Final Report

"Participatory development of an open pollinated early maturating sweet corn for organic production"

Statement of the Problem

The overall goal of this project was to make significant agronomic improvements to an open-pollinated sweet corn population in order to make it available to organic producers. The research started with a population created through participatory plant breeding. From this population, goals for improvement were identified and included: 1) Improved root structure; 2) Reduced lodging; 3) Maintained flavor, texture, and tenderness characteristics. Using diverse, high quality inbred lines, top-cross populations created. These top-crosses were be evaluated in participatory trials and at the University of Wisconsin Agricultural Research Station in Madison and Arlington, Wisconsin on organic land and on an organic farm in Farmington, Minnesota. The goal of the research is the release of an open pollinated sweet corn variety to fill the requirements of producers early in the market season which is aligned with objective three of the Ceres Trust Organic Research Initiative: help make existing organic farms more productive and profitable.

Significance of Project to Organic Agriculture

In the upper Midwest, sweet corn is important for many organic vegetable crop operations. It is in demand by customers of market stands and Community Supported Agriculture enterprises; it is an essential crop. As the demand for organically produced vegetables grows, sweet corn varieties that perform well under organic conditions are becoming increasingly important. Common challenges for sweet corn production include cold, wet soils during the spring, seed killing pathogens, weed competition, and insect and disease damage. Based on these challenges, breeding targets for sweet corn include enhanced germination, early vigor, good husk quality to protect against insects, and, of course, good eating quality. This project will address these and other challenges within the context of organic, participatory plant breeding (PPB.) Over the past several years, an open pollinated population has been under development at the University of Wisconsin in conjunction with Martin Diffley of Organic Farming Works. Through participatory plant breeding in which the farmer identifies specific traits for the breeding program to meet his or her needs, this population has already achieved some of the above goals. Early vigor, husk quality and eating quality are all within acceptable ranges. However, some of the agronomic traits of this population are lacking. Root structure and stalk strength have been particularly problematic, resulting in a population exhibiting an unacceptable degree of lodging. Through this research we intend to:

Objective 1: *Fill a market niche for early germinating and early maturing sweet corn*

Currently, the early sweet corn seed market is dominated by conventionally bred varieties. However, if we improve the agronomic traits of a variety bred for and by organic producers, it could outperform conventional varieties in organic systems. This could provide increased yield, increased revenue for organic farmers, and increased vitality in the participatory plant breeding arena and organic seed industry.

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

Often, participatory plant breeding uses evolutionary breeding or recurrent selection. Upon review of the literature, no evidence of using a top-cross scheme for creating varieties for release by participatory plant breeding collaborations has been found. As the interest in participatory breeding increases, it is important to evaluate the effectiveness of new methods in this context.

Objective 3: *Improve farmers' skills in evaluating progeny from new mating designs*

Using top-crosses to estimate average combining ability and increase performance in the crosses will allow us to engage with farmers in on-farm trials. Increasing their understanding and knowledge about the mating design will demonstrate to them the possibility of improving other varieties in similar ways while allowing the researchers to gain insight from farmers' extensive knowledge of variety performance.

Materials and Methods

Seed produced at the West Madison Agricultural Research station in Madison, Wisconsin was planted for trialing on the three farms in the summer of 2014. Germination and early vigor were visually rated by the farmer, Martin Diffley at Organic Farming Works and by the graduate student, Tessa Peters, at the two UW Agricultural Research Stations 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 be thinned to the density that is standard for the farm, 18,000 plants/acre.

At harvest, the farmers, Mr. Diffley and Mr. Scott Johnson along with Ms. Peters helped evaluate quality traits like ear size, husk and kernel color, ear shape, tip fill, tenderness and flavor, as well as the degree of husk protection. Five plants were rated for each trait. For the traits ear height and plant height, ten plants per plot were measured. All traits were rated 1 to 9. High ratings on the agronomic traits were weighted with greater importance than other qualities. An index was developed to weight agronomic and quality traits and an analysis of variance was conducted using the statistical software, R.

