ORGANIC FARMING RESEARCH FOUNDATION

P.O. Box 440
Santa Cruz, California
831-426-6606
info@ofrf.org
www.ofrf.org

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

Project title:
Breeding an open-pollinated vegetable variety in organic systems: The Public Seed Initiative

Principal investigator:
Molly Jahn
Cornell University
312 Bradfield Hall
Ithaca, NY 14853
(607) 255-8147
mmj9@cornell.edu

Funding provided by OFRF:
$13,426 awarded spring 2004 (year 2)
$10,210 awarded spring 2003 (year 1)

Project period: 2003-2006

Report submitted: January 2007, 12 pages

Project Summary

Through the collaborative work we have done in the Public Seed Initiative (PSI), which has involved trialing existing public vegetable varieties on organic farms, we have realized that for maximum performance we must breed varieties in organic systems and involve organic farmers in the breeding process. Therefore, in the winter of 2002-2003 a project was started to breed an open-pollinated cucumber mosaic virus (CMV) resistant bell pepper that is well adapted for northeastern, midwestern and northwestern climates. This virus has been ranked highly as a widespread problem by organic growers and because of its wide host range, tends to be extremely destructive for growers with diverse cropping systems. Pepper is a very valuable and popular vegetable for most growers, particularly those with Community Supported Agriculture (CSA) operations. CMV can be a severe constraint to pepper quality (it causes disfiguring fruit symptoms) and yield. Using traditional plant breeding methods on certified organic ground, we are working to breed CMV resistance, originally found in a tiny Mexican hot pepper, into the open pollinated bell pepper variety King of the North. King of the North is an early maturing pepper with Tobacco Mosaic Virus (TMV) resistance and is a proven performer in organic systems.

Breeding populations were created in the winter of 2003 using Cornell CMV resistant breeding lines and King of the North. Progenies were planted in two locations in the 2003 season— Peacework Organic Farm (certified) in Wayne County, NY and at Cornell's Dilmun Hill student-run organic farm in Ithaca, NY. Individual plants were selected for earliness, plant habit, fruit shape, and fruit quality. Elizabeth Henderson and Ammie Chickering (2 of the 3 co-owners of the farm), members of Peacework Organic Farm's CSA, farm interns, a Northeast Organic Farming Association-New York (NOFA-NY) employee, and Cornell researchers participated in the selection process. There were a number of progenies that had good quality, earliness, and plant habit. Peacework Organic Farm's selections corresponded very closely to our own selections at Dilmun Hill, which indicates that phenotypic (what is seen) selection worked very well despite two different environments.

We found that partnering with organic growers was very rewarding in terms of selection of desirable progenies. Involving organic growers early in the breeding process to select traits desirable to them ensures that those traits will not be lost and that the final product, a variety, will have traits important to organic farmers.

Introduction to Topic

Background

For nearly 100 years, large public investments have been made in the development of vegetable varieties by university plant breeders. As the vegetable seed industry consolidated beginning in the 1970s, the number of companies serving vegetable growers began to decline precipitously. By the 1990s, this trend had resulted in a very few large multinational companies serving only the most lucrative hybrid markets in major production areas, allowing a number of smaller companies to begin to expand their operations in many regions of the U.S. While large companies have also marketed varieties in these regions, a growing problem for organic growers is that a favorite variety is discontinued by the seed company, and because the variety is proprietary, growers no longer can get seed of that variety. This is a strong argument for using publicly held plant germplasm and crop

varieties, but funding to breed crops in organic systems is lacking. In 2001, Molly Jahn in the Dept. of Plant Breeding at Cornell, her partners at two non-profits, and the USDA launched the Public Seed Initiative (PSI) to enhance distribution of public vegetable varieties to small seed companies and growers interested in selecting their own varieties with a focus on those serving regional, specialty, or organic markets. The PSI has helped us see the need to breed in and for organic systems, and to involve organic farmers in the breeding process. For more on the PSI see the website at http://www.plbr.cornell.edu/psi/

Breeders at Cornell University have never done any breeding in partnership with organic seed companies and we have never selected our varieties in organic systems. When breeders working in conventional production systems have developed disease resistant varieties they often lack quality characteristics that are of high importance to organic farmers. From an organic grower's perspective, it makes little sense to grow a disease resistant variety if it has poor quality. This was shown in the demonstration plots and replicated trials we did with organic farmers in the PSI project during the 2002 growing season. Varieties that had excellent disease resistance were not necessarily preferred by growers, as quality was not up to their expectations.

