Four Organic Breeding Guides - An Introduction to Organic Breeding, and Organic Breeding for Sweet Corn, Carrots, and Tomato

Final Report

Project Summary

We all know that organic farmers' success relies on their appropriate use of practices such as crop rotation, cover cropping, biological pest control, and mechanical cultivation. Many are just coming to realize, however, the key role that plant genetics plays in organic farmers' success. In fact, plant varieties that are well suited for organic production challenges may be able to better access organic fertility sources, compete with weeds, or resist pests, and can make the difference between a successful and unsuccessful season. Currently, however, almost no plant varieties have been bred specifically for organic systems. To increase organic farmers' success, we must increase the number of varieties bred for organic systems. And one of the groups best suited to do this breeding work is organic farmers themselves.

There are a rapidly growing number of organic farmers who are interested in on-farm plant breeding and variety improvement. The objective of this project was to educate these organic farmers on methods of on-farm organic breeding, and to empower them to breed their own crop varieties. To accomplish this objective, we have developed four organic breeding manuals. One manual is an introduction to fundamental organic breeding concepts and techniques, and the three other manuals address crop specific, on farm organic breeding techniques for sweet corn, carrots, and tomatoes.

This project will have a three-fold positive impact on organic farming. First, farmers will have greater success in improving germplasm to meet the conditions of organic systems, resulting in more variety choices for producers. Second, farmers will be able to control the seed of their favorite varieties, maintaining them even if seed companies discontinue the varieties. Third, they will gain skills that improve their ability to participate in breeding projects with public and private breeders, opening new business opportunities and increasing farmers' influence on all organic seed development.

Drafts of the introductory manual have been disseminated at the 2014 Organic Seed Growers Conference (OSGC). All manuals are available through Organic Seed Alliance (OSA)'s website, and will be disseminated at additional events.

Introduction

Fundamental to the success of organic agriculture is the use of plant varieties most suitable to organic production challenges. With a limited number of certified inputs to combat production problems, organic farmers rely on prevention via crop

rotation, soil management strategies, and the use of appropriate crop genetics. While progress has been made in developing best management practices, little has been done to develop varieties suited to organic systems - a strategy that could, over time, be equally important.

Public and private sector breeding research has been slow to respond to the needs of organic farming for a number of reasons, including the difficulty of addressing the complex and diverse needs of fresh market producers. This is compounded by the fact that breeding in minor crops as a whole continues to decline, particularly in regions that are not in the large agricultural vegetable production regions of California, Arizona, Texas or Florida.

Over the past several decades, plant breeding has become increasingly formalized and centralized. Breeding work that was once done mainly in farmers' fields is now done almost exclusively by large seed companies and on state-run agricultural experiment stations. Most breeders working for large seed companies, as well as most public breeders, focus their attention primarily on the largest markets for seed, which are typically large, conventional farming systems located in prime agricultural regions. This focus on the needs of large-scale, conventional agriculture leaves organic farmers without varieties that are adapted to the needs of their systems. Research has found that the lack of organically adapted varieties leaves organic farmers at a disadvantage, resulting in, among other things, lower yields than if they had varieties adapted to their systems. Organic, on-farm breeding work is devoted to serving the needs of these organic farmers.

Building a healthy, sustainable agriculture future requires farmer-centric seed systems at the regional level, where farmers and the communities they serve consciously choose which crop genetics they use, how they are maintained, and how these genetics are controlled.

Done well, organic plant breeding can help ensure that farmers control the seed they use. Breeding work can give farmers free access to genetic resources and the freedom to grow what they please, while supplying them with the knowledge and skills to both grow seed and improve a crop's characteristics to best meet their needs.