The index weighted traits as follows:

$$I = \text{lodging} + 0.5\,(\text{ear length}) + 0.2\,(\text{row count}) + 0.5\,(\text{husk appearance}) + 0.9\,(\text{husk protection}) + 0.2\,(\text{shape}) + 0.8\,(\text{tip fill}) + 0.6\,(\text{plant height}) + 0.8\,(\text{ear height}) \qquad \text{Eq. 1}$$

The lme4 package in R was used to develop a mixed model in which genotype, location, and genotype by location interactions were modeled as fixed effects and reps nested in locations were treated as random effects and the response variable was the weighted index accounting for quality and agronomic traits. Similar models were also developed for flavor and texture, the most important quality traits. Fisher's Least Significant Differences were calculated for the three models. Top-crosses with the highest overall predicted means in all three categories will be considered for seed increase and market release.

Results and Discussion

Objective 1: *Fill a market niche for early germinating and early maturing sweet corn*

Promising results from the first year of trialing top-cross populations against both the original OP and two commercially available hybrids lead us to believe that two candidates for possible release exist based on their predicted means values for 3 linear models (Figure 1). Entries 3 and 8 ranked in the top 5 for the agronomic and quality index, flavor, and texture. A second year of data will be collected and analyzed before the OP varieties will be offered to commercial seed companies to gauge interest in each variety. Table 1 shows predicted means and Least Significant Differences (LSD) (Tukey Correction) for the thirteen entries. Each of the entries in LSD group c also appears in the top 5 ranking of Figure 1. These are the primary entries which might be evaluated for potential release.

Table 1. Predicted Means and LSD for ten top cross populations. Least significant differences $p < 0.05$ level.

Identity	Index	_	Flavor	_	Texture	_

Check 1	181.1359	c	6.5333	a	7.0667	b
Check 2	168.6392	bce	6.2667	a	6.4222	ab
Entry 1	146.62	ad	5.4167	a	4.1	ab
Entry 2	158.0696	abde	3.9556	a	4.6889	ab
Entry 3	164.7763	bce	6.1333	a	6	ab
Entry 4	162.3841	bde	6.0444	a	5.1	ab
Entry 5	157.1656	ade	4.6667	a	4.75	ab
Entry 6	155.4881	ade	4.0056	a	3.7778	a
Entry 7	157.8326	abde	6.0444	a	4.9556	ab
Entry 8	174.0971	bc	6.1889	a	6.2889	ab
Entry 9	164.9593	be	5.7778	a	4.9778	ab
Entry 10	147.7394	ad	5.0889	a	5.8444	ab
Population	143.3015	a	4.9778	a	5.9333	ab
LSD(0.05)	8.90071		1.68109		1.62731	

