Welcome to the webinar!

- The webinar will start the top of the hour.
- To type in a question, use the q and a box on your control panel. We'll read the questions aloud after the presentation for 30 minutes.
- A recording will be available in our archive (see below) and on the eOrganic YouTube channel within 2 weeks at most.
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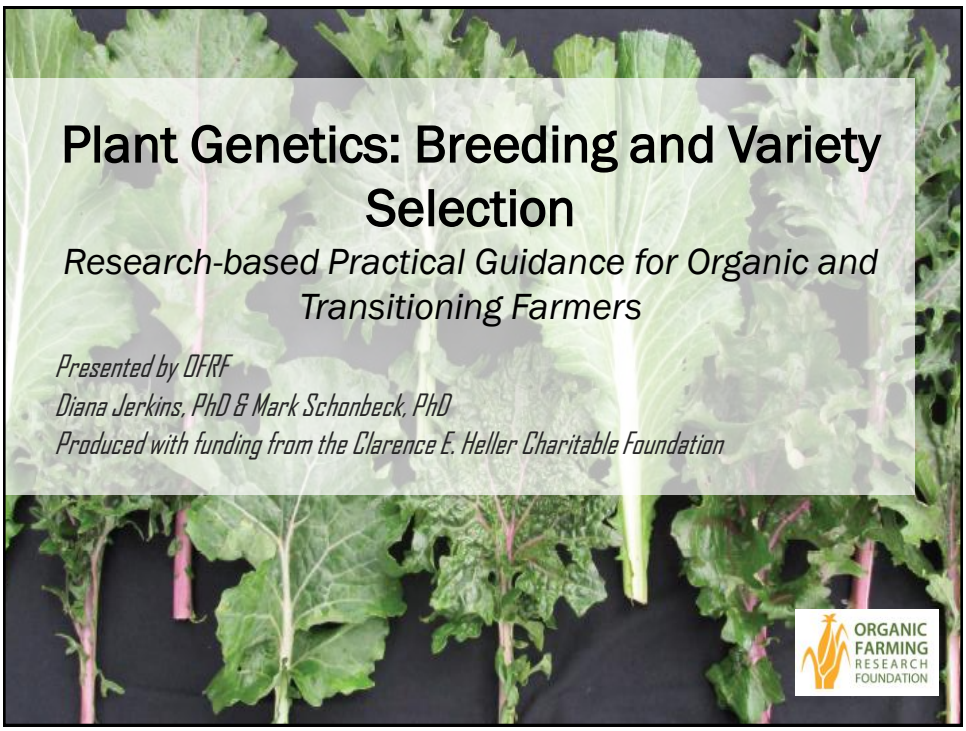

Presenter

Mark Schonbeck, Organic Farming Research Foundation

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Plant Genetics: Breeding and Variety Selection

Research-based Practical Guidance for Organic and Transitioning Farmers

Presented by OFRF
Diana Jerkins, PhD & Mark Schonbeck, PhD
Produced with funding from the Clarence E. Heller Charitable Foundation

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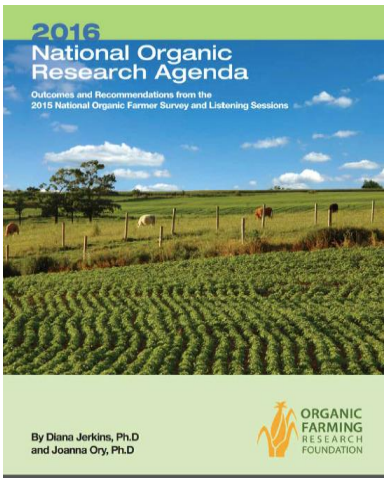

Available at *http://ofrf.org/*.

In a 2015 survey 74% of organic farmers cited soil health as a research priority. In addition, organic farmers need new crop varieties that:

- Thrive in organic systems.
- Utilize nutrients effectively from organic sources.
- Resist major diseases.
- Are resilient to weeds, pests, and climate change.
- Meet market demand for quality and nutritional value.