Crops adapted to organic systems could be an important part of a farmer's strategy to prevent production problems. Besides the fact that the breeding work might not be done if farmers do not do it themselves, another important benefit of on-farm breeding is that varieties can be adapted to the climactic conditions and growing practices of the farm or region rather than the conditions and practices of public or private research farms. Therefore, this project addresses the issue of organic producer need for varieties suited to local, organic farming conditions by giving them the information they need to do their own breeding. It will also help reduce the risk that farmers will be left without a needed variety when a seed company discontinues it. Finally, this project will provide farmers with new skills that allow

them to take advantage of new partnerships and business opportunities with the public and private seed sectors.

Objectives Statement

Our primary objective was to educate organic farmers on methods of on-farm organic breeding, and to empower organic farmers to breed their own crop varieties.

We accomplished this objective by creating and releasing four organic breeding guides, including a guide providing an introduction to organic breeding and crop specific organic breeding manuals covering sweet corn, tomatoes, and carrots.

Educational Approach

This project developed four organic breeding manuals. One manual is an introduction to fundamental organic breeding concepts and techniques, and the three other manuals address crop specific organic breeding for sweet corn, carrots, and tomatoes. These manuals are written for farmers. The techniques in the manuals are those that farmers can use without adding extensive breeding infrastructure, and the manuals are be written to be accessible.

Project Results

Introduction to On-farm Organic Plant Breeding

The introductory manual is 40 pages long and contains the following sections:

Section I: Introduction
- Why plant breeding is important
- The philosophy of organic plant breeding
  - Our farming ancestors never stopped breeding
  - Returning farmers to their role as seed stewards

Section II: Plant breeding basics
- Selection in theory and practice
- How to select
- A crop's mating system and how it affects plant breeding
- Breeding self-pollinated crops vs. breeding cross-pollinated crops

Section III: Developing a plant breeding plan
- Thinking about your target environment
- Determining traits
- Prioritizing traits
  - How can the traits be measured?
  - How easily can the traits be inherited?

Choosing parents
Creating a breeding timeline

Section IV: Theories of field-based organic plant breeding
How genes travel from parents to offspring
How genes determine the appearance and performance of plants
How genes travel together during reproduction
How genes operate in populations
How to see the genetic differences between plants
Understand the effects of the environment
Ensure that plants receive consistent treatment
Use sufficient population and plot sizes

Section V: Examples of farmers breeding for organic systems
'Abundant Bloomsdale' organic spinach breeding project
What were the goals of this project?
Breeding procedure
Winter sprouting broccoli
What were the goals of this project?
Breeding procedure:

Glossary and Index

References and resources

How to Breed Sweet Corn for Organic Agriculture

The sweet corn breeding manual is 18 pages long and contains the following sections:

Introduction

Introduction to Breeding

Breeding Goals

Germplasm

Reproductive Biology and Pollination Techniques

Selection
Inbred-hybrid Development
Mass Selection
Family Selection
Selection Techniques
Breeding Timeline

References and Resources

How to Breed Tomatoes for Organic Agriculture

The tomato breeding manual is 20 pages long and contains the following sections:

Section I: Introduction

Section II: Introduction to Breeding

Section III: Breeding Goals
- Agronomic traits
- Defensive traits
- Fruit Quality

Section IV: Sourcing Germplasm

Section V: Reproductive Biology

Section VI: Pollination Techniques

Section VII: Breeding Methods

Glossary

References and Resources

How to Breed Carrots for Organic Agriculture

The carrot breeding manual is 16 pages long and contains the following sections:

Section I: Introduction

Section II: Introduction to Breeding

Section III: Breeding Goals

Section IV: Germplasm

Section V: Reproductive Biology

Section VI: Plant Breeding
- Mating systems for seed production
- Generating breeding populations
- Making the cross-pollination

Controlled pollination
Strain cross
Mass selection
Family selection
Breeding timeline
Breeding summary

Glossary

References and Resources

Conclusions and Discussion

We expect that by producing manuals that help farmers understand plant breeding techniques, this project will have a three-fold positive impact on organic farming: it will lead to a greater number of organically bred varieties, increased farmer control of varieties, and increased farmer influence on the direction of organic seed development. First, with the education that farmer-breeders will receive from these manuals, they will have greater success in improving germplasm to meet the conditions of organic systems. This will result in an overall increase in variety choices for producers. Second, farmers will be able obtain greater farm security by being able to maintain and improve their own varieties, reducing their dependence on industry and public programs to fulfill their germplasm needs. Third, they will gain skills that improve their ability to participate in breeding and variety evaluation projects with public plant breeders and the organic seed industry, opening new business opportunities and increasing farmers' influence on all organic seed development.

