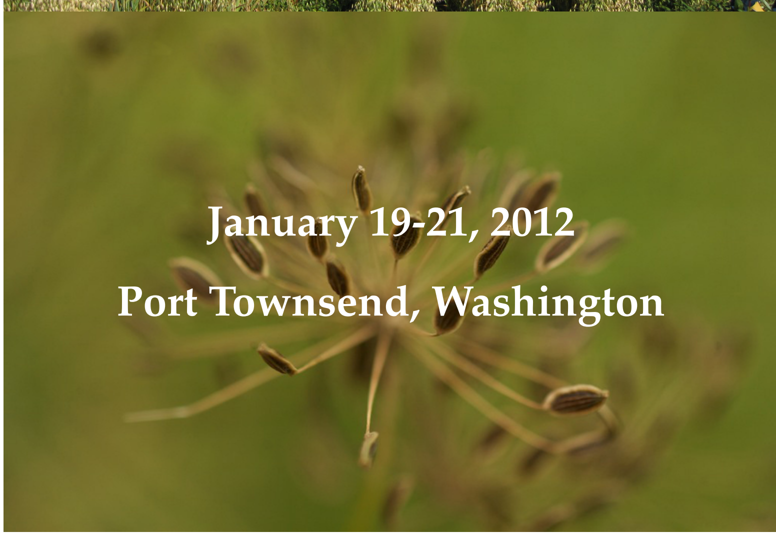
PROCEEDINGS OF THE 6TH ORGANIC SEED GROWERS CONFERENCE





Strengthening Community Seed Systems

Co-hosted by Organic Seed Alliance, Washington State University, and Oregon State University

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Organic Seed Alliance

Mission
Organic Seed Alliance advances the ethical development and stewardship of the genetic resources of agricultural seed.

Vision
We believe seed is both our common cultural heritage and a living natural resource fundamental to the future sustainability of food production. Proper stewardship of our genetic resources involves their conservation and careful management in a manner that allows seed to continually evolve with challenges of the environment, cultural practices of sustainable agriculture, and the need to feed people. Our vision is an organic food system that is built on a foundation of seeds that are adapted to the organic and climatic conditions in which they are sown.

Programs
We engage farmers and other seed professionals in developing regional, decentralized, and community-based seed systems that provide biologically diverse seed options appropriate for organic farming systems. We also aim to influence policy decisions that impact the integrity of the seed systems we help create. Through research programs, collaborative education, and advocacy, we serve organic and non-organic farmers, eaters, university researchers, seed and food businesses, and seed advocates.

Research Our research focuses on participatory plant breeding projects that support organic seed systems and address community food needs.

Education We provide technical assistance in plant breeding and seed production to farmers, students, seed companies, food businesses, and retailers through workshops, consultations, and publications.

Advocacy We advocate for policies that support the ongoing growth and success of organic seed systems.

Advisory Services We offer a range of fee-for-service technical and advisory services to seed and food companies, farmers, and organizations.

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Conference Agenda — Thursday, January 19

7:15 - 6:45	Pre-conference event *Field Tour of Skagit Valley Seed Region*
7:00 - 8:00	Dinner
7:00 - 9:00	Trade Show and Poster Session set-up
8:00 - 9:00	Bill McDorman presents *Extreme Diversity. Inspiration from 30 Years in the Bio-regional Seed Movement*
9:00 - 11:00	Meet and greet and outdoor bonfire

Friday, January 20

7:30 - 8:30	Breakfast
9:00 - 10:30	**Sessions** *Integrating Organic Seed Production into a Diversified Farming Operation* *Introduction to Organic On-farm Plant Breeding* *Farm Bill: Cultivating Support for Organic Seed Systems* *Farmer-owned Seed Companies – How to Get Started*
10:30 - 11:00	Break
11:00 - 12:00	**Keynote address by William Tracy, Dean of the College of Agricultural and Life Sciences, University of Wisconsin - Madison**
12:00-1:00	Lunch
1:30 - 3:00	**Sessions** *Organic Wheat Breeding* *Seed Production 101* *Coexistence or Conflict?* *Participatory Breeding Café* *Managing Disease in Seed Crops*
3:00 - 3:30	Break
3:30 - 5:00	**Sessions** *Breeding Peas, Sweet Corn, Broccoli, Winter Squash, and Carrots for NOVIC* *Harvesting and Seed Cleaning for Small- to Mid-Scale Farms* *Toward Community Seed Systems*
5:00 - 6:00	Seed Savers Exchange presents *Living History*
6:00 - 7:00	Dinner
7:00 - 8:30	Trade Show with regional organic wines
9:00 - 11:00	Music: The Dustbunnies

Saturday, January 21

7:30 - 8:30	Breakfast
9:00 - 10:30	**Sessions** *Organic Corn Breeding* *Organic Variety Commercialization* *Understanding the Seed Needs of the Organic Industry* *Managing Isolation Distances in Organic Seed Production* *Public Seed Commons -- Past, Present, and...Future?*
10:30 - 11:00	Break
11:00 - 12:00	**Keynote address by Eric Holt-Giménez, Executive Director of Food First Institute for Food and Development Policy**
12:00 - 1:00	Lunch
1:30 - 3:00	**Sessions** *Hybrids vs. Open-pollinated Varieties: How Do They Fit into an Evolutionary Seed System?* *Pollinator Conservation Strategies for Organic Seed Producers* *Seeds of Democracy: An International Perspective* *Breeding for Nutrition*
3:00 - 3:30	Break
3:30 - 5:00	**Sessions** *Hands-on Pollination Workshop* *Untangling the Roots of Seed Concentration* *Growing and Marketing Organic Seed Profitably* *Breeding for Positive Microbial Interactions*
5:00 - 5:30	Dan Ravicher of Public Patent Foundation
5:00 - 7:00	Trade Show and Seed Swap
7:00 - 9:00	Banquet dinner
8:00 - 9:00	Closing address from Organic Seed Alliance
9:30 - 11:30	Music: The Pheromones

Sunday, January 22

8:00 - 9:00	Breakfast
9:00 - 10:00	Scott Vlaun presents *Seed People: A Journey into the Organic Seed Movement*

Strengthening Community Seed Systems

The vision of a community seed system is one where seed, a fundamental resource of our food system, is managed in an ethical manner that honors ecological systems, farmers' roles as seed stewards, and the people they feed. This vision can only be realized with the support and investment from the entire organic community, including the food and processing industry, retailers, seed companies, farmers, eaters, plant breeders, researchers, certifiers, policy experts, and so many others. We chose this year's conference theme -- *Strengthening Community Seed Systems* -- to acknowledge the groundswell of activities happening in communities of all sizes. From urban seed libraries to participatory plant breeding projects spanning five states, new models of decentralized seed systems are growing all around us. This conference provides these diverse stakeholders a timely and unique opportunity to trade knowledge, philosophies, techniques, and ideas -- and seed! -- to foster these seed systems and strengthen the larger organic seed community. After all, it is you, the larger organic seed community, that remains a positive force in agriculture by working to ensure an organic seed future.

Thank you for joining us.

ORGANIC seed ALLIANCE

Presentations	Page No.

Organic Plant Breeding

Organic Seed Production, Marketing, and Distribution

Organic Seed Advocacy and Policy

Welcome to the 6th Biennial Organic Seed Growers Conference

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As we gather for the 6th biennial Organic Seed Growers Conference at Fort Worden State Park, the site of our first conference in 2000, I cannot help but reflect on the accomplishments of the organic seed community and the changing landscape of the seed industry over the past 12 years. We chose the term "community seed systems" for this year's theme out of recognition that it takes all of us working together to realize the vision of organic seed -- seed developed to optimize organic agricultural systems, produced with integrity, and managed by and for the organic community.

Thankfully many dedicated individuals from the first conference in 2000 are still with us, acting as mentors for a new wave of innovative farmers, companies, and researchers moving into organic seed. At the time of our first conference there were very few companies selling organic seed, and as Abundant Life Seed Foundation we provided a market for seed growers. Since then the National Organic Program changed the industry considerably, providing incentive for companies to move into organic seed. Today, dozens of companies supply organic seed.

With that shift, Organic Seed Alliance (OSA) has dedicated the last decade to training farmers and industry members in organic plant breeding and seed production. University breeding programs and graduate students are working to develop and test varieties for organic systems, an area of research virtually unheard of a decade ago. OSA and others now offer an array of publications, classes, and online resources on how to grow seed organically and breed for organic systems. OSA's senior scientist, Dr. John Navazio, is now teaching the first organic plant breeding course in the US for university credit through Washington State University. The work of eOrganic, the online extension service resource, is making organic seed resources available on a national scale and will be hosting the entire breeding track of this conference as an online webinar. New online resources are also being created to help farmers adopt organic seed, including an organic variety trial database and organic seed availability database.

In 2010, we completed the first *State of Organic Seed* report to assess our progress and identify and address key issues in organic seed development. Following the report, OSA launched working groups to address challenges and develop solutions in the areas of consolidation, contamination, intellectual property, and organic plant breeding.

While we have much to celebrate, we must continue to face obstacles to building organic seed systems. Genetic engineering remains a threat to organic integrity and a burden on farmers and seed companies who shoulder the costs and other consequences of genetic contamination. Utility patents are widespread, restricting our access to genetic resources and directly impacting organic farmers' and breeders' livelihoods. Lastly, federal funding for traditional plant breeding in the public sector remains marginal.

The Organic Seed Growers Conference provides a venue where we can build relationships that help us create a vibrant organic seed trade, and a community where ethical values go hand-in-hand with practical production needs.

It is my sincere wish that each person leaves this conference with new relationships, skills, and ideas that ensure ongoing collaboration toward an organic seed future. You are the organic seed community. Thank you for your passion and your work.

Breeding More Options in the Corn Seed Marketplace

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Practical Farmers of Iowa and its farmer cooperators have been working with USDA-ARS, Iowa State University, and Michael Fields Agricultural Institute to breed corn for sustainable agriculture. However, while breeders typically work with handful sized amounts of seed, farmers are interested in purchasing sufficient quantities of non-GMO seed to plant at field scale. The US Testing Network (USTN) was created in order to bridge the gap between the participatory corn breeding project and the field.

In February of 2009, the USTN took shape, bringing together public and private corn breeders, independent seed retailers, and farmers. The USTN does two things to help build an alternative seed system. First, the USTN provides a multi-state, rigorous testing network to evaluate germplasm being developed for the organic and non-GMO market. Second, as a network the USTN creates the opportunity for partnerships to develop and facilitate the increase of non-GMO and organic corn to the marketplace. Testing these corn hybrids across a large geographic area allows seed retailers to increase hybrids of varying characteristics demanded by farmers in different regions of the US. This bridge between breeders and independent retailers is needed now more than ever, considering the consolidation in the seed marketplace and lack of funding for public breeding programs that focus on non-GMO and organic seed.

An example of how the USTN can benefit independent breeders and seed retailers is Genetic Enterprises International (GEI), one of the USTN's founding members. Alix and Mary Jane Paez are breeders that founded GEI in 1993. They are located in Johnston, IA. Their breeding program focuses on developing non-GMO hybrids for different maturity areas of the US with emphasis in the Corn Belt.

"Breeders can use publicly available germplasm to develop hybrids for the various maturity zones across the Corn Belt," Alix commented. "I believe there is enough elite, or good, germplasm publicly available to do good breeding."

However, in the marketplace, farmers of all kinds have become concerned about a lack of choice of high quality seed. Alix explained that "seed distributors market the seed that is available; currently, GMO traited corn is the largest volume in the market and there is very little non-GMO seed available, especially from the large seed companies. On the other hand, non-GMO and organic seed availability is somewhat low and expensive because of the lack of volume demand."

GEI is among a growing number of private and public breeders and small seed retailers looking for "new" markets and creating those options for farmers. The Paezs are breeding conventional hybrids and also a product line of specialty hybrids that include high lysine for corn chips: Inca Maiz™ for tortillas and chips; hybrids with resistant starch that have the potential for controlling obesity; elevated pro-vitamin A for eye health; and white and waxy corns and also colored corns for the food market. Paez believes that the best way to ensure that farmers have improved corn that gives them the genetics they want is for breeders to start with good and diverse germplasm.

Alix shared, "Breeders should test the developed hybrids in yield trials across several locations and finally have access to good seed production for quality seed distribution to the marketplace."

USTN is working to make it easier for several small independent seed retailers, public and private breeders, and farmers to have access to improved non-GMO and organic seed in the marketplace. And USTN's membership continues to grow. Last year a hybrid developed at Cornell University, after being tested for two years by the USTN, was licensed, increased and marketed through Albert Lea Seed House. Elia Romano from Albert Lea says that the USTN data confirmed their interest in marketing this hybrid to farmers in the western part of the cornbelt. This hybrid is an earlier, organically produced hybrid that without the added testing available through the USTN might have taken more years to reach the marketplace.

Breeding Corn for Higher Nutritional Value for Organic Farmers

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Summary

Experience is presented on breeding corn for high protein quality and for high carotenoid contents. Methionine and lysine are two essential amino acids that positively affect protein utilization and the growth and health of animals. There is a need for high methionine corn to replace the use of synthetic methionine in feeding organic poultry. Soft and hard endosperm corn cultivars have been developed to possess high levels of protein, methionine, and lysine. The relative advantages of the two kinds of cultivars are discussed. Feeding trials with broilers and layers indicate that the soft endosperm, high methionine corn can replace the use of synthetic methionine. A near infrared spectroscopic (NIRS) method was developed for the rapid and non-destructive analysis of breeding lines. The trade-off between protein and yield is described. Selection emphasizes not only total content of essential amino acids but also their production on a per acre basis. High quality cultivars may yield less than conventional hybrids, but produce considerably more protein and essential amino acids on a per acre basis. Improvement of carotenoid content in our breeding lines was achieved using visual selection of segregating populations for bright orange and yellow seed over multiple generations. The utilization of high quality corn varieties with high protein, essential amino acid and carotenoid content depends on the economic value of these constituents being recognized by pertinent end-users.

Introduction

In a separate talk on our overall corn breeding effort at this conference I discussed our effort to develop inbreds and hybrids that combine quality with high agronomic performance. This contribution will describe our experience breeding corn for both higher protein content and quality and higher contents of carotenoids.

The need

Conventional breeding has emphasized increasing grain yield but this caused a progressive increase in starch and decrease in the protein content of the grain. The protein content and quality of corn is important to produce balanced rations for organic livestock production in light of the role that corn plays in livestock feed and the high price of organic protein. Listening sessions with organic farmers have indicated a keen interest in improving the nutritional value of corn, including its protein content and quality, and vitamin content, as well as improving its taste.

Methionine and lysine are generally regarded as being primary limiting amino acids for humans, hogs, poultry, and dairy cattle. For poultry, the sulfur-containing amino acid methionine is commonly regarded as being the first limiting amino acid for overall health and egg production, and lysine the second. Corn is the major ingredient of poultry food but it is naturally low in the sulfur-containing amino acids methionine, cysteine, and cystine, and in lysine. This deficiency is commonly made up by combining corn with soybean meal and supplementing with synthetic DL methionine. Due to national restrictions on its use, organic poultry producers will start to reduce the use of synthetic methionine in poultry feed and replace it after 2015 (Federal Register, 2010).

Carotenoids from corn are valuable pro-vitamins and antioxidants that are important for human health and especially for eye health. They also color egg yolks and the skin of chickens, and are viewed by US consumers as indicators of quality. In the US, the most pertinent market for high carotenoid corn is probably as chicken feed. Eggs have been shown to be a highly effective source access source for carotenoids in the human diet, possibly due to the cholesterol content of the egg. Feeding chickens high carotenoid corn can turn egg yolks a bright yellow-orange color. This fact is commonly utilized by indigenous people in different parts of the world to achieve higher quality eggs and thereby to enhance human nutrition.

Genetic sources

Breeding sources with high amounts of lysine and methionine in grain have been identified and are being used to develop cultivars. This work involves known genes such as *dzr-1* and *fl-2*, and others. Some high methionine cultivars have seed that has normal, translucent, hard endosperms, but others have seed with soft endosperms. The hard endosperm cultivars produce similar levels of methionine but less lysine than the best soft endosperm cultivars.

Some soft endosperm cultivars have approximately 50% more lysine and methionine than conventional cultivars (Goldstein et al., 2008). This is tied to an increase in fractions of proteins with high nutritional value and a reduction in storage protein fractions called zeins. However, zeins differ in their methionine content. In comparison with conventional cultivars, the endosperms of cultivars with hard endosperms and high-methionine content have greater quantities of methionine-rich zeins.

In our experience, cultivars with hard endosperms and high-methionine content have a relatively fixed level of methionine in their grain protein. In practice, achieving high methionine content in the grain in such cultivars depends on achieving a high grain protein content. The content must be greater than 11% on a dry basis to be of interest for replacing synthetic methionine in chicken feed. However, protein content of grain produced on different farms is variable, not dependable, and this could cause financial risk.

In this regard, the soft endosperm corn cultivars appear to have greater flexibility, achieving higher methionine percentages of the protein when protein content of the grain is lower. Our primary candidate for utilization as a soft endosperm source was the *fl-2* genetic system. Though the *fl-2* gene conditions a soft, high methionine endosperm in our cultivars, it also causes a seed weight reduction of approximately 11%. This yield reduction makes use of *fl-2* untenable.

We have moved away from using *fl-2* in our breeding program in favor of utilizing other genetic sources derived from landraces of corn. These sources condition quality like *fl-2* but do not strongly reduce seed weight.

Feeding trials

Soft-kernelled *fl-2* high methionine and lysine maize bred by the Michael Fields Agricultural Institute (MFAI) program successfully replaced the need for synthetic methionine in poultry feeding trials carried out with broilers by Organic Valley (Levendoski, 2006) and with layers by the University of Minnesota (Jacob et al., 2008). Palatability of the soft kernelled cultivars in both sets of trials was very high. Feed had to be restricted to avoid feeding frenzies. In the future, larger scale trials may be carried out with a team of organic poultry companies called the Methionine Task Force.

Tradeoffs between protein and yield

A pertinent issue being addressed is the tradeoff between high grain yield and high protein yield. High methionine corns are generally high protein corns. Conventional corn generally has 7 - 9% protein on a dry matter basis. Our cultivars have 9 - 13% protein. Selection for high protein can easily result in reduced endosperm and seed size. It is possible to select for corn that produces high protein without a reduction in endosperm size. The physiological changes coupled with higher protein content in corn may have to do with alterations in N acquisition patterns and greater utilization of N from soil organic matter or other sources as described in our companion presentations. Nevertheless, we have found that selection of corn on the basis of a high concentration of methionine and lysine in the grain is by itself untenable and must be coupled with estimates of yields of constituents on a per acre basis. Presently, our objective is producing cultivars that produce very high yields of protein and essential amino acids on a per acre basis and also have high per se contents of those constituents.

At question is what the tradeoff actually is between protein and yield. A recent set of high protein, high-methionine, hard endosperm hybrids (HM) developed by MFAI under organic conditions were tested in 2009 within US Testing Network and USDA-ARS sites. HM hybrids in the USTN trials averaged 87% of the average yield of normal elite hybrids on nine organic sites (87%) but only 81% of the average yield on conventional sites. However, the HM hybrids produced up to one-third more protein per acre where quality was measured on one organic site (Goldstein, 2009 unpublished). To what extent these protein advantages can be achieved under farm production conditions awaits future trials.

Introduction of such cultivars, with inherently higher quality but lower yield, depends on a price incentive coupled with methionine content and other nutritionally significant factors.

Measurement of essential amino acids using NIRS

Breeding for high methionine and lysine varieties has been greatly assisted by the development of new near infrared spectroscopic (NIRS) calibrations for two models of transmission-type NIRS units. MFAI's calibration is the result of work with the Iowa State University Grain Quality Lab (Charles Hurburgh, Connie Hardy, Glen Rippke). This calibration is based on a unique set of MFAI samples that enabled breaking the inherent correlation between the content of protein and the content of its constituent amino acids lysine and methionine. The calibration is presently licensed through the Bruins Instrument company for Bruins and Foss Infratec NIRS machines.

Carotenoids

Visual selection of seed within segregating families has been practiced with emphasis on planting seed with the most intense yellow and orange pigmentation. This practice, applied for multiple generations, generally led to an increase in carotenoid content. Whether the seed is opaque or translucent alters the appearance of the seed and must be taken into account when making selections.

Working together with Dr. Marvin Paul Scott (USDA-ARS, Ames, Iowa) we developed a quick semi-quantitative test for carotenoid content using a concentrated ethanol extractant and a spectrophotometer to quantify carotenoids.

Research by Dr. Wendy White (Iowa State University) using High Pressure Liquid Chromatography showed that some of the varieties we developed with our project have a high carotenoid content, with a few varieties having about twice as much retinoid active carotenoids as a hybrid check.

Again, widespread acceptance of carotenoids as a pertinent constituent of corn grain needs to be factored into the price of the product to encourage farmers to grow high carotenoid corn.

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Breeding Field Corn for Organic Farming in the Upper Midwest

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Summary

A project to breed organic corn began in southeast Wisconsin in 1989 in response to farmer demand for better quality corn. It was carried out at Michael Fields Agricultural Institute (MFAI) from 1988 - 2011, with the initial 14 years being a small program associated with the development of open-pollinated populations. In 2003 we began a partnership with USDA-ARS in Ames, Iowa, and Practical Farmers of Iowa, and started working more with inbred and hybrid development. In 2011, Cornell University, Ohio State University, New Mexico State University, and several private breeders became partners in an Organic Agriculture Research and Extension Initiative (OREI) funded project to breed corn for organic farmers. That same year I left the MFAI to start the Mandaamin Institute[1] to further develop the corn breeding work and related activities.

Our breeding program has been shaped by listening to the needs of farmers, seed companies, and poultry producers. Our objective is commercial hybrids with high protein and carotenoid value that are robust, competitive with weeds, adapted to climatic instability and low-input conditions, and yield at least 90% of the yield of conventional hybrids. The best of these hybrids may produce as much as one-third more protein and essential amino acids per acre than the average conventional hybrid. We are still working on developing and testing reliable inbreds and hybrids. Developing cultivars that combine quality with the high level of agronomic traits demanded by modern agricultural conditions with climatic instability is not a simple task. Assistance from our cooperators is accelerating the process leading to release. Primarily we are developing two heterotic groups for making hybrids. One called 'Nokomis Gold' is based on selection of North American native flour corn with some introgression from Corn Belt corn. The other group is based on crosses between South American Cateto flints and Corn Belt dent inbreds.

Long-term selection for productivity under organic condition may cause subtle, but important differences relative to conventional breeding programs. Results from competition studies showed that breeding and selection under organic conditions resulted in cultivars with better ability to compete with weeds than conventional hybrids. Inbreds from the program exhibit more robust growth under conditions where N is coming from soil sources. Increased grain protein yields and an increase in delta ^{15}N isotope ratio in the grain and tops indicate that more N may be coming from soil organic matter. Selecting

[1] Mandaamin means "Corn," "Corn Spirit," or "Wonder Seed" in the native Algonquian languages.

under organic conditions may affect corn physiology and interactions with microbial communities.

Introduction

Corn hybrids specifically adapted to the needs of organic farmers became an especially relevant issue for organic farmers in the US in 2002 - 2003. At this time transgenic contamination of corn and the effects of seed industry consolidation had become major threats to the availability of suitable seed. That threat has worsened over time. We had multiple listening sessions with organic farmers across the Upper Midwest at that time, and since then we maintained annual feedback sessions at Practical Farmers of Iowa gatherings and at the Upper Midwest Organic Farming Conference. We found that farmers want more than access to non-transgenic seed. They also want cultivars that compete well with weeds and can obtain sufficient nitrogen from soil organic matter or organic manures. Farmers who fed the maize to their own livestock were interested in nutritional value and palatability. Often, they were aware that modern breeding had reduced grain quality (increase in starch production coupled with reduction in protein and minerals) but they had no viable alternative to conventional hybrids. Considerable interest was expressed in obtaining new varieties with increased protein content and protein quality, more minerals, vitamins, and better flavor. The organic poultry industry needed corn that has high contents of the amino acids methionine and lysine. However, most farmers wanted to continue using hybrids because of the vigor and yield advantage and few seemed willing to take more than a 10% reduction in yield for a high quality hybrid.

Interest by small companies that produce non-transgenic hybrids for farmers increased as consolidation of the seed industry has continued. Progressively fewer elite inbreds are available to them from the major breeding companies that are not transgenic nor treated with fungicide.

Are F1, single cross hybrids the way to grow?

Most farmers are presently growing single cross, F1 hybrids. These hybrids are produced by crossing two inbred lines belonging to different but complementary heterotic groups. However, for organic farmers in the US there is some interest in open pollinated varieties or for alternative types of hybrids that may be cheaper and easier to produce due to weed problems. Some farmers are interested in growing open-pollinated populations because they want to save their own seed. Alternative hybrids could include sister line crosses or other three-way crosses, double crosses, top-crosses between diverse open-pollinated populations and inbreds, and the use of modern synthetic open-pollinated populations.

Inbreds are generally weedy crops for organic seed producers because they lack vigor, and do not shade and compete well. MFAI and the USDA tested production of hybrids made by crossing weed competitive open-pollinated varieties with each other or with inbreds rather than by crossing inbreds. This approach was proposed to seed companies and farmers as an alternative to single cross hybrids. It resulted in higher seed yields and less weeds, and some of the alternative hybrids were competitive with commercial hybrids for yield. However, seed companies responded that the hybrids made with populations produced plants that were not uniform enough and might thereby damage their reputations.

Synthetic varieties are populations that are generally created by intermating a set of proven inbred lines. Synthetics can achieve higher yield levels than older open-pollinated varieties that have received little systematic breeding for yield. They can also be propagated for many generations with little loss of yield.

Several studies have shown that synthetics currently produce lower yields that are probably not acceptable to most farmers in the US. The open-pollinated synthetic populations developed for breeding purposes at MFAI generally produce lower yields, often one-third less than conventional hybrids. Some of these populations do have a high protein content in their grain (9-13%) relative to conventional hybrids (7-9%) so that protein and essential amino acid yields may be similar on a per acre basis. Such open-pollinated corn should have a higher feeding value and price as organic protein from other sources is expensive.

The organic breeding program

MFAI's effort to develop high quality maize for organic farmers began in 1988 in response to a request from a group of organic farmers who were concerned about a loss in nutritional value and flavor in commercial varieties. They wanted open-pollinated populations with good agronomic characteristics and nutritional value. In the following decade MFAI bred several open-pollinated populations, one of which ('Nokomis Gold') was released in 1998 and grown by farmers in the organic movement.

From 2004-2012, funding was obtained that allowed for a joint project between the USDA-ARS corn breeding program in Ames, Iowa, MFAI, and Practical Farmers of Iowa to breed high nutritional value maize for sustainable farming. The project fostered breeding and selection under organic conditions and active exchange of breeding lines. Both programs utilized standard inbreeding and selection programs and early yield testing with test crosses. Practical Farmers of Iowa manages multiple field days each year in Iowa, and MFAI had annual field days in Wisconsin. Farmers participated in strip trials, practiced their breeding skills to adapt populations, participated in making hybrids and growing increase seed, and donated land for yield trials. The USDA-ARS unit does yield trials for its program and for the MFAI program on the farms of cooperators and at different research stations on a mix of organic and conventional sites.

In 2011 I left the MFAI to start the Mandaamin Institute to further develop the corn breeding work. That same year, Cornell University, Ohio State University, New Mexico State University, and several private breeders became partners in an OREI funded project to breed corn for organic farmers. The OREI project funded a winter nursery and testing for cold, disease, and insect resistance. The focus of the Mandaamin Institute program in the project is on producing commercial hybrids with high protein value that are robust, competitive with weeds, adapted to climatic stress and low N input conditions, and yield at least 90% of the yield of conventional hybrids. Emphasis is put on development of very vigorous, weed competitive inbreds.

Yield trial data from cooperative trials (Practical Farmers of Iowa's US Testing Network) and from trials by the MFAI and USDA programs suggest that the best of these hybrids may produce as much as one-third more protein and essential amino acids per acre than the average conventional hybrid.

Though we have made a lot of progress, we are still working on developing and testing the final inbreds and hybrids that combine these traits. Developing cultivars that combine stabile quality with the high level of agronomic traits demanded by modern agricultural conditions is not a simple task. Such traits include not only high and stabile grain yields, but also high and stabile protein contents. We also need tolerance or resistance to factors such as lodging, various diseases and insects, heat and cold stress, and droughty and wet soil conditions associated with climatic instability. Assistance from our cooperators, which includes expertise in breeding, pathology, field testing, genetics, stress physiology, and winter nursery seed production, is accelerating the process leading to release.

Though we have experimented with crosses and breeding lines from commercial sources, including ex-PVP lines, over time we find our greatest success in developing two heterotic groups for making hybrids. One called 'Nokomis Gold' is based on selection of North American native flour corn with some introgression from Corn Belt corn. The other group is based on crosses between South American Cateto flints and Corn Belt dent corn. These sources have been most useful in selecting high quality protein, carotenoids, and yield.