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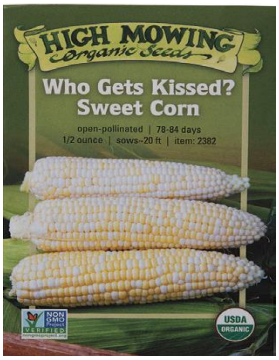
The Role of Crop Genetics in Soil Health

Direct and indirect impacts

Can the right cultivars help organic farmers build healthy soils?

Yes, if heritable traits:

- Facilitate organic production.
- Confer resilience to locally prevalent stresses.
- Reduce need for inputs.
- Reduce erosion, add organic matter, improve tilth.
- Support beneficial soil life.
- Enhance market appeal.



'Who Gets Kissed?' offers earliness, resistance to disease, and great flavor.

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Easy to grow organically

- Regionally adapted
- Resistant to diseases
- Germinate rapidly, vigorous seedlings
- Resilient to drought pests, weeds
- Respond well to organic practices
- Desired market traits

'South Anna' butternut squash combines high vigor, downy mildew resistance, excellent flavor, and long shelf life.

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Need fewer inputs

- Efficiently absorb and utilize nutrients from organic sources
  - ➢ *Need less fertilizer*
- Utilize water efficiently
  - ➢ *Need less irrigation*
- Outcompete, tolerate, or suppress weeds
  - ➢ *Need less cultivation*

'Tennessee red cob' dent corn beat the weeds and yielded well on minimal N input in Virginia.

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Nitrogen-efficient Field Corn

- Requires half as much N as standard hybrids; thrives on organic N sources.
- N-fixing bacteria in the crop root zone meet up to 50% of crop N need.
- Similar yield, higher protein % and quality compared to standard hybrids.
- Maintains yield on poor soils.
- Large root system enhances drought tolerance,

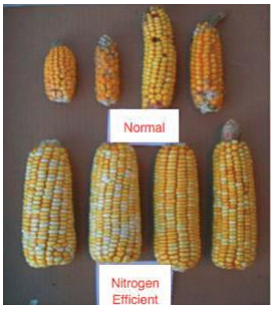
Mandaamin Institute, Elkhorn, WI.
http://www.mandaamin.org/

Mandaamin Institute

On low-fertility tropical soil, a Corn Belt hybrid suffers N deficiency (left) while Mandaamin's N-efficient corn maintains vigor (right).

Restoring soil-enhancing traits in corn

Mandaamin Institute



Ears from standard (top) and N-efficient (bottom) corn grown on soil low in N.

- Decades of corn breeding in N-fertilized soils appear to have:
  - Modified root microbiomes
  - Reduced N fixation capacity.
  - Increase N fertilizer needs.
- Breeding and selection in organic systems have yielded N-efficient hybrids.
- Seed now available to farmers and scientists.

Mandaamin Institute, Elkhorn, WI. http://www.mandaamin.org/

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Growing tomatoes on less water

- 'Arkansas Traveller' yields "flavorful tomatoes [in] drought and high heat where many other varieties fail." (*Southern Exposure Seed Exchange*)
- Some California growers are "dry-farming" tomato to improve flavor and save on irrigation costs.
- 'Early Girl' and 'New Girl' (*Johnny's Seeds*) are especially well suited for dry farming, as their deep, vigorous root systems readily access subsoil moisture.

Tomato cultivars vary widely in drought tolerance and water needs.

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Heritable drought resilience

- Drought-hardy cultivars of pepper, okra, lima bean, and many other vegetables are offered in seed catalogues.
- Drought-resistant cereal grains, corn, rice, and beans have been widely bred and selected in “managed stress nurseries” around the world.




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Carrot Improvement for Organic Agriculture (CIOA)

- Cultivars and lines from around the world showed heritable (genetic) variation in:
  - *Earliness of emergence, seedling vigor.*
  - *Canopy height, width, and density.*
  - *Resistance to leaf blight and pest nematodes.*
  - *Beneficial interaction with soil micro-organisms.*
  - *Flavor, nutritional value.*
- Farmer participatory breeding in CA, WA, IN, and WI to develop improved cultivars with these traits.

