

O.F.R.F. Final Report November, 2014

Title: Create open pollinated sugary enhanced sweet corn varieties. Funded: 2011 - 2014

Summary: The purpose of the grant was to develop sweeter open pollinated corn and to document how this could be done by others. Four years of selection in Top Hat and Tuxana corn and two years of selection in Ana Lee and Festivity corn were completed under this grant.

Introduction to Topic: Selection work in open pollinated sweet corn was largely abandoned 60 or 70 years ago. Nearly all of the sweet corn grown today, organic or otherwise, is hybrid. Hybrids require that farmers buy new seed every year. Open pollinated sweet corn has the advantage to growers that the seed can be saved and replanted. It can be further adapted to specific climate, soil and pest conditions at specific locations. There is little high quality open pollinated sweet corn available. There is little corn available, hybrid or open pollinated, that is bred and selected for organic and low input conditions. It is my hope that "Top Hat" and "Tuxana" sweet corn play a role in filling that gap, and that the methods documented under this grant help others to develop more organic-friendly sweet corn choices.

Objectives Statement: The objectives for the work under this grant were to develop sweeter open pollinated corn varieties, and to document a protocol for sweetness selection in a variable population. Working with different methods of selection for sweetness has been quite a valuable learning experience.

Materials: The materials used in this project are genetic materials. Prior to the beginning of funding, I conducted variety trials and chose the varieties from which I would select new cultivars. I had performed a couple of generations of selection on my own.

Description of the breeding material used in this project:

Top Hat and Tuxana are related varieties and share a parent. Prior to my application for grant funding, I did a trial grow-out, planting one 100' row each of 14 sugary enhanced f1 hybrids from commercial sources. One variety, Tuxedo, was chosen. It stood out in a couple of respects. It was the quickest to germinate, an important trait when weeds are an issue. Two weeks after planting, it was taller than all the rest. Further, the husk of the mature Tuxedo ear covered well past the tip and held tightly to the ear, making it more difficult for insects to get in. Top Hat is stabilized or "de-hybridized" from Tuxedo. Currently this population is in the f7 generation.

In my trials prior to this grant, a diverse Anasazi landrace corn, with Tuxedo providing the pollen, produced large ears (large in diameter as well as length) with good flavor. It produced well in an under-fertilized, and only partially weeded field. More varied, and less common, genetics were present in this Anasazi corn parent. Anasazi, the "mother" parent of the Tuxana, Ana Lee and Festivity corn varieties, has provided unique traits, including what appear to be sweetness genes other than *se*.

The challenges were a great deal of variability (also a benefit) that make more generations of selection necessary, and a lack of sweetness. Before the beginning of grant funding, I had grown out the f2 or f3 populations and begun the process of selection.

Methods: Selection techniques used for general characteristics such as plant quality, ear quality, and productivity, involved simple mass selection (choosing the best plants and best ears), and ear-to-row selection. In ear-to-row selection, "daughter" or "half-sibling" lines, each from a single parent ear, are evaluated. Remnant seed from the parent ears that produced the best families is planted the next year to produce improved seed.

Selection for organic conditions was focused on the ability of corn plants to compete with early weeds and grasses, produce good corn under conditions of only moderate fertility, and sustain a minimum of insect/earworm damage. Selection for the ability to compete consisted of planting seed at triple density into rows in field with a high weed seed load. After planting, weeding and thinning occurred continuously, but only enough at the seedling stage to pick out the most competitive seedlings. Selection for production with moderate fertility consisted of working on low fertility ground, and only applying modest amounts of fertilizer (processed chicken manure). Regarding earworm damage, I generally applied *bacillus thuringiensis* (*Bt*) once, and then looked for ears with undamaged tips at maturity.

A primary purpose of this grant was to achieve higher corn sweetness levels. Over the course of the grant, several methods of selection for sweetness were tested and used. These fall into three categories: selection by taste testing of the secondary ear, individual kernel selection by the rate of commencement of wrinkling, and ear-to-row selection with tasting of "daughter" ears.