Weed competition studies

Weeds are presently a major problem in producing organic hybrid seed because inbreds lack vigor and do not compete well with weeds. Weeds can also be a major problem in hybrid maize when weather does not allow for timely mechanical control. One potential solution is to breed maize that competes better with weeds. Research with weeds tested numerous hybrids and populations of maize that were bred under organic conditions or under conventional conditions. In one set of trials, corn populations, breeding lines, and hybrids were grown in replicated trials on an organic farm. Weed foliage density scores in maize stands were almost two times higher for the conventional hybrids than for hybrids based on varieties selected under organic conditions. Late planted sunflowers into maize stands produced twice as much biomass in the mixture with the conventional hybrids as in mixture with the organically bred cultivars (Goldstein et al., 2006).

MFAI trials compared competitiveness of different maize cultivars with giant ragweed (*Ambrosia trifida* L.), a highly competitive weed for both organic and conventional farmers (Goldstein, 2002 unpublished data). Studies took place under replicated mini-plot conditions with equal numbers of maize and weeds in population stands. Cultivars included numerous F_2 populations derived from crosses between inbreds B73 or Mo17 with different landraces, as well as F_1 crosses between the organically bred 'Nokomis Gold' population with the same (F_1) inbred x landrace crosses. Dry matter yield of the weed in the pure 'Nokomis Gold' plots was 3.1 t ha^{-1}. Weed yields for the B73 or Mo17 based populations or the 'Nokomis Gold' x B73 or Mo17 based populations averaged 4.6 t ha^{-1}, and 3.3 t ha^{-1}, respectively (difference significant at $p < 0.0001$). Crossing with 'Nokomis Gold' appeared to reduce dry matter production of the weed by approximately one-third. Where the dosage of Mo17 and B73 in the F_2 populations went from 50% to 75%, the dry matter production by the weed increased from 4 to 4.6 t ha^{-1} for B73 populations and from 3.6 to 4.7 t ha^{-1} for Mo17 populations (differences significant only for the Mo17 populations at $p < 10\%$). B73 derived inbreds are probably in most hybrids used in the Midwest. However, multiple years of observation of B73 or commercial B73 derived inbreds under MFAI nursery conditions suggests that though they may be useful for contributing to yield they have especially poor per se competitive ability with weeds. This suggests that commercial breeding sources may not be the single best source for breeding for organic conditions.

Breeding organic adapted inbreds that are N efficient

Weeds are not the only issue. The poor vigor of conventional inbreds under organic conditions is a problem that is driving some organic seed producers in Wisconsin to seek permission to use fungicide treated seed. For a number of seasons the MFAI and USDA-ARS breeders have noticed an "Inbred Culture-Shock Syndrome." Some inbred cultivars perform poorly the first year they are grown under organic conditions (yellow-green leaves and relatively stunted), but when they are multiplied a second year under organic conditions their color and vigor improves. Explanations for this phenomenon, if it truly exists, could include undetected outcrosses, epigenetic changes, shifts in the relationship of plants to microbes including the balance of endophytes in seed, or subtle effects of selection practices or complex interactions between these factors. Though maize inbreds are commonly thought to be genetically homozygous, genetic variation has been shown by others to exist within the same inbreds grown in different generations. Growing corn on organic sites may affect genetic and epigenetic variation and/or the ability to distinguish such variation.

In 2010, eight inbred or partly inbred cultivars that had been grown and selected under organic or conventional conditions were compared by MFAI (Goldstein, 2010 unpublished data). Four were conventional commercial inbreds which either had been produced at the organic MFAI farm or were the original conventionally produced inbreds. The other four were derived from conventionally grown S3 lines and further bred either under organic conditions at MFAI or under conventional conditions by USDA-ARS. The resulting lines, most of which had been under numerous years of selection, were grown side-by-side in 2010 with replications on an organic field without fertilizer. Plants from seed that had been grown or bred under organic conditions had consistently higher chlorophyll content of leaves in early September during grain fill with an average positive increase of 16% (range 9 to 28%) relative to the conventionally grown/bred lines (difference significant at $P < 0.001$). These results suggest that the organically grown/bred maize is more efficient at obtaining N because chlorophyll content is linearly equated to the N content of plants (Schepers et al., 1992).

Analysis of N isotope composition is used to produce an indication of the source of N which plants extract from the soil in the form of a delta ^{15}N value. This measurement of the relative enrichment in ^{15}N relative to ^{14}N in plant tissues may indicate differences in the source of N available to the plants. Delta ^{15}N values close to 0 indicate N isotopic composition similar to air. Low ^{15}N values are found in nitrogen fixing legumes where the N comes directly from the air. Soil organic matter has high levels of ^{15}N relative to the air (high delta ^{15}N) due to selective release of ^{14}N during denitrification.

Trials with inbreds developed from our populations versus from conventionally bred, commercial inbred lines were utilized for testing in 2009. Grain samples from our breeding lines had generally higher delta ^{15}N signatures. In 2010, trials were carried out with a range of populations and conventional hybrids. The delta ^{15}N signature was again higher in our populations. There was a higher N content in both tops and grain for our populations. A positive relationship existed between N content of grain and tops and delta ^{15}N. Interpretation of delta ^{15}N results is not always clear due to the many factors that can influence ^{15}N concentrations. One possible explanation for the results is that the populations are capable of extracting more N from soil organic matter. This suggests differences in crop physiology, root function, and microbial relationships. However, in the "culture shock" trials, there was little difference in the delta ^{15}N values for the conventional and organically grown lines, suggesting that differences in chlorophyll might have another or more complex basis.

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Breeding Corn for Positive Soil Microbial Interactions

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Summary

Corn is a heavy feeding crop and is often fertilized heavily with nitrogen containing fertilizers. This is resulting in massive ecological problems with excessive nitrate in both ground and surface waters. The scientific literature suggests that corn can fix some nitrogen from the air in conjunction with different bacteria when N is limiting, but the ability to do this varies greatly with different corn varieties. The objectives of our research are to understand if this is true and to what extent it could be optimized through breeding, seed treatments, and farming practices.

In 2009 we noted differences between cultivars under N limiting conditions for chlorophyll content and for concentrations of ^{15}N in grain. Cultivars tested included a wide range of PVP-cross derived inbreds, inbreds from the Michael Fields Agricultural Institute (MFAI) breeding program, and exotic landraces. Though most of the lines appeared deficient in chlorophyll, several exotic landraces produced almost black-green leaves with levels of chlorophyll that suggested that they had been fertilized. However, the field had not been fertilized in at least four years. Furthermore, delta ^{15}N signatures on N from grain samples suggested that some of these same cultivars might have fixed up to half of their nitrogen from the air.

Factors investigated in randomized, replicated field trials in 2010 and 2011 included differences between varieties, effects of seed disinfection, foliar sprays, root health, and different microorganisms. In conjunction with a company that makes inoculants for organic farmers, we investigated different beneficial bacteria. We tested whether these organisms coupled with a simple seed disinfection can help eliminate *Fusarium* fungal species that commonly inhabit corn plants and seed, and antagonize internal colonization by bacteria.

In 2010 and 2011, warm, moist growing conditions did not seem to limit N uptake as there were no visual symptoms of chlorophyll deficiency. In a set of trials in 2010, disinfection decreased yields for four conventional hybrids but not for four hybrids made with the putative N efficient populations. The N efficient hybrids out-yielded the conventional hybrids but only when the former were inoculated with bacteria. The efficient hybrids produced more protein and essential amino acids per hectare and this was strongly increased by inoculating with bacteria. However, natural delta ^{15}N isotope analysis gave little support for the idea that N fixation had occurred in the 2010 trials. Under more optimal conditions, bacterial symbionts may benefit corn by stimulating plants to take up more N from soil. Therefore, N fixation may be facultative for some cultivars, depending

on need, environmental conditions, and their ability to foster microbial symbionts. However, it may be necessary to grow corn under low organic matter conditions in order to be able to detect fixation in corn using natural isotope abundance techniques.

Origin, Goals, and Activities of the NPSAS Farm Breeding Club

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Members of the Northern Plains Sustainable Agriculture Society (NPSAS) agree with plant breeders from the twentieth century who said that we needed crop varieties that were efficient with nutrients, provided the greatest return of high quality crops per acre, were adapted to the needs of growers and consumers, and were able to withstand weather extremes, pathogens, and pests in order to stabilize yields and income (Hayes et al., 1955). In order to address these needs for organic farmers on the plains, twenty-two members of NPSAS began the Farm Breeding Club (FBC) at our 1999 Winter Conference. We were fired up by *Return to Resistance* (Robinson, 2007) and decided to begin working on adapted, non-transgenic varieties with horizontal disease and pest resistance. The crops we decided to work on first were wheat, sunflowers, oats, potatoes, and buckwheat.

The project was designed to bring farmers together to share seed stock and information about breeding and seed saving. The original goals included enabling farmers in the Northern Plains to develop, maintain, and trade seed of varieties adapted to low-input methods of production, networking with other organizations to conserve biodiversity, and completing the food web by bringing together farmers, processors, and consumers to maintain taste and quality in our major crops. With the focus on local knowledge and diversity, FBC decided to look into the participatory plant breeding model to bring expertise about genetics and sustainable farming together. Grants funded conversations with public breeders across the region and helped us begin several major projects between 1999 and 2009. Collaboration was not always possible due to policies at some Land Grant Universities, one of which suggested to us that participatory breeding was "something they do in the Third World." However, important steps forward were taken with other public breeders, resulting in organic variety trials, a participatory breeding planning retreat, a participatory breeding symposium at a Tri-Societies meeting, field days, seed increases, and the release of a farmer-evaluated wheat variety, 'FBC Dylan,' in 2006. We are grateful to the funders, public breeders, and NPSAS members who came together to make these outcomes happen.

In 2010, the NPSAS board decided to hire a management team for the FBC in order to facilitate expansion of this high priority work. A survey taken of NPSAS members that summer identified disease resistant potatoes, adapted cover crops, general support of NPSAS member projects, commercial emmer, organic corn, and adapted and improved buckwheat as breeding goals that would serve as the club's focus through 2011 and beyond. Since then, potato evaluation and breeding projects for organic systems have been initiated, along with evaluations of field peas, winter peas, hairy vetch, sorghum, emmer, einkorn, buckwheat, triticale, oats, and radishes, among other projects. With the help of public breeders, university agronomists, and active members, we have also put on workshops and field days about the plant breeding process, seed production, and the importance of seed improvement to keep organic and sustainable agriculture productive. We continue to collaborate and communicate with others who have similar projects across the continent, and we look forward to releasing more varieties that meet our criteria during this decade.

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Using Gametophytic Cross Incompatibility for Organic Corn Purity

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Gametophytic cross incompatibility was first noticed decades ago among some lines of popcorn that would set little or no seed if pollinated by dent corn pollen (Thomas, 1955). This incompatibility trait is controlled by a single allele, $Ga1^s$, and incompatible lines are homozygous (Neuffer et al., 1997). Most dent corn is homozygous ga and cannot pollinate such lines, although there are some breeding populations of dent corn with $Ga1^s$ (Kutka, 2009) and a patent was granted for yellow field corn lines with $Ga1^s$ even though some yellow $Ga1^s$ lines already existed. Zeigler and Ashman (1994) reported that the trait is widely used in popcorn production to allow planting relatively close to dent corn fields with much reduced risk of cross-contamination.

$Ga1^s$ works because plants with this trait have silks that do not support normal pollen tube growth (and thereby fertilization) for pollen carrying the ga allele. Lausser et al. (2010) reported 0 - 5% of ga pollen tubes growing 8 cm into silks of homozygous $Ga1^s$ plants with most growing no more than 2 cm. Marcus Zuber, who released white dent corn inbreds with $Ga1^s$ in the early 1990s (Poneleit 2000), reported outcrossing rates of 2 - 5% in homozygous $Ga1^s$ white dent varieties planted adjacent to normal yellow corn. However, dent outcrosses are usually even lower in popcorn fields due to cross incompatibility and the abundance of more competitive $Ga1^s$ pollen in the popcorn fields (Zeigler and Ashman, 1994).

$Tcb1^s$ and $Ga2^s$ are gametophytic cross incompatibility alleles from teosinte that have been crossed into experimental field corn lines by Jerry Kermicle at the University of Wisconsin (Kermicle and Evans, 2010; Evans and Kermicle, 2001). These genes appear to work in a similar fashion to $Ga1^s$ and dent corns of the US are ga2 ga2 and tcb1 tcb1 in genotype. Kermicle and Evans (2010) found that these dominant cross incompatibility traits were not able to successfully cross with plants carrying a different incompatibility trait under most circumstances. These genes open up further opportunities to reduce undesirable outcrossing in commercial yellow and white corn in the US as has $Ga1^s$.

Although powerful tools that can greatly reduce rates of undesired outcrossing, these genes are not a guarantee of long-term genetic purity. Populations with these traits would need to be checked for outcrossing from time to time and normal measures to reduce outcrossing must still be put into place to receive the full benefit of these genetic tools. Of special note would be reducing the number of volunteer plants in adjacent transgenic fields that might be heterozygous for both transgenes and a gametophytic cross incompatibility trait. Such plants would produce some pollen that carried both an incompatibility gene and a transgene, and these could cross with plants homozygous for the same incompatibility gene. If, for instance, transgenic corn was all homozygous for $Tcb1^s$ and varieties used by organic farmers were all homozygous for $Ga2^s$, this threat would be largely eliminated as both varieties would likely be mutually incompatible.

There are other traits that could be used to help control and monitor transgenic contamination. There are several male sterility traits (Neuffer et al., 1997) and some are used for hybrid seed production. If 92% of the transgenic corn plants were male sterile (cross of sterile line with a fertile line that did not restore fertility in offspring), they would likely still be adequately pollinated by the 8% fertile plants mixed in and the amount of transgenic pollen blowing on the wind would be proportionately reduced. This approach is used successfully in the TOPCROSS® high oil corn system from Dupont (Thomison).

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Winter Wheat Breeding for Quality for Northern Plains Organic Farms

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I was involved with the Farm Breeding Club (FBC) of the Northern Plains Sustainable Agriculture Society in their early years when they were first focused on small grains. Our experience of selecting F2 bulk oat populations from the Minnesota oat breeding program, and wondering what to do next with the small amount of seed and large number of potential selections, made it clear that the typical farmer was not set up to efficiently handle early generations of small grains. For wheat (as for other small grains), hosting variety trials seemed to be a better fit for FBC farmers. My career at the time was developing hard white wheat varieties and managing wheat quality testing at South Dakota State University. For the club, I tested four organic locations of spring wheat variety trials in North Dakota and Minnesota. I found that the heirloom varieties, especially 'Red Fife,' had the poorest mixing quality, which translates to poor bread-making quality. This confirmed for me that breeding programs had come a long way in improving varieties for bread quality.

UNL Winter Wheat Breeding Program Background

Testing of winter wheat at the University of Nebraska - Lincoln (UNL) for organic production began seven years ago with variety trials on a farm in western Nebraska and on long-term organic plots in eastern Nebraska to examine whether there are quality or yield differences when compared to nearby conventional plots. There were enough differences among management systems to warrant exploring whether the same would be true in early generation nurseries. By 2007, organic land had been certified at four Nebraska locations representing three agro-ecozones through a USDA grant. We obtained another four-year USDA grant to examine the breeding question, and also to look at whether we could enhance wheat protein content through top-dressing, manure, or a change in the crop sequence.

In early generations where seed is limited, and the traits under selection are highly heritable and common to all of the targeted environments (winter survival, stem rust resistance, and maturity), we evaluate wheat only in conventional environments. At the F5 generation, on the basis of plant type, yield, and disease resistance, we harvest 400 plots from eastern Nebraska and 40 from an irrigated trial in western Nebraska. Immediately after harvest, we do micro-quality tests and retain 280 of the best quality lines. Organic testing begins at F6 with these 280 lines at two locations.

In the organic program, four more years of testing precedes selection of three to five lines to include in variety trials at the four Nebraska locations, Iowa (started in 2010) and

South Dakota beginning this fall. It takes at least 12 years to create a new wheat cultivar.

Organic Breeding Objectives

A 12-member organic advisory group of millers and Nebraska farmers has been our primary sounding board for developing goals for wheat breeding. We were advised to improve protein content of wheat as a top priority, since organic winter wheat in Nebraska often fails to meet the 12 % minimum protein content that historically has been rewarded with large premiums. Recognizing that it is difficult for organic systems to achieve this goal without costly nitrogen inputs, I have been working toward the goal of releasing cultivars that require less nitrogen to produce high quality bread.

At F6, our selection critieria for organic production diverges from conventional criteria. Screening for bread quality and other marketable traits is more stringent for organic production. Whole wheat quality is emphasized, which makes Fusarium head blight (FHB or 'scab') tolerance more important because the DON mycotoxin from FHB is concentrated in the bran. Agronomic traits that receive more emphasis are coleoptile length and canopy cover. Unique traits for organic breeding are nitrogen use efficiency for quality, nutrient density (including antioxidants), dietary fiber content, and, in the future, out-crossing. I will focus on quality traits and will later ask for feedback on a list of traits.

We involve the end-users in the wheat breeding process for both conventional and organic programs. The conventional testing provides long-term data over a large number of environments, which is useful information to supplement the organic data. For conventional breeding, samples of advanced lines from Plains regional nurseries are evaluated for bread, noodle and tortilla quality at a USDA lab in Kansas. Lines that are close to release from each public wheat breeding program east of the Rocky Mountains are milled at USDA and sent to several large companies that have their bakers participate on a panel evaluation at the annual Wheat Quality Council conference. In addition to testing experimental lines in our own lab, we also send samples to a couple of industry partners for in-depth evaluation. The relation is more intimate with the organic industry, because there are fewer players. We have sent samples to Baystate Milling, the largest organic mill in the US; Heartland Mill in Marienthal, KS, which provides white and stone-ground flour to artisan bakers; and to Kelloggs, which sources organic wheat for breakfast cereals. (A summary of industry data in comparison to UNL Quality Lab data will be presented.)

Quality Test Results

We have identified two high-yielding, low-protein winter wheat experimental lines with excellent bread-making quality that yield well in organic systems in Nebraska: NE07444 and NW07505. We have also identified two high protein experimental lines, NW03681 and NE08457, which appear to require the higher protein content to produce acceptable bread. This contrasts with 'Karl 92,' (a high protein variety widely grown in organic systems) which will bake excellent bread at grain protein content as low as 12%.

Several years ago, before we started testing on organic land, we offered a license for an experimental line, 'NE99495' (offspring of 'Karl 92' and 'Alliance'), that did not yield well enough for commercial release, but had excellent bread quality performance. We have since concluded that baking quality is not the same when grown on organic land, and 'NE99495' did not meet the expectations for baking quality. We have found the same to be true of a recent release, 'McGill,' which we intended to target for both organic and conventional production. Under conventional management with high nitrogen fertility, 'McGill' has been an outstanding baker. We discovered that 'McGill' responds dramatically to nitrogen inputs, both in yield and in protein content, and suffers when nitrogen is not high. When grown on two organic farms with obviously low nitrogen fertility, 'McGill' had only 10.4% and 10.8% grain protein, whereas NW03681 had 11.4% and 12.0% protein. Buyers for mills typically shy away from winter wheat below 12% protein. When grown in our organic test plots, baking performance for McGill was not nearly as good as 'Karl 92,' when both tested 12% for protein. Tables will be presented with quality results for several experimental lines and key varieties at 12% protein content, and compared with long-term data in which the protein content is not controlled.

Organic Breeding Challenges

In our next phase of research we will examine the nitrogen use efficiency for quality of promising experimental lines. We will evaluate bread quality at three protein levels of a dozen promising wheat lines to determine the protein content threshold for each line for making good bread. Buyers and end- users need the assurance that a low-protein variety will work for them before we can consider releasing a low-protein variety. A table of other traits of importance to organic breeding will be presented to obtain feedback.

Linking a Germplasm Collection of the Cover Crop Hairy Vetch (*Vicia villosa* Roth) to Traits Related to Improved Nitrogen Fixation

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Introduction

Hairy vetch is used as a leguminous cover crop throughout the United States providing important ecosystem services in agro-ecosystems (Abdul-Baki et al., 2002; Mohler and Teasdale, 1993; Puget and Drinkwater, 2001; Seo et al., 2006; Stute and Posner, 1995). Many traits found in hairy vetch have proven to be valuable to farmers practicing reduced input and organic farming methods and can contribute to overall farming system sustainability by reducing off farm inputs. In spite of all the apparent benefits of a hairy vetch cover crop, there are constraints that have limited its wide scale adoption among vegetable and grain producers. One key constraint to farmer adoption is variability in biological nitrogen fixation among cultivars of hairy vetch available to growers.

Our approach to improving vetch adoption is to: i) begin to document the genetic diversity among most of the hairy cultivars available; ii) link hairy vetch genotypes to traits or phenotypes that are beneficial to the sustainability of agroecosystems; and iii) understand the ecology of hairy vetch and other cover crops within farming systems toward the goal of providing farmers optimized matches between cover crop choice and cover crop expectations.

We previously examined the genetic diversity among hairy vetch cultivars available in the USDA plant germplasm collection (Maul et al., 2011) and found genetically related groups of hairy vetch shared traits valuable to farmers in the mid-Atlantic region. Specifically reduced-till organic farmers that wish to use a non-chemical approach to cover crop kill but leave the surface cover crop mulch intact rely on early flowering cultivars to synchronize cover crop management with cash crop planting. We found distinct clusters of cultivars that were among the earliest flowering plants in the trial, suggesting linkage (or genetic relationship) between the early flowering trait and specific genotypes of hairy vetch cultivars.

In addition, cold hardiness has been a major limitation for adoption of the early flowering varieties of hairy vetch north of the mid-Atlantic region and central mid-west. A number of "variety not stated" (VNS) offerings from seed companies in Nebraska, Minnesota and

Pennsylvania have shown cold hardiness but these flowered late in spring (Maul, field observation). Recent breeding efforts in Keedysville and Beltsville, MD, (Devine et al. *unpublished*) have attempted to select for the traits of early flowering and winter hardiness. Selection for cold hardy individuals from an established early flowering line (PI561947) resulted in the new cultivar 'Purple Bounty' (PB). Inter-crossing PI561947 with AU EarlyCover (PI 575701) and subsequent selection resulted in the cultivar 'Purple Prosperity' (PP, PI 654047).

In this study we examine the complexity of biological nitrogen fixation among hairy vetch cultivars available in the USDA germplasm collection. Through a series of experiments we look at the relationship between vetch genetic diversity and physiological features of the plant that are indicative of the health of *rhizobium* symbiosis in the nodule, including biological nitrogen fixation. We also present preliminary data that explores interactions between hairy vetch biochemistry, microbial mediated decomposition and cultivar genotype.

Materials & Methods

Plant Establishment and Sampling

Sixty-four accessions of hairy vetch available in the NPGS were obtained from the Western Regional Plant Introduction Station, Washington State University, Pullman, WA. Accessions were planted in the field, in 3 m row spacing using 100 seeds per row in single row, randomized design on September 12, 2008, at the USDA-ARS Beltsville Agricultural Research Center (BARC) in Beltsville, MD (39 1'54.34"N, 76 56'10.88"W). Between accession rows, a 3 m alleyway was left bare for weed management.

We preformed Plant Biochemical Analysis, Amplified Fragment Length Polymorphism (AFLP) Analysis, hairy vetch core germplasm identification (Maul et al. 2011), Nodule counts, weights, rhizobium diversity (BOX-PCR) and abundance, (Mothapo et al. *to be submitted* 2012). Vetch biological nitrogen fixation, mid-infrared biochemistry and decomposition (Maul et al. *to be submitted* 2012)

Results

A select group of hairy vetch cultivars were assessed for nodule rhizobial diversity, infection efficiency, plant physiological response to symbiosis. Clear positive relationships between nodulation efficiency and nodule number and total nodule weight were observed as a general response (figure 1a & b).

The AFLP analysis indicates the genetic diversity of hairy vetch species is much larger that what is currently available for use as a cover crop in US agroecosystems (figure 2.).

Most cultivars with seed available at production scale are derived from the same genetic background and are clustered in one or two of the 11 distinct genetic clusters we identified.

As an assessment of biological nitrogen fixation was conducted on field grown hairy vetch selected from the widest breadth of genetic diversity as determined from the relationship tree in figure two. The results indicate that there is significant variation in the proportion of plant nitrogen derived from biological nitrogen fixation (BNF) among all of the hairy vetch cultivars tested.

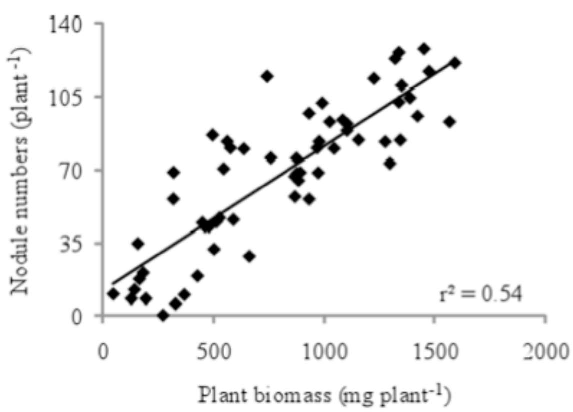

Figure 1a Correlation of hairy vetch shoot biomass and nodule numbers

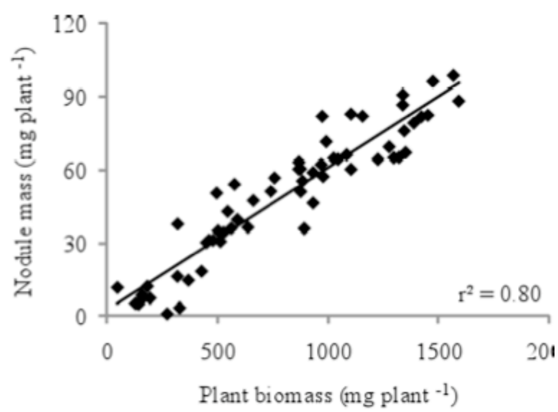

Figure 1b Correlation of hairy vetch shoot biomass and nodule mass

Conclusion

We present here information from an evaluation of the USDA NPGS *Vicia villosa* germplasm collection. For the first time, the genetic breadth and diversity of the complete collection has been described. We have shown that phenotypes important in the management of agricultural systems (flowering time, nitrogen fixation and winter hardiness) can be linked to genetic differences among vetch accessions identified by AFLP marker analysis. Climatic factors such as mean annual low temperature and annual precipitation appear to have had a selective effect on the composition of genetic markers reveled by AFLP analysis. This information will be instrumental for breeders interested in selecting and breeding hairy vetch for use in agricultural systems.

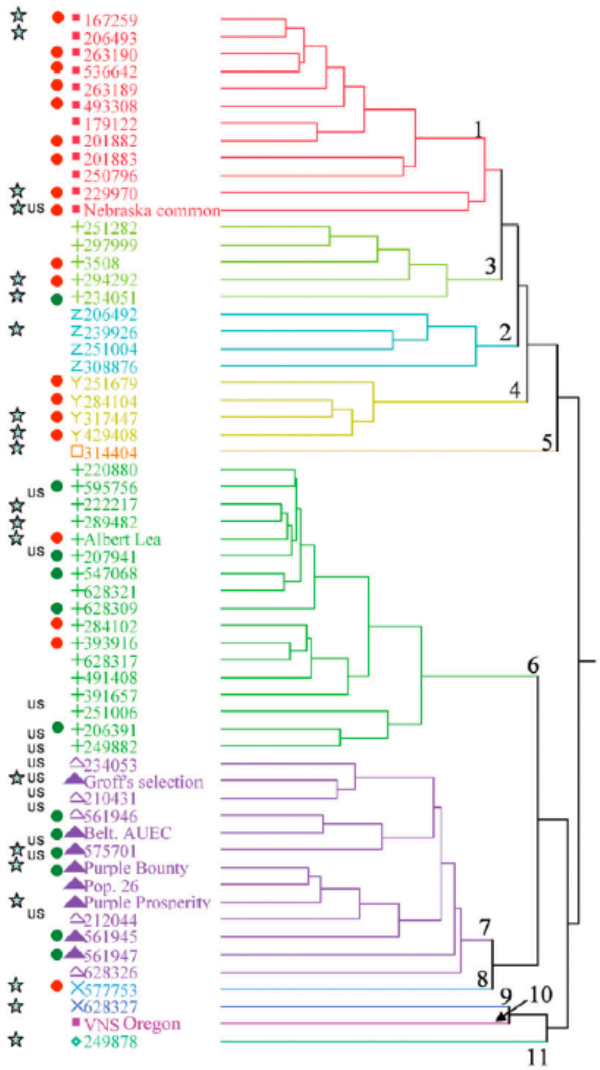

Figure 2. Hierarchical clustering of worldwide *Vicia villosa* accessions based on amplified fragment length polymorphism (AFLP) marker analysis. Eleven groups (denoted by branch color) represent the maximum number of clusters possible while keeping eight accessions of known related provenance within the same group (closed triangles). Accessions labeled "US" originate within the United States. Green circles indicate early flowering accessions; red circles indicate the latest flowering accessions. (See Table 1 for complete list; blue stars indicate accessions selected as the core genetic subset of vetch accessions.)