Outreach

We distributed draft copies of the *Introduction to Organic On-farm Breeding* at the Organic Seed Grower's Conference. We are printing the final versions of all four manuals now and intend to distribute over 200 more at additional events and through direct contact with farmers and researchers.

We have posted the manuals to OSA's publication page and have sent a press release to over 400 national contacts, including journalists and NGOs. We have also shared the press release on OSA's Facebook page, which has over 30,000 followers.

Financial Accounting

See attached budget.

References

Adam, K. 2005. Seed Production and Variety Development for Organic Systems [Online]. Available at: https://attra.ncat.org/attra-pub/download.php?id=70 (verified 30 Apr. 2012). ATTRA / NCAT. Butte, MT.

Allard, R.W. 1960 & 1999. Principals of Plant Breeding, 1st and 2nd ed. John Wiley & Sons, New York, NY

Anderson, D., M. Honeyman, J. Luna and V. Berton. 1999. How to Conduct Research on Your Farm or Ranch Sustainable Agriculture Network [Online]. Available at http://www.sare.org/publications/research/research.pdf (verified 20 Apr. 2012). SARE / USDA, College Park, MD.

Ashworth, S. 1991. Seed to Seed. Seed Savers Publications, Decorah, IA.

Basset, M.J. 1986. Breeding Vegetable Crops. AVI Publishing Company, Westport, CT.

Bernardo, R. 2010. Breeding for Quantitative Traits in Plants. 2nd Ed. Stemma Press, NJ

Briggs, F.N., and P.F. Knowles. 1967. Introduction to Plant Breeding. Reinhold Publishing Corporation.

Ceccarelli, S. 2010. Participatory Plant Breeding (Training Manual) [Online]. Available at http://ceccarelli.files.wordpress.com/2010/01/ppb-manual.doc (verified 20 Apr. 2012).

Colley, M., A. Stone, L. Brewer, B. Baker. 2010. Organic Seed Resource Guide [Online]. Available at http://www.extension.org/article/18340 (verified 20 Apr. 2012). eXtension Initiative, Lincoln, NE.

Colley, M., and J. Myers. 2007. On-farm Variety Trials: A Guide for Organic Vegetable, Herb and Flower Producers. Organic Seed Alliance, Port Townsend, WA.

Colley, M., J. Navazio and L. DiPietro. 2010. A Seed Saving Guide for Gardeners and Farmers. Organic Seed Alliance, Port Townsend, WA.

Deppe, C. 2000. Breed Your Own Vegetable Varieties: The Gardener's and Farmer's Guide to Plant Breeding and Seed Saving. Chelsea Green Publishing, White River Junction, VT.

Fehr, W. and Hadley, H. (eds.) 1980. Hybridization of Crop Plants. American Society of Agronomy, Madison, WI.

Fehr, W. R. 1987. Principles of cultivar development.

George, R. 1999. Vegetable Seed Production. CABI Publishing, New York, NY.

Hawthorn, L., and L. Pollard. 1954. Vegetable and Flower Seed Production. Blackiston Co., New York, NY.

Kaukis, K. and D.W. Davis. 1986. Sweet Corn Breeding. p. 477-522. In Bassett, M. J. (ed.) Breeding vegetable crops. AVI Pub. Co., Westport, Conn.

