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This is a final project report submitted to the Organic Farming Research Foundation.

General topic: Breeding and genetics for organic vegetable systems.

Project Title:

Establishing breeding populations for organic broccoli, sweet corn, and red kale varieties

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Project Summary

Organic Seed Alliance (OSA) worked with four organic farmers and three professional plant breeders in a participatory plant breeding (PPB) model to refine and develop organic breeding populations in three crops. The initial project proposal included three farms; additionally, during the project period a fourth farm and breeding project was initiated at Gardens of Eagan in Minnesota which grew out of the momentum and partnerships of the three initial projects. Each of the farms has diverse fresh market vegetable production and lacks the germplasm in the respective crops for which they have initiated breeding projects. All four projects progressed and all farmers and researchers are committed to continuing the breeding process. The three crops include an open-pollinated, early maturing broccoli; a sugary enhanced (SE) sweet corn with spring vigor and emergence (2 locations); and an open-pollinated (OP) curly red kale with desirable overwintering traits including improved downy mildew resistance and good growth under cool winter and spring conditions. Each population was grown on an organic farm and selected using recurrent selection techniques for general adaptation to organic growing conditions as well as specific farmer-identified desirable traits.

Over the past several years an increasing number of growers have approached OSA for assistance with their on-farm breeding work. In 2007 OSA established an organic plant breeding committee which includes several university-based and private plant breeders to advise on ongoing PPB projects. Funding from OFRF to progress with these projects has provided the foundation for OSA to pursue longer-term funding, has reinforced the growers' and plant breeders' commitment to continue this work, and has inspired a growing interest in PPB for organic systems among farmers, researchers, and the organic foods community. Outreach activities included web-based information on the OSA and eOrganic websites, three field days, the creation of an information flier on breeding for organic systems which highlights the three OFRF funded breeding projects, and presentations by several of the project farmers and breeders at the Organic Seed Growers Conference.

Introduction to Topic

Fundamental to the success of organic agriculture is the use of plant varieties that are most suitable to organic production challenges. If any aspect of the variety is not suited to the on-farm conditions then inputs must be added to mitigate crop stress. Organic farmers have a limited number of certified inputs to combat production problems and so rely on prevention via crop rotation, soil management strategies, and the use of appropriate crop genetics. Developing germplasm appropriate to organic farms is a missing link in the evolution of organic farming systems. This project directly addresses the development of on-farm breeding practices appropriate to farmer-led projects and to organic systems.

In recent years producer interest in on-farm plant breeding activities has risen in response to lack of availability of germplasm adapted to low input production systems, a growing awareness of the value of regionally and organically adapted varieties, and consolidations in the seed industry with the subsequent decline in varietal offerings. Participatory, on-farm plant breeding for organics offers the significant benefit of developing varieties under the conditions of intended use and drawing upon farmers' intimate knowledge of their agroecological systems. Development and refinement of a breeding population is an essential step in conducting a successful on-farm breeding program and in building partnerships between the farmer-breeders and formal-breeders.

Participatory plant breeding (PPB) is a method that has been gaining favor for breeding crops found in marginal agricultural environments of developing countries. The PPB model is also a promising approach to breeding crops for small- to medium-size organic farms in the U.S. which are similarly often characterized by diverse, heterogeneous environments with low external inputs and crop needs overlooked by modern breeding programs. Much of the development of PPB over the past thirty years has involved breeding non-commercial, subsistence crops of small grains and pulses in areas “that have been bypassed by the benefits of formal breeding efforts” (Ceccarelli 1996). It is a collaborative breeding effort that enlists the support, expertise, and judgment of the farmer. In fully realized PPB projects the farmers are true participants in the research process. Their role as a full partner can involve all aspects of the breeding process, from setting the objectives, determining the traits for selection, execution of selection, determining the final genotype to advance at the conclusion of the project, and finally replicating and genetically maintaining the variety for distribution. The PPB efforts in this project included a spectrum of farm-led and breeder-led relationships.

Objectives Statement

The primary project objective was to refine three populations through mass selection, single plant selections, and progeny selection to create sub-populations for subsequent breeding activities. The goal of supporting these first formative years of breeding efforts was to refine the breeding methods, ensure sustained commitment to the projects, and seek additional long-term funding for this work. Additional objectives met during the project period include inspiring new PPB projects and educating on PPB methodologies.