On-going projects in our lab will use a "core germplasm" collection consisting of a reduced set of accessions that capture a range of genetic and phenotypic diversity with the whole USDA NPGS *Vicia villosa* collection. This "core germplasm" consists of PI's 167259, 206493, 229970, Nebraska common, 294292, 234051, 239926, 317447, 429408, 314404, 222217, 289482, Albert Lea, Groff selection, 575701, Purple Bounty, Purple Prosperity, 577753, 628327 and 249878. This subset of accessions was select using criteria to maximize the ability to perform pair-wise comparisons between early flowering and late flowering accession within the same cluster, and compare accessions of similar genetic composition which are either of close or distant geographical origin. To capture the maximum genetic and phenotypic diversity, a disproportionate number of accessions were selected from each cluster based on total cluster size and phenotypic diversity.

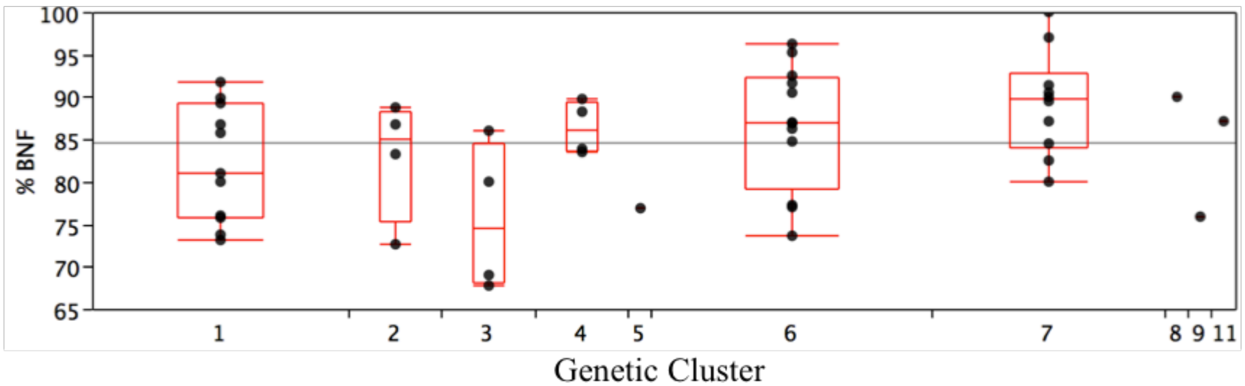

Figure 3 . Box and whisker diagram of the proportion total plant nitrogen derived from biological nitrogen fixation (%BNF). ^{15}N natural abundance relative to a non-leguminous reference plant was used to determine BNF among the eleven genetic clusters identified through AFLP genomic marker analysis of the hairy vetch cultivars available in the USDA plant germplasm collection.

Reducing the number of accessions from 64 to 20 will allow more explicit testing of genetic by environment interactions, which should result in selection for desirable phenotypes that are useful to farmers employing hairy vetch in sustainable farming systems. It is clearly understood that there are many other accessions of hairy vetch available globally that have been improved, on farm or in the research setting, and could be included in a more complete "core germplasm." We welcome collaborators with accessions of interest to submit; description of natural history, genetics and traits of interest to the USDA NPGS *Vicia villosa* germplasm collection.

The interaction between genetic context of each hairy vetch cultivar and subsequent rhizobial community structure within functional nodules will be further explored using the core germplasm collection identified in this report. Preliminary results suggest that plant constraints on rhizobial functionality (capacity to perform biological nitrogen fixation) rather than specific genotype by rhizobial community controls dominate this interaction.

Acknowledgements
Billy Wyant for planting of the vetch and maintaining bumble bee hives to facilitate pollination. Chris Rasman, Milutin Djurickovic, Hanna Poffenbarger for helping with plant and data processing. Tad Sonstegard, for AFLP analysis capacity. Peter Smouse and Rod Peakall for assistance with the Genalex 6.0 software.

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Winter Squash Breeding for NOVIC

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Winter squash breeding in the Northern Organic Vegetable Improvement Collaborative (NOVIC) has focused on enhancing the storability of butternut squash to extend the period that organic growers are able to sell their crop. Winter squash commonly fails in storage due to desiccation and/or black rot. Our goal is to decrease losses in storage while retaining the high quality of butternut squash adapted to organic systems.

An initial survey of *C. moschata* cultivars revealed four with better than average storage: 'Chirimen,' 'Futsu Black,' 'Upper Ground Sweet Potato,' and 'Long Island Cheese.' In order to combine their storability with conventional butternut shape and disease resistance, they were crossed to the powdery mildew resistant butternut, 'Bugle.' We have continued selection for quality, disease resistance, and cucumber beetle non-preference, and now have seed to plant the F4 generation in 2012 and continue their selection and evaluate their storability. These storability trials are performed by harvesting fruit before the frost, curing the squash for two weeks in a greenhouse or high tunnel, then storing several at 50 degrees Fahrenheit and 50% relative humidity. Brix, weight, and eating quality are assessed at the beginning of storage and every month thereafter until the squash are depleted.

'Honeynut' is a miniature butternut squash with exceptional eating quality because of its high Brix, fine grained texture, and rich color and flavor. Requests for improvements from growers mirror what we observed in our organic field plots. 'Honeynut' could be improved by increasing mildew resistance, decreasing desiccation during storage and days to maturity. We addressed mildew resistance and desiccation by again crossing to 'Bugle' and have 40 selections from F3 families that were selected for yield, shape, size, color, Brix, earliness and resistance to powdery mildew and black rot. We also noted that the initial F1 between 'Honeynut' and 'Bugle' was an excellent squash in its own right with many of the positive characteristics of each parent. This new hybrid will be released as 'Amber Delight' for those who don't want to wait for the OP. It was evaluated in 2011 trials and we are producing seed for other sites in 2012. Earliness was addressed by crossing 'Amber Delight' with especially early maturing butternuts. The progeny from this cross flowered nine days earlier on average than other populations

In addition to breeding, we are also testing new production methods to extend winter squash storage. Initially we explored the potential of trellising miniature butternuts, but now rolled down cover crops and other barriers that limit contact between squash and soil seem more efficient and effective.

Breeding Peas, Sweet Corn, Broccoli, Winter Squash, and Carrots as Part of the Northern Organic Vegetable Improvement Collaborative (NOVIC)

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Different crop varieties will not only have different heritable qualities, they will also respond to the production environment in different ways. For example, some may be more heat-tolerant than others in one environment, but their rank may be reversed in another environment. Thus, it is essential to find varieties that are adapted to the conditions that one expects to encounter in their production system. Organic production systems are a unique environment compared to conventional production systems, and varieties are needed for all types of crops that are adapted and productive in organic systems.

The number of crop varieties that have been bred in and are adapted to organic production is quite limited. This situation has been slow to change because private seed companies have been reluctant to engage in breeding for organic systems. When the USDA's National Organic Program (NOP) was first developed, the lack of certified organic seed of crop varieties was recognized as a concern, and an exception was granted that allowed organic growers to use untreated conventionally produced seed when certified organic seed was unavailable. This loophole is gradually being closed, and will eventually disappear as the supply of certified organic seed becomes more plentiful. The Northern Organic Vegetable Improvement Collaborative (NOVIC) is ultimately an effort to increase the availability of certified organic seed for vegetables.

NOVIC is a collaborative project funded by USDA's Organic Research and Extension Initiative (OREI) involving Oregon State University, University of Wisconsin-Madison, Cornell University, USDA-PGRU-Geneva, Organic Seed Alliance, and over 30 organic farmers in Oregon, Washington, Wisconsin, and New York. The mission of the project is to improve organic vegetable production through participatory plant breeding projects and variety trials that use research and on-farm environments, as well as an online resource for distributing findings and results. The four year project was initiated in 2008.

The project has two key aspects: 1) trialing existing vegetable varieties available from both public institutions and seed companies to identify those that are best adapted to organic production, and 2) supporting organic breeding efforts to increase the choice of varieties available and optimally adapted to organic production. Variety trials use a mother-daughter trial design, where replicated trials are grown on organically managed research farms (mother sites) in each of the four regions and several daughter trials are grown on working organic farms in proximity to the mother trial. Each of the three or more daughter trials represents a single replicate of the varieties under trial. These mother-daughter trials also provide a means to evaluate advanced breeding lines generated by the breeding programs.

Five vegetable crops commonly grown by farmers throughout the northern tier of the US were chosen for trialing and breeding. These include broccoli, carrots, edible podded peas, sweet corn, and winter squash. Breeding programs were initiated under an overarching theme of "season extension." Thus, while breeding for adaptation to organic production, we also seek to increase (through genetics means) the ability of the crop to perform under conditions that are less than optimal. For cool season crops such as broccoli and peas, this is defined as productiveness during the heat of the summer. Early season germination and emergence is the main goal of the sweet corn breeding program. With carrots we seek overwintering types that are weed competitive. Extended storage ability is the priority for the butternut squash breeding effort.

Breeding efforts are conducted in collaboration with growers and farmer-breeders. For different crops, different models of the farmer participatory process are employed. Below we describe each of the breeding programs in greater detail.

Breeding Edible Podded Peas for Organic Production

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Most contemporary snap peas have been bred for the processing industry, which prefers varieties that have short stature and a very concentrated pod set to produce the highest possible yield in a once-over harvest. In contrast, organic fresh market growers prefer types that can be trellised and that are more indeterminate, making them suitable for multiple hand harvests. In addition, varieties for fresh market should be flavorful, relatively early in maturity, do not require tying to the trellis, and have vigorous germination, especially in cool soils. For organic management where methods to control pests and diseases are limited, genetic resistance to powdery mildew, fusarium wilt and viruses, especially the aphid transmitted *Pea enation mosaic virus* (PEMV) in the Pacific Northwest is required. An additional trait that is of interest in snap peas is stringless pods. Incorporating this trait into commercially viable varieties has been problematic because of an accompanying reduction in plant vigor, particularly under warm growing conditions. The first stringless varieties that were released showed extreme sensitivity to heat whereas in later bred varieties, the deleterious response is reduced but still present. Building on the release of 'Cascadia,' a stringy snap pea in 1992, Oregon State University (OSU) embarked on a breeding program to develop robust stringless snap pea varieties. Cornell has begun work with a set of heirloom lines crossed with OSU materials to develop materials adapted to the Northeast.

No snow or Chinese pea varieties have been bred with specific adaptation to organic production systems, and in general, only limited numbers of varieties are available. Varieties such as 'Mammoth Melting Sugar' lack the disease resistance needed in a tall indeterminate snow pea.

In the past two growing seasons three advanced breeding lines from the OSU program have been trialed in mother-daughter trials across the northern regions, and have performed well under warm growing conditions. Two lines are snap peas; the other line is a snow pea. All are tall, indeterminate types that climb trellises with minimal assistance. They possess high levels of powdery mildew resistance and have pea enation mosaic and red clover vein mosaic virus resistances as well as fusarium wilt (race 1) resistance. They have yielded well with up to five pickings during the growing season. Flavor is good and although not stringless, pods are low in fiber.

In the meantime, Cornell is using a backcross-inbred program to widen the genetic base of the edible podded peas by identifying new germplasm that show high levels of adaptation in New York. Observation trials, planted in early July, are used to screen for materials that are more robust. This planting date subjects young plants to temperatures over 100 degrees Fahrenheit, and powdery mildew, fusarium root rot, and ascochyta blight on the pods during harvest. Three initial breeding populations in snap and snow backgrounds were created based on input from market growers and chefs, and the stringless selections from 900 backcross F1 plants will be further selected in the field in 2012. A second set of populations are being created now that incorporate the top performing peas from in our screen from 2011, which was exceptionally hot and dry.

Breeding an Open-Pollinated Broccoli for Organic Systems

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Most currently available broccoli varieties are F_1 hybrids. Although these varieties perform well in organic systems, the seed is often expensive and not conducive to direct seeding or seed saving. In an effort to provide an open-pollinated (OP), open source broccoli variety with quality characteristics comparable to contemporary F1 hybrids, the vegetable breeding program (VBP) at Oregon State University (OSU) has been working on a collaborative project involving multiple researchers, many organic farmers, and the Northern Organic Vegetable Improvement Collaborative (NOVIC).

This project began in 1997 with the creation of a broccoli population from a random mating of six F_1 hybrid varieties ('Arcadia,' 'Barbados,' 'Decathlon,' 'Excelsior,' 'San Miguel,' and 'Shogun') and 17 inbred lines that had been developed through the OSU VBP. This was followed by four years of random mating without selection within a conventional system at OSU in order to maximize recombination within the population.

Initially the project was not intended for organic production systems, but when the farmer participation component was added in 2001, it became apparent that the material had good potential to benefit organic systems. For seven years (2001 - 2007), one to six farmers contributed to the population improvement stage using a divergent-convergent strategy. Each season, participating organic farmers and the VBP made selections based on head size, heat tolerance, freedom from downy mildew, and vigor. Selected plants were allowed to randomly mate and produce seed. Farmers returned a portion of their seed to the VBP, where seed from all participating farmers (and OSU) was blended and sent back out for the next year. This process was repeated each year. In 2004, OSU research production was moved to organic transitional ground to facilitate selection and eventual variety development within an organic system.

When NOVIC was funded in 2008, the program shifted from population improvement to varietal development. Two farmer-breeders stayed engaged with the project and continued to make selections along with researchers in the VBP. These farmer-breeders worked independently from OSU with a minimal amount of support with the goal of continually developing varieties that were specifically adapted to their local environments and farming systems. Each year, single-plant selections were planted to rows from which further single plant selections were made in order to achieve greater uniformity. One participating farmer intended to develop a broccoli variety specifically adapted to her production needs (a community supported agriculture, or CSA, operation) and growing environment (low-input, low N, and cool maritime climate). The other participating farmer has begun distribution of the variety 'Solstice Broccoli,' which he developed from this population. Researchers at OSU continue to develop a variety from this collaboratively created broccoli population with an anticipated varietal release in 2013 or 2014.

A critical element of the OSU VBP's ability to begin breeding for organic systems is the collaborative nature of this project; in particular, the knowledge gained from the network of participating farmers. Broccoli turned out to be an excellent crop choice as its lifecycle lends itself well to mass selection techniques, which are easy and accessible for farmer-breeders to use. Farmer engagement helped the VBP to understand what traits are important for organic broccoli production; farmers were engaged to define quality, handling, and harvest traits of primary importance. This involvement benefited farmers by giving them access to resources and skill development that allowed them to implement and follow through on plant breeding projects on their farms. Farmers have also had ownership in the project, which has served to keep the research relevant to their needs as well as increasing the potential for adoption and use of any varieties released from the project. This project has shown that farmer-breeders can develop varieties that are specifically bred for and adapted to organic production systems (e.g., 'Solstice Broccoli').

The organic community at large stands to benefit from the increased varietal options created from such projects. Although this project has already been quite successful in a number of ways, there is still much to learn about the traits necessary for robust organic production and how we can best breed for them. Through the support of the NOVIC project, the OSU VBP will continue to gain understanding and insight into breeding for organic systems through collaborative work with farmers.

Breeding Tomatoes for increased Flavonoids

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Vegetable crops are an abundant source of phytonutrients such as carotenoids, flavonoids and phenolics, glucosinolates, vitamins and micronutrients. The amount that a crop can produce is under genetic control and often the levels can be increased through plant breeding. Carotenoids are the fat-soluble red, orange, and yellow pigments found in vegetables as diverse as watermelon, sweet corn, tomato and carrot. The water soluble phenolics and flavonoids are color fruits and vegetables with yellow, brown, pink, blue, or purple pigments. Yellow onions, red cabbage, and purple eggplant all share this class of compounds. The pink, blue, and purple forms are a subset of flavonoids called anthocyanins. Both carotenoids and flavonoids are antioxidants and are associated with reduction in chronic disease in humans who consume diets rich in fruits and vegetables with these compounds.

Tomatoes are a major source of carotenoids in the human diet by virtue of being high in lycopene and pro-vitamin A, and the second highest vegetable in per capita consumption in the US. Tomato fruits are relatively low in flavonoids, but these compounds can be found in the fruit of wild relatives. In the 1960s and 1970s, plant geneticists crossed cultivated tomato with several wild species and introduced genes that expressed anthocyanins in the tomato fruit. Four such traits were introduced into cultivated tomato, each from a different wild species. The expression of these traits was rather weak, usually producing a purple blush on the crown of the fruit.

We initiated a project to characterize the purple fruited accessions, because at the time, no one knew if they contained anthocyanins, and if so, whether expression could be increased. We discovered that by combining any two of three genes that control anthocyanin expression in tomato fruit and vegetation, we could achieve a six-fold increase in flavonoid content, with anthocyanin going from none in normal red fruit to 415 mg/ g FW in fruit containing two gene combinations. High anthocyanin tomatoes show strong antioxidant activity in the lab with about a 4.5 fold increase over normal tomatoes. The antioxidant activity of the anthocyanins was much greater per gram of fruit tissue than the carotenoids.

Anthocyanin expression is light dependent so that shaded portions of the fruit will show a normal red color. However, if the fruit is turned to expose the shaded area, it will become purple in about a week. This will happen whether fruits are on or off the plant. Anthocyanins seem to have an antimicrobial effect and are much less prone to fruit rot.

A question that we are often asked is how do these differ from existing "purple" and "black" tomatoes? Nearly every other tomato of this sort has a trait called *green flesh*, which prevents normal chlorophyll breakdown when fruits ripen. Instead, a brown pigment accumulates, which produces a muddy purple color when the brown pigment combines with the red lycopene.

Our first release from the breeding program is 'Indigo Rose,' a full season saladette type with good flavor. To differentiate the true anthocyanin tomatoes from other "purple" and "black" varieties, we have decided to always include "indigo" as part of the name. Seed and plants of 'Indigo Rose' will be available in 2012 from several seed companies. Other types of high anthocyanin tomatoes will follow in the near future.

Hybrids Versus Open-pollinated Varieties: How Do They Fit into an Evolutionary Seed System?

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Summary
The relative value of F1 hybrid versus open-pollinated (OP) crop varieties and their role in organic agriculture has been debated from both the practical and the philosophical perspective for close to 40 years. While hybrid breeding programs have rapidly delivered many important new traits in uniform, vigorous crop varieties, organic farmers have long questioned the *de facto* control of genetic resources by seed companies and the absence of breeding for the challenges of organic production and for many of our specialized market needs. The goal of this conference session is to examine the long term breeding needs for organic systems, the implications of the breeding methodology, and the potential to develop an evolutionary plant breeding model that may better serve our needs in the future. This discussion continues to evolve as many of us refine our understanding of the potential role of plant breeding in ecological farm management and as we collectively face issues of consolidated ownership in the seed industry and corporate control of plant genetic resources. This panel includes perspectives of a diversified seed and produce grower (Huber), a regionally focused small seed company (Campbell), organic plant breeding researchers (Navazio and Colley), and a university-based plant breeding researcher and geneticist (Tracy) who serves both conventional and organic agricultural interests.

Background on breeding techniques
To provide a background for our discussion of how hybrids and open-pollinated (OP) varieties fit into an evolutionary seed system, we need to begin by understanding what these terms mean, how hybrids and OPs are bred and produced, and some of the issues involved in producing hybrids in an organic context.

F1 Hybrid varieties: The controlled crossing of two or more separate, parental varieties or inbred lines of the same species, usually with at least one parent line being highly inbred, create commercial F1 hybrid varieties. Each time that a seed company produces hybrid seed it must go back to the original parents and make this same controlled cross to produce the hybrid. F1 stands for the first filial generation after the cross. Subsequent seed produced by F1 hybrids does not breed true to type and will segregate genetically, expressing a wide combination of traits from both parents.

Open-Pollinated varieties: OP varieties are selected and maintained as a population with relatively stable, distinct traits. Trueness to type in an OP population is a statistical feature of the population as a whole; it is not a characteristic of individual plants (Allard, 1999). Seed that is saved from an OP variety will breed more or less true to type from one generation to the next. Technically, the term open-pollination refers to pollinations that occur in nature between flowers in cross-pollinated species; however, most people in the seed trade use the term OP to refer to crop varieties from both cross and self-pollinated species that are not hybrids.

The methods used to breed and produce seed of hybrids and OPs differ in a number of substantive ways:

Hybrid plant breeding consists of two parts: creating inbred lines and creating hybrids. Inbred lines are created either out of existing populations or by selective crossing. They are created by repeatedly self-pollinating individual plants through several successive generations in segregating material. Through subsequent generations the progeny from a self-pollination will become increasingly uniform. At the same time, these inbred lines will become less vigorous if the population contains a significant amount of deleterious genetic traits. In general, commercial breeding programs will be developing hundreds or thousands of inbred lines simultaneously. Once a substantial number of these inbreds become sufficiently uniform, the breeders will produce a large number of experimental F1 hybrids by systematically crossing these inbreds together in all possible paired combinations. These experimental hybrids will be grown and tested in trials to see which ones are worthy of being produced and marketed.

In hybrid seed production, both inbred parents are planted in one field. Pollen from the 'male' inbred pollinates the 'female' inbred, and seed is harvested from the 'female.' Hybrid seed production requires that only pollen from the 'male' inbred is able to successfully pollinate the 'female.' A number of mechanisms are used to ensure that the 'female' inbreds are not able to pollinate themselves, including, depending on the species: genetic or cytoplasmic male sterility, mechanical emasculation (e.g. detasseling corn), self-incompatibility, hand-pollination, and chemically induced male sterility. In addition to producing the hybrid seed, seed companies must produce seed of the inbred parents. These inbreds often lack vigor and can suffer from some degree of inbreeding depression and often require higher degree of care and external inputs, like pesticides, to successfully produce a seed crop. There are a number of cases over the past decade where conventional seed companies have attempted to produce certified organic seed of one of their popular hybrids and have failed due to the poor performance of the inbreds. In several of these cases, the inbreds were not able to produce seed without several of the conventional inputs that would usually be applied but are not allowed when growing the inbreds under organic production practices. In hybrids, inbreeding depression is reversed when the hybrid crosses are made.

In contrast, OP varieties are developed without creating inbred lines or testing hybrid combinations. Instead, once the population being bred has the right constellation of traits that are being sought and is sufficiently uniform for the intended market, then seed is produced for commercial sale. OP varieties in cross-pollinated crops are kept healthy and vigorous by keeping the population sufficiently large and diverse throughout the breeding and seed production process. Because these populations are genetically diverse, constant selection must be practiced during cycles of seed production in order to keep the varieties remaining true-to-type.

Strengths and weaknesses of F1 hybrids and OPs
Hybrids and OPs each hold certain strengths and weaknesses that largely fall into four main categories: 1) cost, 2) intellectual property, 3) uniformity, and 4) evolutionary potential.

Hybrid varieties are commonly bred by seed companies, and require a considerable financial overhead and infrastructure to manage a large breeding program. Two primary benefits of hybrids from a seed company's perspective are the ability to breed new varieties or combine key traits in an existing variety relatively quickly (2 - 3 years), and the ability to retain intellectual property of the variety without obtaining a PVP (plant variety protection) or utility patent. The other benefit often touted by seed companies is the high degree of uniformity and vigor that is available in hybrid varieties. For these key reasons the vast majority of financial investment in breeding programs over the past 75 years has been in hybrid development. For some growers uniformity is crucial for certain production systems, particularly those with mechanical harvesting requiring uniformity in maturation. Vigor is also a key trait, especially in organic systems where weed competition and efficient nutrient utilization are crucial. However, for some growers selling to diversified markets, including Huber and Campbell, a good OP with less uniformity and an extended harvest window can be advantageous for repeated harvests over time. Both Huber and Campbell report that there are several well-maintained OPs even in cross-pollinated crops that excel in vigor and have more than adequate uniformity when compared with their hybrid counterparts. This begs the question of whether vigor, uniformity, and other key qualities can be bred into an OP with the same amount of financial and capitol investment as has been invested in hybrid development over the last 75 years.

Brian Campbell of Uprising Organics comments:

> *Uniformity as a be all and end all of breeding is overrated. Obviously there are advantages to dependable uniformity, but many growers operate in diversified systems where variability is totally acceptable and sometimes beneficial. We plant broccoli, for example, half as often but in bigger plantings when growing our OP than with more uniform hybrids, because we know we can pick it successfully over a longer period advantageously. In many cases we also find that breeding for uniformity of appearance maturity, and generally a more industrial model of production and distribution, comes at the expense of other desirable qualities such as cold hardiness, or flavor and texture, or any host of other qualities that are very relevant to fresh market growers, especially those who market locally. Vigor, however, we find to be in the top tier of importance in OG systems especially, where weed competition and securing soil based fertility requires it. We have not found that attentively maintained OPs suffer from lack of vigor.*

Seed companies, land grant universities, and individual farmer-breeders have traditionally bred OP varieties. The key benefit of OPs over hybrids is the ability to save seed that will breed true to type and therefore the ability for growers, gardeners, and smaller seed companies to select varieties for preferred traits. This aspect allows more entities to engage in genetic maintenance and improvement. Another related benefit is the inherent genetic diversity within an OP variety. Even an OP that has been selected for phenotypic uniformity will have greater genetic variability than a hybrid. Genetic variability is the key to selecting varieties for regional adaptation and resilience over a diversity of climatic conditions. Since organic environments commonly have greater environmental variability than conventional systems, resilience is important for yield stability (consistent yields over time rather than maximized yields under ideal conditions). From a commercial perspective OPs that are held in the public domain are generally maintained and sold by several companies and individuals. This means that they are less likely to be dropped from the seed trade when a company is sold or shifts their product portfolio as commonly happens with hybrid varieties.

The drawbacks to OP varieties is that they are often more phenotypically variable than hybrids and require good genetic maintenance to perform optimally. Variability can be a marketing challenge when communicating expectations with the customer, especially in the wholesale business. Variability in timing of maturity, height, and product size of crop can also be a challenge when mechanically harvesting or when attempting to harvest an entire field at once, which may be more efficient in larger operations. The other drawback of OPs is that the primary means of protecting intellectual property of the variety is to obtain a PVP for the specific phenotype of the variety or to obtain a utility patent for some unique characteristic or genetic sequence of the variety. Both of these options are prohibitively expensive for farmers or small seed companies. Utility patents also significantly restrict access to the genetics of the variety, limiting our collective potential for future innovations and genetic preservation.

What do we need for organic systems?

It is our contention that the long-term success of the organic community (farmers, food industry, and marketers) is dependant upon two key factors: 1) broad access to plant genetic resources, and 2) systems to manage our genetic resources in a manner that maintains broad genetic diversity, allowing continual evolution, improvement, and adaptation to varied environmental conditions. The first point necessitates that we develop systems by which genetic resources are managed by and for the organic community rather than rely upon the conventional seed industry and/or a small number of highly consolidated seed companies. The second point suggests that the best breeding strategy is to invest in development of genetically diverse OP varieties and that breeding schemes that follow evolutionary and participatory plant breeding principles may serve as the best approach to meeting these breeding goals (Ceccarelli, 2009).

Certainly organic farmers need varieties that are productive and meet the demands of the organic marketplace. Many would argue that equally critical is access to varieties that minimize the need for external inputs such as plant protection chemicals and high input fertilizers. Currently, in some crop categories, many organic farmers rely on commercially available hybrids to maximize their productivity and fulfill market expectations for size and uniformity. We are not advocating that farmers stop using hybrids, particularly when they are the most productive option available. But, to ensure that we are steadily developing crop germplasm that is genetically elastic and can be further improved for farmer-breeders and professional breeders, it is important to maintain adequate levels of heterogeneity in genetically diverse material while achieving adequate phenotypic uniformity to meet the demands of the marketplace. In evolutionary systems, the goal is to have a continuous adaptive capability of the material, both for the environmental challenges of the particular region, and for the varied agronomic practices employed by the target growers. By consciously retaining genetic variability in the released OP materials, it is possible to collectively manage our varieties as a continuously evolving, living resource. Otherwise we are relying on private breeding materials for our evolutionary potential, which are commonly held by an individual breeder and developed with an end goal of genetic homogeneity.

If the organic community is to invest in the management of genetic resources, we must consider where to invest our time and limited resources. There may be a place for hybrid development within the organic seed industry; for example, to deliver useful varieties to growers in the short-term that may combine key quality traits or maximize productivity in certain cross-pollinated crops, which currently lack OP development. However the two key advantages of investing in OP development for the long-term are: 1) OPs allow broader participation in genetic maintenance and preservation, and 2) OPs can be continually selected for adaptation to a wide range of environments facilitating diverse, regionally focused agricultural production. Hybrids on the other hand are developed with an end goal of producing many copies of nearly identical, very uniform, monogenotypic individuals of the crop variety. As the parental lines are usually maintained strictly as inbred lines, the resultant F1 hybrids are highly homogeneous and genetically static, thus lacking evolutionary potential (Allard, 1999).