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Weed-Competitive Carrots

'Danvers' carrot forms large, canopy but is prone to Alternaria leaf blight. CIOA has identified lines with large canopy and Alternaria resistance.

"Lines that emerged and formed a full canopy earlier than others resulted in the greatest crop yield in the presence of weeds as well as the greatest ability to suppress weeds. [S]election of lines that favor early and full top canopy growth can be used as a low input, integrated weed management tool."

Philipp Simon, Carrot Improvement for Organic Agriculture, final report for OREI 2011-01962, CRIS Abstracts, http://cris.nifa.usda.gov/

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Protect and build soil, feed soil life

- High biomass, dense canopy
- Deep, extensive root system
- Abundant root exudates to feed soil organisms
- Enhanced association with mycorrhizal fungi and other beneficial soil organisms.

It is not just cover crops that build soil. These sweet potato and squash crops protect the soil and add organic matter.

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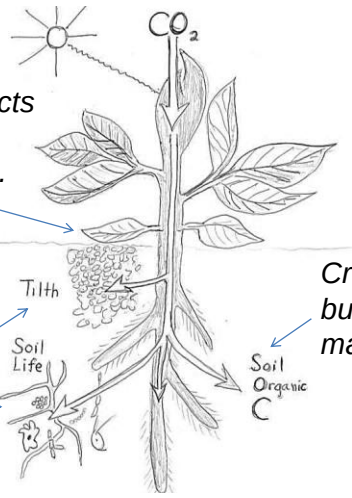
Vigorous, high-biomass crops



Crop canopy protects soil surface and suppresses weeds.

Root exudates enhance soil aggregation and feed soil organisms.

Crop residues build soil organic matter (SOM).

Tradeoff: marketable yield versus *organic inputs to the soil*

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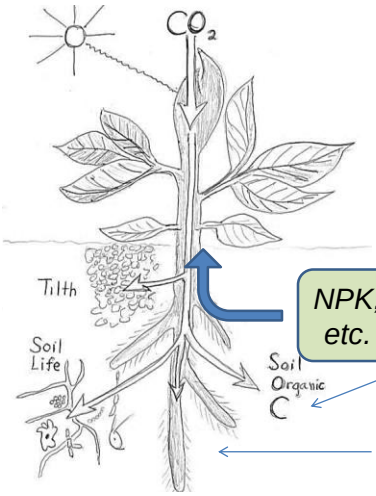
Deep, extensive root system



Larger root mass enhances nutrient *uptake efficiency*

Root residues build active and stable SOM.

Deep roots relieve hardpan, retrieve nutrients, and access deep moisture.

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Root depth, mass, and architecture as heritable traits

Plant varieties within a species show genetic variation in:

- Branching pattern (root architecture)
- Root hair density.
- Maximum root depth, potentially to 6 ft. or more in many crops.
- Most modern cultivars only ~ 3 ft.

➢ Potential to breed crops for deeper roots to build SOM and improve water and nutrient use efficiency.

Italian ryegrass

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Root biomass and drought resilience: an anecdotal example

In the experience of one Virginia gardener, this red leaf lettuce:

- Has greater root development at time of transplanting than other cultivars.
- Tolerates drought.
- Does not bolt for several weeks after other varieties have done so.
- Sustains production and quality in summer weather.

'New Red Fire' lettuce recovered fully when watered after a week of stress in 85°F heat.

