On-Farm Plant Breeding
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Organic Seed Alliance

Supporting the ethical development and stewardship of seed.
Do you have varieties that are adapted to your...

- climate?
- soils?
- production system?
- specific markets?

If so, do you have a reliable source of seed?

- OP that is well-maintained?
- OP that is high quality seed?
- F1 that is a mainstay variety?
- F1 that is well-maintained?
- F1 that is high quality seed?
- Is it organically grown???????

On-Farm Plant Breeding
### Typical Traits to Evaluate
- Plant height
- Plant stature
- Leaf type
- Days to maturity
- Harvestable yield
- Color
- Flavor/texture
- Storage life

### Traits to Consider for Organic
- Seedling Vigor
- Pest Resistance
- Disease Resistance
- Weed Competitiveness
- Nutrient Scavenging
- Specialty Markets
- Drought Tolerance
- Heat/Cold/Wind Tolerance

### On-farm breeding methods should be...
- Easy for the farmer to execute:
  - minimum (or no) hand pollinations
  - minimum note taking
  - minimum # of pedigree seeds lots
- Deliver a reasonable amount of gain for selection per cycle
- Retain adequate genetic variation for further selection/adaptation, yet have adequate uniformity for the marketplace

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Breeding in a nutshell

- Choose the right crop
- Learn the reproductive biology
- Establish breeding goals
- Conduct trials
- Identify useful variation
  - make crosses if necessary
  - you don’t always need to cross!
- Fix important traits in a population

Choose the right crop

- Is it important to you?
- Do you love it?
- Can you produce seed in your climate?
- Does it fit into your system?
- Selfers vs crossers

Reproductive Biology

<table>
<thead>
<tr>
<th>Selfers</th>
<th>Crossers</th>
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</thead>
<tbody>
<tr>
<td>Isolation</td>
<td>Less</td>
</tr>
<tr>
<td>Crossing</td>
<td>Harder</td>
</tr>
<tr>
<td>Self-pollinating</td>
<td>Easier</td>
</tr>
<tr>
<td>Inbreeding depression</td>
<td>Less Likely</td>
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</table>
Identify breeding goals

- Quality - specific traits
- Adaptation - climate/system
- Vigor - seedling/more?
- Resistance - disease/heat/cold/drought

Start with trials

- Evaluate potential varieties
- Is there a variety that already works?
- Is there a variety that almost works? (To cross or not to cross, that is the question!)
- Are there two varieties, when combined, that might work?
- Know your germplasm!
- Learn the fundamentals of conducting trials:


If a cross is necessary then start with a strain cross

- 50-100 plants per variety
- Select 20-30 best before flowering
- Harvest bulk seed from each
- Allow progeny to intermate 1-2 seasons

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On-farm selection methods

- Mass Selection – simplest and most widespread form of plant breeding, can be effective over the long term but is slow!
- Progeny Selection – a fairly simple trick that can speed the breeding process up if used in ways that best fit the reproductive biology of the crop

Mass selection
Selecting individuals from a population

Tips:
- Select before pollination (if possible)
- Large population
- Uniform conditions
- Select from quadrants

Mass selection
- Select evenly from quadrants
Progeny selection - step 1

• Select minimum 50 plants from pop.
• Save seed in individual bags
• Plant 50 individual rows x 2 reps. in the next season

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Progeny selection - step 2

• Select 15-20% of best families based on both reps.

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Progeny selection - step 2

• Select 15-20% of best families based on both reps.
• Eliminate poor families

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Progeny selection - step 2
- Select 15-20% of best families based on both reps.
- Eliminate poor families
- Eliminate 30-40% poorest plants from selected rows
- Allow remaining plants to intermate
- Bulk within families

Progeny selection - part 3
- Plant selected families
- Evaluate
- Bulk as variety if satisfied, or...
- Repeat progeny selection if necessary

Progeny selection vs. mass selection
<table>
<thead>
<tr>
<th>Mass selection</th>
<th>Progeny selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slower</td>
<td>Faster</td>
</tr>
<tr>
<td>Easier</td>
<td>More difficult</td>
</tr>
<tr>
<td>No family information</td>
<td>Families give you insight into hidden genetics</td>
</tr>
<tr>
<td>No record keeping</td>
<td>Must maintain separate families</td>
</tr>
</tbody>
</table>
On-Farm Breeding Example: Nash’s Red Kale