Diversified organic farmer Nash Huber

From the perspective of organic farmer Nash Huber, we need plant varieties for organic agriculture that can utilize the natural biology of the soil to develop vigorous healthy crops. Huber, who grows fresh produce, small grains, pulses, and vegetable seed crops on 400 acres, also recognizes the need for broad genetic diversity in our crops to be able to produce crops under variable cropping conditions and to allow for further breeding possibilities. He has incorporated several on-farm breeding projects into his farm to improve these crops for traits like cold-hardiness, root-rot resistance, weed competitiveness, vigorous regrowth after harvest, and quality traits like better color and flavor.

Regional seed company operator Brian Campbell

As an organic produce grower and owner of a regionally focused seed company, Campbell states that one of the most important breeding goals is to create a wealth of locally adapted varieties for our distinct bioregions -- varieties that are bred and maintained on working farms and responsive to the needs of those farms. Specifically, as a grower in the northern tier, Campbell thinks cold hardiness is a major frontier for breeding efforts, as it is a barrier to diverse, locally grown food year around. Campbell also thinks farmers need to meet varieties halfway and rethink the industrial model of the last 60 - 70 years, even to the extent that the organic movement is still very much rooted in that model. OPs will probably never compete with hybrids in those (industrialized) systems, but as we evolve in our agroecological thinking toward more sustainable models of food production, Campbell believes that the genetic elasticity of the OPs are better suited to changing conditions and climates, and an evolving way of thinking and growing (Ceccarelli, 2009).

Conclusion

This discussion has focused on highlighting the long-term value of OP plant breeding for organic agriculture. The key challenge that remains, and perhaps the reason OPs have historically fallen behind hybrids in development, is how we will reward the plant breeder or garner investments necessary to support breeding programs that don't restrict broad access to genetic resources. For a seed company, hybrids remain the easiest method of controlling intellectual property. Short of acquiring plant patents or PVPs, the best market insurance for a company breeding OPs at this time is to build a reputation for varietal purity and integrity, a high degree of seed quality (i.e. vigorous, disease-free seed), and a consistent seed supply and service for the customer base. With a note of optimism, there are currently efforts underway, by Organic Seed Alliance staff and others, to develop alternative models of intellectual property protection that would reward the breeder while allowing broad access to genetic resources. In recent years there is also a growth in financial investments from the organic food industry in organic seed development and a broader understanding of seed issues among the organic community in general. These efforts are working toward a goal of reinventing how we manage our collective natural resource of plant genetics. We're developing a common vision of a system that results in market investments, preservation of biodiversity, and an evolutionary potential in our food crops. With luck we may continue this discussion and present new models at the next Organic Seed Growers Conference in 2014.

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Breeding a High-Quality, Weed-Competitive, Cold-Tolerant Nantes Type Carrot

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The demand for high-quality, organic fresh market Nantes carrots for local markets continues to grow throughout many regions of North America. In the Maritime Pacific Northwest (PNW), where winter temperatures are relatively mild, there are opportunities to extend this market through the winter months to early spring if the right combination of cultural techniques and appropriate carrot varieties are used. This market demands that the carrots are exceptional in their flavor, texture, and color, and have the characteristic cylindrical Nantes shape. Farmer Nash Huber of Sequim, WA, has developed a set of cultural techniques that enables him to harvest high-quality carrots into mid-February. Late winter roots become pithy, begin sprouting secondary roots, lose their color and sweetness, and are no longer marketable after mid-February. Importantly, the strength and integrity of the tops can often degrade by this time in the season, making the roots unharvestable by mechanical means. Tall, robust, strong tops are also important in order to compete with winter annual weeds that proliferate in the PNW with fall rains.

To address these problems, crosses were made with 'Spring Market,' a New Zealand overwintering carrot traditionally marketed in spring. 'Spring Market' (SM) has several traits that can potentially improve the carrots for this production system. These favorable traits include: carrots with delayed growth of secondary roots; carrots that remain crisp, sweet, and flavorful; and tops that are vigorous, tall, and remain strong and intact through repeated freeze and thaw events. All of these traits could extend the harvest by four to six weeks in the spring. SM was crossed to one of Huber's best performing carrots, 'Rumba' (RB), to combine several traits lacking in SM, including: a cylindrical root shape, darker color (higher *beta*-carotene), and a higher sugar content. The ideotype that we imagine will be a high-quality Nantes type with superior sweetness, flavor, color, and texture that will maintain these characteristics until April. Additionally, strong, vigorous tops that can compete with persistent winter weeds and are also suitable for machine harvest into spring are important in this breeding effort.

F1 roots were harvested in spring and planted into pots in the greenhouse for flowering. A series of selfed (S1) and half-sib (HS1) umbels were harvested in late summer to plant as overwintering families in the fall of 2010. Roots from the most vigorous, healthy families were harvested in early spring 2011 and again planted in the greenhouse. A series of S2 and HS/S1 families were harvested this fall (2011) and planted in our overwinter nursery for harvest of roots in the spring of 2012. These roots will again be selected for vigor and planted into pots in the greenhouse to produce S3 and HS/S2 families.

Greenhouse seed from these families will be planted in Nash's winter carrot plots in the summer of 2012. All materials are being evaluated for their ability to suppress weeds. The relationship between the carrot height, carrot stand density (% cover of row) and the weed density (% weed coverage per m^2) are being measured at 90 days and 150 days of growth using a quadrat for visual rating and dry weight of biomass of both weeds and carrot foliage. All families will then be evaluated and selected in April 2012 for all root quality characteristics. Both family and individual root selections will be made for greenhouse increase to repeat the process for the winter of 2012.

Introduction to Organic On-farm Plant Breeding

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Summary
Since the rediscovery of Mendel's Principles of Heredity in 1900, formal plant breeding has been largely relegated to the trained geneticists and their research fields. However, with the increased interest in the principles and practices of organic agriculture and in farming practices that emphasize low external inputs, there has been a concomitant interest in on-farm breeding. Compared to crops grown under high-input conventional systems, crops produced with low external input organic farming practices are frequently exposed to a greater set of environmental challenges. These challenges include variable nutrient availability, drought conditions, and weed or pest pressure (Desclaux, *et al*., 2012). On-farm breeding can successfully produce crop varieties for the diverse environments and diverse challenges of organic cropping systems.

Over the past several years, a growing number of complaints have been issued from organic farmers who are frustrated by the lack of available crop varieties that meet the challenges of their varied low external input cropping systems. Many of these growers voice the opinion that, when they sometimes find crop varieties that perform well in their cropping systems, the seed of these varieties is: 1) only available for a few seasons before being discontinued, 2) is an older variety that has a limited or inconsistent supply available for sale, or 3) is of a lower varietal quality or *per se* seed quality than many of the newer, featured varieties being heavily promoted by commercial seed companies. There have also been complaints among growers that many of these newer, featured crop varieties often lack quality traits that are highly valued in the organic marketplace like flavor, tenderness, and unusual color.

Developing crop genetic resources adapted to low input, diverse organic cropping systems is essential for the continued improvement of organic agriculture. Genetically elastic, heterogeneous crop varieties have proven to produce higher, more dependable yields in low-input, subsistence agricultural systems than the more narrowly selected, genetically homozygous crop varieties of modern agriculture. The methods of population improvement, conducted under the challenges of environmental stresses in low-input systems, make it possible to breed better varieties for organic farming. These genetically diverse, heterogeneous varieties can have greater adaptive advantage to the environmental variables and cultural practices of organic farming than many existing commercial crop varieties. Examples from three ongoing, on-farm population breeding projects in European kale (*Brassica oleracea*), sweet corn (*Zea mays*), and zucchini squash (*Cucurbita pepo*) will be discussed with an emphasis on population breeding methods that meet individual farmers' needs for environmental adaptation and market acceptance. The breeding methods used in this work are "farmer friendly" and require little or no hand-pollination or specialized tools in their execution.

Introduction

The development of regional seed systems for organic agriculture is a very important component in the health and stability of the agricultural economy of any distinct agricultural region. It is a well-accepted idea that agricultural genetic resources (crops and livestock) that are adapted to the environment and cropping systems of a particular region are more likely to thrive and provide an economic return for the farmer than those plants and animals that are not genetically suited to that region. Breeding crops for the "area of intended use" is a time-tested concept used by some of the most successful seed companies in the last century (Satterlee, 1996). Certainly, genetic selection of crops that excel under given seasonal temperatures, fluctuations in precipitation, and the particular types of soils native to a region will usually produce varieties that perform better than varieties bred in other climates. If these varieties are also selected to withstand the biotic and abiotic stresses of drought, heat or cold stress, native diseases or insect pests, then they have the potential to perform better than other varieties (Ceccarelli, 1994). This is in sharp contrast to the trend among large seed companies, where company consolidations have resulted in an increasingly narrow breeding focus, abandoning many regional market segments, and breeding and testing new varieties only in the highest profile agricultural market areas.

On-farm breeding methodology

Organic Seed Alliance (OSA) has been involved in three participatory on-farm breeding projects using three variants of a recurrent selection that is based, in part, on progeny selection with the population as a tester (Hallaeur, 1985). These breeding methodologies have been fashioned to meet three important criteria to ensure their utility by farmers:

1) The method must be relatively easy for the farmer to execute in the field with minimum hand pollinations, note taking, or maintenance of extensive pedigreed seed lots.
2) The method must deliver a reasonable amount of gain from selection per breeding cycle.
3) The product of the breeding work needs to retain adequate genetic variability for favorable traits to allow for continued farmer selection and environmental adapta-

tion in future generations, while attaining a phenotypic uniformity that suits the needs of the marketplace.

All three of these breeding projects are with cross-pollinated vegetable crops. Sweet corn and zucchini are facultative out-crossing species, with mechanisms that favor cross-pollination, though they will readily self-pollinate in nature. European kale, on the other hand is an obligate out-crossing species that rarely self-pollinates in nature. These differences, combined with the varied and unique reproductive structures of these three crops, led to three somewhat different breeding strategies within a basic recurrent selection for population improvement strategy (Allard, 1960).

Cross-pollinated crops ("crossers") lend themselves to recurrent selection, especially as concerns on-farm breeding, as they will naturally cross without the need for hand manipulation. This natural outcrossing makes it much easier for the farmer-breeder to intermate selected individuals in each breeding cycle to produce potentially superior individuals in the next cycle. Crossers are also more likely to remain in a heterozygous state through generations of random mating as open-pollinated populations. This lends itself to retaining allelic diversity when an OP population is released, a stated criteria of this work.

A biological disadvantage in breeding crossers is that it is harder to ensure self-pollinations when there is a desire to do so to reveal deleterious traits in the progeny evaluation stage of this breeding method (see specifically European kale which has self-incompatability). Also, crossers require greater physical isolation to avoid any unwanted genetic mixing from other varieties of the same species, therefore, forethought in determining isolation from other members of the same species is always necessary.

'Dark Star' Zucchini: The development of 'Dark Star' zucchini began with Bill Reynolds of Eel River Farm in Shively, California, producing both the F1 hybrid 'Raven' and the OP 'Black Beauty' ('BB'). Frustrated with the repeated shortages of 'Raven,' which served as the market standard, Bill saved seed from the BB, not realizing that he had seed that was a cross between the two varieties. Bill planted this seed thickly for his commercial vegetable crop under typical field conditions, selecting heavily throughout the season for seedling vigor, water scavenging ability, open plant habit, and favorable fruit characters. This mass selection for these traits was repeated for five cycles, with Bill drilling the seed at up to six times the normal sowing rate to accommodate the heavy selection pressure. This resulted in an M5 population with a high degree of favorable traits.

In the first year of the recurrent selection breeding scheme, a series of self-pollinations were made on 52 phenotypically favorable plants from the zucchini population in a 3 ha production field. From these self-pollinations, a series of families were evaluated in year two. Of the 52 families in the field that year, only four families were selected. These four families were allowed to intermate and produce seed, while the remaining 48 unselected families were eliminated prior to pollination. In year three, these four families underwent further field testing. One of the four half-sib families exhibited surprising uniformity with a preponderance of plants with key traits found in 'Raven.' Selected plants from that family were allowed to intermate to form a new population. From year four through year six, this population was massed with stringent selection to the ideotype for the desired traits of his production system. The resultant variety, 'Dark Star,' has now found success as a regional market standard in the original area of intended use, coastal Northern California, and is also being produced extensively as a winter crop in Baja California, Mexico, for export into the US winter market.

'Nash's Red' Kale: This European kale breeding effort began with the chance discovery of two purplish-red kale plants in a field of typically blue-green 'Vates Blue Scotch Curled' kale in the mid-1990s by Nash Huber of Nash's Organic Produce in Sequim, Washington. Nash dug these plants up and crossed them to several tall hybrid Brussels sprouts plants. His intent was to incorporate both the height and stature of the Brussels sprouts (the variety that he used for this cross is long forgotten) into the rather short and prostrate 'Vates' plant type. Seed from both sides of the cross was bulked and planted in late summer. Obvious hybrids between the two types were selected and intermated. Over the next ten years, Nash planted and performed mass selection on this evolving population, selecting for robust kale-like plants with a deep red color, high degree of leaf curl, and good stature. There was also always selection for cold hardiness and vigorous early spring growth. After these ten cycles of mass selection there were still between 5 - 10% of green, or light "greenish-red," plants in the population.

At this point a recurrent selection breeding program was initiated. In a 4 ha field of the 'Nash's Red' population there were approximately 50 plants that were identified with superior stature, leaf curl, red color, regrowth, and cold hardiness at the end of winter. These plants were dug up and moved to an isolated spot and allowed to intermate. The option to self-pollinate these plants was limited, as individual plants of *Brassica oleraceae* have a self-incompatibility system, which does not allow them to accept their own pollen. Hence, seed harvested from the individual plants represented half-sib (HS) families. Of the approximately 50 plants constituting the basis of this population there were 36 plants that successfully produced a full complement of seed for further evaluation and selection.

Seed of these 36 HS1 families was planted into family rows for progeny evaluation. These families were evaluated at various stages of their development for growth rate, stature, degree of leaf curl, color, cold hardiness, and resistance to Downy mildew (*Peronospora* *parasitica*). After the ten cycles of mass selection for their ability to overwinter and produce a healthy, productive vegetable crop, we were very pleased to find that most of the 36 families that we were evaluating had very similar levels of cold hardiness and resistance to Downy mildew. However, there were in fact only 13 families with all red plants. The other 23 rows were eliminated and these 13 rows were allowed to openly pollinate after eliminating a number of plants with less than adequate leaf curl from each family. Seed was harvested separately from each of the 13 HS2 families. We are now preparing to begin the second round of recurrent selection with these 13 HS2 families.

Wisconsin Early and Late Sugary Enhancer Sweet Corn: Martin Diffley of Gardens of Eagan in Farmington, Minnesota, was concerned that there seemed to be fewer sweet corn varieties available each year with an ability to germinate and grow vigorously in cool spring soils. Bill Tracy of the University of Wisconsin had developed two cold-tolerant, vigorous, sugary-enhancer sweet corn populations (cycle 0) that they agreed would be used in a participatory breeding project. One hundred single-row plots were planted for each population, with 30 kernels per row from a single ear representing a full-sib (FS) family. Remnant seed from each ear was preserved in cold storage. For evaluation, percent germination and early vigor were rated at the V4 stage (fourth leaf with visible collar). At harvest maturity each row was evaluated for flavor, texture, husk coverage, tip fill, ear shape, and rust (*Puccinia sorghi*) resistance. Any row containing corn smut (*Ustilago maydis*) was eliminated. Based on the ratings, the best 12 FS families from each population were selected.

The remnant seed from each selected ear was sent to a winter nursery in South America in October 2008. At the winter nursery, individual plants within each population were inter-mated via the bulk-entry method without parents (Eberhart *et al*., 1967). With this method, a single row is planted with remnant seed from one selected ear. The adjacent row is planted with a mixture of seeds from each of the remaining selected ears. The two rows are then cross-pollinated, creating approximately 100 new full-sib families per population. Seeds returned from the winter nursery represented the next cycle of selection (cycle 1) to be planted in Minnesota that spring of 2009. This process has continued for three cycles of selection and recombination. Cycle 4 of this project will commence in the spring of 2012.

Summary

In these three on-farm breeding projects the gain from selection was based on the narrowing of the respective populations through identifying the best families, while eliminating the sub-optimum families as well as the poorest performing plants from the selected families. This mild inbreeding that is possible in recurrent selection serves to concentrate the most favorable traits, while maintaining genetic variability and increasing the chance of recombination between the most favorable individuals. In this way, the farmer-breeder is increasing the genetic frequency of alleles that confer important favorable traits, with less chance of the random loss of favorable genes that is possible when developing inbred lines in traditional pedigree breeding programs (Allard, 1960).

Conclusions

These three projects are all at various stages of completion and all of them seem to be meeting the important criteria for success with the farmer breeders that are utilizing these methods. The methodology practiced on the respective farms has been easily accomplished by the farmers and co-operating breeders, with minimal time spent above the normal cultivation practices and time needed to evaluate the materials. In all cases, the gain from selection for each cycle seems to have exceeded expectations for the parties involved. Lastly, even though it is evident that there is certainly a substantial amount of phenotypic variation that remains in each of these populations, there are farmers seeing this material in trials and in commercial production (as with the zucchini) who are very interested in acquiring seed for their own production.

Bill Reynolds began using the 'Dark Star' zucchini before the variety was ever deemed to be finished because of the shortage of 'Raven' seed. This was a case where another one to two cycles of recurrent selection could be performed to derive an even better product. However, due to a lack of funding for continued breeding and Bill's diligent work at performing repeated cycles of mass selection, 'Dark Star' has proven to be a very successful farmer bred variety. Its genetic resilience has helped it hold up to the harsh, dry windy conditions of winter production in Baja California for the past two winters, even surviving temperatures of -1C that devastated much of the commercial export zucchini crop in the states of Sinaloa and Baja California, Mexico in January 2011. It has also become very valuable to several organic producers in Baja as it is able to produce fruit for at least four to six weeks longer than the F1 hybrid zucchini currently used for winter cropping.

While completing the first full cycle of recurrent selection on 'Nash's Red' kale, we have been surprised to learn just how important the kale population that our material first came from has become. Nash's original OP population has become much more commercially important to his farm in the past two years, despite the fact that it still has 5 - 10% green off-type plants. In the winter of 2010 – 2011, western Washington experienced unusually cold temperatures that damaged much of the regional kale crop. The original source population of 'Nash's Red' proved to be more cold hardy, and when it was harvested in late winter and early spring of 2011 it proved to have much less Downy mildew (*Peronospora parasitica*) than other kale crops in the region. These events made us realize the full genetic potential of this genetic material.

During the evaluation of Cycle 3 of the 'Wisconsin Early and Late Sugary Enhancer Sweet Corn' during the summer of 2011, the breeding group that was doing the "bite test" of the two populations was pleasantly surprised at the degree of improvement that the corn had gone through since our evaluation of the Cycle 2 families. There was a degree of skepticism that it would be possible to derive an OP sweet corn through recurrent selection that was up to the standards of modern hybrid sweet corn. This is due to the fact that the quality traits in sweet corn are largely conditioned by recessive alleles and are quantitative by nature. We are encouraged to know that through recurrent selection it is possible to gather enough favorable genes in a number of the full-sib families to have some consistency in quality across a number of families in each of the two populations.

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Breeding Sweet Corn for Organic Growers

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Organic growers face unique challenges when raising sweet corn, and benefit from varieties that exhibit superior cold germination, early vigor and disease and insect resistance. But wind-pollinated crops such as sweet corn can prove cumbersome and labor intensive for growers wanting to develop adapted varieties on the farm. Participatory plant breeding offers a useful strategy to combine the resources available through a land grant university breeding program with the distinct ecosystem and grower knowledge found on organic farms. Martin Diffley, an organic farmer in Minnesota, joined sweet corn breeder Bill Tracy from the University of Wisconsin-Madison, and vegetable breeder John Navazio from Organic Seed Alliance, to develop an improved open-pollinated sugary-enhancer sweet corn variety on Diffley's farm.

In 2008, two populations of sugary-enhancer sweet corn were planted on Diffley's farm from vigorous and cold-tolerant germplasm that Bill had developed (cycle 0). One hundred single-row plots were planted for each population, with 30 kernels per row from a single ear representing a full-sib family. Remnant seed from each ear was preserved in cold storage at the University of Wisconsin-Madison. For evaluation, percent germination and early vigor were rated at the V4 stage (fourth leaf emerged). Approximately 21 days after pollination, each row was bite-tested by the breeding group. Ratings based on a 1 - 5 scale were given for flavor, texture, husk coverage, tip fill, ear shape and rust (*Puccinia sorghi*) resistance. Any row containing corn smut (*Ustilago maydis*) was immediately discarded. Based on the ratings, the best 12 families from each population were selected. The remnant seed from each selected ear was sent to a winter nursery in South America in October 2008. At the winter nursery, individual plants within each population were intermated to create at least 100 new full-sib families per population. Seeds returned from the winter nursery represented the next cycle of selection (cycle 1), and were planted in May 2009 on Diffley's farm.

This process of recurrent selection continues to the present. Currently, the two populations have undergone four cycles of selection, and improvements have been made in germination, rust resistance and perhaps most importantly, flavor. All of the collaborators involved in the project will determine the best process to release the open-pollinated population to farmers interested in growing it.

Researcher-Farmer Collaboration in Participatory Plant Breeding

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As a part of the Northern Organic Vegetable Improvement Collaborative (NOVIC), I am engaged in a project that brings together farmers and breeders to develop high quality sweet corn for organic agricultural systems using a participatory model. Each growing season, the collaborators evaluate sweet corn populations grown on organic land, and make selections based on traits of interest identified by the farmers. Using a process of recurrent selection, the selections are recombined in a winter nursery to form successive cycles of improved seed. Our goal is to provide growers in northern US latitudes with sweet corn varieties that thrive in organic systems.

When designing a participatory breeding project, all collaborators must share a common overall goal for the project. In addition, however, the farmers and researchers may have individual goals that are quite varied, and may even be in conflict with one another. For example, a farmer may be interested in a project design that utilizes a minimal amount of his or her land, while a researcher may prefer a design with multiple replications that could be published in the scientific literature. Understanding such differing goals, and finding solutions to ensure that they are all achieved, is a crucial aspect of the participatory process. The focus of this portion of the "Participatory Breeding Café" is to identify these issues and discuss ways to effectively resolve them.

Breeding for Nutrition: Prospects and Challenges for Plant Breeders

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The need for a reliable food supply provided the motivation for the development of agriculture over the last ten millennia. Consequently, modern civilization is dependent upon agriculture to feed most of its population. While domesticated crops have been recognized as a solution to hunger since the beginnings of agriculture, the complex mixture nutrients with independent contributions to health found in crop plants has only been recognized for the past several centuries. In fact, the first vitamin, vitamin A, was only described in 1913 (McCollum and Davis, 1913). Since then, food composition analysis has clearly demonstrated that there is very broad genetic variation for most nutrients in crop plants, not only between different crops, but among cultivars covering the breadth of germplasm of a given crop.

In spite of the broad genetic variation for nutritional value, relatively little effort is placed in improving crop nutritional value today. Notable exceptions are the Quality Protein Maize project (Vasal, 2001) underway by CIMMYT since the 1970's to improve maize lysine content, and the more recent international efforts of HarvestPlus to increase the vitamin and mineral nutritional quality of staple crops in the developing world (Bouis, 2002). Diet is implicated globally in the cause and severity of many diseases, including cancer, heart disease, and diabetes, so genetic selection for nutrients that ameliorate the affects of these diseases is expected to reduce health care costs and consequently have an economic benefit (Cordain et al., 2005). Healthier staple foods have the potential to alleviate both the incidence and severity of these diseases, as well as obesity, which is a causal factor for many chronic diseases (Heber and Bowerman, 2001).

While obesity has taken the spotlight as the major nutritional challenge for the US, the Dietary Guidelines Advisory Committee (2004) identified inadequate, or shortfall, intake for three minerals (Ca, Mg, and K), two vitamins (A and C), and fiber for at least half of the US population, with less than 15% of the population with adequate intake of vitamin E among US consumers, 35% with adequate magnesium intake, and 45% - 50% with adequate intake of vitamins A and C, potassium, and fiber. Folate intake was not evaluated adequately in this sampling, but was also thought to be a shortfall nutrient.

Crop plants, especially vegetables and fruits, are significant dietary sources of all of these nutrients, especially vitamin C and fiber. All of those crops significantly contributing to each of these nutrients demonstrates wide variation among cultivars and more diverse germplasm (Simon et al., 2009), indicating ample opportunities for increasing the nutrient content of the diet in plant breeding programs.

While plant breeders have been extremely successful at improving productivity of crops, there are few success stories documenting genetic improvement of nutritional value. There are several reasons for this observation.

Consumers, while aware of the link between diet and health, place flavor as the most important factor in food selection (IFIC, 2007). Sensory appeal, including color, is also important to consumers when selecting many fresh fruits and vegetables so that high-color carrots, potatoes, and tomatoes, for example, are preferred by consumers. Consequently, breeding to increase consumer appeal by improving flavor, color, convenience, or shelf life will increase consumer intake of nutrients more than improving nutritional value. Breeding for these consumer-driven traits will also confer the additional benefit of increasing intake of fruits and vegetables, which is important for addressing approaches to reducing the incidence of obesity.

Even if a plant breeding program decides to include improvement of nutritional value as an important breeding goal, success in delivering improved cultivars to consumers brings challenges. A successful selection program requires high and economical throughput of samples, and, outside of pigments, selection for most vitamins, minerals, and other phytonutrients can be slow and expensive. If selection is successful and the cultivar developed has a higher nutritional value, the producer may expect to realize added economical value for an improved product, yet for added value to be realized with nutrients, specialized handling to segregate and differentiate cultivars would be required in the market.

Labeling requirements and restrictions further complicate and limit marketing of nutritionally-enhanced cultivars. Because of these challenges, breeding for improved nutritional quality may have little effect on average consumer nutrient intake until most of the cultivars grown for a given crop are improved. One study suggested that nutrient content has declined in nearly all US vegetable crops between 1950 and 1999 (Davis et al., 2004) as nutrient content was lost in the trade-off between yield and nutrient content. Carrots were one exception, reflecting the effort to improve color, along with yield and flavor, in the majority of new cultivars developed in that time period (Simon, 2000).

Another important consideration in undertaking plant breeding approaches to improve nutritional content is to include food scientists and nutritionists along with breeders in a team approach to crop improvement. This team approach has been taken in developing quality protein maize and the HarvestPlus program.

Greater consumption of healthier foods not only improves human health, but also has positive economic benefits to US agriculture. A USDA Economic Research Service report indicated that consumer adoption of the recommendations of the 2005 Dietary Guidelines for Americans would significantly alter food demand and production with positive economic impact (Buzby et al., 2006). The far-reaching positive effects of plant breeding to improve crop productivity are well-documented for farmers and consumers. Plant breeding to improve nutritional quality can be equally successful, based upon the breadth of genetic variation in nutrient content available in germplasm used by plant breeders. But to realize an improved nutritional value of crops in the marketplace, improved economic value for the grower, and culinary quality for consumers, must also be realized.

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Organic Spring Wheat Breeding and Agronomy Research at the University of Alberta, Edmonton Canada: 2001 - 2011

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Introduction
In 2006, there were about 3,500 certified organic farms in Canada, representing 1.5% of all farms in the country. Nearly half (45%) of these farms are situated in the Prairie Provinces, with Saskatchewan accounting for about one-third of the nationwide total. Like their conventional counterparts, most (95%) organic producers on the Prairies are engaged in the production of hay or field crops, primarily wheat and barley, but also including a variety of other grains, pulses, and oilseeds.

We began our research in organic wheat breeding and agronomy at the University of Alberta by conducting a farmer survey in 2002 to obtain knowledge of Albertan organic crop and commodity selection practices, land usage, fertility management, perceived research needs, and recognized constraints to sector viability. Albertan organic farmers felt they were constrained by markets, soil fertility, weeds, and production costs. *Plant breeding and cultivar choice was not actually considered very important by farmers surveyed at that time.* Albertan organic producers reported that they would like to see more research focused on improving and protecting soil productivity, developing profitable and sustainable crop rotations, identifying alternative livestock vaccines and feed supplements, and comparing organic and conventional farming systems.

In 2001 we began conducting field experiments on the agronomy and breeding of hard red spring wheat on an 11 acre field in Edmonton AB Canada (which has been managed organically since 1999) and on two certified organic farms within 120 km of Edmonton. The following article outlines some of the things we've learned over the last 10 years.

