Trialing and Seed Increase of Promising New Vegetable Varieties for Organic Systems

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Project Summary

The main purpose of our project was to deliver the outcomes of several years of organic vegetable breeding to the organic community. Previous support of vegetable breeding at Cornell resulted in the engagement of university plant breeders with organic growers, discussion that identified needs and resources, and effort in participatory breeding and evaluation of vegetables that were selected for performance in organic systems. The final step in making these vegetables broadly available and realizing the benefit of this investment was the availability of a substantial homogeneous seed stock. With this seed stock in hand, we would be able to distribute samples of a single seed lot to a variety of growers and seed companies for evaluation as well as archiving this same seed lot in our seed storage facility for future distribution and preservation.

Many of the crops we developed are outcrossing species which complicates seed production given the need to isolate the cultivars from each other as well as other members of the same species in the same general area. Pollination cages were selected as a solution favored by USDA germplasm curator collaborators and mentored us in the adoption of these structures. By maintaining a hive of bees within the cage, pollination labor was dramatically reduced. The cages also excluded insects that damage the plants and act as vectors of disease, some of which could further be seed borne. Although some plantings were lost to rodents that tunneled into the cages and viruses that infected populations prior to transplant, in general we affordably produced an abundant stock of healthy seed to distribute.

Originally designed as a two-year project, we were surprised to have completed our ultimate goals within the first year. Multiple cultivars will be available in seed catalogs as organic seed. Seed will continue to be available to interested growers to trial and we have doubled the number of cages from four to eight this year. Our strategy of including multiple crops within each cage had mixed success. By reducing the number of species in each cage, reducing plant density, and staggering flowering periods we hope to optimize our approach. This year, seed is being produced of cultivars and breeding lines with disease resistances that are priorities for organic production in the Northeast and are now leveraged to provide seed for two other organic projects. The Toward Sustainability Foundation has funded us to evaluate and produce stock seed of cucumbers with downy mildew resistance and for our role in the Northern Organic Vegetable Improvement Collaborative (NOVIC), a federally-funded team that will breed and trial vegetables for organic growers in the Northern U.S.

Introduction

Organic seed is a critical part of organic vegetable production. Not only is the use of organic seed required when available for certified organic growers, it supports organic practices in a crucial step in the organic supply chain. In conventional agriculture, crops grown for seed production tend to receive more pesticide than crops grown for food because of the need to maintain plants in the field to seed maturity and to reduce the potential for distributing diseased or low vigor seed. These goals are highlighted in organic systems due to the critical need for healthy seed and fewer control measures for pests and disease.

Insects are vectors of disease in peppers and cucurbits. In our region, aphids transmit cucumber mosaic virus (CMV) to pepper and cucurbits and watermelon mosaic virus to cucurbits. Not only do these viruses harm seed yield and quality, a strain of CMV has been shown to be able to be seed transmitted in pepper. In cucurbits, cucumber beetles devastate foliage and transmit bacterial wilt and squash mosaic virus (SqMV). Squash mosaic virus is well known as a severe seed-transmitted virus. While the symptoms of squash mosaic virus are obvious, they are not always diagnostic. We previously determined that the use of Immunostrip assays (Agdia, Elkhart, IN) allows cost-effective SqMV screening of up to five plants at once as a pooled sample.

Objectives

Our original objectives were designed for a two-year project in which we would focus on seed production our first year and distribute these seed for evaluation by growers the second year with overall goals of increasing the availability of seed to organic growers and expediting this process by providing a more substantial quantity of seed to organic seed producers. Typically vegetable seed is provided to companies in small quantities requiring them to do two rounds of seed increases before they have a sufficient quantity to offer for sale. By providing a larger quantity of seed, this time is reduced by one growing season.

Stated Objectives:

A. Produce seed in sufficient quantity to distribute to organic producers for:
   - 3 melon varieties
   - 3 cucumber varieties
   - 3 pepper varieties
   - 3 squash varieties

   Measurable outcome- Enough seed of each variety is created to distribute to 30 growers and provide stock seed to 5 seed companies

B. Distribute stock seed to collaborating growers and seed companies

   Measurable outcome- Seed is distributed to at least 30 growers and 5 seed companies.