Taste appears to be the most reliable method of measuring sweetness available to the farmer. In the first 2 years, we experimented with using a refractometer for measuring sugar content. This method is slower, and I think less reliable, than human taste. Cleaning and drying the tools (refractometer, knife and garlic press) between each sample is a challenge in the field. Also, a person can pick up an off-flavor that the refractometer will not. Furthermore, I have since learned that, in sweet corn, soluble solids other than sucrose can read as brix, affecting the reading. Most people can tell a sweeter ear from a less sweet one. Tasting proved to be the most reliable way to evaluate sweetness.

One year we did time delayed taste testing in the Top Hat. Both the primary ear and the secondary ear were marked on the husk with the same number. The secondary ears were harvested and stored for two days. Then a group of tasters came over and rated them by number, with higher numbers representing sweeter corn. It was not possible for to measure the amount of additional benefit gained by selecting for the ability of an ear to hold sweetness after harvest. It takes a lot more time to delay tasting. We performed delayed taste testing of 300 Top Hat ears one year, and that was a challenging project, although it was a fun and interesting community event. Keeping a larger plant population seemed to be of more value

than the more intensive scrutiny of delayed tasting. I was able to select from a population of 1500 - 2000 tasting directly in the field.

Two tasters, working adjacent rows, and cross checking or consulting with each other regularly, can go through two 100 foot rows in about an hour. A person will usually last two or at the most three rows before taste burn out. A key to getting tasters to last is to convince them to only take tiny bites and perhaps spit the corn out rather than swallow at the beginning. The taster who "chomps down" on the first ears of corn (as many are tempted to do) will be overdosed a hundred ears later. We experimented with a number of methods, but this using two people across from each other on adjacent rows proved to be the best way to select the corn populations in this project.

Taste testing became an annual community event at Lupine Knoll Farm. In exchange for coming out to taste and select, participants could take home enough corn to put up for the winter. There were as many as 12 tasters out making choices on some days. Tasters look only at plants with two good ears, then they harvest and evaluate the qualities of the secondary ear, leaving the primary ear from chosen plants flagged and left undisturbed to mature seed. This process leaves many hundreds of primary ears that were not selected available to harvest for food.

Individual kernel selection is choosing the last kernels to commence wrinkling as dry down begins. The process involves harvesting the corn as early as it becomes able to produce viable seed. The ears are left in the husks, checked daily and shucked and opened to the air as the first kernels on that ear begin to wrinkle. As dry down begins, the last kernels to maintain full plumpness are colored with a felt marker. This method, first shown to me by Dr. Carol Deppe, was the method (along with taste testing) that was used in Top Hat to select for sweetness.

In the lines with an Anasazi parent, individual kernel selection did not increase sweetness. I believe some other characteristic present but variable in the Anasazi corn has a larger influence on wrinkling than does sugar content. Individual kernel selection led to the creaminess present in the Tuxana corn, an unintended but positive consequence. After selecting individual kernels in 2011 and 2012 and not getting gains in sweetness, I changed to a method of taste testing secondary ears followed by conducting ear to row growouts for the 2013 and 2014 seasons in the Anasazi cross lines ,.

Ear to row selection (also known as mother-daughter or half sibling selection) involves shelling seed from candidate ears into separate numbered individual bags, and growing out mini-rows from each of these parent ears. The mini-rows, rather than single plants, are evaluated and compared, and the best families are chosen. In Tuxana we evaluated 300 and picked the best 100. The remnant seed from only the chosen 100 is combined and grown out the following year. Replanting remnant seed, and not using the seed produced by the daughter plants, speeds improvement by eliminating pollen from inferior ears from the population.

All of these methods are shown and described shown in my "making corn sweeter" presentation.

Project Results:

"Top Hat" and "Tuxana" sweet corn cultivars, selected for two or three years prior to this grant, and for four years under this grant, will be grown in 2015. I plan to have seed available for sale next fall. Both of these varieties would benefit from further cycles of selection. After growing for production in 2015, it is my hope to further improve these varieties in future years.