Materials and Methods

Each of the three initial breeding projects started with identified breeding populations which contained the desired traits and were developed over several generations through crossing and mass selection activities on organic farms. The breeding population for the fourth project was developed by Bill Tracy, University of Wisconsin, from materials with the desired focus trait, cold soil emergence. Each population began as a very broad population containing a diversity of genetic materials including desirable and undesirable individuals in the population.

OSA staff and the formal breeders worked with the producers to develop a four-year breeding plan. These materials will continue to be developed by the project partners and eventually released as truly "farmer-bred for organics" varieties. Details on methods of each project are described below.

OP Red Curly Kale, Nash's Organic Produce, Sequim, WA

Introduction

Nash Huber's red kale population was originally developed with several primary goals. Huber needed a vigorous, tall, good yielding red kale with a high degree of curl for bunching at a mature stage. This kale had to have good market appeal with superior color, texture and flavor. The only commercially available European type kale (*Brassica oleracea*) with significant red color, 'Redbor,' has a very tough texture and lacks the flavor profile that is associated with kale produced under favorable conditions. Huber enlisted the help of John Navazio of the Organic Seed Alliance (OSA) to advise on breeding strategies and methodologies for this project.

Materials and Methods

Starting with two individual red plants discovered in a population of 'Vates Blue Curled Dutch' kale in the early 1990s, Nash Huber crossed them to two exceptionally tall, vigorous Brussels sprouts (*B. oleracea*) plants creating a segregating population of tall "kale-like" plants. After at least eight generations of mass selection, Nash's red kale population consisted of plants that were highly attractive with a high degree of leaf curl, reasonably good levels of red color, tender texture, and flavorful. Furthermore the plants had good height, produced good regrowth during cool, low light conditions of winter, and exhibited a higher degree of Powdery Mildew resistance than the standard market varieties 'Redbor' or its green compliment 'Winterbor.' The population, however, was still segregating for most of these traits with plants that were too short, not adequately curled, and having less than adequate height still appearing. Most importantly there were still about 10% green plants and a number of the red plants did not have the degree of red pigmentation that was desired in the marketplace.

In the spring of 2006, with assistance from Navazio and OSA, Huber selected the best 50 plants with a mixture of desirable traits out of approximately 500 overwintering plants. These plants were dug and transplanted in an isolated field for flowering and seed production. These plants were allowed to openly-pollinate, thereby randomly intermating. At seed maturity the seed was harvested in the late summer of 2006 from plants individually, as a single plant harvest into individual bags. This seed was subsequently planted within weeks in half-sib family rows, 50 rows X 2 replicates (one row in each of 2 reps per family) = ~100 rows total. Each row had at least 60 to 80 half-sib plants, which we considered enough individuals to make an accurate breeding assessment of shared characteristics. These rows of kale overwintered in the field. In the spring of 2007 these progeny rows were evaluated for growth rate, uniformity of color, uniformity of curl, height, upright stature, and flavor. Rows that contained any all-green plants were eliminated. Remaining all-red rows were evaluated for all other traits. Rows with poor to medium performance on any of these traits for a majority of plants in the row were also eliminated. All remaining rows were then rogued for the minority of poor performing plants within these remaining, selected rows. The original plan was to have these remaining well selected rows intermate in the open. Unfortunately, there was a conflict with having this crop flower in proximity to a commercial cauliflower (*B. oleracea*) which would have been disastrous for both crops. The appropriate alternative for Huber was to dig 50 of the best plants from the best rows and put them into a commercial screen isolation cage (often used by seed companies for insect pollinated, cross-pollinated crops) and allow them to intermate. This strategy was foiled when the plants didn't flower properly as a result of transplant shock.

The progeny row evaluation was reinitiated in the spring of 2008. Remnant seed from the original 50 plant half-sib families of 2006 was planted again into 50 half-sib family rows X 2 replicates = 100 rows total in 2 blocks at Huber's farm. Evaluation will begin in earnest in the late fall of 2008 and poor performing rows as well as poor performing plants within good rows will be eliminated in the late winter of 2009. Seed will be harvested from remaining selected rows as half-sib family row masses and then be replanted in the fall of 2009 for another progeny row evaluation in 2010.