C. Collect and compile grower feedback

   Measurable outcome- Feedback is solicited from growers and seed companies, summarized, and distributed back to the participants. This feedback will be used as the primary criteria for variety evaluation.

D. Recommend production of identified varieties to seed companies

   Measurable outcome - At least three new varieties are available. At least one seed company is distributing seed in their 2011 catalog.

Fulfillment of Objectives:

A. Quantities of seed produced are listed in Table 2. Except for the pepper crop failure, we successfully produced seed from four melon, three cucumber, and six squash varieties compared to our goal of three of each. (Germination has improved since listed tests.) Pepper seed production of two lines is being pursued this summer.
B. Trial seed was intended to be distributed in 2010, however in 2009 we distributed seed to seven companies and five growers. Multiple varieties were sampled by each.
C. Grower feedback was primarily a 2010 objective
D. Of the breeding lines we identified to be included in this project, six will be offered as cultivars between five different companies. It was this result that prompted us to feel the project had achieved its goal in the first year

Materials and Methods

Plant Growth

Plants were grown according to organic practices at all stages at facilities certified organic by NOFA-NY. A panel of vegetable lines was selected, sown in McEnroe Soilless mix in 72-cell trays, and grown in a greenhouse at the Guterman complex at Cornell University. Seedlings were hardened off in adjoining cold frames prior to transplanting. A field on the Freeville Organic Farm was amended with compost and three raised beds with plastic mulch and drip tape were formed to run the length of each pollination cage. A twelve-foot wide, six-foot tall and forty-eight-foot long metal frame was constructed over these beds using pipes prepared by Fingerlakes Truck and Welding Supply (Waterloo, NY). Upright posts were secured by inserting them into holes created by driving a metal spike into the soil. The mesh fabric for the cages was sewn by Lumite Inc. (Gainesville, GA) to fit the supports with an additional flap around the bottom edge to be sealed and secured by soil and a zippered entrance on either end. Transplants (see Table 1) were planted inside the mesh cages at the density indicated, fertilized with fish emulsion, and irrigated as needed.

Once the cages are erected, the caged plants require similar attention to plants in the field. Weeding is done until vines cover the ground sufficiently. The plants should be scouted regularly for disease and insect pests. Although the cages generally do a good job of excluding insect pests from the crop, we have experienced occasional aphid outbreaks inside the cage. Interestingly, aphids have only been an issue for cages containing pepper plants and did not spread to other cages or within the cages to the cucurbits. We expect that the aphids were brought into the cage on the transplants. We now use ladybugs and lacewings (introduced on egg cards) as beneficial insects within the cages. Disease is minimized or at least significantly delayed within the cage as compared to the open field, partially due to the cage mesh filtering out airborne spores.

Watering is best done via drip irrigation. Opening and closing the cages was generally avoided. Bees from the field are often attracted to the bees within the cage and allowing these bees the opportunity to enter and carry pollen from the field is a concern. The start of harvest usually coincides with the end of pollinations so, although the cages are generally kept closed over the crop, we are not too concerned about cross pollination by then.

Hives of honeybees were introduced at flowering to pollinate the crops. In New York, squash of the *Cucurbita pepo* species and cucumbers flower approximately four to five weeks after transplant. Melon and butternut squash (*C. moschata*) flower six to seven weeks after transplant. While bumblebees are commercially available, they were not as effective as honeybees in our experience. A bumblebee hive tends to contain far fewer individuals and is sensitive to handling during shipping and placement of the hive in the cages. Honeybees immediately flow from the hive by the hundreds when the hive is opened and swarms of bees are active in the flowers the same day. Honeybee hives can often be borrowed or rented from a local apiary. Rather than a large hive, a small nuc such as the one pictured (Figure 1) is more than sufficient. After about a month, the hive should be swapped out of the cage because there are not enough flowers in the cage to sustain the bees. While we are aware that others successfully feed their bees and keep a hive in the cage much longer, rotating the hive to a field of alfalfa provides ample food for the bees and does not risk contaminating the crop with vegetable pollen.

At a minimum, a smoker, and face and hand protection are highly recommended for handling nucs. We tended to place the nuc centrally in the cage. An alternate strategy is to place the nuc amongst the crop that needs more visits from the bees to get good seed set. This way the bees pass through this crop on their way to the other crop and again on their way back to the hive.