Spring wheat agronomy and breeding studies in the very northern (53° N, 113°W) Great Plains

The use of competitive spring wheat cultivars may reduce the negative effects of weed competition in organic and conventional systems. A series of studies were conducted to evaluate the agronomic performance and competitive ability of spring wheat cultivars under organic and conventional farming systems, and to identify traits conferring competitive ability in organically grown wheat. Twenty-seven Canada Western Red Spring wheat cultivars, representing 114 years of Canadian wheat breeding, were grown under organic and conventional management in field trials conducted from 2002 - 2004. Cultivars performed differently in the two management systems, suggesting that there may be some cultivars better suited to organic than conventional management systems. Of the 27 bread wheat cultivars, five were selected to be evaluated for their bread making quality when grown in the two management systems. Although differences were detected between the two systems, results suggest that growing high quality bread wheat under organic management systems in north-central Alberta is possible. There was no evidence in either of these studies suggesting that older cultivars are better suited to organic production than modern cultivars.

The Canadian hard red spring wheat cultivar 'Park' (an older cultivar preferred by some Albertan organic wheat farmers) was grown in Edmonton, AB, Canada on paired conventionally and organically managed land in close proximity. Organic grain contained more whole meal protein than conventional grain, but both were greater than 14% protein, indicating excellent grain quality for yeast-leavened bread. Conventional flour produced stronger bread dough than organic flour. Visual observation confirmed these findings as conventional flour produced larger bread loaf volume. Fourteen sensory attributes were generated by a descriptive analysis panel. There were no differences in flavor, aroma, or color attributes, but the panel did perceive organic bread to be more "dense" in texture with smaller air cells in the appearance of the crumb than conventional bread.

A set of 11 spring wheat and barley cultivars differing in height, tillering, and maturity characters were grown at recommended (300 seeds m^{-2}) and doubled seeding densities, with or without competition from tame oats, under organic management in 2003 and 2004. Cultivars differed in their abilities to achieve and maintain grain yield under competition and to suppress weeds. Barley was generally more competitive than wheat. Doubling the seeding rate increased grain yield, weed suppression, and economic returns, suggesting that it is a suitable strategy for overcoming weed competition in organic grain production. We investigated the stability and adaptation of nine wheat cultivars in differing natural weed environments. Older cultivars were the most yield stable across a wide range of environments, while semi-dwarf cultivars were the least weed stable (i.e., did not consistently suppress weeds). Height, early season vigor, time to heading and maturity, and tillering were identified as traits related to cultivar competitive ability. A competitive crop "ideotype" (ideal body type) for organic agriculture would be a tall plant with strong early season vigor, and early heading and maturity.

Mixtures of wheat cultivars and cereal species mixtures may be more competitive, produce higher yields, and provide greater environmental stability than growing sole crop wheat. We conducted an eight site year study on both organic and conventionally managed land, testing 16 modern wheat cultivar mixtures with and without simulated weed pressure between 2003 and 2005. A 1:1 mixture of a vigorous semi-dwarf (AC Superb) and an early maturing (AC Intrepid) wheat cultivar performed well in both conventional and organic systems. Sole-crop AC Superb produced high yields but was not as stable as some mixtures. Wheat cultivar mixtures may be useful for both organic and conventional producers in western Canada.

Some traits are known to confer a competitive advantage to spring bread wheat, but complex relationships between the competitive traits makes breeding for competitive ability difficult. The International Triticeae Mapping Initiative (ITMI) population was used to study the genetics of traits associated with competitive ability. Grain yield without weed competition, and under experimentally sown cultivated oat competition, exhibited similar heritability. Similar heritability estimates between competition treatments suggest that selection in a weed-free environment can lead to improvement in a weedy environment, but our results suggested that some high yielding lines under competition would be eliminated during selection. Quantitative trait loci (QTL) analysis of the population found a region of the genome (a QTL) associated with vigor, days to heading, anthesis, and maturity, and cultivated oat grain yield suppression on chromosome 5A. Genetic correlation analyses supported the idea that early maturity provides a competitive advantage in northern grain growing regions.

To investigate the feasibility of organic wheat breeding we used a random population of 79 F6-derived recombinant inbred sister lines from a cross between the Canadian hard red spring wheat cultivar 'AC Barrie' and the CIMMYT derived cultivar 'Attila.' The population, including the parents, was grown on conventionally and organically managed land in 12 environments over three years. Six environments had detailed agronomic data, and heritability estimates differed between systems for five of the 14 traits recorded. Direct selection in each management system (10% selection intensity) resulted in 50% or fewer lines selected in common for four important agronomic traits (yield, protein, test weight, and plant height). Overall, 12 environments direct selection within management system resulted in three lines retained specific to each system. The results of these studies suggest that selection differences occur across multi-location tests, and selection for grain yield in organic systems should be conducted within organic systems. However, data garnered from conventional yield trials does have some relevance towards breeding for organic environments.

It may be possible to tailor crop management to encourage diverse soil microbial communities and beneficial microorganisms, and produce high quality food products. Studies were carried out between 2005 - 2007 to evaluate the impact of spring wheat cultivar on soil microbial communities in organic and conventional systems, and subsequent wheat quality. Five wheat cultivars were grown organically and conventionally to evaluate grain bread making quality and micronutrient content and their impact on the soil microbial community. Organic grain yields were roughly half of conventional yields, but quality levels were all acceptable for Canadian Western hard red spring wheat. Measured soil (0 - 15 cm) microbial profiles (by phospholipid fatty acid analysis) differed between the two management systems, and amongst cultivars in the conventional system. The most recent cultivar in the study, 'AC Superb,' exhibited the highest levels of fungi, suggesting that breeding efforts in conventionally managed environments may have resulted in cultivating mycorrhizal dependence in that environment.

In general, many of the studied grain micronutrients were greater in the organically grown wheat system. Maximizing grain micronutrient content through wheat cultivar choice was dependent on management system. The presence of fungi biomarkers appears to have improved uptake of Mn and Cu**.** We are presently conducting studies to unravel the importance of weed presence for sustaining mycorrhizal communities in organic systems.

We used a randomly derived recombinant inbred line population (n=180) from a cross between the Canadian spring wheat cultivar 'CDC Go' and the CIMMYT spring wheat cultivar 'Attila' to elucidate selection differentials of various traits in very weedy organic and non-weedy conventional management systems. The population, along with parents and checks, was planted in replicated designs in paired organic and conventional management system trials from 2008 - 2010. Heritability and correlation estimates for various traits were different in both management systems and varied significantly over years. Overall, gain yield, plant height, 1000 kernel weight, test weight, tillers m^{-2} and canopy coverage was lower and lines matured earlier in the organic system, but protein contents were higher during 2008 and 2010. Selection differentials were also noted between two management systems, which again suggested that wheat breeding for organic farming should be conducted on organically managed lands. These data will be further subjected to genome wide QTL analyses to uncover putative QTL conferring competitive ability.

The registration process for wheat cultivars in Canada is such that, by law, any Canadian Western hard red spring wheat line must pass stringent agronomic, disease, and quality testing over 30 station years of publicly run cooperative trials throughout western Canada. These registration trials are not conducted on organic land and therefore any developed or registered cultivar at the present time cannot be developed solely for organic systems to be released through the present regulatory system. This does not imply that lines developed in the present system may not suit organic management strategies. It is simply that all quality, disease resistance, and agronomic characters must initially be satisfied in the conventional cooperative trial system. This means, of course, that releasing cultivars specifically for organic systems is somewhat difficult.

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Participatory Plant Breeding Practices

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Organic farmers need crop varieties that are adapted to the challenges of organic systems: varieties that can better access organic fertility sources, compete with weeds, and resist pests. 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.

Participatory plant breeding (PPB) is a highly effective breeding method, and a method that is well suited to organic systems. PPB involves a close collaboration between farmers and researchers, with much of the breeding work often done in the farmers' fields. It enables farmers to select and adapt crop varieties to the specific environmental conditions of their regions and to the organic cultural practices that they use.

PPB can be broadly defined as breeding "based on a set of methods that involve close farmer-researcher collaboration to bring about plant genetic improvement within a crop" (Morris and Bellon, 2004). Although not strictly part of the definition, much PPB work is decentralized from research station to farm; the breeding is based on input and results from many farmers and farms in many locations. The strengths of the PPB model rest on these two parts: 1) farmer-research collaboration, and 2) the decentralization of the breeding process onto farms.

Farmer-researcher collaboration leverages the strengths of both parties to create useful varieties in an efficient manner. The best farmer partners are experts in their crops and cropping systems, and are often better than researchers at identifying the requirements for a new variety. For example, in their participatory barley breeding program in Syria, Ceccarelli and Grando (2002) discovered that stalk height and palatability to sheep were fundamentally important traits for the farmers, but had not been part of the barley breeders' decision process prior to working with farmers. Farmers can also identify the ideal time to evaluate traits. Finally, in organic farming, many of the advances in production are due to farmers' rapid adoption of new techniques, so farmer partners are often the best equipped to identify the most up-to-date production systems to test in. Formally trained breeders can improve the efficiency and quality of the program. For example, trained breeders can help farmers identify the best field designs to minimize error, the best pollination processes to ensure rapid and reliable crossing, and new germplasm that farmers may not be aware of.

A decentralized, on-farm approach to PPB can help lead to varieties that are better adapted to environments and systems of organic farms. When breeders select plants in the controlled, high-input conditions of a research farm, they are assuming that the best varieties on their ground will translate to the best varieties in farmers' fields. But many organic farmers' fields are managed differently than research ground. This leads to research farm varieties being not as good for organic farms as they could be. For example, Murphy (2007) found that the highest yielding soft white wheat varieties on organic farms were different than the highest yielding varieties on conventional farms. By fostering collaboration between farmers and researchers, PPB offers an economical way to develop varieties that are adapted to organic farms.

PPB can successfully leverage the strengths of all participants. However, many PPB projects are challenged by a lack of clear planning and communication. Farmers and university or industry-based breeders are experts in their own fields, but may not have training in how to methodically assess the needs and capacities of all partners, how to work together in project planning, or how to maintain clear and timely communications.

From the experiences of past PPB project participants, we know that there are practices that can lead to more successful partnerships. For example, it is vital to the success of participatory plant breeding projects that regular and clear communication exists between all parties, from project inception to completion. PPB projects can be sabotaged by unspoken and unrealistic expectations, unmet needs, and unclear responsibilities. Goals and roles need to be determined in an egalitarian way. Additionally, the best PPB projects use breeding designs that make the best use of all the participants (e.g. testing breeding populations at many farm sites, while still making use of the infrastructure of a university or other institution to make crosses or conduct laboratory analysis).

Seed production and plant evolution are key parts of the ecological cycle of agriculture. On-farm PPB incorporates plant breeding into the ecological systems of working farms. By moving from a top-down system, where the farmer's only interaction with breeding is to receive the end product, to a system where all participants are peers, a well-managed PPB project can foster healthy and fair relationships between farmers and researchers, while producing valuable new varieties.

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Growing and Marketing Organic Seed Profitably

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1. **Set your financial goals**
   1.1. Plan your salary
   1.2. Plan your farm income
   1.3. Plan your expenses

2. **Profitability in Space**
   Warning: These formulas mix metric weights and imperial distances with reckless abandon.

   2.1. Set profitability targets
   - **a. Gross Sales ($) ÷ Growing Area (acres) = Target $/acre**
   - **b. Target ($/ac) x Bed Width (ft) ÷ 43 560 (sq ft/ac) = $/bedft**

$/acre	$/bedft
$60 000	$7.50
$40 000	$5.00
$20 000	$2.50

   2.2. Calculate Actual Crop Yields
   grams harvested ÷ bed length (ft) = Yield (grams/bedft)

   2.3. Calculate Current Profitability
   Yield (grams/bedft) x $/grams = $/bedft

3. **Profitability in Time**
   3.1. Set profitability targets
   - **a. Gross Sales ($) ÷ harvest time (hr) = Target $/hr**
   - **b. Harvest time = approximately 400 hours per person per year**

   3.2. Calculate Current Profitability
   grams harvested x $/grams ÷ harvest time (hr) = $/hr

4. **Seed Yields from Tourne-Sol Cooperative Farm**

Crop	grams/bedft	Crop	grams/bedft
Solanaceae	3-6	Beets/Chard	100
Brassicas	25-100	Lettuce	10-28
Beans	75-100	Alliums	25-50
Cucurbits	25-100	Peas	50-75

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Managing Disease in Vegetable Seed Crops and Planting Stock

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This paper addresses disease transmission with planting stock other than true seed. Such non-true seed planting stock could include bulbs, tubers, rhizomes, transplants, and rooted or un-rooted cuttings from various plant parts including woody plants.

Those involved with organic crops have been attracted philosophically and sometimes necessarily to two practices that can lead to disease problems in crops: (1) saving their own seed, and (2) exchanging seed. These practices may be done for a number of reasons. First, at times it may be necessary to preserve and increase sources of rare genotypes. Second, seed saving and seed exchange can keep unit costs low. Finally, seed saving allows commercial dealers to be bypassed. However, the risk of spreading disease from saving and exchanging seed may be higher than the cost of planting material obtained from sources that focus on disease control.

It is prudent to learn about the diseases of any crop before growing it. Horticulturists and gardeners are regularly blindsided by diseases that arrive with vegetative seed that may have been avoided. This is especially unfortunate for diseases that may be difficult to manage once introduced into previously non-infested areas. For example, many garlic growers trade garlic seed for some years before suddenly going out of business from bulb nematode, never being been aware of this disease until all or most garlic die. Similarly, introduction of a single sclerotium of the Allium white rot fungus may result in the inability to successfully grow onions and garlic in the future.

Diseases of both vegetative and true seed result from all pathogen classes (fungi, bacteria, viruses, nematodes), but vegetative seed has the following characteristics that somewhat separate it from true seed:

- Vegetative seed may be more associated with soil than true seed, thus diseases that are associated with infested soil, roots, dirty equipment, boxes and bags are more common than they are with true seed. Less obvious perhaps are the small or even tiny amounts of soil associated with stem plates of bulbs and tubers, even if all root material and visible soil is removed.
- Cutting tools such as knives can quite easily become infested with fungal spores, viruses, and bacteria found in plant sap, and may spread disease with every subsequent cut.
- It is not uncommon for pathogens of one type of plant to be transmitted with vegetative materials on some unrelated plant. For example, sclerotia of the Allium White Rot fun-

gus may travel with dirt attached to carrots or potatoes and the equipment used in those crops.

The reasons vegetative seed is used are numerous:

- More rapid establishment of larger plants than can be achieved with true seed.
- Genetic continuity and uniformity.
- Some plants do not form true seed, or true seed of parental phenotype, so in that case vegetative structures are required for propagation.
- Some plants need regular division and re-planting to maintain vigor, spacing, or other characteristics.
- For many woody plants (and increasingly with some herbaceous plants, such as tomato), there is additional horticultural utility from grafting buds or stems from one plant type onto different rootstocks. The rootstock may be grown from seed or from vegetative sources. While grafting may add further disease complexity, the principles of disease management don't really change.

The role of clean seed programs

Quality seed and commercial experience can be greatly enhanced by programs that ensure freedom from one or more critical diseases, or that at least limit the incidence of these diseases to tolerable levels. As with everything else, the programs vary with the biology of both pathogens and hosts, the relative risks of the diseases involved, and costs and efforts involved.

The following are some steps that can be taken to reduce disease incidences:

- Quarantines, which usually have limited and temporary effectiveness.
- Visual field and plant inspections, which cannot detect pre-symptomatic infections.
- Laboratory testing of plants and soil, which are useful and recommended, but can be limited by sampling and testing procedures, and cannot detect low incidence with certainty.
- Either informal or formal certification programs with criteria for inspection and testing and quantification of tolerances allowed. These are usually government or industry managed.
- With some crops, no such programs exist, but growers can take some measures them selves, such as inspecting seed and seed sources, having samples tested in qualified labs, and being familiar with supplier histories.

Examples

Bacterial blight of Pelargonium and Geranium: ***Xanthomonas campestris*** **pv** ***pelargonii***
This bacterium spreads and infects without symptoms when air temperatures remain below 70 F. It is commonly spread via tools used for stem cuttings, but can also spread with irrigation water and by other tools that contact multiple plants.

For many large-scale propagators, cutting stock is acquired from nuclear seed programs that certify stock is free from this pathogen, based on tissue culturing and lab testing. Propagators increase the stock by stem cuttings from nuclear stock, in flats and crowded pots in greenhouses, typically in winter and spring for late spring distribution to retailers.

Although certification programs exist, they are not perfect. Many propagators have less than perfect greenhouse sanitation and *X. campestris* can be difficult to detect in some very popular varieties. Once *X. campestris* gets into propagation greenhouses and spreads, plants may die throughout one or many greenhouses when weather warms. Ultimately, disease control still depends on clean nuclear stock and the reputations of sellers of such, and greenhouse cleanliness and sanitation practices. Non-certified sources of cutting stock may be safe if source plants for cuttings have routinely proven free of disease during warm periods.

Stem and bulb nematode of garlic (and other bulbs): ***Ditylenchus dipsaci***
Ditylenchus dipsaci is a rapidly reproducing disease that spreads with infected garlic cloves and bulbs. It spreads via water on plant surfaces and short distances in or on wet soil, frequently spreading widely in seed lots before symptoms are noticed. Symptoms include a slight stunting as the disease population increases from low to moderate levels inside plants. Later symptoms include the bloating of storage leafs and the separation of stem plate. Ultimately the plants die, with symptoms sometimes being confused with fungal infections as plants break down. Often the disease is noticed when many plants die at once.

Ditylenchus dipsaci can be a challenge to control because it has many alternate hosts and races, and can survive for years in dried garlic debris, such as storage areas, equipment, and boxes. Control measures include four-year non-Allium crop rotations, hot water treaments, field observations, lab testing, and using seed sources with long histories of no problems. The best control is seed from "limited-generation" seed programs and routine testing (see below). At a minimum, growers should require lab testing when scheduling seed from new sources, and perhaps even traditional sources, and should sample plants and roots in season (but not soil) throughout a field, or bulbs after harvest and before planting.

White rot of garlic and onions (and other Alliums): *Sclerotium cepivorum*

Sclerotium cepivorum is a cool weather disease limited to Allium species. The fungus becomes dormant below 50 F soil temp, and stops growing above 70 F soil temp. Because of this, it will not be a problem where onions are grown in hot summers, for seed planted in spring, and bulbs harvested in fall (or for summer green onions). However, for overwintered Alliums, and summer Alliums in cool regions, it is the worst disease of this family of plants.

The fungus persists for many years in soil as dormant sclerotia. These sclerotia germinate in response to Allium flavor and odor compounds leaking from roots. Once the roots become infected, the infection grows toward bulbs, crossing over onto roots of neighboring plants. The Allium plants will die in clusters as the infections grow into the stem plate and bulb. Ultimately, the bulbs essentially become converted into many sclerotia, with some additional sclerotia forming on the roots. This is a slow process, and if the soil heats above 70 F in the bulb area, infections on the lower root system become stranded such that few or no sclerotia form, and plants show no symptoms.

This disease can be moved passively with incipiently infected bulbs or roots. However, it is more commonly moved with soil on equipment, boxes, feet, irrigation pipe, and non-Allium root crops. *Sclerotium cepivorum* does not spread with true seed itself, but could travel with dirty equipment used in onion seed fields.

Because it may lie dormant for years until activated, crop rotation is an ineffective strategy. The following are the recommended methods of control.

Prior to getting the disease, exclusion and avoidance are far preferred. Avoid dirty equipment, or clean all soil and plant particles. Know the field histories of seed sources. Walk and look for plant death late in season in seed fields, and verify the activity of *S. cepivorum* – this is the basis for several formal and informal certification programs, which are not fool-proof.

After the disease arrives, a number of steps should be taken to limit the spread of this devastating disease. Rouge every prematurely dying plant to minimize reproduction; if *S. cepivorum* verified, then also dig out soil at least one foot beyond any plants with symptoms. Because nearly every old sclerotium is stimulated to germinate in the season that Alliums are grown, future disease depends on reproduction of that current crop. Rigorous rouging will maintain the population down to very low levels, and must be practiced every season.

Irrigating diluted Allium juices during non-Allium rotations can assist in population management, because *S. cepivorum* cannot survive on non-Alliums and won't reproduce on the diluted juices. Dilute onion juice (1:20) or dilute garlic juice (1:50) and irrigate onto old white-rotted areas when soil temperatures are expected to stay between 45 - 70 F for one - two months (although fall applications will carryover and continue to activate sclerotia into spring where soil temps fall below 50 F). Diluted Allium juices applied to soil warmer than 70 F will be ineffective.

For regions with hot summers (see temperature range above), planting summer onion bulbs or green onions in early spring can achieve the same as above by forcing sclerotia to germinate early, but at a time when soil temperatures rise to prohibit infection of bulb areas.

Viruses of garlic, potatoes: Several distinct viruses of the *Potyvirus* group
There are several related but distinct potyviruses that infect both garlic (Onion Yellow Dwarf Virus, Leek Yellow Strip Virus) and potatoes (PVY). The potyviruses that go to garlic do not go to potatoes, nor vice versa. These viruses are vectored by aphids. In cold regions, aphid pressure is low and the potyviruses spread slowly. Most virus-free seed potatoes and virus-free garlic seed cloves are grown at high altitude and latitude to avoid high aphid activity. Where aphid pressure is high, viruses spread rapidly and widely, but symptoms usually are absent or mild during the first season of infection.

The longer that potyviruses exist in planting stock, the worse the symptoms are. Typically, symptoms appear as stunting on garlic, although many people fail to realize this and consider infected garlic as "normal." Typically, when viruses are removed from garlic, bulb diameters will double and bulb weights increase proportionally. It may take a year or two after re-infection for bulb sizes to drop, and three to five years to lose all benefits of previous virus freedom. On potatoes, PVY reduces yield; other symptoms vary with variety. Co-infection of potyviruses with other garlic or potato viruses can worsen symptoms.

Larger production systems use a seed production system that initially eliminates all viruses (and other disease agents), and controls the level of re-contamination over several seed generations. This is known as "limited-generation seed production." Virus-free plants are produced from meristem tip culture. Plants are then regenerated in test tubes and verified as being free of potyviruses (and other agents). Potato mini-tubers or small garlic corms are planted into the field and increased over three to five years in low-aphid regions. Virus infection is monitored at each seed generation with only small increases in frequency of plant infection allowed at each generation. Commercial crops planted in warmer, high-aphid regions with virus-free seed may become infected, but infection in the current year does not lead to noticeable symptoms or size/quality problems. For this reason, commercial crops should not be used as seed.

Potyviruses move easily with tools that move plant sap. Many varieties of potatoes with large tubers are cut into pieces to increase the number of vegetative seed pieces available.

Cutting PVY-infected seed will result in every seed piece being infected, along with seed pieces cut from subsequent tubers. To reduce the chance of infection, verify your seed tubers are from a virus-free program and sterilize all cutting knives between each tuber and/or plant only small tubers whole without cutting. This will also assist in limiting other seed-borne diseases of potato.

Virus spread may occur in garlic during scape removal, from either knives or hands. Wiping knives and hands with a diluted bleach solution can prevent such transmission if the crop is thought to be relatively virus free. For crops that are already highly infected, there is no such benefit. Personally, I use a cotton glove over a rubber glove. In this way, I can keep the cotton glove damp with a diluted bleach solution, without getting the bleach on my skin.

There are many governmentally managed limited-generation programs for potatoes, so it usually is not too difficult to find virus-free seed stock. Avoid using virus-infected seed or re-planting your own seed in high-aphid regions.

There are no governmentally managed limited-generation programs in garlic, so virus-free seed stock can be difficult or impossible to find, especially for varieties outside of the large commercial sources from California, China, Argentina, and Mexico. Much of the seed garlic for large commercial ventures is grown under an in-house, privately-managed limited-generation program. Thus, most hard-neck and many soft-neck varieties in the organic and market garden trade are virus-infected, even though this isn't widely known or considered. A few small clean seed programs are in development (e.g., my own seed program, a governmentally managed program in Ontario, Canada, and perhaps others in different countries).

Potyviruses are irregularly distributed in garlic bulbs. Some cloves naturally may be free of potyviruses. It is possible to select the most highly vigorous plants as future seed bulbs, with some likelihood that these may have come from virus-free offshoots if the original stock was infected. In high-aphid areas, this may be of limited value because of near-certain aphid activity will have resulted in virus infection of those vigorous plants. There isn't data on whether some top set bulbils of garlic similarly may be free of viruses, but I'm working to get such data.

Strawberry anthracnose*: Colletotrichum acutatum;* Vinca stem blight*: Phoma exidua*

Both *Colletotrichum acutatum* and *Phoma exidua* cause lesions and death of stems, runners, and crowns (and fruit for strawberries). Both of these fungi can persist for most of a year in soil and on plant materials, with spore production, infection, and symptom development worse in warm weather and with wet foliage.

For strawberries, *C. acutatum* is commonly spread from field to field with infected field-grown transplants. For vinca, the pathogen persists in plants used in greenhouse propagation beds. Neither disease is very evident in strawberry nurseries or vinca propagation beds because of cool conditions.

Unfortunately, both diseases are nearly impossible to control once established in the field. For strawberries, the best practice is to obtain planting stock certified free of the anthracnose fungus. For vinca, there are no certification programs, but one can try to increase one's own plants from rooted cuttings of vinca populations that have been free of stem blight for some years. At this point, there are no fully effective organic (or non-organic) chemical controls for either disease. For strawberries, hot water treatment, cleaning transplants of all dirt, and dead material help (see: http://www.ipm.ucdavis.edu/PMG/r734101011.html). Drip irrigation (or at least limiting foliage wetness in some manner) for both diseases assists substantially in reducing both spore production and infection.

Peppermint and spearmint verticillium wilt: *Verticillium dahlia*
Peppermint is a perennial plant with no perennial structures: new rhizomes form in fall and old rhizomes die over winter. Spearmint is similar, but old rhizomes sometimes survive a sedond year. *Verticillium dahlia* as a species has a very wide host range, but specialized forms also occur. The *V. dahlia* that attacks mint does not reproduce well on other species of plants, and vice versa. Initially, the roots are infected, but the fungus grows systemically in the xylem, resulting in occlusion of water-conducting capacity and thus wilt.

Mint rhizomes are dug in the field, broken into pieces, and used to plant new fields. *V. dahliae* commonly is moved with both infested soil and infected rhizomes (or roots attached to rhizomes). Once *V. dahlia* is established in a field, that soil is permanently infested, and crop rotations are ineffective. Over years, *V. dahlia* will worsen as soil inoculum builds. *V. dahlia* in all forms can persist as asymptomatic root surface infections.

To control *V. dahlia,* certified verticillium-free rooted cuttings can be purchased. In areas where mint verticillium doesn't already occur, the best practice is to obtain certified rooted cuttings. If mint verticillium already is present, the variety "Native Spearmint" is resistant. Other varieties have limited but unreliable resistance.

Farmer-owned Seed Companies: How to Start One

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About our farm

Oatsplanter is a five-acre farm in Port Townsend, Washington, with 1.5 acres in seed and vegetable production. The farm started in 1988 with gardens and orchards developed for self-reliance and farmers market sales. The seed business started in 2009 following several years of selection for optimum local production. Organic seed stock and organic practices are used, with the organic grower being the targeted end user.

A strong sense of experimentation is part of my approach to growing seed. When told it would be difficult to grow leek seed in Jefferson County, I was challenged to try. Having a small farm allows me the time and space to pay close attention to seed stock. The physical isolation of my farm also gives me some control over pollination drift.

Our seed list is short, focusing primarily on winter hardy, Pacific Northwest short season varieties. Having said that, each year we look for new material and spend at least a three-year grow-out of seed stock that is shared or recommended by fellow growers in our region. Currently we carry open-pollinated varieties of basil, shelling beans, broccoli, celery, dill, kale, leek, lettuce, orach, parsley, parsnips, peas, peppers, spinach, and a few varieties of flowers.

Advice in starting a new seed company

- Seed production requires a different mindset from growing produce. When you walk rows and see a plant that has the optimum color, taste and size to sell, you leave it there. It's about harvesting at a different stage of the plant life cycle.
- Don't get big too fast. Start with a variety you are passionate about. Use it to figure out the "seed growing mindset" that experiences the plant from seed-to-seed.
- Seed production is a good alternative source of revenue for small farms. It requires less space, but does add a more lengthly and sometimes complicated harvest and storage period. The downside of production in a small space is paying attention to the barriers (time, distance, or structural) that are needed if you grow several varieties of the same species. In my case, three varieties of kale are the challenge.
- Talk to any close neighbors about what they grow to make sure that crops you select have a low risk of contamination from other fields.
- Regarding financials, pay as you go -- don't use credit. This is a personal bias, but it has been effective in keeping me out of debt. Nothing was lost in this venture. Any seed improvement that didn't result in direct sales resulted in enhancing quality.

- My connection to customers was selling produce out of the back of my 1954 Chevy pickup at the farmers market. The truck was a unique trademark of my produce, so I used it as the logo for my seed packaging.
- The first year we sold seed, we sold it alongside our vegetables at the Chimacum Farmers Market. The second year I made wooden seed racks for two local stores with customers seeking organic produce. This year (our third) we will sell at the Port Townsend Saturday Market (with a strong tourist base) to expand the consumer base. Sales always need to be balanced with our production capacity. We have no desire to get bigger, just better.