Project Focus – Breeding a Well-Adapted CMV Resistant Pepper

Cucumber mosaic virus (CMV) severely affects pepper yield and quality. The virus infects hundreds of plant species, is widespread worldwide, and is non-persistently transmitted by many aphid species. CMV causes plant stunting and deformed and discolored fruit, leading to lower marketable yields. There are currently no CMV resistant bell pepper varieties available in any seed catalogs. According to the results of the 1997 National Organic Farmers' Survey, mosaic viruses were included, along with other diseases, as "the most difficult to manage" (Walz 1999). Varieties that have mosaic virus resistance and high quality would be a tremendous benefit to organic farmers.

We have selected this disease and the crop focus because we already have the expertise, and we will be able to produce improved varieties for organic growers while demonstrating the importance of actually making selections in organic systems. The impact of this project will go far beyond improved pepper varieties to demonstrate that the university can be accountable to a community that has historically been ignored, although it represents the only sector of North American agriculture that shows significant growth each year. To begin the process of breeding with and for the organic community, we have started with a high quality, early bell pepper that is already grown and liked by the organic community in the northeast— King of the North, and a disease that is widespread and a significant challenge, and also one with which we have considerable experience and resources to address.

Objectives Statement

The project objective is to breed a CMV resistant bell pepper using King of the North as a commercial parent. King of the North, which has been provided by Turtle Tree Seeds (located in Copake, NY), is an early, cold tolerant bell pepper variety. It is described as a superior variety for both market and home gardeners that matches or surpasses many hybrids. While seeking to add CMV resistance we do not want to compromise on quality or earliness, but rather improve on these traits that are very important to organic growers.

A second project objective is to involve Turtle Tree Seeds[1] and organic growers in the variety development process. They will be able to provide valuable input on breeding in organic systems. In addition, they will provide input on variety characteristics that are important to the organic community. Turtle Tree Seeds is a biodynamic and organic seed company that sells open pollinated varieties. The Northeast Organic Farming Association-New York (NOFA-NY), which represents a large section of the organic community in New York, will play an advisory and support role. They are also a partner in the PSI project.

This project will be done in organic systems or in systems in transition to organic. In sum, at the end of the project we hope to have an open pollinated pepper that is CMV resistant and has all the quality and type characteristics of King of the North, and is hopefully even better than King of the North in terms of earliness and quality.

Materials and Methods

In the winter of 2002-2003 fifteen different Cornell pepper breeding progenies were inoculated in the cotyledon stage with a severe isolate of CMV. These progenies varied for CMV resistance, plant habit, fruit type, earliness, and fruit quality. Approximately 24 plants/progeny were inoculated with CMV. From this group, twenty-six resistant selections (plants) were crossed to King of the North. Many of these resistant plants were segregating for fruit shape and plant habit so the F_1s were selected on an individual plant basis for earliness, fruit shape, flavor, yield and plant habit in the field season of 2003. We grew these F_1s on Cornell's Dilmun Hill student-run organic farm as well as on Peacework Organic Farm in Wayne County, NY.

At Dilmun Hill plants were grown in single rows on black plastic mulch. They were transplanted at the seedling stage in early June and were 24 inches apart. Plots were in beds that were previously buckwheat at the end of the 2002 season, and rye over the winter of 2002-2003. No organic amendments had been added in the last year. Although pepper can outcross to other pepper varieties, we saw no need for isolation as there were no other peppers nearby. The soil type is heavy clay. In previous years large amounts of organic matter have been added, thus improving the soil quality.