Figure 1. A honeybee nuc amid a cucurbit crop in a pollination cage.

<u>Exceptions to Original Plan</u>

Pepper transplants were excluded from these cages after it was determined the planting became infected with a virus. We have replanted two of these pepper lines for the summer 2010 season and are attempting a seed increase in the pollination cages and also in an organic greenhouse as a backup strategy. Initially the space between rows was mulched with straw, however the remnant seed heads attracted rodents that also destroyed some of the melon planting. The straw and rodents were removed with no further incident. Substitute melon plants in an adjacent field were pollinated manually to make up for the seedling losses. The only other pest problems for the remainder of the season were whitefly that emerged in the fall. No pesticide needed to be applied at any time and it was noted that the plants were healthier than the plants in the neighboring field.

Seed Processing

Fruit was harvested at maturity. Cucumber and melon are generally ready for harvest six weeks after pollination and are harvested in batches. Squash seeds are mature after eight weeks and are more resilient fruit, so only a single late harvest tends to be done on our farm. Fruit that had any symptoms of disease or had started to rot were discarded to avoid contaminating seed lots. Seed extraction has become a popular student activity; rather than hiring staff to spend hours performing a monotonous activity, classes that visit us in the fall on field trips joyfully scoop seeds from pickup-truck loads of cucumbers and smash open squash with cinderblocks to get at the seed. We take care that each lab group works with a single cultivar of each crop and crops with seed that can all be distinguished from each other. For example, butternut, zucchini and cucumber seed are obviously different, but cucumber and melon seed are too similar to confidently avoid cross-contamination when being processed by a large, enthusiastic student group.

Seeds were allowed to ferment, rinsed, and dried at 30°C in a forced-air oven. Dry seed was cleaned using an air column. The germination of all seed lots was tested November 20, 2009, by placing 20 seeds on wet paper in petri dishes and incubating for 10 days at 28°C (see table 2). Seed were packaged for transfer to the seed storage building at Cornell, a facility that maintains low temperature and humidity year round.

Table 1. Identity and Amount of Transplants per Cage

ID#	**Cage #1**	**# of Plants**
09-180A	Golden Gopher-derived powdery mildew resistant (PMR) melon #1	8
09-177A	'Silver Slicer', long white PMR cucumber	8
19-192	Orange striped summer squash selection #1	12
09-166	Large PMR Butternut selection #1	11
-	**Cage #2**	-
09-183	'Farmer's Daughter', PMR melon similar to 'Collective Farmwoman'	14
09-176	small white, PMR cucumber	34
09-162	'Oro Verde' green striped PMR butternut	14
-	**Cage #3**	-
09-181A	Golden Gopher derived PMR melon #2	14
09-177B	Long White PMR cucumber selection #1	14
09-194B	Improved Costata Romenesco type squash	12
09-167	Large Butternut Selection #2	14
-	**Cage #4**	-
09-188	Medium sized PMR Honeydew	14
09-176	small white, PMR cucumber	34
09-165	'Bright Eyes', small butternut with "eye spots"	14

Project Results

A substantial quantity of seed was produced for each crop (see Table 2.) Some crops were highly productive. Cucumbers produced more than ten fruit per plant with abundant seed which germinated at 85% or better. Melons averaged closer to one fruit per plant with variable yield and generally good germination. Summer squash and butternut produced about two fruit per plant. Early germination was abysmal but increased upon storage to more than 50%.

Table 2. Seed Yield and Germination

ID#	Crop	# Plants	# Fruit	Seed Weight (g)	Germination %
09-180A	Melon	8	10	13.8	90
09-177A	Cucumber	8	101	389.6	85
19-192	Squash	12	19	305.3	60
09-166	Butternut	11	27	259.4	>50%*
09-183	Melon	14	37	204.6	85
09-176	Cucumber	34	314	1173	92
09-162	Butternut	14	32	223.3	>50%
09-181A	Melon	14	10	91.0	60
09-177B	Cucumber	14	171	708.0	100
09-194B	Squash	12	31	500.8	>50%
09-167	Butternut	14	25	298.4	>50%
09-188	Melon	14	10	20.2	100
09-176	Cucumber	34	333	1264.1	88
09-165	Butternut	14	165	337.4	>50%

Conclusion and Discussion

Cucumber seed production was superb. Manual pollinations of cucumbers are especially laborious due to the small flower size, need to use two male flowers per female, and sensitivity to rain during pollination. The cages greatly increased the efficiency of seed production by producing abundant seed with excellent germination.