Seed management skills
- Through experimentation and observation, you learn the optimum time for seed harvest for each species.
- Drying seed: Our farm has racks built into the kitchen above the wood cook stove. After drying to the maximum in the garden, the seed heads and pods spend time on drying racks in the house. Many winter evenings are spent threshing and cleaning seed. Currently our sales do not include wet seed varieties.
- Seed cleaning is done by hand, with winnowing being done in large bowls with lung or fan powered bursts. I framed several 18x18 inch screens and fit them into a box for cleaning and collecting chaft. There are charts that I reference for screen size for particular seed.
- Seed storage varies with each species, but is typically a space that is dark, dry and cool. Right now we have our sugar peas in the freezer to preempt any possible weevil. Our bean seed is cleaned and stored in half-gallon jars in a dark and cool food shed. Each is labeled by year. We keep records of annual yield for each variety.

Why I started a seed company
- I never thought about selling seed until I became involved with Organic Seed Alliance. With a background in selling produce at the farmers market and being a small farm, there was room in the highly competitive produce market for a seed seller, that niche had not been filled in our local community.
- Seed industry consolidation and seed varieties disappearing were the major motivation for me moving into seed production. And, with each year of farming, I noticed a difference between local and imported seed. There was a difference in vigor when local seeds were planted.
- A farmer-owned business eliminates the middle man. The farmer deserves a larger share of the returns for his labor. It's simple math: If I put 100% of the labor into my product, I should receive 100% of the earnings.

Resources I recommend
All of Organic Seed Alliance's publications, which are free to download at www.seedalliance.org.

Ashworth, Suzanne. 2002. *Seed to Seed*, Seed Savers Exchange, http://www.chelseagreen.com/bookstore/item/seed_to_seed

Maynard, Donald and George Hochmuth. 1997. *Knotts Handbook for Vegetable Growers,* John Wiley and Sons, Inc. New York: NY.

Wheat Varietal Selection and Annual vs. Perennial Growth Habit Impact Soil Microbes and Apple Replant Disease Suppression

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Abstract

Wheat can be grown as a cover crop to disrupt soil-borne pathogens and reduce disease in subsequent crops. Modification of the soil microbial community resulting from cover crop cultivation is believed to contribute to decreases in disease incidence. Varietal differences can impact soil microbial community composition, but there has been little effort to actively select for this trait in wheat or develop new varieties with greater ability to suppress soil-borne pathogens. Using soil from an apple orchard with documented pathogen infestation, we evaluated annual wheat genotypes representing historic, high-input and organic selection conditions, as well as wheat genotypes with a perennial growth habit for their capacity to enhance resident microbial antagonists and suppress apple replant disease. Results indicate that selecting wheat genotypes under organic management and further development of perennial wheat will result in new varieties with greater capacity to modify the soil microbial community and suppress soil-borne pathogens. Similar pathogen complexes affect various crop plants, thus findings from these studies are likely to be of value across multiple systems.

Introduction

Soil-borne pathogens adversely impact establishment and productivity of agricultural crops. In apple systems, pathogens and parasites belonging to the genera *Rhizoctonia*, *Pythium*, *Phytophthora, Cylindrocarpon* and *Pratylenchus* severely reduce tree seedling survival and lower yield over the life of an orchard; this phenomenon is commonly termed apple replant disease. Effective suppression of soil-borne pathogens is difficult in organic systems where synthetic fungicides and fumigants are not allowed. Disease control has become increasingly problematic in conventional systems as a result of growing incidence of fungicide resistant isolates and the loss of fumigant chemistries due to regulatory action.

Cover crop cultivation has reduced disease incidence in multiple crop systems (Janvier et al., 2007). In some cases, these reductions have been correlated with measurable changes in the composition of the soil microbial community (Benitez et al., 2007; Janvier et al., 2007; Larkin et al., 2011). Plants can exude signaling molecules and carbohydrates from their roots to attract and support beneficial microbial species in exchange for protection from pathogens. However, plant varieties differ in the amount and composition of these exudates, influencing pathogen dynamics (Rengel, 2002). For example, annual wheat varieties differ in their capacity to enrich beneficial *Pseudomonas spp.* and suppress root infection by *Pythium spp.* and *Rhizoctonia solani* (Gu and Mazzola, 2003).

Conducting breeding programs in low-input and organic systems and developing plants with larger root systems could aid in identification of varieties with greater capacity to sustain interactions with beneficial microbial species. Crop varieties selected prior to the widespread adoption of agrochemical use and those selected recently under low-input conditions are better able to benefit from association with microbial species that facilitate nutrient acquisition (Hetrick et al. 1993; Baldini et al., 2002; Kiers et al. 2007). Perennial wheat genotypes derived from crosses with *Thinopyrum spp.* have deeper and more extensive root systems than annual wheat, which may increase their capacity to enhance microbial transformations in soil.

Objectives

- Determine whether selection conditions and a perennial versus annual growth habit impact the ability of wheat genotypes to increase beneficial soil microbial species
- Evaluate the ability of annual and perennial wheat genotypes to support microbial antagonists of apple root pathogens and enhance apple seedling health

Methods

Greenhouse trials were conducted using soil collected from a field site previously planted to apple in Washington State with documented pathogen infestation. Treatments consisted of three, 28-day cycles of the following (5 reps per treatment): 1) control, 2) pasteurized, 3) one of four historic annual wheat genotypes (selected prior to the widespread use of agrochemical inputs), 4) one of four high-input annual wheat genotypes (selected under high input conditions), 5) one of four annual wheat genotypes from advanced organic breeding program, 6) a wheat relatives (*Thinopyrum intermedium*) used in the perennial breeding program, 7) one of four perennial wheat genotypes from advanced perennial breeding program, and 8) annual ryegrass. After each cycle, annual biomass was cut, soil stirred to stimulate tillage and replanted; perennial biomass was cut and allowed to regrow. Following wheat cultivation, three six-week old Gala apple seedlings were planted in each pot and harvested after 10 weeks. Apple seedlings were analyzed for shoot and root biomass. One genotype from the perennial, high-input and organic groups with the greatest improvement in apple seedling health was selected for analysis of beneficial and pathogenic microbial species in the apple rhizosphere. The experiment was repeated.

Field trials were conducted at two sites (Fuller and Tukey) previously planted to apple in Washington State with documented pathogen infestation. Treatments consisted of the high-input annual wheat genotype (cv. Penewawa) with the best performance in greenhouse trials, *T. intermedium* (cv. Rush), a mixture of perennial wheat genotypes due to lack of sufficient seed for individual genotypes, fumigated or pasteurized, and control. A wheat genotype selected under organic conditions was not included due to lack of sufficient seed. Wheat was planted in spring and mowed down in fall. Soil was collected for microbial analyses and greenhouse trials the following spring. At the Tukey site, a mixture of *Brassica juncea* and *Sinapis alba* seed meal was applied as the fumigated treatment and apple seedlings (Jonagold/G11) were planted in all treatments.

Results and discussion

Wheat cultivation improved apple seedling health relative to annual ryegrass in greenhouse trials, but the magnitude of the impact was dependent on the genotype and conditions under which the genotypes were selected. When averaged across the four annual genotypes representing each breeding category, cultivation of wheat genotypes from the advanced organic breeding program significantly increased apple root biomass relative to historic genotypes (Fig. 1). In contrast, differences in apple root biomass following cultivation of high-input genotypes did not differ from historic genotypes. While historic varieties likely hold valuable traits that may have been lost in high-input breeding programs, our results suggest that recent efforts to select wheat with improved yield under organic conditions has inadvertently selected for genotypes with greater capacity to suppress soil-borne disease. None of the cover crop treatments with annual growth habits improved apple root biomass relative to the control, which likely resulted from nutrient depletion following cover crop cultivation. Greater applications of fertility amendments following cover crop cultivation are advised.

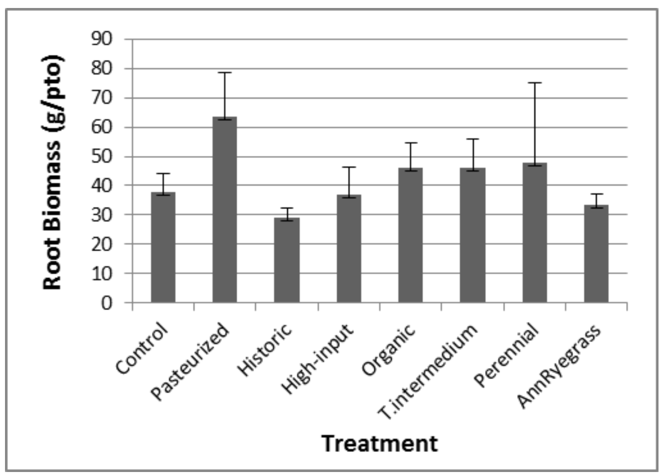

Figure 1. Impact of cover crop cultivation on apple root biomass in two greenhouse

Cultivation of perennial wheat genotypes significantly increased apple root biomass relative to annual ryegrass and historic wheat genotypes. When averaged, perennial genotypes also performed better than annual wheat genotypes selected under high-input and organic conditions, but results were not significant due to high variability among perennial genotypes. One perennial wheat genotype (P-0006), increased apple root biomass equal to the pasteurized treatment, while the other perennial genotypes did not positively impact apple seedling health (data not shown). These data indicate that continued selection of perennial wheat genotypes has potential to function in an integrated system as an alternative to the use of pre-plant fumigation to control apple replant disease.

Improvements in apple seedling health following wheat cultivation were correlated with modification of the soil microbial community. Cultivation of the genotype from the perennial, high-input and organic groups with the greatest improvement in apple seedling health significantly increased beneficial microbial spp. and reduced pathogenic spp. relative to the control treatment (Table 1). These results support the hypothesis that modification of soil microbial community composition likely plays a role is disease suppression following cover crop cultivation. Our results also support studies demonstrating differences among wheat genotypes and their ability to enhance populations of biocontrol *Pseudomonas* spp. (Gu and Mazzola, 2003; Meyer et al., 2010).

Table 1. Rhizosphere microbial populations in greenhouse trials (CFU per 0.5g apple root)

Treatment	Beneficials: *Fluorescent Pseudomonas*	Beneficials: *Fusarium*	Total pathogens†
Control	31.6 X 10^8 bc*	9 X 10^4 c	58 X 10^4 a
Pasteurized	6.05 X 10^8 c	62 X 10^4 a	15 X 10^4 c
T. intermedium (cv. Rush)	93.5 X 10^8 a	5 X 10^4 c	14 X 10^4 c
Perennial (P-0006)	94.4 X 10^8 a	28 X 10^4 b	32 X 10^4 b
Organic (Onas/Madsen)	93.9 X 10^8 a	13 X 10^4 c	32 X 10^4 b
High-input (cv. Penewawa)	70.7 X 10^8 ab	27 X 10^4 b	15 X 10^4 c

* Means in the same column followed by the same letter are not significantly different (P > 0.05; n=10); †*Cylindrocarpon, Pythium, Rhizoctonia*, and *Verticillium*

In soil collected from field trials, wheat cultivation also modified the soil microbial community and improved apple seedling health. Cultivation of the annual wheat variety, Penewawa, significantly reduced pathogen populations (data not shown) and improved apple stem diameter relative to the control (Fig 2). Despite poor establishment and productivity in field trials, cultivation of the mixture of perennial wheat genotypes also significantly reduced pathogens equal to the pasteurized treatment (data not shown); however, this treatment did not improve apple seedling growth. Planting perennial genotypes in the fall rather than spring will likely improve establishment and improve disease suppression and productivity in subsequent crops.

Conclusions

Results of our study provide evidence that breeding programs can be designed to exploit beneficial plant-microbe interactions and release new cover crop varieties with greater capacity to suppress soil-borne pathogens. However, this has not been a target of traditional plant breeding programs. Lack of awareness of beneficial varietal X microbial interactions and the historic inability to culture many microbial species has contributed to lack of selection for this important trait. Improving our understanding of plant-microbe interactions and utilizing molecular techniques employing genetic approaches will help facilitate selection for this trait in modern breeding programs. For example, in tomato, induction of induced systemic resistance to *Pythium torulosum* by *Bacillus cereus* was linked to three quantitative trait loci (QTL) (Smith et al., 1999), and mycorrizal competence to a single gene (Larkan et al., 2007). Identification of markers for genes that facilitate interaction with beneficial microbial spp. will allow breeders to rapidly screen for this important trait. Conducting breeding programs in soils with documented pathogen infestation and in the absence of fungicides and fumigants will also improve selection for cover crops with greater potential to suppress soil-borne pathogens.

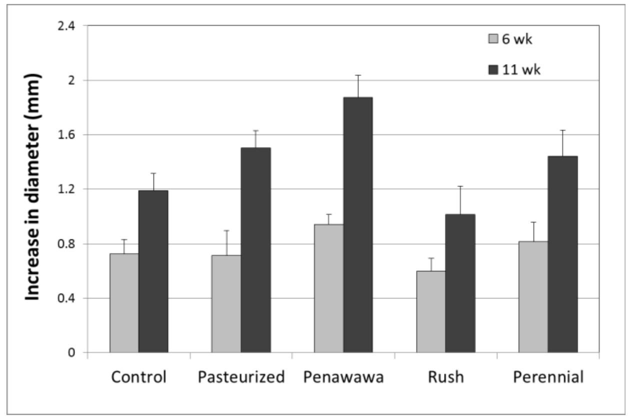

Figure 2. Impact of wheat cultivation on apple stem diameter in soil collected from

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How Do Seed Companies Decide What Varieties to Sell?

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Decisions around adding new varieties to a retail seed catalog take place over a multi-year window. Every year in October, just as the current catalog is about to be released, the people responsible for making variety decisions meet to develop a plan for the next year's catalog additions and potential additions for the next two years after that. We begin by identifying and discussing current trends among vegetable growers, areas of potential growth within our catalog, and overall vision for adding and dropping varieties. We then initiate a series of six or seven meetings in which we discuss each individual crop type separately to identify potential varieties to add or drop within that crop type over the course of the next three years. We also look to identify gaps for which we would like to add one or more varieties but do not yet have a specific variety to consider. Because our company sells only NOP-certified organic seed, we are more limited than most other seed companies with respect to what we can buy outright, and thus many of our discussions revolve around production capacity – i.e. can we grow it or have it grown for us?

During these meetings we carefully evaluate many sources of information in order to make strong decisions. We pour over our own data from trials conducted the previous summer, we examine sales data to look at trends and performance of individual varieties and crop types, and we collate and discuss our observations from visiting university breeding programs, seed company trials, commercial farms, conferences, and any other sources for potential new material. Our trials data includes information on yield, flavor, various crop-specific traits, and then an overall average rating for each variety using a scale from 1 to 5. Whenever we see new material at a breeding event or a vendor trial, or just by word of mouth, our first step is to put the variety into our own trials to see how it performs under organic conditions in a northern climate. We reason that varieties that do well here will do well in most places. At times we trial material that we expect to do better in warmer climates, but we still want to see it with our own eyes. If needed, we will then trial at a location that gets more heat than we do up here in the far north.

Out of this series of meetings comes a three-year plan for which varieties we want to trial, which we definitely want to add to our catalog, which we might want to add based on other variables, and which we likely want to drop. The three-year plan then gives rise to a series of planning projects, including the current Trials Plan, Farm Plan, and Contract Production Plan.

For varieties that we cannot purchase and must grow ourselves, we have another level of maintenance with respect to stock seed – i.e. the seed that is planted for a seed production. Stock seed is typically the best seed, both for genetics and vigor. When we wish to add a variety that we will license from a university, the initial seed will come from the university breeder. Some universities are able to give or sell us enough seed to plant a full production. More commonly we can only get a small amount of seed, which requires that we do a seed increase before we can plant a full production. Seed increases for outcrossing crops are typically performed in pollination cages containing 50 or 100 plants each, thereby allowing us to do a number of small productions in a single location without concern that they will cross-pollinate. Seed coming from our own breeding program is treated similarly, going through a round of stock seed increase before getting planted for production. The stock seed phase also allows us to spot any off-types or other inconsistencies that will make a problem in larger grow-outs.

Whereas some university seed comes ready "as is," other times the variety requires some work before we can plant it for production, either because it isn't yet exactly the variety we would like to grow and sell, or else because it lacks uniformity. In these cases we typically put the variety into our breeding plot (for outcrossing crops) so we can hand-pollinate and make single-plant selections. Single-plant selection is a powerful means to introduce greater uniformity. In some cases, repeated rounds of this kind of selection will generate inbreeding depression, which is appropriate only where hybrids are being developed, but in most cases there is enough variability in the genetics of a variety that one or two rounds of self-pollination doesn't make it unsuitable to use for an open-pollinated population. Once the variety has gone through this "clean-up" phase, it gets increased into stock seed in preparation for production the following year. This whole process can easily take three to four years. Once production is planned and planted, though, that variety is a definite addition to the catalog either for the current or following year, depending on the crop type.

Final decisions about what to add to a given year's catalog come in the summer while we're building the current catalog. We go ahead and make decisions on any varieties that are not in our trials for one reason or another, and then we meet periodically throughout the summer to evaluate the newest trials data regarding varieties that we could add for the upcoming catalog. We make decisions about spinach and other salad greens in mid-June; lettuce, cole crops, and onions in mid-July; and then tomatoes, peppers, eggplants, summer squash, and melons by mid-August. Crops that mature later than our catalog deadline often must get pushed off to the subsequent year.

Once decisions on varieties are finalized, we move forward with purchasing where necessary, writing a description, and making sure we have a catalog photo. When we commit to adding a variety to our catalog, that commitment is for at least three years (barring unforeseen problems with supply). After three years, we evaluate sales performance to see whether a variety is earning its keep, as it costs a certain amount of money to keep a variety in the catalog. Luckily we've found that by three years most new varieties have found a following and sales are growing quickly.

Pollinator Conservation Strategies for Organic Seed Producers

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Summary

Organic seed producers are facing new challenges. In recent years, several bee-pollinated seed crops such as alfalfa, canola, cotton, and beets have been at the center of a global debate around issues of crop sovereignty and seed security. Indeed, the organic production of these and other seed crops is increasingly compromised by the threat of undesirable outcrossing from genetically modified (GM) and non-organic crop varieties.

This situation is further complicated by the biology of honey bees, which forage over wide areas and are transported long distances where they pollinate countless crops. In contrast, native bees, which forage over shorter distances, offer a functional alternative for seed producers to reduce the need for managed pollinators and to exercise greater control over their pollination needs.

Similarly, the tremendous diversity of organic crop varieties necessitates a wide range of pollinator species. Honey bees are valuable generalist pollinators that can be supplied in large numbers. On a bee-for-bee basis, however, specialist native bees, such as squash bees in cucurbits and bumble bees in heirloom tomatoes, have been documented to significantly increase seed yield.

Current science

In early 2010, the Xerces Society conducted a review of research findings related to the pollination of alfalfa seed and the potential for contamination of organic alfalfa by GM alfalfa seed crops. Based upon a review of that research, it was our conclusion that the findings of the GM seed industry were flawed and that several fundamental issues of crop pollination were mischaracterized.

This request was followed directly by additional questions posed to us by organic seed producers in Washington, Wyoming, Minnesota, and elsewhere about the expansion of GMO crops; the security of organic foundation seed sources; and the foraging distances of various bee species. Based upon these requests, we identified a critical need to provide organic seed producers with more information about how to most effectively encourage pollinator populations in a way that is compatible with their needs.

Indeed, the extent to which viable GM pollen is transferred via managed pollinators is uncertain. However, differences between managed honey bees (and alfalfa leafcutter bees) in contrast to wild native bees may play a role in determining the level of this risk.

For example, the foraging distances of honey bees make them likely to encounter significant populations of plants beyond a farm's boundaries. In one study, honey bees were placed at a distance of 250m from a field of GMO corn surrounded by a 3m buffer zone of non-GMO corn. Of the pollen sampled from the hives, 52% contained the transgene (Reiche et al., 1998).

In contrast, wild bees typically forage over much shorter distances, often less than a mile away from their nest site (Greenleaf et al., 2007). This shorter foraging range could provide a natural limitation against crop pollen from off-farm sources.

The cross-country movement of managed bees represents another potential pathway for pollen contamination to occur. For example, researchers know that viable stray pollen exists within honey bee hives and that such stray pollen routinely adheres to the bodies of departing foragers (DeGrandi-Hoffman et al., 1984). In one study, newly emerged honey bees (that had not yet flown) were coated with enough "second-hand" pollen that researchers were able to successfully hand pollinate apples with the bees' bodies (DeGrandi-Hoffman et al., 1986). Based upon this scenario, the cross-country movement of honey bee hives may have the potential to introduce pollen from far beyond a farm's boundaries.

Similarly, industry studies of GM alfalfa have failed to examine the potential for transgenic pollen to spread within alfalfa leafcutter bee cocoons and nesting equipment. Alfalfa leafcutter bee (*Megachile rotundata*) cocoons are sold in bulk quantities within the seed trade and are routinely shipped across national boundaries (Mader et al., 2010). Such bulk cocoons are typically coated with stray pollen that may adhere to emerging bees during their release in the field. Little published information exists on the ex situ longevity of alfalfa pollen, however, even fairly old research has demonstrated the viability of alfalfa pollen for several years under optimal storage conditions (Hanson and Campbell, 1972).

In contrast, wild bees by nature are not transported by humans, reducing the likelihood of them introducing non-local pollen sources. Such native bees are also widely recognized as extremely effective pollinators of crops, such as squash and heirloom tomatoes, increasing seed set in comparison with honey bees (Tepedino, 1981; Greenleaf and Kremen, 2006).

Native pollinator conservation also provides a number of secondary benefits to farmers. For example, the same habitat features that support native bees also enhance populations of other beneficial insects (Isaacs et al., 2009). Pollinators also serve as a tangible representation of on-farm biodiversity, with the same habitat features that support them providing benefits to other wildlife, water quality, and soil health (Vaughan and Skinner, 2008). Native pollinator conservation is a win-win scenario—providing direct economic benefits to organic producers, and creating a role for beneficial wildlife in agro-ecosystems.

Recommendations

Undeveloped areas on and close to farms can serve as long-term refugia for native wild pollinators. Protecting, enhancing, or providing habitat is the best way to conserve native pollinators (Kremen et al., 2007). On farms with sufficient natural habitat, native pollinators can provide all of the pollination for many crops (Kremen et al., 2002; Kremen et al., 2004; Winfree et al., 2007).

Pollinators have two basic habitat needs: a diversity of flowering native or naturalized plants, and egg-laying or nesting sites. In addition, farmers can take an active role in reducing mortality of the pollinators themselves. While insecticides are an obvious threat to beneficial insects like bees, other farm operations or disturbance, such as burning, grazing, and tillage can also be lethal to pollinators (Kim et al., 2006).

To address this need for habitat, the 2008 Farm Bill makes pollinators a priority for all USDA Natural Resources Conservation Service (NRCS) conservation programs. Specifically, Farm Bill provisions promote the creation and protection of wildflower plantings and pollinator nest sites through federal conservation programs such as the Environmental Quality Incentives Program (EQIP), the Wildlife Habitat Incentives Program (WHIP), the Conservation Stewardship Program (CSP), and others (Vaughan and Skinner, 2009).

The Xerces Society's Agricultural Biodiversity Program works directly with the NRCS to provide in-depth technical assistance to farmers nationwide for the conservation of native bee crop pollinators, as well as for beneficial insects that control crop pests ("conservation biological control"). The Agricultural Biodiversity Program shares three joint staff positions with the NRCS, and is actively supporting applied research and habitat enhancement projects on farms nationwide.

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How (and Why) We Started a Farmer-owned Seed Company

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Adaptive Seeds is located near Sweet Home, Oregon. We steward rare and Northwest-adapted seeds for gardeners and growers who value the resiliency of biodiversity and value seed saving. Our goal is to provide high quality seed stock that can be continually improved in place and can be used as foundations for new regional varieties. We hope to offer varieties that surpass hybrid seed in quality, and also offer a wide array of heritage Northwest varieties.

Adaptive Seeds was founded in 2009, but the story begins over the winter of 2006 - 2007, when we, Andrew Still and Sarah Kleeger, spent four months traveling Northern and Eastern Europe, collecting and sharing seeds, and the stories that come with them.

We called ourselves The Seed Ambassadors Project, and our goals were to connect stewards of open-pollinated seed in Europe with their comrades in the Pacific Northwest, learn as much as we could from the people we met, and promote seed saving along the way. We were also particularly interested in finding vegetable varieties that would do well in places with a short growing season, and we sought out varieties that could grow in winter gardens in the maritime Pacific Northwest.

When we left for Europe, we brought along some top-rate varieties bred in Oregon by public domain plant breeders to share and swap along our journey. We visited small seed companies, institutional plant breeders, outlaw grain growers, seed saving organizations, and unaffiliated seed heroes. By the time we were done with that first trip, we had collected well over 700 varieties of heirloom and open-pollinated seed, most of which were unavailable in the US. Since that inaugural trip we have made several more and collected even more seed.

In 2007 we began growing out some of these varieties and evaluating them for suitability to our place and tastes. We expanded The Seed Ambassadors Project and began teaching seed saving workshops and hosting seed swaps where we shared the varieties that had done well for us. We also distributed many of our varieties through the Seed Savers Exchange (SSE) Yearbook.

At some point around this time we realized we needed a better way to distribute our seeds than just through seed swaps and SSE, and so Adaptive Seeds was born. We also hoped (and still hope) we would be able to get some financial sustenance from the seeds that we were sustaining.

In 2010 we moved on to leased land and started our own farm, Open Oak Farm. In addition to the seed company, and along with one other farm partner, we grow staple foods (dry beans, corn, small grains); run both summer and winter vegetable Community Supported Agriculture (CSA) programs for about 60 families; attend farmer's markets, and do some wholesale. The businesses are separate yet complement each other: Adaptive Seeds provides seed to the farm business, and the farm provides trialing ground for new varieties.

About 90% of the 250 varieties available from Adaptive Seeds are not available commercially from any other source in the US. A similar percentage of our seed catalog is also grown by us on our farm. The varieties that we do not grow ourselves are grown by our friends in close proximity to our farm. We do not purchase and re-sell mass produced seed.

We think of Adaptive Seeds as targeting serious home gardeners in the Pacific Northwest, yet the reality is that most of our customers are located outside of the Pacific Northwest, and many are outside of the US. About 25% of our online orders are from small farms, many of which are located on the east coast of the US.

Now for more numbers: Adaptive Seeds has managed to more than double every year since we started in 2009, without advertising or Google search optimization. We hope this trend continues, and that we can keep up with it. In 2011 our gross sales were around $18,000. Our website generates about 60% of our sales. We have two wholesale accounts in local garden stores, which account for 30% of total sales. We hope to increase this part of our business in 2012.

Through 2011, all of our seed was sold in $3 packets. In 2012 we are introducing larger seed pack sizes for many of our varieties in response to requests from our customers.

Our diversity is our greatest asset and our greatest weakness. It is time consuming and inefficient, but it also attracts a lot of our customers and makes our work fulfilling.

Challenges

- Isolation – Figuring out isolation on- site and/or finding interested and capable gardeners and farmers to grow out seed lots can be difficult. We are starting to transition to buying more seed from our local grower network. For new seed growers we try to stay local because it is easier to be part of the seed growing and selection process.

- Processing – most of the processing we do is by hand, dancing (or driving our pickup) on tarps, and winnowing in front of a fan. Small hand screens help a lot. Seed is dried in a large food dehydrator. Artisan is time consuming.
- Germination testing – This is the most tedious part of the business. Federal germination guidelines are available online. We have to hire this task out because of lack of time, and we simply can't make ourselves do it all.
- Seed lot size – Since we grow so many varieties, we are limited in the lot size we can grow, process, and store for many crops, so we often sell out early. At the same time, some crops produce abundant seed, but are not very popular. Finding the right balance is difficult, especially with a growing business. The size of our grow-outs is a balance between many factors: number of plants needed for a healthy population, projected seed demand over three years, available garden space, and the time and skill we have for the crop. Many of our best selling varieties are for vegetables that are direct sown. Weak sellers are vegetables that require customers to produce transplants.
- Time – The number one reason our seed company hasn't grown faster is because we haven't had the time to put into it and/or the money to pay someone else to put the time into it. Running a seed company while running a farm means no off-season, and many tasks peak at the same time. For example, seed harvest time coincides with grain harvests and winter vegetable planting.
- Organic Certification – Our new farm will not be certifiable until fall of 2012. This limits our market, as many of our customers either prefer certified organic seed, or require it for their own customer needs.
- Diversity – Growing all of the species listed in a typical seed catalog is also really challenging, as each species has its own requirements that we may not be easily able to provide.

