**Project Title**: Participatory Plant Breeding to Improve Sweet Corn for Organic Farmers

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**Project Summary**
This project is a collaboration among farmers, university researchers, and experts at non-profit organizations to develop high quality sweet corn germplasm for organic agricultural systems. 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. The participatory plant breeding model enables researchers and farmers to work together to develop varieties that exhibit the specific traits identified and selected for by the growers.

We worked with three experienced organic sweet corn farmers to grow two sweet corn breeding populations in their fields. Selections of rows within each population were made based on the ratings the farmers gave for the traits they valued most. Seed saved from the same ears that planted those selected rows were planted in a winter nursery and inter-mated to form the next cycle of selection. This novel methodology allows the farmers to have complete control over the selection process, while removing the logistical challenges of pollinating and seed saving. It also speeds up the process by allowing a breeding cycle to be completed in one year.

Seed derived from the selected and inter-mated families in 2009 will be planted again in 2010 for another year of selection and breeding. This cycle will continue with the ultimate goal of creating three populations of improved sweet corn that meet the needs of each participating farmer. By improving sweet corn for organic systems, we intend to give growers in the upper Midwest more tools to succeed in their farm enterprises

**Problem Addressed**
In the upper Midwest, fresh market sweet corn is an important part of many diversified organic vegetable operations. Many organic farmers consider sweet corn crucial for attracting customers to their stands or to their CSAs. However, organic sweet corn

growers face many serious challenges, including cold, wet soils that harbor seed-killing pathogens, weed competition, insect damage and diseases. Organic farmers need varieties with superior cold germination, early vigor to out-compete weeds, husk protection against insects, disease resistance, and, of course, high eating quality. The purpose of this project is to develop sweet corn germplasm that answers these needs.

**Project Objectives**

*Objective 1: Development of improved sweet corn germplasm for organic farmers in the upper Midwest*

Our objective is to obtain an open-pollinated sweet corn with early vigor, high percent germination under cool soil conditions, good eating quality, disease resistance, ear worm resistance, and productivity. Although breeding involves an element of chance, and success is never assured, we expect to see continued improvement in our breeding populations from one year to the next. Within four years, we aim to see an open-pollinated population that is comparable to the commercially available open-pollinated varieties in our farmer's fields. Eventually, our goal is to produce open-pollinated varieties that will outperform the best commercial hybrids when grown in organic conditions in the upper Midwest.

*Objective 2: Evaluation of a novel methodology for participatory plant breeding*

Participatory plant breeding requires a high degree of farmer involvement, direction and control in the breeding process. When breeding out-crossing species such as corn, substantial effort must be taken in the middle of the growing season to ensure that only desirable pollinations occur. In this project, we are evaluating the use of off-site, winter nurseries to make controlled crosses based on the evaluations made during the on-farm summer trials. We expect to find that this methodology allows farmers complete control over the selection of germplasm throughout the process, while eliminating the labor and management-intensive work of pollinating during summer. Through on-going interviews with our farmer collaborators, we are able to determine the strengths and weaknesses of this system. By creating a way to easily breed out-crossing crops on working organic farms, we hope to expand the breeding efforts for organics, giving us more and better crop varieties for organic farmers.

*Objective 3: Improved farmer skills and involvement in on-farm breeding*

The three producers engaging in on-farm breeding are gaining the skills and confidence to initiate and manage on-farm breeding projects. They are sharing this knowledge with other growers through annual organic breeding workshops. This project demonstrates to farmers the possibilities of breeding at the farm level. We also anticipate that farmers who become knowledgeable about plant breeding will more actively support public policy aimed at improving germplasm for organic systems. This impact is being assessed through interviews and workshop participant evaluation questionnaires.

*Objective 4: Graduate student training in participatory plant breeding for organic systems*

Graduate students, working at the University of Wisconsin with Dr. Tracy, are coordinating this project. They are actively involved in planning the breeding methodology, collaborating with growers, and communicating the results. Limited opportunities exist for plant breeding students to engage in breeding for organics. This project helps train the geneticists of tomorrow to fill the ranks of the organic seed houses. The future success of organic agriculture depends on such breeders, who will work to develop new varieties for organic and low-external-input systems.

**Methodology**

*Farmer initiated:* This project began as a result of conversations with Martin Diffley, of Organic Farming Works (OFW) at Gardens of Eagan in Farmington, MN. Mr. Diffley is an experienced and successful organic sweet corn grower who needed a sweet corn that could successfully germinate and grow in his earliest time slot. Mr. Diffley identified several critical traits including vigor in cold conditions, smut and rust resistance, large ears with great flavor, and ease of harvest. After one year of selection at OFW, David Perkins, from Vermont Valley Farm (VVF) in Blue Mounds, WI and George Kohn from West Star Farm (WSF) in Cottage Grove, WI joined the project as farmer-collaborators.