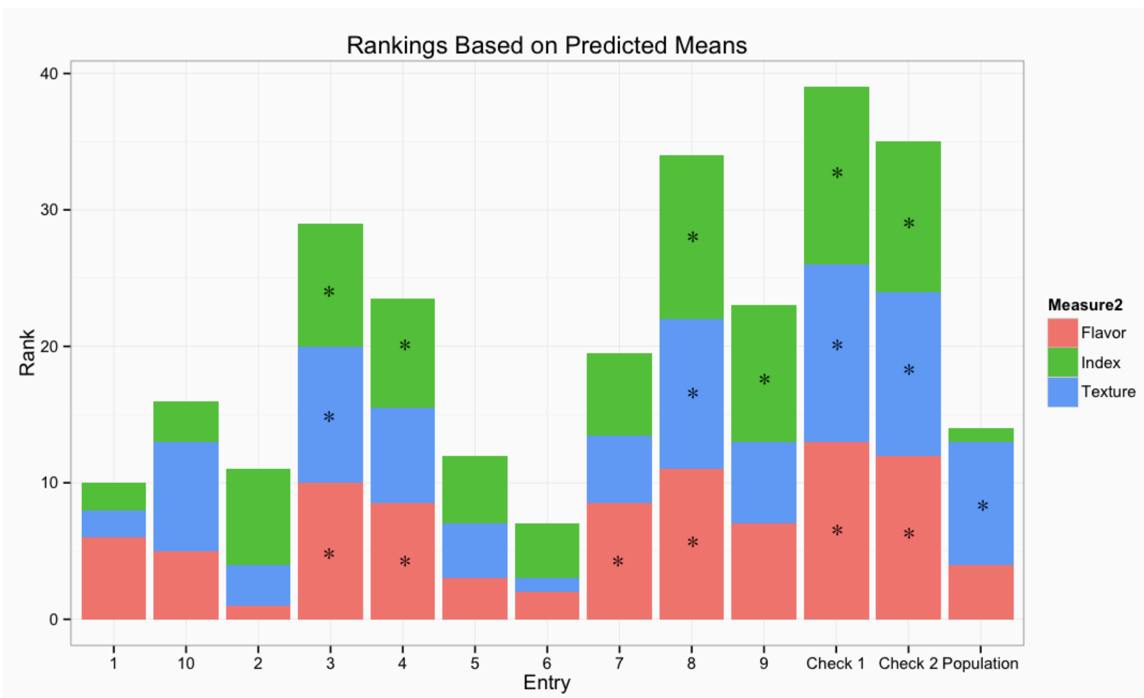

Figure 1. Rankings based on predicted means from each of three linear models. High ranking entries are desirable. Checks 1 and 2 are commercially available varieties. Population represents the original OP used as the female in each of 10 topcross entries. Entries 3, 4, 8, and 9 show promise for further development with 3 and 8 showing promise in all categories. Asterisks identify the top 5 entries in each category.

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

Using the top cross for PPB introduced some new issues in the collaboration. Firstly, the spread of maturity in the OP's increased with the addition of new genetics. This made it difficult to arrange a harvest date during which each plot would be in the correct maturity range. However, we were able to find a day that worked. The logistics of trialing these top crosses was not much different than trialing cycles of selection from recurrent selection programs, with which Mr. Diffley was familiar. The new element was the production of seed in a new way. This happened before Mr. Diffley was involved, but his expertise in evaluation was invaluable.

Objective 3: *Improve farmers' skills in evaluating progeny from new mating design*

Despite the wording of the objective, the true objective became clear early in the evaluation process: improving the researcher's skill in evaluating progeny from a new mating design. Mr. Diffley was extremely skilled at differentiating flavor and texture among entries (Figure 2). The variance that Mr. Diffley was able to distinguish when making ratings on our scale of 1-10 provided clear information about which of the entries was promising for future variety development. His discerning eye for agronomic traits made his input invaluable during the evaluation process.