Resources

- Organic Seed Alliance seed production workshops and publications teach us a lot about seed growing.
- Suzanne Ashworth's book *Seed To Seed* has good species ID, isolation distances, and population size guidelines, but is lacking in efficient processing techniques.
- Mentors are critical! We have learned so much from Alan Kapuler of Peace Seeds, Frank Morton of Wild Garden Seeds, Tim Peters of Peters Seed and Research, Carol Deppe, Jim Meyers of OSU, and many others along the way.
- Craigslist and Auctions – For general and seed cleaning equipment.
- Community College Small Business Development Center – For help with business plans, accounting, etc. The stuff that makes the dream the reality.

Growing and Marketing Organic Seed Profitably: A Whole Farm Perspective

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Mission/Purpose

- Customers to be served
- Farmer-direct seed sales
- Contracting with seed companies
- Stock seed production
- Plant breeding

Infrastructure

- Financial resources
- Buildings
- Equipment
- Irrigation system
- Field labor
- Technical expertise

Biological & Ecological Considerations

- Climate
- Soil quality/maintenance/improvement
- Crop rotation
- Water resources
- Disease and pest issues
- Isolation distances
- Beneficial habitat

Primary Question

- Does your resource base match your production, financial, and personal goals?

Advantages of Mixed Farm Enterprise (Seed/Produce/Field Crop/Livestock)

- Reduced financial risk and steadier cash flow throughout year
- Produce market helps determine seed varietal selection
- Culls from stock seed production go to produce market
- Livestock and field crops provide good crop rotation

Pitfalls of Mixed Farm Enterprise

- Available labor spread too thin

- Lack of technical expertise
- Produce crops cross-pollinate with seed crops

Establishing a Market

- Who are your buyers/customers?
- Developing business relationships
- Seed contracts and agreements
- Value-added seed production (stock seed, selection, breeding)

Integrating Organic Seed Production into a Diversified Farming Operation

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Canyon Bounty Farm has been in operation for 12 years. After operating a Community Supported Agriculture (CSA) program in Portland, OR, I decided to return to my hometown in southwest, Idaho, in 1999. Over time I have developed three revenue streams for the farm:

• For six weeks in the spring, we operate a retail greenhouse business on the farm. Gardeners can buy all kinds of organic bedding plants with an emphasis on vegetable starts.

• In the field (all seven acres) we raise a variety of vegetable seed crops. We average about 15 - 18 different crops that have been contracted with four or five different seed companies. We grow dry beans, green beans, soybeans, onion, leek, peppers, flowers, watermelon, cucumber, and muskmelon seeds. Plus there are always lots of new seed projects to play with.

• About five years ago I added hard red spring wheat to the crop rotation. That started a whole wheat flour business and accidentally created weekly farm income. Flour is sold to bakeries, restaurants, and co-ops.

Making seed fit

Growing organic seed seemed like a good fit for me since the National Organic Program (NOP) had just finalized the new organic rules, which included the vague requirement that organic farmers use organic seed. Also, my family has been seed farmers for several generations, and I was familiar with that kind of farming.

Any time I start a new agriculture project I try to take baby steps so that the wreck is small or the success keeps me modest. So I played around with seed crops, acquiring equipment and skills in an attempt to become efficient. Over time I've figured out which seed crops fit in my system but am always game to try a new crop. Here are a few guidelines I use for my organic vegetable seed business:

Work backwards

This is my standard method of operation when I am considering a new seed contract or project. I analyze the various stages of seed production starting with the last step.

1. Do I have the equipment to clean the crop or does the seed company have the equipment to finish cleaning the crop if I don't?
2. Can I harvest the crop mechanically or by hand?
3. When is the crop mature for seed and how does it fit with other seed harvests in that timeframe?
4. Competition with weeds, and will it need extra weeding?
5. Can I direct seed or does it have to be transplanted?

Budgeting
I was having a hard time trying to figure out how to create a budget for my seed business. It became easier after deciding I would only try to take contracts that were $1,000/crop.
Of course there are exceptions to this figure, but that's the basic number. The efficiency increases if you can have one crop going to several different seed companies. At season's end, that simple figure makes it easy to decide if the crop was a good fit financially, emotionally, and time-wise.

Wet vs. dry seed
I like having both of these crops in my fields. Wet seed crops, like peppers and melons, take more time to harvest, because they're all hand-harvested, and much of the seed cleaning happens during the wet seed process. Typically these contracts are high-value, too. I've come to justify the wet seeds in my fields by growing larger volumes of the crop. It's one area of my work load where I have to be really careful to not have too many wet seed crops because of the time they demand in September and October.

For dry seed crops like beans, wheat, and flowers, I try to grow a large enough quantity to combine them. This is much easier for me than hand thrashing, but there is much time spent on combine prep and cleaning.

Small vs. large seeds
My rule of thumb is the smaller the seed the more difficult it is to clean. I have invested in some seed cleaning equipment and am not sure how much more I want to buy. Seed cleaning is another skill set, and I am in awe of those who do it well. I've learned that running the seed over a simple seed mill is just the beginning step. Typically several other steps (and different types of equipment) are needed to get the seed presentable. But if you don't have a seed mill then invest in several box fans to winnow the seed and chaff. To eliminate some of my seed cleaning frustration, I have learned to contract the small-seeded crops with companies that have invested in these highly-specialized pieces of equipment and can much more efficiently clean the seed. They may charge a fee, but it is well worth it.

Pivotal moments

My seed business didn't really take off until I could get my organic certification. So in the three years of transitioning to organic, I experimented with different crops, found machinery, and tried to learn a lot about seed production. Once certified, it was easier to get contracts and the seed had a higher value. After I bought a small plot thrasher, I was able to add more small seeded crops to my line-up. I use an old AC All-Crop (pto powered) combine for leeks, onions, flowers, and other miscellaneous lots. This combine has really changed and diversified my operation for the better.

This should have been an easy thing to figure out but flower seeds are a higher value crop than most vegetables. And while I've always put an emphasis on vegetable seeds, adding flowers is rewarding both financially and to increase beneficial insects in the fields. Sometimes flower seeds can be more difficult to clean, so it's important to watch how much time it takes to clean them. Always try to overproduce the seed crop. Depending on how the seed cleans up, you may lose good seed in the process. If there is extra seed, it may be bought by the contracting seed company.

It's all about the germ

Seed is the final phase of the plant's long life. Waiting for the seed to mature is nerve wracking: these crops take a full season (and then some) to mature and are more at risk to weather and pest pressures. And after all the trials and tribulations of the season, if the seed doesn't pass germ, then there's no payment. There are published federal germination standards. Those are the bare minimum, and most seed companies I work with want it better than the federal minimum. Whether poor pollination, ill-timed winds, or a nasty pest, I've encountered my fair share of crops that didn't pass the germination test. It's the risk of seed farming.

Networking

I mentioned earlier, I come by seed farming genetically. It has been my single greatest asset to have family who are generous with their time, knowledge, and equipment. Plus I am surrounded by seed farmers who have answered my questions, given their insight, and shared equipment. I have also spent a lot of time visiting seed cleaning facilities in my area trying to glean nuggets of information. So, I'm fortunate to live in a seed community that has offered me a lot of insight into production methods and equipment.
It's amazing what you find when you start poking around in the farm community. Farmers are well networked and have lead me to some incredible “aha” moments.

OTA's Approach to Protecting Organic Integrity in the Face of GMOs

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The Organic Trade Association (OTA) has an official board-adopted policy on genetically modified organisms (GMOs) that guides the work of OTA in this arena. The position is as follows:

1. **OTA shall continue to call for a moratorium on GMOs in agriculture**. More independent research and regulation are necessary before any more GMOs are allowed in the food system. In fact, there is increasing scientific evidence that GMO crops can cause environmental and health problems.

OTA shall adopt policy positions that uphold the long-term goal of a moratorium on GMOs. Until that goal is reached:

2. OTA supports mandatory labeling of all agricultural GMOs and their products. OTA supports the consumer's right to know, and to choose foods, fiber, and personal care products based on environmental, personal health, religious, dietary, or other preferences. Labeling of GMO seed, products grown from GMO seed or stock, or made with ingredients and byproducts of GMO crops is necessary for farmer, supply chain, and consumer choice.

3. OTA shall also adopt policies that address the problems the industry shall face as a result of continued GMO deregulation.

- OTA shall advocate for a more robust regulatory framework for federal oversight of GMO crops that includes economic, environmental, and human health impacts of GMO crops petitioned for deregulation.
- OTA shall adopt policy positions that lead to a review of currently deregulated crops under an improved framework.
- OTA shall directly engage in dialog with agencies and Congress regarding GMO policy.

4. OTA shall bolster organic as the gold standard by advocating for continuous improvement of the organic practice standard.

- OTA shall adopt policy positions that strengthen the organic standards to minimize GMO contamination and increase enforcement on the prohibition of the use of GMO crop varieties while minimizing the negative impact to farmers.

    - OTA shall advocate for GMO testing by certifiers as part of the requirement for periodic residue testing to verify compliance and enforcement of the standards.
    - OTA shall adopt policies that encourage the reduction of testing costs to organic farmers, handlers, and certifiers wherever possible.
- OTA supports the incorporation of a GMO threshold for crops that have genetically engineered counterparts into the National Organic Program (NOP) regulations at the appropriate time. OTA will work with industry stakeholders, the National Organic Standards Board, and NOP to that end.
- OTA shall facilitate data collection and analysis on the extent of low-level contamination or adventitious presence of GMOs in organic and the best practices for prevention at critical control points in the supply chain.

5. OTA shall advocate for policies that assign the cost of contamination prevention and market loss to the developers of GMO technology.

6. OTA recognizes the critical role of seed in the supply chain and shall advocate for policies that secure a seed supply to the organic sector that is free of GMOs. To that end:

- OTA shall advocate for a seed purity standard.
- OTA shall advocate for more robust germplasm repositories for non-GMO seed.
- OTA shall advocate for re-emphasis of classical plant breeding.

7. OTA shall educate the public and policy makers regarding the environmental and health concerns emerging with GMOs.

- OTA shall educate the public on the extent to which organic farmers and food and fiber manufacturers work to prevent GMOs from entering the organic supply chain.
- OTA shall educate policy makers on the challenges to agriculture from transgene flow and low-level contamination of organic crops by GMOs as they relate to meeting marketplace and consumer expectations.

The policy stated above was adopted by OTA's board of directors on July 28, 2011.

OTA is involved in a range of priority initiatives aligned with the board-adopted policy on GMOs in general and seed integrity, specifically:

Compensation: The public policy discussion on compensation for organic and identity preserved farmers that suffer market losses due to contamination of crops with genetically engineered (GE) material is the focus of USDA's Advisory Committee on Biotechnology and 21st Century Agriculture (AC21). As OTA's Executive Vice President, I was appointed to serve on the AC21 committee. The AC21 met for the second time December 5 - 6, 2011. USDA Secretary Tom Vilsack gave the committee the following charge:

1) What types of compensation mechanisms, if any, would be appropriate to address economic losses by farmers in which the value of their crops is reduced by unintended presence of GE materials?

2) What would be necessary to implement such mechanisms? What would be the eligibility standard for a loss and what tools and triggers would be needed to verify and measure such losses and determine if claims are compensable?

3) What other actions would be appropriate to bolster or facilitate coexistence among different agricultural production systems in the United States? This only will be addressed upon completion of 1) and 2).

AC21 will hold three more meetings prior to the November presidential elections. The committee is expected to deliver a final recommendation to the Secretary at that time. We have established working groups to move forward the discussion between meetings and collect and vet available data. The working groups consist of AC21 members as well as additional ex-officios (non-voting participants) for the working groups only. Organic representatives and ex-officios have been assigned to the identified working groups:

- Scope and scale of risk
- Mechanisms for compensations
- Tools, triggers and thresholds
- Who pays?

Stakeholder involvement from the seed and grower community is critical to this process going forward. The panel discussion will provide updates and outline ways to get involved.

The Seeds Savers Exchange Yearbook: A Tool for Community Seed Systems

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Seed Savers Exchange (SSE) has facilitated a seed exchange for over 30 years, during which time SSE members -- gardeners, breeders, and farmers -- have exchanged hundreds of thousands of heirloom and open-pollinated varieties. The Yearbook is an encyclopedic volume that in 2011 offered 13,876 different varieties (and 21,711 total listings) to members from members. In late fall members send us a list of the varieties they want to offer for exchange, and we compile this list and mail the Yearbook to members in late January. Members exchange seed directly with each other, but members do not have to offer seed to participate in the exchange. This national exchange model allows members to find locally and regionally grown seed, as well as diverse germplasm for breeding projects. The exchange has created a community that encourages the transfer of information directly from person-to-person, through our online forum, and now through the Member-Grower Evaluation Network (M-GEN).

In its first year, the M-GEN consisted of 41 members growing seven different varieties in 24 states, Ontario, and Belize. M-GEN's volunteer participants contribute to SSE's varietal evaluation process. They receive a certain variety from SSE that they then grow and provide data on plant characteristics and performance. We often identify what M-GEN volunteers will grow based on valuable feedback obtained through an annual member survey about varieties they have grown through the Yearbook exchange.

Take this example from SSE member Robert Miller. He requested Tomato 64, 'San Pablo,' from the Heritage Farm listings in the 2011 Yearbook. Miller has had a long-standing history with this variety and sent us these comments.

> *I've grown it since 1981 in Redding Calif. Few seeds, very easy to skin, heavy yielding grown organically, no problems or diseases. Moved to Stanfield, NC in 2011. Disaster, high humidity caused even fruits above ground to mildew. Redding was very hot (115F in summer) and no pollen sterility resulted from heat. Great for extremely hot dry deserts. All fruit will spoil on plants in continued 97% humidity. I am now in North Carolina. Wonderful variety for sauces in California and Arizona. Great in extreme dry heat. No problem even when unevenly watered.*

Information collected through M-GEN will be shared with members and will provide valuable information on which varieties may perform best in their different regions.

However, the Seed Savers Exchange Yearbook faces challenges. New listed members are needed to identify and preserve unique varieties in need of preservation. Maintaining varietal purity and integrity in the Yearbook are also important issues. Preventing duplication and poor or unknown standards for isolation are challenges we face every year in compiling the Yearbook. Both of these problems call for more education and the passing of knowledge from current listed members to aspiring listed members. SSE continues to work toward participatory preservation to ensure that these unique varieties are effectively preserved and utilized.

Understanding the Seed Needs of the Organic Industry

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Seed needs of organic farmers
I would suggest the following as basic seed needs for organic farmers:

- Diversity of crop species (needing seed for crops besides corn and soybeans).
- Adequate and consistent supplies of desired seed.
- Seed varieties/hybrids that can perform well despite pressure from diseases, weeds, insect pests, and unfavorable weather conditions, and without the aid of herbicides, pesticides, and artificial fertilizers.
- Varieties/hybrids that maintain stable yields in a a variety of environments.
- Seed with excellent varietal and physical purity with strong germination and emergence.
- An ongoing research and product development effort that results in new and better organic seed products in the future. These improvements result from traditional breeding efforts, rather than being the result of artificial genetic modifications.
- Sources of information that will help organic farmers make sound varietal choices, and in-season management decisions.

Adequate supplies of organic seeds
One of the common concerns about organic seed is whether adequate supplies exist. It is difficult to know exact amounts of seed inventory held by organic seed companies, individual farmers, and public institutions. However, based on the experience of my company, and comments made to me by organic seed providers and organic farmers, the points below seem generally true:

- Sales of organic seed for field crops has generally been increasing over the last five years.
- Even when adequate organic seed supplies do exist, conventional untreated seed is still a major competitor.
- Organic seed inventories are increasing.
- Organic seed inventories could be substantially increased if demand warranted it.
- Organic seed inventories for specific varieties may sell out, but many organic seed providers have un-sold inventories at the end of a planting season. Some of this inventory can be used the next year, a small amount is sold into the conventional market, but a significant amount is discarded.

Obstacles to adequate supplies

The single biggest obstacle to meeting the seed needs identified above is lack of adequate sales and income from those sales. Attracting more growers and better growers, purchasing equipment to clean seeds and to develop adequate infrastructure for future seed improvements, requires money. Organic seed prices need to be sufficient to create margins so that investments can be made to bring new and improved varieties to market. These margins also need to fund services for the organic customer. One such service is providing information regarding performance and yield. At present, margins on organic seed are often inadequate. Margins are held down because too often exemptions are given for conventional seed, and organic seed is either un-sold or the price is discounted in order to be competitive with lower priced conventional seed. Reasonable, but consistent, enforcement of the organic seed rule will, in the end, result in adequate funding of organic seed and its improvement.

PuraMaize, developed by Blue River, might be considered as a case history of organic seed development. PuraMaize is an innovative gene system that in effect "blocks" foreign pollen, whether the foreign pollen came from blue corn (resulting in color impurities) or from GMO field corn. Bringing PuraMaize to the commercial market was a four-year process and was made possible in large part by sales of organic seed, and a portion of the resulting income invested in development and testing. The PuraMaize concept and other innovative organic seed products can be more readily developed and commercialized if there is adequate organic seed sales and re-investment. Development and improvement of organic seed may result from work done either in private companies or in public institutions, but either way, a source of funding is needed.

Conclusion

Developing seed to meet these needs, producing the seed in sufficient quantities, and distributing the seed in a timely and efficient way are major challenges. Having personally been involved with organic seed for the past 13 years, I know there is much work to be done, but am thankful for substantial progress already made.

Seed Companies Strive to Prevent GMO Contamination

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Introduction
Seed companies are receiving many questions about contamination of seed by genetically modified organisms (GMOs), and an organic seed company receives even more than most. Those of us at High Mowing Organic Seeds have had numerous discussions over the past several years as to how best to ensure that our seed remains GMO-free while also refraining from adding an undue cost to the seed. Out of these discussions, we have instituted a combination of prevention measures with post-production testing procedures to ensure GMO-free seed at acceptable cost.

High Mowing Organic Seeds GMO Policy (excerpt)
Here is how we keep our seed clean from GMO contamination:

1. As a 100% certified organic seed company, our fields and our growers' fields are certified by a third party, accredited by the USDA. This means that they are required to develop protocols in their Organic Systems Plan to eliminate the risk from GMO contamination. So, the fact that we are 100% certified organic already means that there is an outside party obligated to ensure a level of heightened awareness about this issue.
2. All of our contracts for corn seed production clearly state that there be a minimum of two miles isolation from all corn fields, including any GMO or any corn field of unknown genetics.
3. Our stock seed that is used to plant our corn seed crops comes from non-GMO seed and is GMO tested if needed to ensure that the seed production process is starting clean from any contamination.
4. Visits to growers' fields for inspections, as well as field reports throughout the season, help make sure that any potential contamination issues are discovered before seed is harvested.
5. The risk of our corn seed physically mixing with any GMO corn seed is prevented by the use of dedicated equipment for harvest, processing, cleaning, and bagging at certified organic facilities.

These steps minimize and hopefully prevent GMO contamination, and the GMO testing process is just a final step in that process. If we have any concern, we have several GMO testing methods that we have researched, tested,and used. Any crop found to be contaminated with GMOs will *not* be sold.

Discussion

Rather than address the issue by testing after seed is already grown, High Mowing has instead focused the bulk of attention on preventing contamination. To do this we are exceedingly careful about where contract seed crops are grown. We are especially concerned about corn because the pollen travels long distances by wind, and GMO field corn is nearly ubiquitous these days. For this reason, our contract seed corn crops are only grown where there is no other corn of any type for at least a full two-mile radius, and usually farther. Said another way, we only grow seed corn in non-corn growing regions. This can make economic sense because of the value-added nature of both organic seed and hybrid sweet corn.

For the few exceptions of seed crops that we purchase and cannot be completely sure of where they were grown, we do test seed by several methods. For corn, we do not sell any field corn, but all of our flint and sweet corns receive a careful visual inspection upon arrival. As we sell only colored flint varieties, any contamination by GMO field corn or sweet corn would be immediately apparent in the seed in the form of an abnormal number of smooth, yellow kernels. Even when the visual inspection appears normal, all of our incoming flint corns are tested by a protein strip test that detects contamination to a level of 1 in 800 seeds. If we have any concern whatsoever, we would then follow up with a PCR test.

For sweet corn, any contamination by field corn is immediately apparent in the form of smooth, yellow kernels that stand out from the paler, wrinkled sweet corn kernels. Formerly it was the case that GMO sweet corn was grown in small quantities in a restricted few regions of the country, but the use of GMO sweet corn has spread rapidly over the last several years. This means we can no longer rely on the appearance of flint-type kernels to indicate contamination, as contamination by GMO sweet corn would be invisible to the eye. Also, the protein strip test method does not apply to sweet corn because the sugar in the kernels makes it impossible to grind the seed and separate off a liquid fraction. Sweet corn thus requires a routine PCR test unless we know exactly where the seed was grown with an assurance of a multi-mile isolation.

For beet and chard seed, the issue is less of problem because the varieties are biennial, and thus do not make seed unless specifically grown for seed. As the preponderance of conventional beet and chard seed production takes place in the Willamette Valley of Oregon, the danger of contamination is very low to nearly nonexistent in all other regions. Organic seed growers in or near the Willamette Valley are hyper-conscious of the issue and routinely test their seed. As other GMO crops are developed, we will develop new policies to address the issues unique to those crops.

Supporting a Community-based Seed Movement

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Over the last ten years there has been incredible interest and enthusiasm to rebuild our local food systems. Unfortunately there is a link in developing a healthy local food system that has been neglected, and that is seed. Diverse, healthy, and resilient local food systems require seed systems that mirror these values. Diversity is necessary for resilience not only in crops and genetics but also in the human component – we need universities, farmers, non-profits, gardeners, and community groups all involved in the protection and improvement of seed. An exciting community-based seed movement has been growing and has the potential to integrate seed into the localization movement, putting seed at the center of a healthy food system.

Seed Matters, an initiative of the Clif Bar Family Foundation, advocates for the improvement and protection of organic seed to ensure healthy, nutritious, productive crops. Seed Matters goals are: Conserving crop diversity; Promoting farmers' rights as seed innovators and stewards; and Reinvigorating public seed education and research (CPR). Our initial work has focused on supporting the work of our nonprofit partners such as Organic Seed Alliance and Organic Farming Research Foundation, expanding their capacity for organic seed research and education. In 2012 we launched Seed Matters Fellowships, funding PhD students in organic plant breeding – investing in a new generation of thoughtful leadership at our public institutions, and improving organic seed for the needs of organic farmers. Seed Matters recognizes that organic food systems include not only organic farmers and food companies, but the tens of thousands of people growing food in home, school, and community gardens. Many of these growers are now turning to seed, recognizing that seed self-determination and sufficiency is an essential element in their community food systems. Inspired by this emerging movement of small-scale, locally based seed projects, Seed Matters has created an exciting new project: Community Seed Startups. The goal is to encourage dozens of diverse community seed systems, promoting the sharing and exchange of seed, knowledge, and skills.

Community gardeners, educators, and food activists may be aware of the loss of crop diversity and risks to the resource of seed, but often lack the means and ways to get involved. Community Seed Startups will help spark and encourage grassroots engagement in seed. There is no singular approach to creating a seed system that works best for all communities. Instead, we want to support the diversity of models that can arise from creative thinking, information sharing, and networking. The exciting models that are popping up in communities across the US range from seed banks and seed libraries to seed gardens and plant breeding clubs.

Seed Matters is working with leaders of community seed projects to create resources and toolkits to assist in creating viable community seed systems. As these new startups take off, we'll help link these new seed efforts with existing community seed banks, libraries, swaps, dedicated seed gardens, and plant breeding clubs. New models of curating, stewarding, and co-creating seed diversity can arise in an environment rich in information and inspiration.

Finally, we are working with nonprofit leaders to refine technical information on seed saving, expanding on the rich body of work that has been developed by community seed educators around the US, and increasing access to that information. There are many questions that we must work with as we develop this vibrant collective movement:

- As we develop community seed projects, how do we ensure that the quality of seed, varietal integrity, and historical accuracy (in cultural information) are maintained? Again, does one size fit all?
- How can we, with limited resources and often a volunteer work force, best manage seed inventory and data?
- What are successful models of collaboration, communication, and decision making in what are often non-hierarchical community-based structures?

Seed Matters' Community Seed Start-ups is a grassroots approach to reclaiming seed as a public resource and empowering citizens as conservators and curators of seed. We believe every farmer and gardener can be a seed breeder and seed saver. Caring for the diversity and beauty of our seed legacy is a responsibility we all share, but one that can bring great enjoyment, connection, and benefits when we work on it together.

Olympia Seed Exchange: Working Toward a Strong Community Seed System

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To strengthen community seed systems, social infrastructure has to be in place. The concept of community can't be realized without this. One approach is to invest in cultural capital by creating social networks with a seed–focused central hub.

This is what the Olympia Seed Exchange – acting as a free seed bank – has been cultivating for five years. We are a reliable source of seeds, and we are spreading our knowledge in plant selection and seed saving to create a growing social network of urban farmers and gardeners. The network is made up of people who value, save, and exchange seeds, with the bank acting as the intermediary.

Even though many people in our community purchase seeds from regional seed companies, we are also cultivating locally adapted seeds that are successful in our challenging environment. We do this on donated land, and grow a handful of crops each year to supplement the donations we receive. For other communities around the US, if there are no small seed companies serving them, a seed bank may be the only resource for locally adapted seeds. Creating a community seed bank as opposed to, or in addition to, hosting occasional exchange events increases the number of people who have access to the seeds. We are open three days a week through spring and summer, and are busy for several months out of the year. Some people come to ask questions about a particular crop, or to access our growing library of books, magazines, and articles on a range of food, garden, and seed–based topics.

Unpopular seeds that are hard or impossible to find in catalogs can be part of a seed bank like ours, because we don't work within a capitalist (profit–making) model. We are volunteer–run, in a donated space, with free seeds— thus eliminating overhead. Some hard–to-find seeds may be old family heirlooms, or important to community members from different cultures. As Olympia becomes increasingly culturally diversified, food needs will follow suit.

We also teach people how to successfully save seed. Part of our education is teaching the value of open–pollinated, locally–adapted seeds. We discuss concentration in the seed industry, genetic contamination by GMOs, and the importance of genetic diversity. We invite other experienced seed savers within the community to demonstrate seed saving techniques, and are present at many social events promoting seed saving and community networking. The events allow people to meet each other to exchange information and ideas, thus encouraging cooperation around the community's seed needs. For instance, meeting other people who use the seed bank allows people to realize the impact of their choice to save seed. Some people decide they want to act as stewards of a seed for the whole community. This concept is especially ideal for urban dwellers, forced by lack of space to limit seed saving to one or a few crops. Being a steward of a single crop for the whole community allows an individual to specialize, while also freeing them from learning how to save seed from many different plants.

For cities, seed banks will take on an important role in the future. With increases in population and development of farmland, it is folly to imagine that all of the world's food and seed should and can come from rural farms. We will soon be forced to rely more on urban farmers and gardeners to produce seeds and food. Developing networks now will only make this transition easier.

A Public Breeder's Perspective on the Closure of the Genetic Commons

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Up until the 19th century, seeds of crop varieties were generally regarded as a public good, and were freely exchanged locally, regionally, and nationally. Early settlers in America had few indigenous varieties, especially of old world crops, which caused the early federal government to initiate seed collecting expeditions around the world. The collections were initially carried out by the US navy, but later, the nascent USDA took over these expeditions, and initiated government seed distribution programs to farmers. The resulting varieties that came into commerce were developed by farmers who saved their own seed. Seed companies were almost nonexistent, but public agricultural research was strongly supported by the federal government, which established the land grant system to promote agricultural research.

By the turn of the 20th century, many public plant breeding programs had been initiated, and public institutions, rather than farmers' fields, became the main source of new varieties. Plant breeding became more scientific with the rediscovery of Mendel's laws of genetics. An outcome of this research was the development of F1 hybrids, which were high yielding and uniform, and whose development stimulated the growth of the private seed sector. During this time period, seed companies sought less public sector competition and were successful in having governmental seed distribution programs halted. They also lobbied for legislation to strengthen private enterprise in agricultural research, which resulted in several legislative acts during the 20th century. The first was the Plant Patent Act of 1930 that provided intellectual property protection for vegetatively propagated varieties. In 1970, the Plant Variety Protection Act was implemented for seed propagated crops. Utility patents came into the picture for crops in 1985 when the US Patent and Trademark Office extended the ability to patent microorganisms (granted in 1980) to plants. Congress passed the Bayh-Dole Act in 1980, which clarified ownership for technologies developed with federal funds by public and private institutions. Ownership was explicitly transferred from the government to institutions, and this created strong incentives for institutions to seek intellectual property protection and commercialize their products.

Biotechnology applied to crop plants increased the use of utility patents as private institutions sought intellectual property protection for transgenic varieties. The biotechnology movement is also the source of novel strategies (not yet implemented), such as gene use restriction technologies (GURTs) that allow the owner of a variety to control seed viability. All of these events are milestones on the road to the commoditization of seed as we moved into the 21st century.