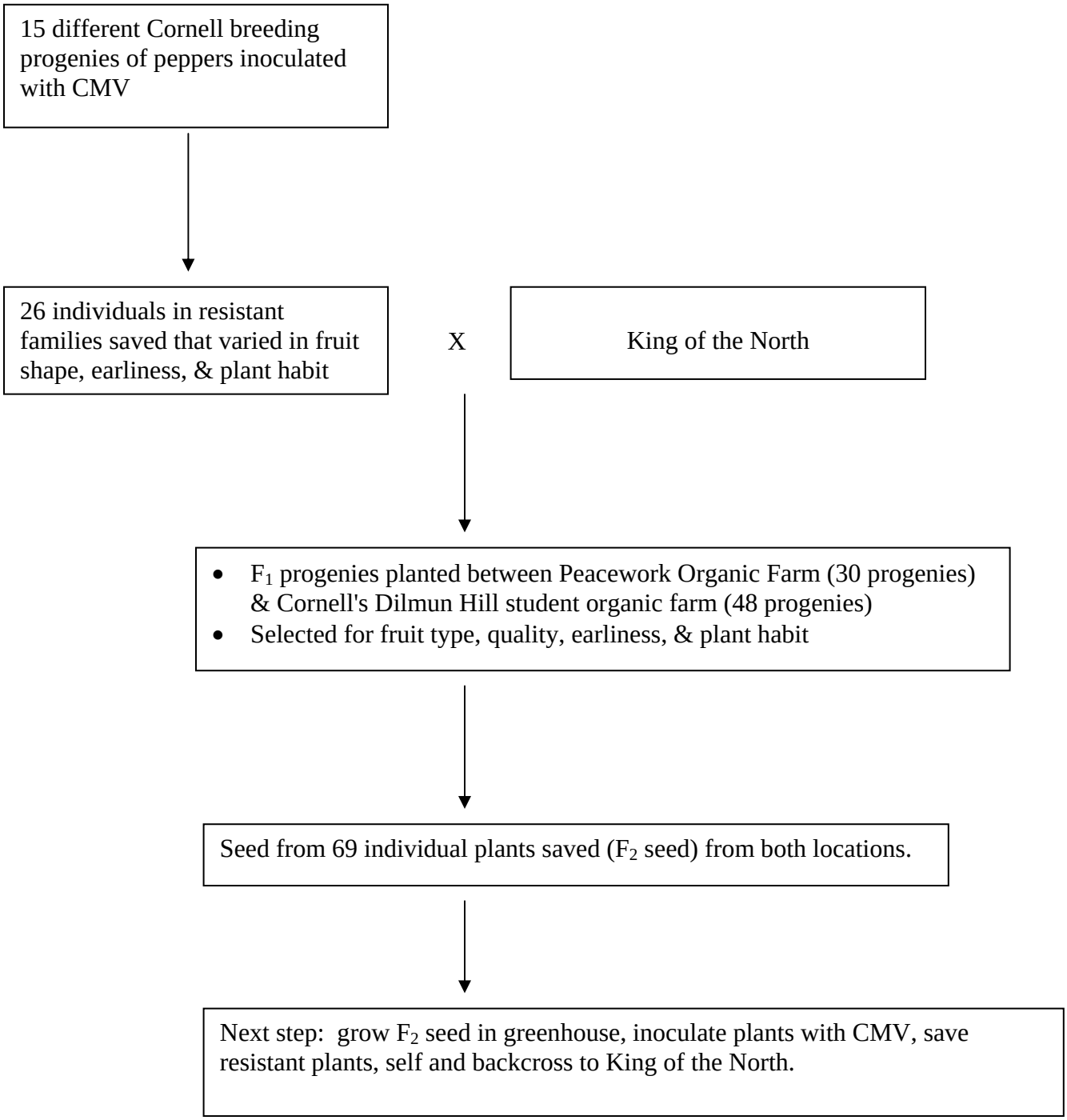
At Peacework Organic Farm, peppers were grown on one bed in a double row on gravelly loam soil. The bed was seeded to rye in October, 2002. For fertility, well-aged horse manure mixed with straw and woodchips was applied at the rate of 10 tons per acre on the bed and spaded into the soil with the rye residue in May, 2003. The bed was spaded one more time before transplanting the peppers. Peppers were transplanted at the seedling stage in early June and were 18 inches apart. Trickle tape was set up for irrigation, but was not needed during the very wet season. There were other pepper varieties on the farm, but we feel they were far enough away so as not to affect the breeding population by cross pollination.

Elizabeth Henderson and Ammie Chickering made observations and notes on earliness, plant habit, and most importantly flavor. Their farm interns also tasted peppers for quality. In addition, the farm's CSA members tasted peppers from plants that were selected for seed harvest. NOFA-NY

[1] This year Turtle Tree Seeds was not able to participate due to a prior commitment.

staff member Michael Glos was on hand to record their observations. Cornell and NOFA-NY staff made several visits and took more detailed notes on earliness and plant habit.