Results

During the evaluation of the half-sib progeny rows in 2007 we found that approximately 60% of the 100 rows (30 rows X 2 – we always considered both rows of each accession) had a small percentage (<10%) of green plants. These rows were eliminated. The remaining 20 (X 2) all-red rows were then evaluated for the intensity of red pigmentation across the plants in each progeny row. Several of these rows with plants exhibiting lower levels of pigmentation were eliminated. The remaining ~15 (X 2) progeny rows were then scrutinized for their growth rate, uniformity of color, uniformity of curl, height, upright stature, and flavor. Half of these rows were eliminated for poor performance in one or more of these categories. The remaining selected 8 rows (8 X 2 = 16) with a majority of good plants still each had a minority of either poor or less than ideal plants. These individual plants were eliminated from the selected rows. The remaining plants in the best 8 rows (X 2) were then meant to be left *in situ* to flower and intermate. Unfortunately, they had to be moved in order to flower. Only 50 individuals could be dug and placed in a pollination tent. These plants never flowered properly after their untimely transplanting at such an advanced stage and seed was not collected.

Conclusions

The evaluation and progeny selection of the half-sib families of Nash's red kale in the spring of 2006 was very revealing of the overall and specific breeding value of this population. Approximately 40% of the progeny rows contained plants that all had some degree of pigmentation. While the red pigmentation trait is quantitative and is presumably expressed in degrees of intensity, it is also well known that the presence of red pigmentation in *B. oleracea* is conferred by a major dominant gene. To have a progeny row with all plants expressing pigmentation confirms that the seed-bearing maternal parent plant was homozygous dominant for the major dominant gene for pigmentation. Thereby, eliminating all progeny rows containing any green plants in a progeny evaluation before the plants go to seed is a nearly fool-proof way of eliminating the heterozygous half-sib families from contributing to the next generation.

To continue this work we currently have a nursery plot with 50 progeny rows of Nash's Red Kale that was started this year from remnant seed from Huber's original 50-plant selection. It will be selected for the various important traits discussed previously as the winter becomes spring in the coming months. These progeny rows have been planted in a location where they will remain during the 2009 season through the various stages of selection and seed maturation. The best performing progeny rows will be selected and allowed to intermate openly during the 2009 season. Seed of this massed population will be harvested separately from individual progeny rows and replanted for further selection as "half-sib progeny rows with a population tester" in late summer 2009.

OP Broccoli, Common Ground Farm, Olympia, Washington

Introduction

Jim Myers of Oregon State University (OSU) and Julie Puhich of Common Ground Farm (CGF) collaborated on developing an open-pollinated broccoli broadly adapted to organic growing conditions in the Pacific Northwest with specific traits that fit the CSA/market grower niche for producers like Puhich. Common Ground Farm's goal is to harvest broccoli consistently from late May through the fall season. They sell primarily through a CSA so uniformity of head appearance or harvest timing is not as crucial as it is for a contract producer. The early market (May harvest) is the most important window as there are very few available crops at that time. They stretch broccoli availability throughout the season by sowing about 6 varieties, 4 times/yr. They currently use multiple F1s[1] and would like to have an OP available for a number of reasons: 1) to gain the ability to direct sow seed and minimize green house efforts (F1 seed is too expensive for direct sowing), 2) to reduce overall seed cost by maintaining their own seed supply, and 3) to develop a variety well suited to their production needs and climatic constraints. Key broccoli traits of interest to Puhich include earliness, head size, medium heads (~5 in. dia.), high side-shoot production, good growth under cool spring soil conditions which tend to have low N availability in organic systems, convex dome, small bead size, blue-green heads, medium

[1] The first "filial" generation of plants resulting from a cross-mating of distinctly different parental types. (Wikipedia)

plant height (~ 3 ft.), strong stems, and moderate head-to-leaf ratio. As noted, CGF does not demand as uniform a maturity as most F1s provide but narrowing the timing of maturity is desirable so that a given sowing is not in the field over a very long time. It is easier for them to manage consecutive harvests through multiple sowings than by continually picking from one field.

The starting population for this project was developed by Jim Myers. It was originally created by randomly intermating several commercial broccoli varieties and several OSU breeding lines developed by Dr. Jim Baggett. It was subsequently broadly selected on a diversity of organic farms, including CGF, for 6 generations.