*Germplasm creation:* Two breeding populations for this project were created by Dr. Bill Tracy at the University of Wisconsin. Dr. Tracy bred the populations from vigorous, cold tolerant, sugary-enhancer (SE) germplasm with desirable flavor and other quality traits. Prior to the start of funding for this project, the populations used at all three farms was selected at OFW for one year, and recombined into full-sib families, as described below.

*Selection:* A recurrent selection program has begun for the two breeding populations. At VVF, OFW and WSF, the trials were planted on dates that coincide with each farmer's planting date for their earliest sweet corn. Approximately 100 single row plots, 11.5 feet long by 2.5 feet wide, were planted per population. Each plot was planted with 35 kernels from the same ear, representing a full-sib family. A border of commercial sweet corn was planted around the trial field, to protect it and to provide a reference when evaluating the population. The variety was the farmer's favorite for the early planting time slot.

*Evaluation:* Percent germination and early vigor were visually rated by the farmers around the time that the fourth leaf was fully emerged (V4 – three to four weeks after planting). Each plot was rated as a whole on a 1 to 5 scale, 5 being best. After rating, the plants were thinned to the density that was standard for the farm.

At harvest, farmers evaluated quality traits such as ear size and shape, husk protection, tip fill, tenderness and flavor. The farmer-cooperators also took ratings for rust, smut, and any other diseases that were present to an economically damaging degree. These ratings were taken between anthesis and harvest and were also recorded on a 1 to 5 scale; 5 being best.

*Selection:* Following harvest, the best 12-13 families in each population were chosen based on a selection index, i.e. an average of the individual ratings, weighted for each trait by its importance. The weight for each trait was determined by the farmer.

*Recombination:* Each sweet corn family had remnant seed maintained at UW-Madison. Remnant seed, from the 12-13 selected families, was packaged and sent to a winter nursery in Chile. Within each population, individual plants were inter-mated via the bulk entry method without parents, creating at least 100 new full sib families per population. When the ears arrive at Madison from winter nursery, they will be shelled, with part of the seed from each ear packaged for planting and the remaining seed kept in cold storage. The packaged seed will be planted on the respective farms in 2010, and the selection cycles will continue.

**Results**
Conclusive results have not yet been obtained, as this project has four more years before completion. In 2009, the unseasonably cool spring led to crop failures at Vermont Valley Farm and West Star Farm. Data was collected on the ear rows that did emerge, but the overall stand was poor and thus plowed under before reaching maturity. Early vigor ratings did correlate, however, with those taken at OFW, where evaluations and selections were made.

Few comparisons can be drawn between the selections made in 2008 and 2009 at OFW in Farmington, Minnesota. In both years, a similar number of ears were selected to be recombined for the next cycle. In 2008, 12 ears from the early population and 11 ears from the late population were selected. In 2009, 13 ears from the early population and 12 ears from the late population were selected.

The mean ratings for the selected families were higher than the population mean ratings for almost all traits evaluated in 2008 and 2009 (Tables 1 and 2). All rows were not evaluated for all traits. If a row had a very low rating for a trait that the farmer deemed crucial, the evaluation of that row ceased and it was not considered in the final selection. In 2008, resistance to common corn smut was rated. In 2009, any row exhibiting smut was immediately rejected and no further ratings were made. Ear size was rated in 2008, but not in 2009, and tip fill was rated in 2009, but not in 2008.

Comparisons cannot be made between the mean ratings for the selected families in 2008 and 2009 (Table 3). The rating scale is relative to the population and the year. More cycles of selection must occur before determining if improvement has been made in the quality of the populations.

**Conclusion**

The funding provided by the Organic Farming Research Foundation played a crucial role in initiating this participatory breeding project to improve sweet corn for organic farmers. As a result of this seed money, further funding has been secured from USDA-ARS to continue this project. Although quantitative results cannot yet be obtained, we are encouraged by the progress made in these first two years. We are now working with researchers at Cornell University, Oregon State University and Washington State University to make improvements in four other vegetable crops, in addition to sweet corn. This new project, called the Northern Organic Vegetable Collaborative (NOVIC), will continue for four years.

With this continued funding, quantitative comparisons can be made between each year of sweet corn selections. After four cycles of breeding, remnant seed from each cycle will be grown out together in one season, and data collected on the changes that occurred in each population. The results will determine the extent to which improvements have been made in the specific traits selected for by the farmers. In addition, each farmer will have access to the sweet corn seed that he has helped to breed for use in his farming operation.