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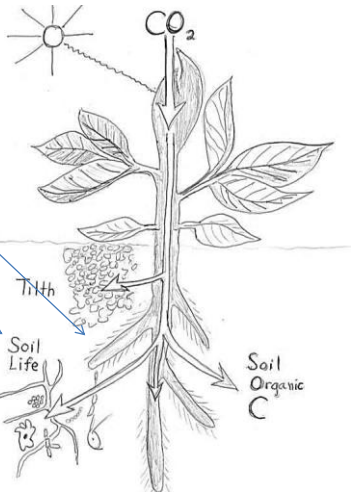
Effective Teamwork with Soil Microbes

Enhanced quantity and quality of root exudates

Specific chemical signals to beneficial soil organisms

Enhanced root zone microbiome:
- *N fixers*
- *Mycorrhizae*
- *Disease antagonists*
- *Other*



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Induced systemic resistance (ISR) for tomato disease management

Tomato Organic Management and Improvement (TOMI): integrated disease management through breeding, biofungicides, and *ISR*:

- *Trichoderma harzianum* inoculum in root zone stimulates plant defenses against foliar diseases.
- Land races show much better ISR and growth response to *T. harzianum* than modern varieties.
- Breeding goal: introduce ISR trait into modern tomato cultivars.

ISR protects some but not all tomato cultivars from late blight (above) and gray mold.

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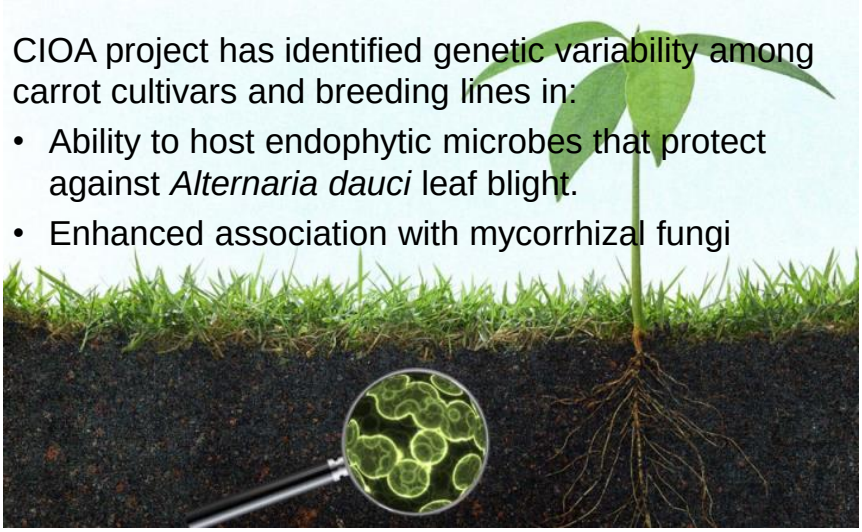
Plant genetics and root-microbe interactions: more examples

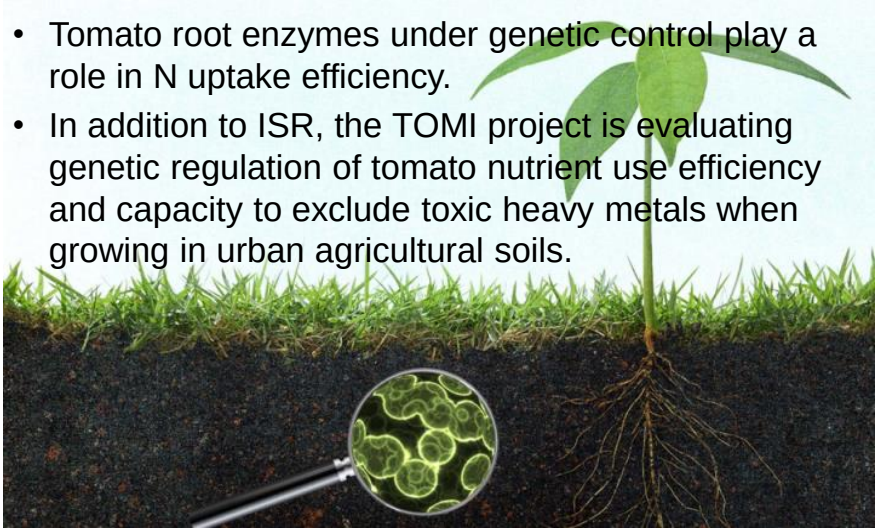
CIOA project has identified genetic variability among carrot cultivars and breeding lines in:

- Ability to host endophytic microbes that protect against *Alternaria dauci* leaf blight.
- Enhanced association with mycorrhizal fungi



Plant genetics and root-microbe interactions: more examples

- Tomato root enzymes under genetic control play a role in N uptake efficiency.
- In addition to ISR, the TOMI project is evaluating genetic regulation of tomato nutrient use efficiency and capacity to exclude toxic heavy metals when growing in urban agricultural soils.