Materials and Methods

In 2007 Puhich started seed from the Myers OP population in 72-cell flats in the greenhouse in mid-February. 150 seedlings were transplanted into the field in mid-April. In mid-March seed was also direct seeded into the field and then thinned down to a final population of 150 plants. The greenhouse transplants and direct seeded population were side by side creating one plot of broccoli. The direct seeding was done after the greenhouse plants were started in order to ensure a large enough population for selection. In each sowing, greenhouse and field, seedlings were selected and thinned for the most vigorous plants. After selections for vigor a final population of 300 plants remained. Final spacing was approximately 42-inch row centers and 18 inches in row spacing.

The 300 broccoli plants were selected down to a final population of 46 plants. A temperature spike in late May caused premature heading (buttoning) in a portion of the population. In April and May cabbage root maggot also affected a portion of the population. A total of 75 plants were removed during this time period due to early heading or cabbage maggot damage. Loss of plants was about evenly split between these two events. The remaining 225 plants were selected by Puhich for presence of a head, domed heads, and smaller, tighter beads. The final population after selection for head quality was 46 plants. The 46 plants were harvested individually in September and retained in separate bags (half-sib families).

In 2008 Puhich started seed from each of the 46 plants (half-sib families) from 2007 in 72-cell trays in the greenhouse in mid-February. A few of the families were lost in the greenhouse. One turned out to have some seedlings with leaves that had a shape like Mizuna leaves and was not transplanted in the field. She successfully transplanted 40 of the half-sib families into the field as progeny rows in mid-April. Each family was planted in two reps with a total of 80 plots, 12 plants per plot, 18-inch in-row spacing and 42 inches between rows. Puhich also started a flat of the original OSU OP population in the greenhouse at the same time and planted a row of 50 plants from this population in the field. This was done on recommendation from Myers to ensure that enough genetic diversity was retained in the population since the 2007 population had been selected down to 40 plants and fewer than 50 plants in a population can result in inbreeding depression (Myers, personal communication).

A cold period in May resulted in an overall stress in the population. This resulted in several early heading and early bolting individuals in the population making it difficult to evaluate true head quality for the second year in a row. Puhich did however evaluate entire plots (half-sib family progeny rows) for presence of early bolters, uniformity of timing of heading within the family plots, presence and size of heads, tightness of beads, and domed heads. She eliminated both reps of 27 family populations based on these criteria, leaving 13 plots in the field. She also selected the 50-plant OSU OP population down to 12 plants. She did not select within the plots so this resulted in 13 plots x 12 plants per plot + 12 plants from the OSU population = 168 plants. Seed from these plants was harvested as a bulk population.

Results and Conclusions

The broccoli breeding population was highly variable in appearance, timing of heading, and timing of flowering. Some plants did not produce heads at all. The phenotypic variability included variation in color, plant size, head size, bead size and texture, and leaf size. Most heads were smaller than optimum market size, less than 6 inches across. The population was, however, very vigorous in the seedling stage, outgrowing seedlings of hybrid varieties planted on the same dates. While the population included a relatively low proportion of marketable heads and may require many more years before it is ready for release as a good commercial variety, it has many desirable qualities including enough decent heads to warrant continued selection. It is unclear whether the early heading in the population was solely attributable to the weather conditions in the early spring of 2007 and 2008 or if the population is genetically predisposed to this trait.

OP sugary enhanced Sweet Corn, Gathering Together Farm, Philomath, Oregon

Introduction

The original breeding population for this project was a population that Frank Morton produced using mass selection at Gathering Together Farm (GTF) each year since 2001. By producing seed for several generations under dependably cool spring soil conditions, he hoped to eventually develop a more vigorous, cold tolerant variety for fresh market. However, although the population seemed to have a good level of cold soil tolerance, there was concern that it may lack good eating quality as it has some toughness of the pericarp and could use additional improvement overall. Frank’s starting population was developed by project partner, sweet corn breeder Bill Tracy. The population was created by random mating of vigorous, cold tolerant material along with commercially available hybrid sugary enhanced (se) varieties with desirable flavor and other quality traits. During 2001-2006, the population was mass selected at GTF for stalk strength, two ears per stalk, red pigmentation in the plant, early emergence, and early maturity.