Aspects of the seed production could be improved for butternut, summer squash, and melon. Plant density could have been too high for good fruit set and germination for summer squash and butternut. Where we anticipate requests, we have replanted squash seed lots at a lower density. We can easily improve melon performance by discontinuing the use of straw mulch and being vigilant about rodent control in the cages. In the 2010 seed increases we are also reducing the number of crops per cage from as many as four to no more than two. The original concept was that since we could combine crops that did not cross-pollinate, they could all be caged together. However, the honeybees seemed to have a flower preference so when given a choice would fail to pollinate their non-preferred flowers. This year we have combined plants that flower at different times so that we can use a partition within the cage to focus the bees on the crops sequentially and still increase a diverse set of crops.

Despite the health and vigor of the plants in the pollination cages, cleanliness in seed production is a critical step to prevent the spread of disease. While our cages kept out most insects that could serve as vectors of disease, cucurbit seeds can still be contaminated by diseases that do not require insect vectors. Bacterial fruit blotch of watermelon is an example of such a disease that is a serious concern. Fermentation is effective at reducing seed-borne pathogens but does not necessarily eliminate them from the seed. We have identified an OMRI-approved compound, peracetic acid (aka peroxyacetic acid) that has been shown to be effective against the main cucurbit seed pathogens that we could not protect against with the cages alone. We will try using this OMRI-approved seed treatment this year as a way to ensure the health of the seed we distribute to our organic partners.

CU Small White 09-176 First Harvest

We have been actively involved for several years in the improvement of vegetable varieties for organic systems and now many of these are available commercially to organic growers. Cucumber mosaic virus (CMV) resistance was chosen as a breeding target in pepper due to the myriad of crop and weed hosts of the disease. Our first successful cultivar from these efforts was released as ‘Peacework’, an early, red bell pepper developed in collaboration with several organic growers and most notably its namesake, Peacework Farm. We published on the resistance and performance of this cultivar (Mazourek et al., 2009 HortScience 44:1464) and are proud to say this variety is featured by Fedco seeds.

In partnership with High Mowing Seeds, another red bell pepper with some CMV resistance was developed, ‘King Crimson’, and seed is available from them. Recently, CU Small White has become available from Johnny’s Selected Seed and released as ‘Salt and Pepper’. To the credit of our new pollination cage system, we were able to provide them with a quantity of seed from organically grown cucumbers and make this new cultivar available to growers sooner than would have been possible otherwise. We are proud to say that Johnny’s has chosen to make this cucumber available as organic seed. These cultivars and others have also been described in Farming Magazine (http://www.farmingmagazine.com/article.php?id=6103).

Beyond our anticipated impacts of facilitating the availability of these cultivars to organic growers, other benefits of this newfound capacity for seed production have emerged. Some cultivars come and go from seed catalogs. We are now able to maintain these cultivars so they are not lost and to preserve seed in a special seed storage facility at Cornell. We also find ourselves working behind the scenes and have been able to offer replacement stock seed quickly if a seed company has issues with their seed production. This helps insulate the organic growers that market these cultivars from seed shortages.

Outreach

We completed four outreach events during the year. The Cornell Horticulture 1010 class visited the cages September 9 and 10, 2009, to learn about organic seed production. The regional community participated in two events that showcased this work: the Freeville Organic Farm Field Days August 17, 2009, and the NOFA-NY Field Days at Freeville Organic Farm July 8, 2009. Vegetable seed companies learned about our work to increase organic seed and make it available to them at the Cornell Vegetable Breeding Institute Field Days August 31, 2009.

Citation

Mazourek, M., Moriarty, G., Glos, M., Fink, M., Kreitinger, M., Henderson, E., Palmer, G., Chickering, A., Myers, J.R., Rumore, D.L., Murphy, J.F., Kramer, C., Jahn, M. 2009. ‘Peacework’: An early red bell pepper for organic systems with *Cucumber mosaic virus* resistance. *HortScience* 44:1464-1467.

Addenda

-Handout provided to seed companies interested in caged seed production
-Pictorial guide of cage assembly