The purpose of the work under this grant is to develop new sweet corn varieties and to document how this can be done. What follows is the status of the individual varieties after four years under the grant:

Top Hat has been selected in each of the four years under this O.F.R.F. grant. The 2014 grow out was the f7 generation. I grew about 2/10 of an acre of Top Hat from ears chosen in the f6. Out of about 1200 plants, 300 were chosen, taking into consideration both taste and appearance. This "best of the Top Hat f7" is the stock seed for the f8 generation. There are about 40 lbs. of this selected seed to carry forth with Top Hat. This seed will be used to grow seed for sale, and, hopefully, also for future cycles of selection and improvement of Top Hat corn.

Tuxana corn has also undergone four generations of selection under this grant. Tuxana went through an ear to row selection in 2013, choosing 100 parent ears out of 300 evaluated. In 2014, remnant seed from the 100 selected f6 ears was grown out on about 1/3 of an acre. Roughly 2000 secondary ears from two-eared plants were taste tested, and about 550 were chosen based on sweetness and flavor. The primary ear from these selected 550 plants was harvested and dried. I further selected for quality and uniformity in appearance of these ears as they dried, and 250 ears were chosen. The seed from these selected 258 ears has been bulked and is the stock seed for the f7 generation. This seed will also be grown for sale next year, and I hope, for future cycles of selection and improvement of Tuxana corn.

Festivity being multi-colored, remains more diverse than the other lines from the Anasazi x Tuxedo cross. An ear-to-row evaluation was completed in 2013, evaluating the progeny of about 200 parent ears from the f5 generation. Of these, 100 were chosen on the same general criteria used in the Tuxana. In 2014, remnant seed from the 100 selected f5 ears was grown out on about 1/4 of an acre. The field crew tasted all the secondary ears and flagged about 450 based on taste. There are some very sweet ears in this population. Of these, about 250 have been selected based on appearance of the primary ear. These will be individually shelled into paper bags to allow a second cycle of ear to row selection to occur in a future year. In addition, there are 77 individual-ear bags selected from a related population grown in 2012 to be included in the next ear to row growout. Further cycle(s) of selection in Festivity are warranted.

Ana Lee will be a yellow corn selected from the same parentage (Anasazi x Tuxedo) as Tuxana and Festivity. Breeding in Ana Lee (earlier dubbed "Tux Yellow") has occurred for two generations under this grant. In 2013, about 1/4 acre of Ana Lee was grown and harvested, and 300 ears were selected and evaluated in an ear to row grow out in 2014. Of these 300 f5 parent ears, 100 were chosen by the quality of their progeny. Remnant seed from those chosen 100 will be grown out in a future year. Further cycle(s) of selection in Ana Lee corn are warranted.

Conclusions and Discussion: The cycles of breeding proposed in the original grant request have been completed. I plan to grow Top Hat and Tuxana corn in 2015 as seed for sale.

Top Hat and Tuxana both would benefit from further cycles of selection. I was perhaps overly optimistic about the degree of uniformity I could attain in the six generations of selection before and under this grant. Further cycles of selection will make them better for the mainstream sweet corn market. Both Top Hat and Tuxana, however, can now produce good quality corn that is sweeter than most other open pollinated sweet corn currently available.

The Festivity and Ana Lee varieties received a "boost" of two years of selection under this grant. Both varieties look and taste promising, yet they will require more generations of selection before they can be considered for commercial release.

During the course of this work, I have stopped referring to a *se* (sugary enhancer) gene and begun referring simply to sweetness. I have now learned that there are several genes that impact sweetness. In the Top Hat, created by stabilizing a modern (1990's) fi hybrid, the sweetness stabilized was in all likelihood, *se*.

The Tuxana, Ana Lee and Festivity lines have an Anasazi corn parent that is highly diverse. It is my belief that earlier people developed the Anasazi corn with the intention of collecting diversity and not creating uniformity. These lines are likely to become sweeter with further breeding. Sweetness in these varieties involves *se* as well as other genes that enhance sweetness.