Plant variety protection (PVP) differs from utility patents in that PVP was specifically designed with the unique qualities of crop varieties in mind. For example, PVP has breeder and farmer exemptions. Breeders are allowed to cross the PVP protected variety and farmers are allowed to save seed of a protected variety for their own use. In contrast, utility patents do not have these exemptions, and the owner of a variety can completely control how a farmer, breeder, or processor uses that variety for a period of 20 years. To be granted a PVP certificate or a utility patent, certain criteria must be met. For PVP, a variety must be distinct from other varieties, uniform, and stable over time. A variety receiving a utility patent must be novel, useful, non-obvious to one "skilled in the art" and there must be no "prior" art (similar technologies in the published literature or public domain). For plant varieties, some of these criteria (e.g., novelty, non-obvious, no prior art) may be ambiguous, and it depends on the subjective interpretation of the patent examiner as to whether various claims are allowed based on these criteria.

What has been the impact of the increasing commoditization of seed? A major consequence has been that the number of varieties released with intellectual property constraints has skyrocketed, and the sharing of data, germplasm, and technology has been greatly restricted. Globally, developing countries have slammed the door shut on germplasm collection and exchange with developed countries. The international crop centers have restricted germplasm access and now require a standard material transfer agreement to exchange germplasm. There has been increased consolidation of seed companies, and now, a small minority of multinational corporations controls a significant amount of the production of our staple crops. We are creating a two-tiered germplasm system consisting of public domain unimproved materials and proprietary elite germplasm with major constraints on use for genetic improvement. This has led to a decrease in the overall rate of genetic improvement because each seed company has its own improved gene pool, but there is no exchange among these gene pools.

For public breeders whose work is partially supported by federal and commodity organization funds, there is a major quandary in deciding how to release varieties in a manner that is as free from intellectual property constraints as possible, yet allows breeders to be compensated monetarily for their labors. PVP can be used effectively, but does not solve all the problems facing the public breeder. Another potential venue for public releases that minimize intellectual property constraints but still compensates the breeder is use of an open source model or the granting of a general public license. Such efforts are only beginning to be explored, and have yet to be widely applied to crop varieties.

One of the worst aspects of utility patents from a genetic improvement standpoint is the lack of a breeder's exemption. In the Netherlands, Plantum (a seed company organization) has advocated for a breeders exemption to be included in the European Biotechnology Patent Directive. Similar actions have taken place in France and Germany, and while the effort is still in its infancy, it may eventually influence patent law throughout the European Union.

My additional recommendations would include: prohibition of patenting of public domain germplasm and varieties, conditional exemption of traits that are critical for national food security, limiting the scope of utility patents for varieties and traits, establishing a peer review system to assist patent examiners in prior art discovery, and raising the bar for novelty, non-obvious, and prior art criteria in utility patents.

Rebuilding Diversity and Resilience in a Concentrated Seed Sector

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The passage of the Bayh-Dole Act in 1980 allowed research and inventions funded by public dollars to be patented and licensed to private companies. Decreased funding for basic public plant breeding under USDA's National Research Initiative has resulted in the erosion of public breeding programs (Taxler et al., 2005) coupled with a lack of adequate funding and infrastructure for germplasm conservation (Jahn, 2007; Sligh and Lauffer, 2003). New intellectual property regimes based on the patenting of genes and genetic traits have fueled:

- an increasingly restricted flow of proprietary germplasm (Falcon and Fowler, 2002; Kloppenburg, 1988; Kloppenburg, 2008)
- the loss of farmers' right to save, use, barter, and sell seeds reproduced on their farms (Vía Campesina, 2008; Kloppenburg, 2008; ETC Group, 2008)
- massive consolidations in the seed industry (ETC Group, 2008; Howard, 2009).

These changes have resulted in losses of public plant breeders (Taxler et al., 2005), regionally-based small seed companies (Fernandez-Cornejo, 2004; Hendrickson and Heffernan, 2003) and commercially available varieties. "In recent years, due to a pronounced consolidation of the global seed industry, the range of variety choices has dwindled; some of the very best varieties for organic growers are no longer available" (Jahn, 2007; Colley and Dillon, 2004).

As the seed industry has consolidated into a system dominated by multinational biotechnology companies, many seed markets are underserved (Henning and Jahn, 2003). Changes in university funding have precipitated a shift away from public seed breeding efforts to an increasing focus on genomics and on developing proprietary breeds profitable to industry research partners (Colley and Dillon, 2004). One university plant breeder stated, "One of the downsides of the current system is we almost never deal with those folks looking for specialty things." Another plant breeder participant concurred, adding, "It is fair to say most seed markets in the United States are underserved. One of those really important ones [is] organics."

Organic farmers in the Northern Plains region stress that the biggest threat to the ongoing viability of organic agriculture is the lack of access to competitive genetics, resulting in a yield drag in organic farming systems (Personal communication, 2011). The variability of organic farming systems and environments coupled with the diversity of farmers' needs translates into a sizable challenge for plant breeders, a lack of interest from the formal seed sector, and a lack of adapted varieties (Murphy et al., 2005; Desclaux, 2005). Organic producers are highly dependent upon plant varieties bred for industrial agriculture (Lammerts Van Bueren et al., 2008; Colley and Dillon, 2004). The "green revolution" breeding goals of maximum yields and uniformity are not well suited to variable, stressful, or challenging environments (Wolfe et al., 2008). There is little or no selection work for traits of interest to organic farming and marketing systems, including adaptation to local climatic and soil conditions, weed competition, durable disease and pest resistance, beneficial soil microorganism root interactions, nutrient uptake, yield stability, and nutritional and quality traits (Colley & Dillon, 2004; Lammerts Van Bueren et al, 2008).

Alternatives

A new orientation in plant breeding for agroecological systems must integrate ecological adaptation and adaptation to farm management practices to provide appropriate genotypes and yield stability (Dambroth and Bassam, 1983). Current trends toward a more local, diverse, and sustainable agriculture require linkages between plant breeders and farmers "to assure that a new set of goals and methods is taken up to meet the needs of this new, developing agriculture" (Sligh and Lauffer, 2003).

Agroecosystems are co-evolving ecological and socioeconomic systems based on enhancing sustainability (Altieri, 2002). Walker and Salt (2006) state that resilience is the key to sustainability. Resilience is the ability of a system to (1) absorb disturbances or changes without crossing a threshold, (2) retain basic function and structure (Holling, 1973; Walker et al., 2002), (3) ensure opportunities for innovation and renewal (Berkes and Folke, 1998), and (4) provide needed goods and services (Walker & Salt, 2006).

Sustainability entails investing resources in the development of forms of capital that do not deplete other forms (Flora, 1998). Organic agriculture's principle of ecology reiterates this principle; organic agriculture should strive for ecological balance through the design of its farming systems, maintaining genetic and agricultural crop diversity (IFOAM, 2005). Biodiversity enhancement practices are commonly used in organic farming systems (Thrupp, 1998).

Participatory Plant Breeding

Incorporating ecological and socioeconomic systems into plant breeding systems for organic agriculture, which is inherently knowledge intensive, context specific, and place-based, requires a system of participatory plant breeding (PPB) (Pretty, 1995; Warner, 2006). PPB provides a decentralized, social learning model to generate, improve, and supply a diversity of ecologically and economically viable crops (Lammerts Van Bueren and Struik, 2004; Chiffoleau and Desclaux, 2006). Integrating a plant breeder's formal knowledge with the farmer's knowledge about their management systems, agroecosystems, and market demands will require "new communities of practice" (Kirschenmann, 2007). A holistic knowledge model acknowledges both farmers' and scientists' knowledge of plant breeding as grounded in objective observations of reality integrated with intuition, skills, empirical data, theory, and values (Soreli et al., 2002).

Inspired by Raoul Robinson's book, *Return to Resistance* (1996), members of the Northern Plains Sustainable Agriculture Society formed a Farm Breeding Club in 1999 with the purpose of fostering farmer collaboration with public breeders and research agronomists in the evaluation and development of crop varieties suitable to organic and low-input farming systems. The goals of PPB are to:

- provide plant varieties suitable to agroecological farming systems

- encourage *in situ* maintenance of diverse plant populations adapted to local environments (Berg, 1995; Ceccarelli and Grando, 2002), and enhance agrobiodiversity (Witcombe and Virk, 2001) and resilience (DiFalco and Chavas, 2006; Walker and Salt, 2006)

- empower farmers/rural communities (Desclaux et al., 2007; Weltzien et al., 2000)

Involving local people in managing the resilience of social-ecological systems supports adaptive learning, generating responsiveness and success in dealing with current and future needs (Walker and Salt, 2006). Ethnobotanist, Gary Nabhan (2009), asserts that it was this locally bred diversity that geneticist Nikolay Vavilov (1887- 1943) recognized as the main buffer against famine. Nabhan makes the case that it is the main buffer against potential global famine in our own time. PPB redefines end-users of newly developed varieties as partners in resilience selection and management. Participation is a means to an end, rather than an end in itself (Morris and Bellon, 2004). The process can be formal-led (scientists inviting farmers' participation), or farmer-led (farmers inviting scientists' participation). Nabhan (2009) states "it is the social, economic and political access to seed diversity at critical moments that can make or break a community's means of achieving food security." Now is the critical moment.

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An Overview of OSGATA, et al. v. Monsanto

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In March 2011, on behalf of 60 family farmers, seed businesses, and organic agricultural organizations, the Public Patent Foundation (PUBPAT) filed suit against Monsanto Company to challenge the chemical giant's patents on genetically modified (GM) seed. The organic plaintiffs were forced to sue preemptively to protect themselves from being accused of patent infringement should they ever become contaminated by Monsanto's GM seed, something Monsanto has done to others in the past.

The case, Organic Seed Growers & Trade Association, et al. v. Monsanto, was filed in federal district court in Manhattan and assigned to Judge Naomi Buchwald. Plaintiffs in the suit represent a broad array of family farmers, small businesses and organizations from within the organic agriculture community who are increasingly threatened by GM seed contamination despite using their best efforts to avoid it. The plaintiff organizations have over 270,000 members, including thousands of certified organic family farmers.

This case asks whether Monsanto has the right to sue organic farmers for patent infringement if Monsanto's transgenic seed should land on their property. It seems quite perverse that an organic farmer contaminated by transgenic seed could be accused of patent infringement, but Monsanto has made such accusations before and is notorious for having sued hundreds of farmers for patent infringement, so we had to act to protect the interests of our clients.

Once released into the environment, GM seed contaminates and destroys organic seed for the same crop. For example, soon after Monsanto introduced GM seed for canola, organic canola became virtually extinct as a result of contamination. Organic corn, soybeans, cotton, sugar beets, and alfalfa now face the same fate, as Monsanto has released GM seed for each of those crops, too. Monsanto is developing GM seed for many other crops, thus putting the future of all food, and indeed all agriculture, at stake.

In the case, we are asking Judge Buchwald to declare that if organic farmers are ever contaminated by Monsanto's GM seed, they need not fear also being accused of patent infringement. One reason justifying this result is that Monsanto's patents on GM seed are invalid because they don't meet the “usefulness” requirement of patent law. We cited evidence in our opening filing that proves that GM seed has negative economic and health effects, while the promised benefits of GM seed – increased production and decreased herbicide use – are false.

Some say transgenic seed can coexist with organic seed, but history tells us that's not possible, and it's actually in Monsanto's financial interest to eliminate organic seed so that they can have a total monopoly over our food supply. Monsanto is the same chemical company that previously brought us Agent Orange, DDT, PCB's and other toxins, which they said were safe, but we know are not. Now Monsanto says transgenic seed is safe, but evidence clearly shows it is not.

In June 2011, new threats by Monsanto led to the filing of an amended complaint. Twenty-three new plaintiffs were also joined with the original 60 in the amended complaint, bringing the total number represented in the case to 83. The plaintiffs in the suit now include 36 family farmer, food, agricultural research, food safety, and environmental organizations representing hundreds of thousands of members, and include several thousand certified organic, biodynamic, or otherwise non-transgenic family farmers.

Our clients don't want a fight with Monsanto, they just want to be protected from the threat that they will be contaminated by Monsanto's GM seed and then accused of patent infringement. We asked Monsanto to give our clients reassurances they wouldn't do such a thing, and in response they chose to instead reiterate the same implicit threat to organic agriculture made in the past.

Soon after the March filing of the lawsuit, Monsanto issued a statement saying they would not assert their patents against farmers who suffer "trace" amounts of transgenic contamination. In response, and in the hope the matter could be resolved out of court, our attorneys wrote Monsanto's attorneys asking the company to make its promise legally binding. Monsanto responded to our request by hiring former solicitor general, Seth P. Waxman, a partner in the Washington, D.C. office of WilmerHale, who rejected our request and instead confirmed Monsanto may indeed make claims of patent infringement against organic farmers who become contaminated by Monsanto's GM seed.

One of our plaintiffs, Don Patterson of Virginia, responded: "Monsanto's letter was an empty, indefensible, and self-evident evasion showing they are only interested in spinning propaganda without taking serious steps to resolve the problem created for organic and non-transgenic agriculture...With the Monsanto letter signed by Waxman, the company rolled out their biggest legal cannon, but they fired off only fluffy wadding and smoke...The letter shows Monsanto wanting to protect their freedom to threaten farmers with patent infringement suits...Both the threats and the lawsuits are clearly important to their marketing strategy and business model."

“The serious issues being engaged in this case require a constructive and socially-acceptable response from the defendant in the public interest,” added Maine farmer Jim Gerritsen, President of OSGATA, the lead plaintiff in the suit. “In the absence of that, we reassert the essential importance of the arguments stated in March and reinforced now by the additional evidence of the Monsanto intransigence. Monsanto's utter failure to act reasonably to address our concerns has only reaffirmed the need for our lawsuit.”

Marty Mesh, Executive Director of Florida Organic Growers, one of the newly added plaintiffs, said, “We join this suit with sadness but feel compelled to seek justice. If organic farmers, seed growers, and companies have no assurance that technology they have never asked for, never signed a licensing agreement to use, have no desire to be a part of, and in fact, go to great lengths to avoid, can still trespass on their farms and subject them to a lawsuit by the patent holder who seemingly escapes all liability for that trespass, then it is not only morally wrong, ethically unjust, but also legally perverse.”

Francis Thicke, an organic farmer from Iowa and owner of Radiance Dairy, one of the newly added plaintiffs to the suit said, "We don't think we are asking too much to want assurance that if Monsanto's transgenic genes contaminate our crops we will not be sued by Monsanto. It is bad enough that we face the threat of contamination of our organic and non-transgenic crops. The least Monsanto can do is give us assurance that they won't sue us for their own genetic trespass."

Ruth Chantry of Common Good Farm in Nebraska, another newly added plaintiff to the suit, added: "It is outrageous that our entire farm, family business and livelihood could be at risk because of Monsanto's backwards and oppressive response and enforcement towards farmers in regards to transgenic pollen drift, unasked for and unintended, and the subsequent results in their fields. Any transgenic pollen drift that would ever come onto our farm is of great detriment to us, and as such, is an invasion upon and a contamination of our crops, to the multi-species habitat we are assisting and creating here and to the integrity of how we are farming organically and biodynamically."

In addition to supplementing the complaint with Monsanto's most recent statement confirming its threat to the plaintiffs and GMO-free agriculture, the new group of 23 organizations, seed companies, farms and individual farmers include fourteen organizations: Weston A. Price Foundation, Center for Food Safety, Beyond Pesticides, Northeast Organic Farming Association of Rhode Island, Northeast Organic Farming Association of New Hampshire, Northeast Organic Farming Association of Connecticut, Northeast Organic Farming Association of New York, Western Organic Dairy Producers Alliance, Manitoba Organic Alliance, Michael Fields Agricultural Institute (Wisconsin), Midwest Organic Dairy Producers Alliance, Florida Organic Growers, Peace River

Organic Producers Association (Alberta and British Columbia) and Union Paysanne (Quebec); two seed companies: Seed We Need (Montana), and Wild Garden Seed (Oregon); and seven farms or individual farmers: Common Good Farm, LLC (Nebraska), American Buffalo Company (Nebraska), Full Moon Farm, Inc. (Vermont), Radiance Dairy (Iowa), Brian L. Wickert (Wisconsin), Bruce Drinkman (Wisconsin), and Murray Bast (Ontario).

These plaintiffs join the 60 plaintiffs from the original filing of the lawsuit in March, which included twenty-two organizations: Organic Seed Growers and Trade Association; Organic Crop Improvement Association International, Inc. (OCIA); OCIA Research and Education Inc.; The Cornucopia Institute; Demeter Association, Inc.; Navdanya International; Maine Organic Farmers and Gardeners Association; Northeast Organic Farming Association/Massachusetts Chapter, Inc.; Northeast Organic Farming Association of Vermont; Rural Vermont; Ohio Ecological Food & Farm Association; Southeast Iowa Organic Association; Northern Plains Sustainable Agriculture Society; Mendocino Organic Network (California); Northeast Organic Dairy Producers Alliance; Canadian Organic Growers; Family Farmer Seed Cooperative; Sustainable Living Systems (Montana); Global Organic Alliance; Food Democracy Now!; Family Farm Defenders Inc.; Farm-to-Consumer Legal Defense Fund; twelve seed companies: FEDCO Seeds Inc. (Maine); Adaptive Seeds, LLC (Oregon); Sow True Seed (North Carolina); Southern Exposure Seed Exchange (Virginia); Mumm's Sprouting Seeds (Saskatchewan); Baker Creek Heirloom Seed Co., LLC (Missouri); Comstock, Ferre & Co., LLC (Connecticut); Seedkeepers, LLC (California); Siskiyou Seeds (Oregon); Countryside Organics (Virginia); Cuatro Puertas (New Mexico); Interlake Forage Seeds Ltd. (Manitoba); and, twenty-six farms and farmers: Alba Ranch (Kansas); Wild Plum Farm (Montana); Gratitude Gardens (Washington); Richard Everett Farm, LLC (Nebraska); Philadelphia Community Farm, Inc. (Wisconsin); Genesis Farm (New Jersey); Chispas Farms LLC (New Mexico); Kirschenmann Family Farms Inc. (North Dakota); Midheaven Farms (Minnesota); Koskan Farms (South Dakota); California Cloverleaf Farms; North Outback Farm (North Dakota); Taylor Farms, Inc. (Utah); Jardin del Alma (New Mexico); Ron Gargasz Organic Farms (Pennsylvania); Abundant Acres (Missouri); T & D Willey Farms (California); Quinella Ranch (Saskatchewan); Nature's Way Farm Ltd. (Alberta); Levke and Peter Eggers Farm (Alberta); Frey Vineyards, Ltd. (California); Bryce Stephens (Kansas); Chuck Noble (South Dakota); LaRhea Pepper (Texas); Paul Romero (New Mexico); and, Donald Wright Patterson, Jr. (Virginia).

The National Organic Coalition's Farm Bill Platform

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National Organic Coalition Farm Bill Proposals

Organic agriculture is one of the fastest growing sectors of agriculture, creating jobs in rural America and lucrative market opportunities for American family farmers. Strong consumer demand has fueled the growth in organic agriculture, helping farmers stay in business even through one of the worst economic downturns in US history. Nationwide, the organic sector has become a $29 billion industry, creating jobs at four times the national rate and served by over 14,500 organic family farmers.

Currently, domestic demand for organic food and beverages exceeds domestic production. With a modest investment in USDA research, marketing, and farmer assistance programs to support the US organic sector, we can close the gap and expand this critical job base here at home. In order to meet projected market demand with domestic production by 2015, we will need 42,000 organic farmers in the U.S.

To foster that growth, we urge a continued and expanded federal investment in the following USDA programs:

The **Organic Agriculture Research and Extension Initiative (OREI)** is USDA's flagship competitive research and extension grants program dedicated to organic agriculture. Unique in its scope and function, OREI funds research and extension projects to help meet the production, marketing, and policy needs of the growing organic industry. The program is very competitive and each year funds only a small percentage of eligible proposals. To meet the growing sector's research and extension needs, **OREI should be funded at $30 million in mandatory funds annually, and retain its authorization for appropriation.**

The **National Organic Certification Cost-share Program (NOCCSP)** is essential in helping small and medium-size businesses become certified as organic, a critical step if we are to meet growing consumer demand for organic products and maintain diversity in scale of organic operations. The annual process of organic certification is a necessary step for ensuring that all organic operations meet stringent organic standards, in order to ensure the integrity of the USDA organic seal and meet consumer expectations. But certification costs can be prohibitive for small, mid-sized, and beginning businesses. This cost-share program enables certified organic farmers and handlers to offset the costs of certification by providing a small reimbursement of currently no more than $750 per year, capped at 75% of total certification costs. **NOCCSP should be funded at $30 million in total mandatory funding over the five-year life of the next Farm Bill.**

The **National Organic Program (NOP)** enforces the national organic standards, accredits certifiers, develops equivalency agreements, and handles complaints – in essence, NOP ensures the integrity of the organic seal. These are essential functions to the survival and growth of the organic sector. Additionally, the program requires a capital investment in innovative technologies that will position the program to be able to grow with the organic sector, providing domestic and international oversight, and transparency and streamlining of systems, data, and information. NOP should receive a one-time infusion of $5 million in mandatory funds for the technology upgrade, and then should be authorized to receive appropriations increasing at a rate of 20% annually beginning with $10 million in FY 2013.

The **Organic Production and Market Data Initiatives (ODI)** is a small but significant multi-agency initiative that ensures that USDA collects organic statistics, conducts organic price reporting, and releases organic economic reports. The Economic Research Service, the National Agricultural Statistics Service, and the Agricultural Marketing Service all collaborate on this data collection initiative. Access to segregated organic data is critical to help organic farmers and handlers make wise business decisions, and to policymakers needing to assess trends in agriculture. **ODI should receive $5 million in mandatory funding over the life of the next farm bill, and retain its authorization for appropriations.**

The 2008 Farm Bill included important provisions in **Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP)** for organic farmers in recognition of the historical lack of participation and conservation benefits of these systems. However, both programs are in need of reform to address the unique needs of organic farming systems. **Issues such as the unfamiliarity of NRCS staff with organic systems, overlapping planning requirements with the National Organic Program, and lack of adequate planning assistance should be addressed in the next Farm Bill.**

One of the basic building blocks of any successful agricultural system -- conventional or organic -- is **farmer access to seeds** that are well adapted to local soils and climates. Farmers nationwide have fewer choices of seeds to meet changing environmental stresses and consumer demands. Often, the seeds that are available are not bred to address local soil and climate conditions, placing entire regions at a competitive disadvantage. The federal government has largely stopped funding **classical breeding** efforts at state land grant institutions to develop public cultivars, and has largely shifted agricultural germplasm research toward only patented varieties that prevent farmers from saving seeds. The problem is particularly acute for organic farmers whose farming systems demand seeds that are well adapted to their local conditions. The 2008 Farm Bill addressed this growing crisis by requiring USDA to make classical plant and animal breeding a priority with the Agriculture and Food Research Initiative (AFRI), but USDA has not complied with that Congressional mandate. To require USDA to get the job done, **the next Farm Bill should require a set aside of 10% of annual AFRI funding to be used for classical breeding efforts to ensure meaningful public seed variety choices for farmers.**

USDA currently does not provide appropriate **risk management tools** for organic producers. The agency charges an unjustified surcharge to organic farmers who participate in federal crop insurance program, and for most organic crops, does not pay organic farmers at the organic price when they experience a loss. In addition, the agency does not provide appropriate tools for diversified farmers. The 2008 Farm Bill required USDA to remove the unjustified organic crop insurance surcharge and to provide organic price elections. While USDA has started the process for some organic crops, it has fallen far short of the 2008 Farm Bill mandates in that regard. **The next Farm Bill must fully remove these unnecessary and unjustified disincentives to organic farmer use of USDA risk management tools.**

Seven Steps to Fair Farming

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Prior to any deregulation of new genetically engineered (GE) crops, or discussions of "co-existence" between GE and non-GE products, the following seven points must be addressed transparently and fairly (for all stakeholders involved).

1. Establish a USDA "Public Breeds Institute" to ensure the public has access to high quality non-GMO breeds and germplasm.

2. Create a "Contamination Compensation Fund" funded by GE trait patent holders, to provide immediate assistance to those contaminated by GE material, from seed to table.

3. Completely eliminate the deregulation of GMOs, including prior deregulations, with ongoing oversight and public evaluation of compliance and enforcement.

4. Conduct comprehensive, independent, longitudinal studies on the health, environmental, and socio-economic impacts of GMOs prior to approval.

5. Prohibit the growing of promiscuous GE crops that are likely to cause contamination.

6. Prevent food security risks associated with the concentration of our food system in the hands of a few companies.

7. Institute an immediate labeling protocol for all GE crops, products, and ingredients.

See the National Organic Coalition's "Contamination Prevention Plan" for more details: http://www.nationalorganiccoalition.org/GMO/GMOContaminationPrevention.pdf

Organic Seed Use in Washington State

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Program Overview

The Washington Organic Food Products Act, chapter 15.86 RCW, was enacted in 1985 and amended in 1987 to implement one of the first state organic certification programs in the nation. The Organic Program is located within the Food Safety and Consumer Services Division of the Washington State Department of Agriculture (WSDA). The Organic Program is entirely funded by fees; no general funds or tax dollars are received to operate the program and provide organic certification services.

In 1988, WSDA began certifying 68 organic farms and a total of 2,000 acres. Processor certification services were added in 1990, and handler certification in 1992. This same year, the Organic Program received ISO Guide 65 Accreditation, opening up the program's ability to offer certification to international organic standards. The program received USDA accreditation in April 2002 and began certifying in accordance with the new National Organic Program (NOP) regulation. Two years later, WSDA's Organic Program became one of the first government bodies to receive accreditation with the criteria of the International Federation of Organic Agriculture Movements (IFOAM).

The program currently offers national and international organic certification services to producers and handlers in Washington State and neighboring areas. In 2011, WSDA certified over 100,000 acres and more than 1,100 producers and handlers of organic products. WSDA is currently the largest state-operated certification agency in the US in terms of number of operations and acreage. The program has 23 established staff positions.

In addition to organic certification, WSDA's Organic Food Program provides registration of input materials through inclusion on an approved list, the Brand Name Material List (BNML). In 2011, over 750 input materials were reviewed and approved for use in organic production. The approved list is provided as a resource to all certified parties, and is regularly updated on our website: http://agr.wa.gov/foodanimal/organic/default.htm.

Organic farms are found throughout the state of Washington and represent a diversity of crops, sizes, and marketing options. Organic tree fruit, vegetables, and forages are the dominant cropping types. Organic dairy production represents 10% of the producers certified by WSDA. Organic handling facilities are as varied as the crops produced. Included in the list of certified handlers are retail establishments, coffee roasters, wineries, frozen vegetable processing facilities, fruit packers, produce distributors, and juice processors.

Organic Seed Use in Washington State

In 2011, the Organic Program certified 752 producers in accordance with the USDA National Organic Standards. We certify a variety of organic seed producers, from those that raise seed for the commercial market to those that raise seed for their own use. All of our producers are required to submit an Organic System Plan as required by the National Organic Standards. The Organic System Plan is an agreement between a certified organic operation and their certifier, and contains a description of how the operation plans to comply with the National Organic Standards.

We randomly chose 111 Organic System Plans and reviewed them for information pertaining to their seed usage. Each producer reports the percentage of seed that they use, either organic or non-organic. They also report their plan to verify that organic seed is not commercially available prior to using non-organic seed. The information gathered from this brief survey is summarized in the table below.

Crop Category	# of operators	Average % of organic seed	Average % of non-organic seed	Comments
Mixed Vegetables	53	78%	22%	8 producers indicated they saved their own seed.
Hay	12	47.5%	52.5%	4 didn’t use seeds
Grain	11	50%	50%	
Grapes	1	0%	0%	Producer doesn’t use seed
Herbs	2	99%	1%	
Tree Fruit	10			No tree fruit producers use seed
Small Fruit	2	50%	50%	
Livestock	12	75%	25%	4 livestock producers don’t use seed
Row Crops	6	9%	91%	Specific or proprietary seeds are used, not available in an organic form

Of the 111 producers that were surveyed, 12 producers save all or some of their seed. These producers were either mixed vegetable producers or grain producers. Three producers specifically noted they consider the integrity of the seed company when sourcing organic seeds. Finally, 14 producers indicated that they require a specific variety due to season length, disease resistance, or processor specifications.

In order to assist our producers with using certified organic seed, we have developed a fact sheet pertaining to seed use. We also distribute a form that can be used to document commercial availability. Both forms are online at http://agr.wa.gov/foodanimal/organic.

Seed People: A Photographic Journey into the Organic Seed Movement

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Photography can play a significant role in furthering the goals of social movements, whether it be opposition to war, eliminating child labor, or as in this ongoing project, promoting seed saving and the widespread use of organic seeds.

While photographs are excellent vehicles for illustrating techniques and sharing information, photography can also play an important role in putting a human face on a movement, galvanizing its base, and recruiting new members and activists.

For the last eighteen years, supported by seed companies and non-profit organizations, Scott Vlaun has had the opportunity to interview and photograph many of the seminal figures in the organic seed movement. The pictures and stories reflect a diversity of approaches to seed saving, plant breeding, on-farm crop improvement, and organic seed production.