King of the North Breeding Process as of December, 2003



Project Results

The plants in this project were mostly a large segregating F_1 population. There was noticeable (and expected) segregation within and between F_1 families for earliness, fruit shape, and plant habit. In other words, there was variability for these traits. From Peacework Organic Farm and Dilmun Hill we selected 69 F_2 families and one F_3 family to be tested for CMV resistance in the greenhouse this winter. Selections were based on earliness of fruit production and good plant habit. Good plant habit is when fruits set such that they do not touch the ground, the plant is sturdy (no lodging), and there is a good leaf canopy. Peacework Organic Farm made selections based on fruit type, earliness, plant habit and flavor. Notably, they found green fruit from one progeny (03-16) that tasted almost as sweet as a red pepper. There were other plants that produced good fruit, were early, and had nice plant habit.

The farm's selections for earliness corresponded very closely with our own selections from the Dilmun Hill farm. According to Peacework Organic Farm, flavor is the single most important trait in this project, followed by yield, early ripening (to red), good leaf canopy (prevents sun scald), and the fruit growing on the plant such that they do not touch the ground (prevents rot). The following photos show some of the nicest fruit. Information is written on 4 x 6 inch index cards.

Figure 1 – King of the North

Figure 2 – 03-16-4, selected by Peacework Organic Farm for excellent taste

Figure 3 – 03-16-8 selection from Peacework Organic Farm; early and nice fruit shape, good taste

Figure 4 – Early maturing progenies with good fruit type from Peacework Organic Farm.

Conclusions and Discussion

As resistance to CMV is a complex and recessive trait we will test up to 100 plants from each 2003 field selection for CMV resistance in the greenhouse (winter 2003/2004). Testing a large number of plants will give us a better chance of finding resistant individuals. Resistant plants will be self pollinated and backcrossed to King of the North to develop F_3 and BC_1F_1 populations for the 2004 field season. Progenies from this winter greenhouse generation will be grown out on organic land and selected again for earliness, yield, flavor and habit. We plan on continuing to involve organic farmers in the breeding process.

We see this project as a great partnership between organic growers, Cornell, and NOFA-NY. Peacework Organic Farm provides an excellent organic environment, and the farmers made selections in breeding populations according to their criteria of what is important. Their input will help ensure that a variety is produced that organic growers want. Collaborating with the farm has been invaluable to the project. Cornell is able to do off-season greenhouse work to screen for disease resistance and do more intensive (plant by plant) data collection. NOFA-NY provides Cornell with a connection to the grower, as well as an "organic mindset" for Cornell researchers who, for the most part, are only familiar with conventional agriculture.

Our hope is that this project will provide improved varieties, demonstrate the value of participatory plant breeding methods and grower-based selection and lay the groundwork for more breeding in and for organic systems. In many ways this project has been an impetus for us to look for more funding for participatory organic breeding. To that end we have applied for additional funding from the Northeast Region Sustainable Agriculture Research and Education (NE SARE) program that will help breed for traits (in other vegetables and with other public breeders) that are important to organic growers in the northeast.

Elizabeth Henderson commented that, "All of us – farmers and interns – learned more about breeding. Ammie and I enjoyed taking the time to observe the plants closely and to describe the size, shape and distance from the ground of fruit. We are happy to participate in further breeding ventures."

Outreach

We have summarized the results of this project at the American Society for Horticulture Science (ASHS) meeting in Providence, RI in October. Results were presented in an ASHS workshop on organic plant breeding. Results were also presented at Restoring Our Seed's (http://www.growseed.org/index.html) November workshop in Vermont, and at Cornell's Organic Program Work Team meeting in December. This project has been referenced in a NE SARE proposal entitled "Collaborative Breeding in and for Organic Systems." Results will be included in Cornell's Vegetable Breeding Institute (VBI) annual report for 2003. This publication goes to seed companies of all sizes and types both nationally and internationally. A write-up of the project was in NOFA-NY's mid-fall 2003 newsletter. Results will be summarized in the 2003 PSI Trials and Demonstrations Report, which will be available at the January 2004 NOFA-NY annual conference. This report contains results of on-farm (organic) replicated trials and simpler demonstration plots of vegetable breeding material. This project has been described in "Funding and Accountability in Participatory Plant Breeding (PPB): Evaluating experiences of scientists involved in participatory plant breeding," a Master's Thesis by Julia Kolanoski. This is available upon request.

We intend to present the results at the NOFA-NY pre-conference on breeding and seed saving, which will be held just prior the main conference in January (see: http://nofany.org/index.html). We will also publish an article on our PSI website: http://www.plbr.cornell.edu/psi/.