The work improving these open pollinated corn lines is not completed. I hope to find funding to continue refining this set of promising new sweet corn varieties. The cycles of selection proposed in this grant have, however, been completed.

Useful Tools, Information and Resources for Farmers:

The tools and resources created under this grant are genetic resources. With some further refinement, open pollinated corn finally begins to emerge as a real option for growers of sweet corn.

The information is about how new varieties can be created that are suited to low input and organic conditions, and how to increase sweetness. Importantly, I have shown how these crop improvements can be made, or new varieties created, without advanced technology or large amounts of money. Others may see that they too can step up from gardening or farming to

plant breeding and crop improvement. It may help return crop improvement and varietal ownership to the farmer. This information may have particular value in poorer nations where old and inferior native varieties compete with patented GMO hybrids. This knowledge may help to empower rural people in poor nations to grow more and better food.

Outreach:

The most valuable reaching out with the knowledge gained under this grant was a talk and power point presentation titled "Making Corn Sweeter" that I made at the 7th annual Seed Growers sponsored by Organic Seed Alliance Corvallis, Oregon, January 2014. This presentation was recorded and is available from E-organic on YouTube. I discussed taste-testing, individual kernel selection and ear-to-row selection as tools for improving sweetness in open pollinated corn. It is a "how to" presentation that shows how sweet corn can be improved using methods within the reach of the average farmer.

Two farm tours at Lupine Knoll Farm, including discussions about corn and corn breeding were conducted during the time period of this grant.

Posters describing individual kernel selection were posted at Organicology or Organic Seed Growers conference in 2012 and 2013.

Short articles "The Top Hat corn story" and "The Tuxana corn story" have been prepared and printed in small and local publications.

Financial accounting: The great majority of the expenses under this grant were for my labor, charged at \$20/hr. All the work planned in the initial grant and in the annual grant requests has been performed. In more cases than not, my hours exceeded those anticipated. Several expenses in the work performed were self-funded. I had asked no payment for such expenses as cover cropping between corn cycles, or the labor in removing irrigation and mowing after harvest. The funded hours were completely and gainfully used. In 2014, electricity cost estimate for drying seed was a little high (it was an early season, less heat was needed) but fertilizer was underestimated as costs went up. These expenses about balanced out.

Leveraged Resources: I submitted an application to continue my sweet corn improvement project to NIFA / AFRI #10.310 in April of 2014. This was, unfortunately, not funded. I have not yet found funding to continue this project.

References: The references I used were mostly human references. Special thanks to Dr. John A. (Jack) Juvik (University of Illinois), Dr. James R. (Jim) Myers, (Oregon State University), Dr. John Navazio and Jared Zystro (Organic Seed Alliance), Dr. Carol Deppe, and Dr. Alan Kapuler. All of these people gave of their time to answer my questions or make suggestions to improve my work. The book that most inspired me towards plant breeding is "Breed Your Own Vegetable Varieties" by Carol Deppe.

Photos and addenda:

The YouTube presentation "Making Corn Sweeter" can be viewed at:

<http://youtu.be/wKWPYkTOqk?list=PLZMuQJAJ6rOpFS40cWZ8Xn4O96tKisMHb>

The attached "Top Hat Corn Story" and "Tuxana corn Story" were printed in local publications

Photo descriptions for attached pictures:

"Top Hat" is an ear of Top Hat corn.

"Tuxana52" is Tuxana corn with Doucet Plum tomato.

"Corn Festivity LKF 6632" is Festivity corn, drying on the ear.

"Me247" is Jonathan Spero with Top Hat corn.

"People 6540" is corn tasters evaluating rows in an ear to row selection.

"IMG 3157" and "IMG 3168" are pictures of a farm tour conducted at Lupine Knoll Farm showing the process of ear to row selection. These two photos taken by Chuck Burr, Restoration Seeds.