- Red-purple curly kale
- Downy Mildew resistant
- Upright stature
- Overwintering
- Vigorous regrowth
- Tender and flavorful

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Redbor F1: market standard

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Cross and Mass Selection:

- Two red plants in large field of ‘Vates Dwarf Scotch Curled’ Kale
- Crossed with much taller Brussels Sprouts
- 10 years of mass selection (1997-2006)

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2008: A signature crop
Qualities:
80-90% true to type OP
Compared to Redbor:
• Better flavor
• More tender
• More cold tolerant
• Better Downy Mildew resistance

Progeny Selection

In 2008: selected best 50 plants
- Quality traits = leaf type, curl, texture
- Stature
- Color
- Cold hardiness
• Allowed 50 plants to intermate
• Saved seed into individual bags
• Planted 50 short progeny rows in 2009

Evaluation based on progeny row performance
Eliminated:
• Rows with green plants
• Rows with poor curl
• Rows with poor stature
• Rows with early bolters
Present Population

• Resulted in 13 all red rows
• Seed harvested as single row bulks
• To be planted as 13 x 2 rows and evaluated again.

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OP Dark Green Zucchini
Participants: Bill Reynolds, Eel River Produce & 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
No irrigation, farming on Eel River flood plane
Black Beauty
• Open-pollinated variety
• Dark fruit
• Extensive rooting system
• Long harvest season
But...
• Has closed canopy
• Many off type fruit: bulbous, tapered, curved
  – Only 20–25% plants "Grade A" fruit

History of Black Eel Zucchini
Raven F1' X 'Black Beauty' Population Development
Bill grew field with a large field of Raven & Black Beauty / harvested lbs. of seed (1998)
Drilled large population (20,000 seeds) on 2 acre field and thinned in 3 rounds of selection; 1) vigor, 2) plant type, 3) fruit type / for 4 yrs
This 4 yrs of mass selection produced ‘Black Eel’ OP / “Seeds Of Change” variety

Resulted in ‘Black Eel’
Self Pollination and Progeny Testing
Participatory On-farm Breeding

Season 5 attempted selfs on 50 best plants
(2003) / 26 successful selfs
Saved seed of 26 in separate bags. Each bag =
full-sib family.
Planted 26 full-sib family progeny rows in
Season 6 (2004) – 4 selected
Planted 4 half-sib families in Season 7 (2005); only 1 half-sib family selected and bulked
Mass selection to increase seed in Season 8
Year 1: Make a series of S2 sells in a M4 population

(If hindrance to selfing – select single OP plants.)

Only 26 of 52 pollinations produced seed.

From the 26 S1 Families - only 4 are selected, others are eliminated. Selects are allowed to OP/cross. Seed of 4 families is harvested as individual half-sib families.

Year 2:

From the 36 S1 Families – only 4 are selected; others are eliminated. Selects are allowed to OP/cross. Seed of 4 families is harvested as individual half-sib families.

Year 3:

From the 4 half-sib families that are evaluated, only 41 has seed set. One selected, intermated, seed bulked.
2006 Baja Zucchini Trial

Tested by large zucchini grower

- Resilient population
- Yielded 5-6 weeks longer than 'Raven'
- Male flowers until the end
- Stocky, open plants
- Low spines
- Less Virus and Powdery mildew symptoms
- More variable than F1's, but "stable" yield

2007 - 2011

- Maintained via mass selection
- Alternate stock seed and production seed years
- Increased acreage in Baja
- Winter 2010-2011: freeze in Baja, 'Dark Star' was the only Zucchini in Whole Foods for most of February

Participatory sweet corn breeding in Minnesota

Martin Diffley, Gardens of Eagan & Dr. Bill Tracy, University of Wisconsin
Background:
- “Temptation” was choice for spring planting
- Fewer good seed sources

Martin’s needs:
- Cold germination
- Early vigor
- Good husk protection
- Disease resistance
- Eating quality

- 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

1st selection: Early vigor
2nd Selection: Diseases and pests, quality

Summer: trial and select
Spring: plant part of winter seed and save part
Winter: recombine selected
Fall: Seed to nursery based on summer selects

Participatory Plant Breeding: 3 Examples

- Nash Huber’s Red Kale
- Martin Diffley’s Sweet Corn
- Bill Reynolds’ Dark Star Zucchini

2/8/12