Breeding cover crops for soil health

Genetic variability in:

- Vigor, biomass.
- N fixation (legumes).
- Cold hardiness.
- Flowering date.
- Ease of termination.
- Weed suppression.
- Disease and pest nematode suppression.
- Water use efficiency.

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Heritable traits in cover crops

Cold hardiness:

- Fava bean lines hardy to Zone 6b in eastern WA .[1]
- Hairy vetch hardy in MN.

Maturity date:

- 'Abruzzi' rye heads ~3 weeks before other rye varieties.
- 'Purple Bounty' vetch flowers 2 weeks before other vetch.[2]

1. Landry et al., 2015. J. Plant Registrations 9: 367-370.

2. Windy Acres Farm, 2017. Presentation at Southern SAWG Conference

Most fava beans (left) are hardy to ~20°F. New lines lines hardy to < 0°F have been developed. Hairy vetch (right) varieties differ maturity date and response to roll-crimping.

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Breeding Hairy Vetch, Crimson Clover, and Austrian Winter Pea for organic systems

Project objectives

- Address farmer breeding priorities:
  - *N fixation*
  - *Winter hardiness*
  - *Biomass, early vigor*
  - *Weed suppression*
- Develop and release new cultivars.
- Establish long-term endeavor.

Project methods

- Research station and on-farm trials in all four USDA regions.
- Partner with universities and farmer groups.
- Farmer participatory breeding and evaluation.
- NRCS plant materials centers in 9 states.
- Seed increase in WA, TX.

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Challenges in Finding the Best Crop Cultivars …

… to build healthy soil and make a living organically

Challenge #1: Today's crop varieties are not designed for organic systems

"Cultivars are most productive under the conditions for which they were bred ... [C]ultivars bred under conventional management – aided by synthetic fertilizer, herbicides and pesticides – will likely not be as productive under organic management."

Hultengren, et al., 2016.

Today's broccoli cultivars can be grown organically, but require >200 lb N/ac for optimum yield. Half of this N is lost to leaching or denitrification.

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Challenge #2: Cultivar choices are limited and often not adapted to locale

- Seed industry privatization and consolidation results in loss of regionally adapted cultivars.
- Private breeders with for-profit companies focus on "large" targets: corn, wheat, soy, etc.
- "Minor" or specialty crops have received less attention from plant breeders.
- Corn, soy, cotton, canola seeds are mostly GMO, not suited for organic production

An unusual flour corn, not widely available.

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Challenge #3: Public plant breeders are an "endangered species"

- Diminished funding for university and USDA public plant breeding and cultivar development programs.
- Steep decline in numbers of University and other public plant breeders.
- Urgent need to recruit, train, and establish the next generation of plant breeders.

Organic Seed Alliance

Researcher from Organic Seed Alliance pollinating kale. The private non-profit sector aims to develop new cultivars for 21st century producers.

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Challenge #4: Intellectual property, and farmers' rights

Open Source Seed Initiative (OSSI).

- Users are free to grow, share, sell, or trial and study, OSSI seed, and use it to breed new lines.
- Any new variety developed from OSSI germplasm must remain Open Source.

"I wish my work to be shared, not monopolized," Frank Morton, lettuce breeder for Fedco Seeds.

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Challenge #5: Intellectual property, and breeders' rights to make a living

- License agreements between University or non-profit plant breeders, and vendors and end users of seed.
  - Royalty (e.g., 10%) to support ongoing breeding.
  - Example: Nokomis Gold Seeds marketing Mandaamin N-efficient corn
- Plant Variety Protection Act (PVPA)
  - Can save seed for on-farm use but not for resale.
  - Can use PVP variety to develop new lines.
- Utility patent
  - On-farm seed saving prohibited.
  - Germplasm use by researchers severely restricted.

