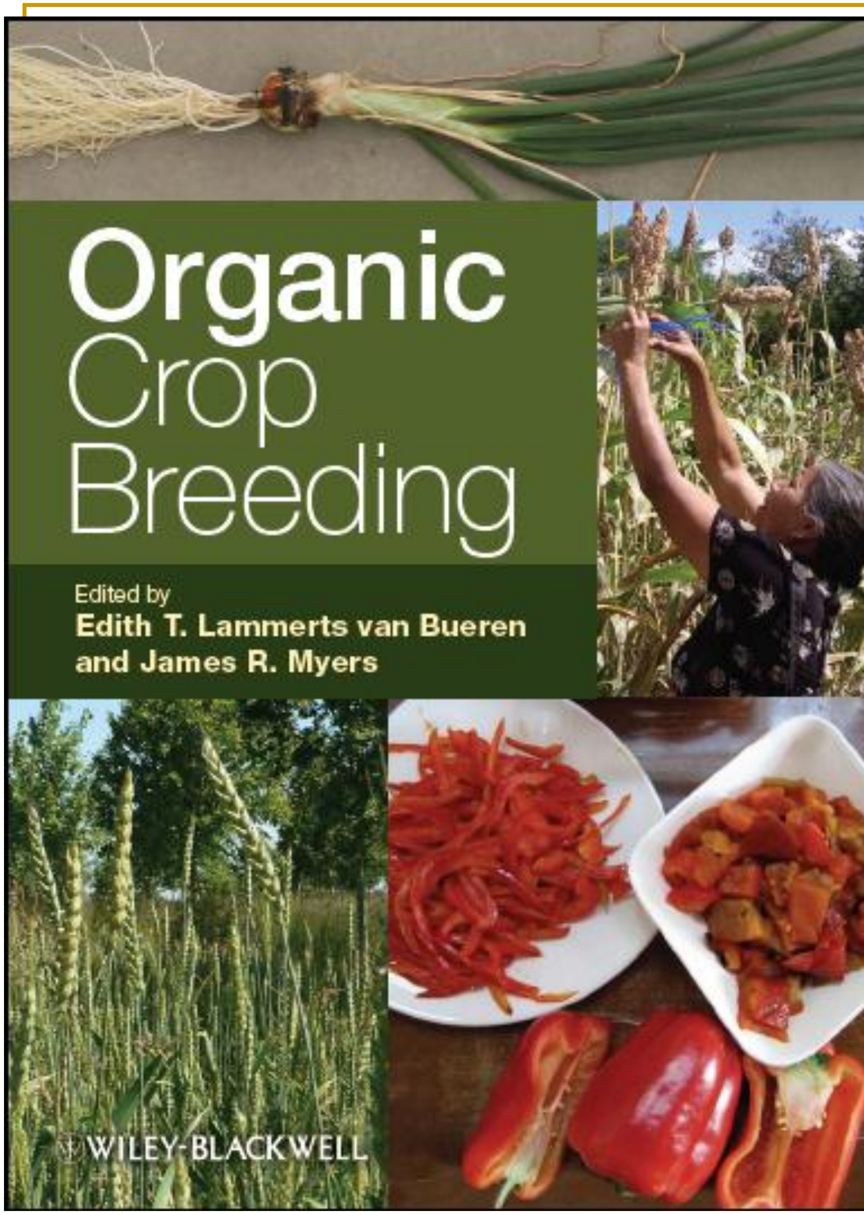
State of Organic Seed, Organic Seed Alliance, 2010

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