During the growing season members of Peacework Organic Farm's CSA tasted fruit of a number of progenies, providing invaluable data. Cornell and NOFA-NY staff were on hand to discuss the project.

This project was part of the Cornell's Vegetable Breeding Institute Field Day held on August 25, which is an opportunity for seed companies to see Cornell breeding material in the field. Staff from Turtle Tree Seeds attended this field day.

References

Kolanoski, Julia. *Funding and Accountability in Participatory Plant Breeding (PPB): Evaluating experiences of scientists involved in participatory plant breeding*. Master's Thesis. Institut für Sozialwissenschaften des Agrarbereichs, Universität Hohenheim. November 2003.

Walz, E. 1999. Final results of the third biennial national organic farmers' survey. Santa Cruz, CA: Organic Farming Research Foundation. Online at http://www.ofrf.org/publications/survey/1997.html

Breeding an Open-Pollinated Vegetable Variety in Organic Systems:

The Public Seed Initiative – Progress Report for 2004-2006

In the winter of 2003-04 seed was planted from 69 field selections along with the recurrent parent (King of the North) and two new possible parental candidates, Early Red Sweet and Yankee Bell. The strain of Early Red Sweet we received was selected by the family of Frank Kutka (graduate student) in northern Minnesota for cold tolerance and early maturity. Yankee Bell was provided by Rob Johnston (Johnny's Selected Seeds) after discussion of the program.

A total of 4070 F_2 seedlings were inoculated in the cotyledon stage with CMV (V27) and again one week later. Two weeks were allowed for symptoms to develop before the plants were classified. Seedlings showing any virus symptoms were discarded leaving 339 individual plants representing 44 of the initial 72 selections. The survivors of the virus screen were transplanted to six inch clay pots and allowed to grow alongside the recurrent parents. Early Red Sweet was the first parental line to flower followed a week to ten days later by King of the North and another 10-14 days later by Yankee Bell. Any of the F_2 virus tested progenies that did not have at least flower buds at this time were discarded for being too late flowering to suit the objectives of the grant. On all of the remaining plants we attempted to obtain at least one self pollination, one back cross to King of the North, and one cross to each of the potential new parents (Early Red Sweet and Yankee Bell). After the four fruit were set from the pollinations mentioned above the

plants were allowed to set fruit normally so we were able to estimate yield potential. Other selection criteria for this population consisted of fruit size, fruit shape and time from pollination to maturity.

The spring-summer planting for 2004 was left uninoculated due to the fact that several of the breeding lines would be planted on the certified organic land of our cooperators. 96 F3 families generated in the winter screen were divided between Peacework Organic Farm (certified) in Wayne County, NY and Turtle Tree Seed Company (biodynamic) in Copake NY. Where we had enough seedlings the families were split between the above two locations. In a few instances there were enough plants to have a replicate on Cornell ground as well.

A separate planting at Cornell consisted of 112 other F_3 families, 94 Back cross 1 F_1, 60 new F_1's with Early Red Sweet and 37 new F_1's with Yankee Bell. The planting at Cornell was designed to keep related families next to each other to facilitate comparisons within related populations. An example of the planting plan is shown in the Table 1, below.

Table 1

F3 sel 1	F3 sel 2	F3 sel 3	F3 sel 4
F3 sel 1 X KON	F3 sel 2 X KON	F3 sel 3 X KON	F3 sel 4 X KON
F3 sel 1 X ERS	F3 sel 2 X ERS	F3 sel 3 X ERS	F3 sel 4 X ERS
F3 sel 1 X YB	F3 sel 2 X YB	F3 sel 3 X YB	F3 sel 4 X YB

KON = King of the North, ERS = Early Red Sweet, YB = Yankee Bell

The summer of 2004 turned out to be quite wet and much to our surprise the peppers did great. Throughout the summer selections were made at the Cornell plot for earliness of flowering, plant habit, fruit shape, early maturity, uniform maturity and yield. In many instances early flowering did not correlate with early maturity. Cornell and NOFA staff visited both cooperators' sites to assist with selection. The plantings at Peacework Farm looked very similar to the Cornell plantings. The plantings at Turtle Tree had a much different habit, they were much taller with smaller leaves and fruit but the days to maturity were similar. At harvest time we also took into consideration the number of mature fruit per plant, fruit size and flavor while deciding what to harvest for seed. After harvest a soluble solids sample was taken and read through a hand held refractometer to obtain a brix reading. The % brix was used as a measure of sweetness and weighed into our decision of what to plant for our winter virus screen.