**Outreach**

*Workshops and Presentations*

In August 2009, the Organic Seed Alliance and the University of Wisconsin collaborated with farmers Martin and Atina Diffley to host an on-farm breeding field day at OFW in Farmington, MN. Approximately 20 participants learned about the sweet corn breeding project, in addition to receiving general instruction on how to engage in on-farm breeding projects.

John Navazio, senior plant breeder for the Organic Seed Alliance, presented the work from this project as part of participatory plant breeding seminars given at:

1. University of Minnesota Plant Breeding Symposium, March 2009
2. IFOAM Conference on Organic Animal and Plant Breeding, August 2009

*Printed Materials*

In February 2010, Dr. Tracy's graduate student will be presenting a poster of the sweet corn participatory breeding project at the Midwest Organic and Sustainable Education Service (MOSES) annual organic farming conference in La Crosse, WI.

We are in the process of posting information about this project on the eOrganic online forum - http://eorganic.info/

**Addenda**

Table 1

***2008 OFRF-funded Sweet Corn Evaluations at Organic Farming Works: Farmington, MN***

Based on rating scale of 1-5: 1=worst and 5=best

| Population | Mean Rating | Early | Flavor | Texture | Rust | Smut | Husk | Ear | Ear |
|---|---|---|---|---|---|---|---|---|---|
| Early | Population | [illegible] N=136* | [illegible] N=67 | 3.4 N=57 | [illegible] N=82 | [illegible] N=77 | [illegible] N=55 | [illegible] N=37 | 3.2 N=36 |
| Early | Selected families | **3.0** n=12 | **3.8** n=12 | **3.9** n=12 | **4.2** n=12 | **4.3** n=12 | **3.9** n=10 | **3.9** n=11 | **3.7** n=10 |
| Late | Population | **3.3** N=92** | **2.6** N=65 | **2.7** N=51 | **3.3** N=64 | **3.4** N=62 | **4.1** N=45 | **3.6** N=31 | **3.2** N=24 |
| Late | Selected families | **3.4** n=11 | **3.8** n=11 | **3.5** n=11 | **4.1** n=11 | **3.8** n=11 | **4.3** n=10 | **3.9** n=10 | **3.3** n=8 |

* 136 total rows, not all rows were rated for all traits

** 92 total rows, not all rows were rated for all traits

Table 2

***2009 OFRF-funded Sweet Corn Evaluations at Organic Farming Works: Farmington, MN***

Based on rating scale of 1-5: 1=worst and 5=best

* 95 total rows, not all rows were rated for all traits

** 92 total rows, not all rows were rated for all traits

| Population | Mean rating | Early Vigor | Flavor | Texture | Rust Resistance | Husk Protection | Tip Fill | Ear Shape |
|---|---|---|---|---|---|---|---|---|
| Early | Population | **2.1** N=95* | **2.9** N=36 | **3.1** N=29 | **3.5** N=45 | **3.2** N=42 | **2.5** N=31 | **2.5** N=31 |
| Early | Selected families | **3.0** n=13 | **4.4** n=13 | **3.8** n=13 | **4.0** n=13 | **3.5** n=13 | **2.9** n=12 | **3.0** n=13 |
| Late | Population | **1.4** N=92** | **2.1** N=31 | **2.5** N=26 | **3.8** N=32 | **4.5** N=31 | **3.0** N=29 | **3.4** N=28 |
| Late | Selected families | **1.5** n=12 | **2.6** n=12 | **2.3** n=12 | **4.0** n=12 | **3.7** n=12 | **3.4** n=12 | **3.7** n=12 |

Table 3

***Mean Ratings for Selected Families in 2008 and 2009 at Organic Farming Works: Farmington, MN***

Based on rating scale of 1-5: 1=worst and 5=best. Ratings are relative for each population and year, and not directly comparable.

* This trait was not rated

| Population | Year | # Rows Selected | Early Vigor | Flavor | Texture | Rust Resistance | Husk Protection | Ear Shape | Tip Fill | Smut Resistance | Ear Size |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Early | 2008 | 12 | 3.0 | 3.8 | 3.9 | 4.2 | 3.9 | 3.7 | * | 4.3 | 3.9 |
| Early | 2009 | 13 | 3.0 | 4.4 | 3.8 | 4.0 | 3.5 | 3.0 | 2.9 | ** | * |
| Late | 2008 | 11 | 3.4 | 3.8 | 3.5 | 4.1 | 4.3 | 3.3 | * | 3.8 | 3.3 |
| Late | 2009 | 12 | 1.5 | 2.6 | 2.3 | 4.0 | 3.7 | 3.7 | 3.4 | ** | * |

** In 2009, all rows with smut were immediately rejected

**Photos taken at Organic Farming Works: Farmington, MN**

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*n evaluations: 2009*