Lammerts van Bueren, E. and Myers, J. (eds.) 2012. Organic Crop Breeding. Wiley-Blackwell, West Sussex, UK

McCormack, J. 2010. Bean Seed Production [Online]. Available at http://www.savingourseeds.org/pub_bean_seed_production.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Brassica Seed Production [Online]. Available at http://www.savingourseeds.org/pub_brassica_seed_production.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Cucurbit Seed Production [Online]. Available at http://www.savingourseeds.org/pub_cucurbit_seed_production.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Isolation Distances [Online]. Available at http://www.savingourseeds.org/pub_isolation_distance.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Pepper Seed Production [Online]. Available at http://www.savingourseeds.org/pub_pepper_seed_production.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Seed Processing and Storage [Online]. Available at http://www.savingourseeds.org/pub_seed_processing_storage.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

McCormack, J. 2010. Tomato Seed Production [Online]. Available at http://www.savingourseeds.org/pub_tomato_seed_production.html (verified 20 Apr. 2012). Saving Our Seeds, Charlottesville, VA.

Miller, B., E. Adams, P. Peterson, and R. Karow. 1992. On-farm Testing: A Grower's Guide [Online]. Available at http://pnwsteep.wsu.edu/onfarmtesting/EB1706.pdf (verified 20 Apr. 2012). Washington State University Cooperative Extension, Pullman, WA.

Mueller, D. and R. Pope. 2009. Corn Field Guide. [Online]. Available at: http://www.agronext.iastate.edu/corn/docs/corn-field-guide.pdf (verified 28 Mar. 2014). Iowa State University, Ames, IA.

Myers, J. Intellectual Property Protection: What Do I Need to Know When Growing and Breeding Organic Crops and Seeds? Available at http://www.extension.org/pages/18449/intellectual-property-protection:-what-do-i-need-to-know-when-growing-and-breeding-organic-crops-and#.Uys14FymDlM (accessed 3.20.14)

Navazio, J. and J. Zystro. 2014. Introduction to Organic On-farm Breeding. Organic Seed Alliance, Port Townsend, WA.

Navazio, J., M. Colley, and J. Reiten. 2010. Principles and Practices of Organic Carrot Seed Production. Organic Seed Alliance, Port Townsend, WA.

Navazio, J., M. Colley, and J. Zyskowski. 2010. Principles and Practices of Organic Beet Seed Production. Organic Seed Alliance, Port Townsend, WA.

Navazio, J., M. Colley, and M. Dillon. 2007. Principles and Practices of Organic Bean Seed Production. Organic Seed Alliance, Port Townsend, WA.

Navazio, J., M. Colley, and M. Dillon. 2007. Principles and Practices of Organic Radish Seed Production. Organic Seed Alliance, Port Townsend, WA.

Tracy, W. F. 2000. Sweet corn. pp. 155-199, In A. R. Hallauer (ed.) Specialty Corns Second Edition. CRC, Boca Raton, FL.

Webber, H. J. 1908. Plant Breeding for Farmers. Nabu Press, Charleston, SC.

Whealy, K. 2000. Garden Seed Inventory: An Inventory of Seed Catalogs Listing All Non-Hybrid Vegetable Seeds Available in the United States and Canada. Seed Saver Publications, Decorah, IA.

White, R. and Connolly, B. 2011. Breeding Organic Vegetables: A step-by-step guide for growers. NOFA – NY, Rochester, NY.

Zyskowski, J., J. Navazio, F. Morton, and M. Colley. 2010. Principles and Practices of Organic Lettuce Seed Production. Organic Seed Alliance, Port Townsend, WA.

Zystro, J., A. Shelton, and S. Snapp. 2012. Participatory Plant Breeding Toolkit. Organic Seed Alliance, Port Townsend, WA.

ATTACHED:

(1) Final Budget

(2) *Introduction to Organic On-farm Breeding*

(3) *How to Breed Sweet Corn for Organic Agriculture*

(4) *How to Breed Tomatoes for Organic Agriculture*

(5) *How to Breed Carrots for Organic Agriculture*