Materials and Methods

In 2007 Morton established 5 breeding subplots that together included a stand of 600 plants. All plots were planted with Morton's most recent population, selected in 2006. Plots 1 and 2 were planted on May 2nd at his home farm, Shoulder to Shoulder (S2S), 5 miles from Philomath, Oregon. A third plot was planted at S2S on May 13th. Two plots were planted at GTF in Philomath, Oregon, one on May 6th and one on May 13th. Morton intensified his selection for good germination under cold conditions by selecting seeds from his mass population that germinated well and were most vigorous in a wet paper towel under cold conditions. He placed approximately 1000 seeds in moist paper towels and placed them outdoors under cool conditions of 30-40 degrees F nighttime temperatures. Of the seeds that did germinate he selected out those that had the longest length coleoptiles (the sheath around the emerging seedling). Some seeds had coleoptiles up to 1.5 inches long. This pre-germinated seed was planted in each of the 5 subplots at a spacing of 8 to 12 inches.

Plants in all 5 plots were evaluated for desired traits including earliness of tasseling, stalk strength, and 2 ears/plant. The 20 earliest tasseling plants in each plot were tagged and the second ears on the plant were bagged on July 8th. Each of these ears was subsequently self-pollinated by hand as the silks emerged. The remaining plants and the first ears on the tagged plants were allowed to freely intermate. In the fall Morton saved seed from each of the 20 self-pollinated ears in each plot individually. He also harvested seed from the first ears on these plants and the rest of the selected plants in the patch as an open-pollinated (OP) population. A sample of this population (2007 OP) was sent to Jim Myers, OSU, for inclusion in a sweet corn emergence trial and sweet corn variety trial (results below). A second sample was sent to Bill Tracy, University of Wisconsin, for inclusion in an on-farm evaluation at Gardens of Eagan, the site of a participatory sweet corn breeding project described later in this report.

In 2008 Morton planted progeny rows of seed from the 38 full-sib family ears from 2007 in mid-April. Soil and weather conditions were cold and wet. The plots even received a dusting of late snow in April. He evaluated each progeny row for early emergence and vigor and rated each plot on a scale of 1 to 9 for these traits. In May the trial was lost due to a farm cultivating mistake. Morton then utilized the data from the evaluation to select the top 19 earliest emerging lines. 1200 seeds from these 19 ears were planted in early June. These 1200 plants were selected down to 600 plants that were earliest emerging. The remaining 600 were evaluated for early tasseling and the earliest 200 plants were tagged. The remaining plants were detassled, but left in the field to maintain plot integrity and avoid lodging. The remaining 200 were evaluated for earliness of pollen shed and ranked on a scale of 1-9. They were then allowed to openly intermate creating a new open-pollinated (OP) population. At harvest the 200 ears were sorted into earliest ranking class (7-9), medium rank (4-6) and latest rank (1-3). These ears are currently drying in the greenhouse and will be evaluated for ear characteristics and saved for planting in 2009.

Results

Evaluation of germination under cool soil conditions:

Morton's 2007 OP population was included in two trials for early emergence under cool soil conditions, one at Gardens of Eagan (GOE) and one at Oregon State University (OSU).
Each year at OSU, Jim Myers conducts a cold soil emergence trial for the sweet corn industry. The trial includes sweet corn se and sugary (su) hybrid varieties with several fungicide treatments and untreated checks. In April 2008 Myers included Morton's se OP corn population as an untreated entry. 2008 was one of the coldest Aprils Myers could recall and the trial plots even received a dusting of snow. The untreated hybrid varieties had an average germination rate of 3-5%. The fungicide-treated hybrid entries had an average germination rate of 5%. The highest germinating entry was a hybrid variety that was treated with several different fungicides and germinated at 74%. Morton's untreated open-pollinated population had a 54% germination rate, ranking it closer to the hybrid with multiple seed treatments than to the single treatment hybrids.

Myers also conducts regular vegetable variety trials each year and included Morton's corn in his 2008 variety trials. In the 2008 test it was among the earliest emerging varieties and had a good, tender eating quality.