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Meeting the Challenges

Working together to develop seeds for healthy soils and healthy organic farm profits

Farmer participatory plant breeding (PPB)

- Farmers and scientists collaborate to identify priorities, evaluate breeding lines, and develop, and release new cultivars.
- USDA Organic Research and Extension Initiative (OREI) funds PPB endeavors for vegetable, grain, dry bean, and other crops.
- Select for multiple priorities, not focused on single traits.

'Kentucky Rainbow' dent corn in on-farm trial conducted by Common Wealth Seeds in Virginia

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Northern Organic Vegetable Improvement Collaborative (NOVIC)

- Funded through OREI since 2010.
- Farmer-breeder network hubs in OR, WA, WI, NY.
- NOVIC cultivars available in seed catalogues:
  - Broccoli – 'Solstice' and 'Myers Best'
  - Butternut squash – 'Honeynut' and two new lines '661' and '898' released in 2018.
  - Tomato – 'Iron Lady' and 'Brandywise'
  - Sweet corn – 'Who Gets Kissed,' 'Tuxana,' and 'Top Hat'.
- More on the way.

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Farmer-researcher collaboration

OREI funded PPB networks develop or identify valuable cultivars for organic systems, such as this disease-resistant 'Ho Lan Dow' snow pea.

Farmer-plant breeder Edmund Frost (left) works with Cornell plant breeder Michael Mazourek to develop mildew-resistant cucumbers, melons and squash.

PPB: researcher enthusiasm and practical challenges

"More than 70% of the organic seed research projects conducted … involved farmers. One researcher shared, 'We could not do this project without [farmer] involvement. Helpful is not a strong enough word. They are required partners.'"

Hubbard and Zystro, 2016

Challenges in PPB:

- Learning curve: farmers must acquire new skills.
- Farmers must receive sufficient compensation to do plant breeding.
- Cultivar development takes time: 4 – 10 years for breeding, and 2 – 4 years to bring new cultivar to market.

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Tips for Finding the Seeds you Need

Selecting cultivars for soil health, and performance in organic systems

Making the best use of what's available

- Seek locally produced seed.
- Choose cultivars bred in and for organic systems
- Select regionally adapted varieties that:
  - Emerge and establish rapidly, compete with weeds.
  - Resist major diseases and pests in your region.
  - Utilize nutrients from organic sources efficiently.
  - Tolerate drought or other stresses.
- Conduct on-farm variety comparisons.

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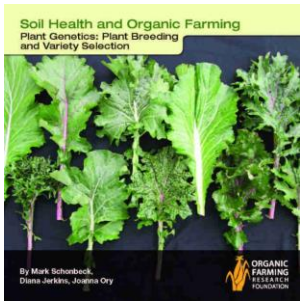
Sourcing and choosing organic seed

- Directory of Organic Seed Suppliers, updated Aug. 2018. https://attra.ncat.org/attra-pub/organic_seed/.
- Organic Seed Alliance, http://www.seedalliance.org/.
- Some vendors provide detailed information on cultivar traits:
  - Blue River Organic Seed
  - Southern Exposure Seed Exchange
  - Fedco Seeds



The OFRF Soil Health Guide on plant genetics includes listings of organic seed sources by region.

Cultivar description examples

Gold Coast okra – "… well-developed root system, has good drought and heat tolerance, as well as tolerance of root-knot nematodes."

Sophie's Choice tomato – "…Quality is best in cooler climates - does not handle heat or drought well."

Super Italian Paste Tomato – "… Vigorous, high-yielding plants … withstood both flooding and drought in 2015."

Danvers 126 Carrot – "Especially suited to growing in clay soil, and the strong tops aid harvesting."

Imperator (Tendersweet) Carrot – "Requires loose, deep soil to achieve its full potential."

Southern Exposure Seed Exchange, 2018 online catalogue.