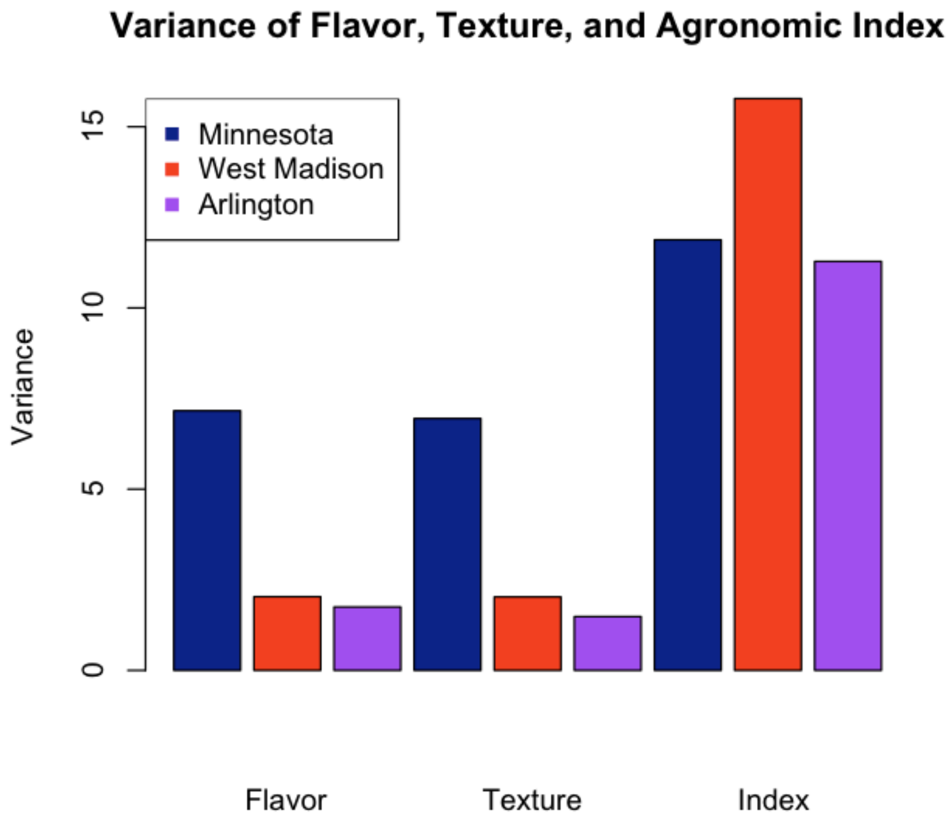

Figure 2. Variance in flavor, texture and agronomic index ratings for different locations. The higher variance is desirable since it more clearly distinguishes the high quality and low quality entries.

Agronomic traits did not experience the same variance at the Minnesota location where Mr. Diffley was involved in taking ratings. This is due to the fair weather and lack of lodging conditions that this location experienced in the 2014 summer. The Arlington location experienced a similar lack of unfavorable conditions. However, West Madison's organic sweet corn plot was on top of a hill and the variance here was much larger than that of the other two locations (Figure 2). In general, Mr. Diffley's experience evaluating sweet corn varieties for his own farm, meant that he was able to provide much information about what kinds of traits to evaluate and what specific things to look for during the evaluation process.

In conclusion, two entries were identified for possible further evaluation and possible release in the future. An additional year's data is necessary to fully rely on this data.

Scholarly and Educational Products to be Produced

The results of this study will be presented at the Organic Research Symposium preceding the MOSES Organic Farming Conference in a poster form. Publication will be sought after a second year's data is collected and continued opportunities to present the information will be sought at meetings such as Organicology 2015.

Budget and Financial Report

As intended, the funding was used just as we had planned in our proposed budget.

Budget for Organic Farming Works Trial (Martin Diffley) *Martin Diffley (Farmer for Organic Farming Works – a non UW employee) will complete the following tasks for $50 / an hour*	
Prepare and manage trials in field – rent equipment, prepare field, fertilize, hand weed and mechanically weed, harvest: 24 hours x $50 / hour:	$1200.00
Provide fencing and irrigation for trials	$1000.00
Data collection – At germination, in early season for vigor, at harvest for quality: 8 hours x $50 / hour:	$400.00
300 plots needed x 14.5 feet long x 2.5 feet wide = 0.24 acres. An experienced organic produce grower could be expected to make as much as $10,000 per acre off of productive land.	
.24 acres x $10000 / acre:	$2,400.00

Organic Farming Works Subtotal:	**$5,000.00**
Budget for University of Wisconsin (Bill Tracy and Tessa Peters)	
Pay rate of $20 / hour is standard for a student graduate hourly worker and $10 / hour is standard for a student undergraduate hourly worker	
Planning trials - Phone meeting to establish trial layout/design, planting schedule, data collection: 18 hours x $10 / hour	$180.00
Seed management – shelling seed, packeting seed, arranging seed in planting order: 46 hours x $20 / hour	$920.00
Planning and presenting poster at conference: 20 hours x $20 / hour	$400.00
Managing nursery and trials: field preparation, fertilization, mechanical weeding, and hand weeding: 30 hours x $20 / hour for graduate and 30h hours x $10 / hour for undergraduate worker	$900.00
Data synthesis: work with farmers to create selection index from traits and rank families: 40 hours x $20 / hour	$800.00
Preparation of material for peer-reviewed journal: 40 hours x $20 / hour	$800.00
Travel: twice per season to each farm: 276 miles x $0.465 per mile: Fringe rate for hourly: 3.5%	$256.68 $8.98
Supplies and expendables: Pollination supplies including pollination bags, staples, knives, belts Harvest supplies including coin envelopes, labels, paper clips, storage bags and boxes	$1000.00
University of Wisconsin Subtotal:	**$5,265.66**

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