At Gardens of Eagan farm in Minnesota, Tracy contributed 250 early generational inbred lines from his University of Wisconsin sweet corn breeding program for a participatory plant breeding (PPB) project conducted by John Navazio, Jared Zyskowski, and Martin Diffley. Morton's corn population was included in this breeding test and was one of the earliest emerging varieties; however it did not receive high marks for eating quality.

Conclusions

Morton's corn population has exhibited a high degree of cold soil tolerance, good early emergence and vigor in Oregon tests. It has served well as a local-market OP variety for Gathering Together Farm. It appears that the overall eating quality and uniformity of maturity could use improvement and it will be crossed to the best material generated by the Gardens of Eagan PPB project.

OP Sweet Corn, Gardens of Eagan, Farmington, Minnesota

As word of the sweet corn project spread there were other farmers who expressed interest in participating. One farm in particular seemed like a particularly good location for an expanded sweet corn project. Gardens of Eagan in Farmington, Minnesota, has several important attributes for a project like this. It is in a part of the country where sweet corn production is very important. Farmington is approaching the northern limits of the area where sweet corn is commercially produced in the Midwest and has cool spring weather; hence it is a good location for testing for cold soil vigor. The Gardens of Eagan farm tries to offer the first early organic sweet corn to the Minneapolis market, planting the crop early and risking seedling losses to cold, wet soils. Martin Diffley has 30 years of experience growing a large commercial crop of sweet corn organically and understands the agronomic and market traits that are necessary in a successful variety.

Materials and Methods

Bill Tracy, University of Wisconsin, created two sweet corn populations by crossing several commercial hybrid sweet corn varieties. Each of these varieties contained a combination of the following traits: 1) ability to germinate in cold soils, 2) early seedling vigor, 3) good husk protection of the ears, 4) horizontal disease resistance to corn smut and common rust, and 5) good eating quality (tender pericarp, true corn flavor, and high sugars). After several generations of recurrent selection for these traits, at least 150 plants in each population were self-pollinated. Seed from each ear was harvested separately into an individual bag and represented an S1 (“selfed once”) line. Seeds of 92 S1 lines from population #A [(Ambrosia x Incredible) x (Argent x Delectable)] and 136 S1 lines from population #S [(Sugar Buns x Mistique) x (Miracle x Ambrosia)] were planted into single rows (35 seeds/row) at Gardens of Eagan in mid-May 2008. Each family row was 11.5 feet long. ‘Temptation,’ the standard early se sweet corn, was planted as border rows and as a control as it is used as the first early corn with good cold soil emergence and seedling vigor at Gardens of Eagan.

Rainy, cool weather followed planting and an evaluation of seedling emergence was done 10 days after planting. Poor emergence and poor seedling vigor affected > 60% of the lines in each population. The stand (or lack of a stand) and overall vigor was recorded. The crop was fertilized and cultivated exactly as the other 20+ acres of commercial organic sweet corn on the farm. No external disease control measures were taken. At the time when a majority of the lines had ears that were at or close to a good eating stage, we evaluated for flavor. Lines that had rated poorly for emergence or vigor were not evaluated. Remaining lines were scrutinized for poor husk cover or presence of disease and eliminated from consideration if either flaw was excessive. For the remaining 20 to 25% of the line rows, we harvested ears from 4 to 5 plants, husked them and performed a “bite test.” We used three tasters for this task. If a majority of the ears from each line could be described as tender and sweet by all tasters then it was rated and described for further consideration.

Results

The incidence of cool, rainy weather throughout the latter half of May was very welcome for this breeding study to exert selection pressure on the large number of lines being tested from both sweet corn populations. At least 30% of the lines had either no stand or very few plants, while another 30% of the lines had a stand with about 50 to 70% of the plants emerging from the original number of seeds planted. This was not considered acceptable and lines with either of these “less than optimum” results in establishing a stand were not selected to be continued in the experiment.

Environmental conditions conducive to spread of the two most prevalent diseases of sweet corn in Minnesota, corn smut and common rust, were favorable in 2008. Corn smut was exceptionally bad and appeared in at least 50% of the experimental lines throughout the plots, therefore at least half of the plots with adequate stands were eliminated due to the presence of corn smut. Common rust was not as problematic, although there were many plants that had some degree of lesioning. The host resistance for this disease is quantitative or horizontal and many of the lines from these two sweet corn populations exhibited fairly high levels of resistance under what seemed to be moderate disease pressure. About 10% of the lines in these breeding plots had enough disease symptoms to warrant concern. We eliminated a number of the plots with adequate stands based on their susceptibility to common rust.