Winter '04-'05

For our winter virus test we took into consideration flavor, soluble solids and number of ripe fruit along with all of the criteria for field selection. We included 24 F_4 families selected by Elizabeth Henderson in Newark, NY and 16 F_4 families selected by Beth and Nathan Corymb of Turtle Tree Seed Company in Copake, NY. All other selections included in the winter screen were from Ithaca, NY and consisted of six F_4 selections, nine BC1 F_2 selections, seventeen F_2's with Early Red Sweet and two F_2's with Yankee Bell.

We inoculated a minimum of 30 plants for each F_4 selection and tried to have 100 plants of each F_2 selection. The seedlings were inoculated in the cotyledon stage and again one week later. Seedlings were classified 10 to 14 days after inoculation (3507 susceptible plants were discarded

leaving 1047). To further reduce this population any plant that had not flowered by the time King of the North had open blooms was discarded. Self pollinations were attempted on all remaining plants, the earliest flowering plants were also intercrossed.

Summer '05

With several lines becoming fairly uniform we decided to include a few of them in trials organized through the Organic Seed Partnership as well as with our original cooperators (Elizabeth Henderson and Turtle Tree Seed Company). Seed was also sent to Mark Hutton (Extension U. Maine), West Coast Seed in Delta B.C., one grower in Glen Rock, PA, five Northeast Organic Farming Association (NOFA)-affiliated growers throughout NY and two growers in New Mexico to see if these lines hold up under hot dry conditions.

Turtle Tree Seed Company received four F_5 lines, three F_3 families with Early Red Sweet and one new F_1 between two early flowering F_4 selections. Elizabeth Henderson received thirteen F_5 lines (two of them were yellow fruited), one yellow F_4, one BC1 F_3, two F_3's with Early Red Sweet and sixteen new F_1's resulting from crosses between early flowering selections in the winter virus screen. On Cornell organic ground at the Freeville research farm we planted twenty-two F_5 lines, sixteen F_3's with Early Red Sweet, twenty-three BC1 F_3's to King of the North and forty-five new F_1's resulting from crosses between the earliest flowering lines from the winter virus test. All transplants were through black plastic mulch at two foot spacing with drip irrigation. On other Cornell farms the planting consisted of six F_5 lines, 39 F_3's with Early Red Sweet, six BC1 F_3's to KON, four BC1 F_1's with ERS and 22 new F_1's. These were also planted at two-foot spacing through black plastic mulch with overhead irrigation.

The summer of '05 turned out very hot and dry. One of the major observations made was the breeding lines with King of the North and CMV resistant material dropped their flowers in the heat resulting in a split fruit set or a late fruit set. The vast majority of lines with at least one cross to Early Red Sweet selected for cold tolerance maintained their flowers and set fruit all through the summer resulting in an early and sustained yield. With so many selections being made at all the locations we decided to use very strict criteria to reduce the number of families to be carried forward in this program.

Winter '05-'06

Only four of the most advanced lines (F6) met the criteria to be carried on for the winter screen. All of these had a brix reading of 8% or higher, large blocky relatively early maturing fruit and an upright stocky plant habit with good foliage cover. Eight (BC1 to KON F4) families met the same criteria. Thirteen Early Red Sweet F4 selections that held their flowers during the heat and produced a very nice crop rounded out the winter screen. Our virus culture was contaminated with Tobacco Mosaic virus and confused the results so much that this winter screen had to be replanted.

Summer '06

The same lines were planted in the spring and inoculated. Survivors were taken to the field and observed throughout the growing season. The best performing lines from the winter screen were sent to OSP hubs for replicated trials. Replicated trials were located at Cornell University

Freeville Organic farm, Oregon State University, University of California-Davis, Alcorn State University-Mississippi, West Virginia State University and University of Wisconsin-Madison. All of the data has not been compiled at this time but our plan is to select the best performing lines, run them through another virus screen and increase the seed in isolation and offer it to seed companies for commercialization. Observational trials (not replicated) were held at 12 locations in NY (coordinated through NOFANY) and one location in each of the following states Maine, Montana, New Jersey, Oregon and Wisconsin. Many of the same lines included in the replicated trials were also included in the observational trials. Data from all sources will be included in the decision of which lines to commercialize.