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Get involved: breed and grow better seed for organic farms in your region

- Learn organic seed production, cultivar evaluation, and plant breeding skills.
- Save and select seed from favorite cultivars.
  - *Always start with non-patented seed – OSSI or locally shared seeds are best; PVP is OK.*
- Participate in local seed swaps and crop variety conservation efforts, such as Seed Savers Exchange, https://www.seedsavers.org.
- Contract with a local seed company to grow organic seed or evaluate breeding lines.
- Participate in farmer-participatory plant breeding.

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Resources for participatory plant breeding and organic seed production

- **Organic Seed Alliance** (OSA) http://www.seedalliance.org/
  - Manuals and training workshops in plant breeding and organic seed production.
  - Variety trial information.
  - Proceedings of Organic Seed Growers Conferences.
  - Technical support for farmer-led breeding projects.
  - Breeding populations for additional on-farm selection.

Organic Seed Alliance

Organic spinach grown in OSA farmer participatory breeding project, which developed 'Abundant Bloomsdale' adapted to Pacific Northwest.

Resources for participatory plant breeding and organic seed production

- **The Experimental Farm Network**, open source network of 300 farmers and scientists, http://experimentalfarmnetwork.org/.
  - Upland rice, perennial grains and beans, etc.
- **NOVIC, TOMI, CIOA,** etc. (link from http://eOrganic.info and OSA web sites)
- **Kevin Murphy, Washington State U.** http://css.wsu.edu/people/faculty/kevin-murphy/.
  - Evolutionary participatory plant breeding (EPB).
  - Barley, quinoa, spelt, other specialty grains.
- **Seed Companies with PPB programs**
  - High Mowing Seeds, Johnny's, Common Wealth Seed Growers, etc.

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Recent Developments in Public Plant Breeding for Organic

Research funding and cultivars "in the pipeline"

USDA funds plant breeding for organic

"Strengthen organic crop seed systems, including … plant breeding for organic production, with an emphasis on publicly available releases. Goals … can include, but are not limited to: disease, weed, and pest resistance; stress tolerance; nutrient use efficiency; performance in soil-improving and climate-friendly systems such as organic no-till; quality and yield improvement; and … cover crop breeding for enhanced performance in organic systems."

USDA, National Institute for Food and Agriculture. 2017. Organic Research and Extension Initiative, 2018 Request for Applications, Priority 4 (p 5).

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OREI program news

2018 OREI Awards include:

- NOVIC 3 – continue PPB in sweet corn, tomato, cabbage, pepper, cucumber, winter squash
- Cover crop breeding – continued funding for Mirsky and colleagues at USDA ARS Beltsville, MD.

Delay in Farm Bill has temporarily suspended OREI

- Current awards through 2018 will continue.
- No 2019 RFA until Farm Bill passes.

OREI funding likely to increase under new Farm Bill.

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Looking into the near future

Some promising cultivars in the pipeline include:

- Tomatoes resistant to six major fungal and bacterial diseases (TOMI).
- Improved red and purple carrots; breeding stock resistant to two pest nematodes (CIOA).
- Several widely adapted sweet corn varieties, and one specifically for Olympic Peninsula (NOVIC).
- New varieties of red cabbage, pepper, delicata squash, tomato, snow and snap peas (NOVIC).

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Thank you to the following organizations and foundations for their long term support of OFRF

California Department of Food & Agriculture | Clarence E. Heller Charitable Foundation | United States Department of Agriculture's Risk Management Agency | Western SARE | Forrest C. & Frances H. Lattner Foundation | Marisla Foundation | Agua Fund | The Ida and Robert Gordon Family Foundation, Inc.

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- Find all upcoming and archived webinars at http://articles.extension.org/pages/25242 and the eOrganic YouTube channel. This recording will be available within 1-2 weeks.
- Find the OFRF Soil Health Guides at http://ofrf.org/soil-health-and-organic-farming-ecological-approach
- Have an organic farming question? Use the eXtension Ask an Expert service at https://ask.extension.org/groups/1668
- Please send your feedback! We will email you a survey about this webinar later today.
- Thank you for coming!

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