Quality evaluation for texture, corn flavor and sweetness was not as easy to determine as we thought it would be. We spent a substantial amount of time determining our textural and flavor criteria. Very few of the remaining lines survived the bite test as there were surprisingly few lines that truly tasted as good as a good commercial sweet corn. We were able to settle on 11 lines in each of the two populations that combined good eating quality with the other agronomic traits that were identified as important for sweet corn production in an organic system. Seed of these two groups of 11 lines are being grown as an openly crossing population in a winter breeding nursery in Chile this winter of 2008-09.

Conclusions

This first year of sweet corn breeding for organic systems in Minnesota was a great success as several of the most important traits were easily distinguished in the breeding plots. Much of this was made possible by the wonderful synergy that developed between John Navazio and Jared Zyskowski, the breeders, working with two corn farmers, Martin Diffley and Gene Mealhow. This was an excellent example of PPB at its best. The farmers understood the traits of interest, how and when they appeared and the degree to which they could be tolerated or rejected in their cropping system. The breeders knew the technical aspects of breeding corn and the growers knew the nature of the traits of interest and how they reacted in the environment.

We were very pleased to get such a good selection on the cold soil germination and eliminate all of the poor germinating stocks. This is extremely important for growing sweet corn organically and will make these populations much better. The disease pressure encountered was also very important to our selection progress for organic systems. Hardest of all was getting the right combination of flavor and texture. Selecting just 11 lines from each population demonstrates how unusual it was to identify lines that combined the best agronomic traits with good flavor. The 11 lines from each of the two populations has been sent to Chile to be grown in a contra-season breeding nursery using the "Paired Rows" recombination technique developed by Jim Coors at the University of Wisconsin.

Two rows are needed for each line. The first row in the pair is planted with kernels all from the same line, e.g. all from line 1. The second row in the pair is planted with a bulk formed from an equal number of kernels from all the remaining lines, e.g. families 2 through 11. This planting is repeated for all lines, e.g. 2 paired with bulk of 1, and 3 through 11, 3 paired with bulk of 1, 2, and 4 through 11, etc. Each row in the two-row pair then serves as a pollen donor for its opposing row, so that a bag placed on the tassel of a plant in row 1 will be used to pollinate an ear on row 2 and vice-versa. This technique will allow approximately equal recombination between all lines and will produce ears with full-sib seed from within each of the populations. Seed of each ear will be harvested individually and planted as an individual row in the 2009 breeding plots at Gardens of Eagan.

Overall Project Conclusion

The farms and researchers involved in this project represent a spectrum of participatory breeding relationships. Morton represents a more farmer-led breeding approach than most PPB projects. With a good working knowledge of basic plant breeding protocols, Morton continually modified his methods over the past 2 years in response to project results and farming capacity and conditions. This fact highlights the value of flexibility and creativity in on-farm plant breeding which allows the farmer-breeder to respond to the ongoing farm dynamics. In Puhich’s case the project was initiated by the researcher, Myers, and Puhich took on the project in part as a learning opportunity. Puhich’s farming expertise was highly valuable to the breeding project as she clearly knew what quality traits she desired in a broccoli. The breeding decision- making process was greatly improved by the breeder-researcher involvement.

In the case of Diffley, who has a strong production farming focus, advanced on-farm breeding activities were not of interest. Diffley’s involvement in the project was focused on evaluation of potential breeding materials with Navazio and Zyskowski, while Tracy’s breeding program executed the more advanced activities of self-pollinations and crosses among selected materials.

Huber was highly motivated and interested in carrying out a breeding project on his own which he managed independently for about 8 years. While this on-farm effort did result in a new population of value to his production system, it also reached a point where improvements in the desired traits become more difficult to achieve. With the assistance of Navazio he was able to implement more advanced on-farm techniques to move the population forward and begin significantly reducing the unwanted recessive genes contributing to the green color in his population. In this case the farmer was willing to do the work on-farm and also benefited from the assistance of a formal breeder's knowledge. Each of the four breeding projects benefited from the cumulative efforts and expertise of the farmer and the formal breeder involved and each project was strengthened by the participatory approach.

Two of the four breeding projects have already resulted in a variety or "population" that is in production on the participating farm, Morton's corn and Huber's kale. These two populations are not quite at a level of uniformity for marketing or releasing as a finished variety, but with on-farm roguing or selection they are still of production value and fulfill a needed on-farm niche. Morton's corn overcomes his cold soil challenges and Huber's kale overcomes his preference to affordably direct seed and continue productive harvests into the winter season. These two projects demonstrate the ability of on-farm, farmer-led breeding efforts to address the needs of organic farmers.

The four projects span 1-10 years of on-farm efforts. The original funding from OFRF was for conducting breeding in 2007. While OSA pursued additional funding for 2008 and beyond, none was received. In the absence of continued funding all three original projects persisted and an additional project was added to the scope of activities. This demonstrates the interest and dedication of all project partners to continue the breeding work even though it costs time and labor on-farm. All of the university-based breeders involved have also generously donated their time to these projects. Over the course of the last two years, OSA has established a plant breeding committee which includes 5 university-based breeders who are interested in developing organic and participatory approaches to plant breeding. OSA also receives ongoing requests for support from farmers interested in engaging in on-farm breeding activities. While public and private funding has been slow to recognize the need for this work, OSA's staff feels that the interest and potential positive impacts of developing participatory, on-farm breeding for organic systems is a priority research area that the organization intends to continue pursuing. OSA is currently working on several public grant proposals and is seeking private funding to support this area of research.

Outreach

Engaging in on-farm participatory breeding projects creates an ideal learning environment for farmers and others to become familiar with field breeding approaches and impacts. Each of the four project farmers benefited educationally from involvement in the projects. Additionally, at each farm, interns, workers, and visitors benefited from seeing the breeding fields and hearing about the breeding projects from the farmers, breeders, and OSA staff. At Puhich's farm in July 2007, a class of about 30 Evergreen College students visited the farm and learned about the broccoli project from Puhich and Colley. At Gathering Together Farm, farm staff involved in the corn breeding learned about the process and one lead farm-worker in particular has expressed interested in pursuing an advanced degree in plant breeding, partly inspired by involvement in the on-farm breeding activities. At Gardens of Eagan, approximately 250 visitors learned about the on-farm corn breeding project from Diffley and Navazio during a two-day farm tour. Attendees included a broad audience from the organic foods industry and organic farming advocates. In September 2008, 100 visitors learned about Huber's kale project during a farm walk hosted by Tilth Producers and Washington State University's Small Farms Team.

Over the past two years OSA staff and project partners have presented on PPB for organic farming and included the four projects as examples. In January 2008, Navazio presented on the topic at the Organic Seed Growers Conference. His proceedings paper is included in the addendum of this report. In November 2007, Colley gave a talk on PPB focusing on the four funded projects at the Louis Bolk Institute in the Netherlands. In August 2008, Tracy and other members of the OSA Plant Breeding Committee gave a talk and led a field tour at the Maine Organic Farmers and Gardener's Association (MOFGA) Common Ground Farm with approximately 100 attendees. The talk was on PPB for organic farming and the field tour included plantings of samples of plant populations from several OSA PPB projects. In October 2008, Zyskowski, a graduate student of Tracy's, presented on behalf of OSA at an international Seed Technology conference in Saltillo, Mexico. OSA, Colley and Navazio, assisted in development of his presentation which focused on three of the breeding projects. In November 2008, Huber and Colley presented on integrating organic seed production into a diversified organic farm and included his kale breeding project in the presentation and discussion.

OSA created a color-print flier on PPB for organic systems which focused on the OFRF-funded projects as case studies. The flier is used as an informational bulletin and has been distributed widely at OSA and related events including most of the above mentioned activities and presentations. The flier is included in the addendum of this report. An additional handout focused on the Diffley project was created for the Gardens of Eagan tour and is also appended to this report.

The OSA website includes a write-up of OSA's PPB program and photos and a narrative of all four breeding projects in the research section.
http://www.seedalliance.org/index.php?page=Research

References

Ceccarelli, S. 1996. Adaptation to low/high input cultivation. Euphytica 92:203-214.