Organic farming research report submitted to:

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Title: ***Developing Open-Pollinated Corn Varieties for Organic Farmers***

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Project Summary:

The purpose of this project has been to develop and evaluate our open-pollinated corn varieties for organic farmers. Our major efforts have been to increase the qualitative value and future marketability of these populations and also to increase their genetic diversity and agronomic value. This year we continued to breed ***white, yellow, red, and blue field corn*** varieties towards fitting niche markets that would give farmers that used this corn economic benefits. This included the following tasks: 1) We made crosses between blue and red populations with white populations in order to broaden the genetic diversity of these colored crns and to breed for white endosperms. 2) We made crosses between our population of ***large-seeded, white flour corn*** in order to diversify the population and increase its agronomic value. 3) We evaluated 46 different lines of our ***high-lysine, high-oil, and high vitamin E corn*** in replicated trials for yield and standing ability. 4) We inter-mated our high oil, lysine, and vitamin E corn populations with inbreds from the University of Illinois that possess high oil, carotenoid, and vitamin E contents in order to try to add the high carotenoid trait to our populations. 5) We crossed one of our white seeded populations with white seeded inbred populations from South Dakota State University with the goal of deriving a set of white seeded populations with different maturity dates.

We discussed the project with farmers at ***three field days.*** The first was at the Walworth County Farm on Sept. 22. Thirty-five people attended, mostly farmers, and there was a lively discussion with a lot of questions. 'The following week a group of farmers were shown how to select corn on the farm of one of our cooperators. Two field days (July and September) were held on an organic farm for (Mike Hartmann, Gibbon, Minnesota) for a group of 12 farmers that are growing our variety Nokomis Gold 98 in Minnesota. They learned how to selectively de-tassle corn before pollination and learned, hands-on, how to select it at harvest (considering plant type, stalk strength, standing ability, health, grain moisture, and yield).

Farmers would like to know whether mass selection on their farms over several years might increase the value of corn for their individual farms. Therefore, we carried out mass selection on several organic farms with the variety Nokomis Gold 98 under their normal field conditions. Farmers either did the selection themselves, were assisted by us in making selections, or we made selections for them. The selected corn will be planted again in the following years and hopefully re-selected each year. Seed from each harvest will be kept and eventually grown out together to on farms to show whether we have made progress.

Introduction to Topic:

Farmers are interested in open pollinated varieties because: 1) they can have enhanced quality (protein, oil, and taste); 2) it is possible to save true-to-type seed; and 3) these farmers are searching for alternatives to hybrids. Our varieties represent 12 years of breeding to create competitive varieties. Nevertheless, our corn still lags behind the commercial corn in terms of yield potential, standing ability, and insect resistance, and it needs continued breeding input.

Up to now we have released only one field corn variety that is suited for feeding livestock (Nokomis Gold 1998). But we have other varieties in different stages of development that could fit more valuable marketing niches. These include food grade varieties with white, yellow, blue and red seed. They also include corn that has enhanced nutritional value because it has a high content of oil, protein, and vitamin E. None of these have been released for farmers because they need more improvement.

In the year 2000 we focused on three efforts; these were: 1) to evaluate and improve these specialty corns; 2) to educate farmers about our program and to train them on how to do their own selections; 3) to begin to select corn on farms in order to see if long-term mass selection might improve the variety for individual farms.

Blue corn has sold at high prices ($12-$16/bushel). Yields of open-pollinated varieties are generally low (40-60 bu/acre) and there are great problems with lodging and disease. However, our blue population has a narrow genetic base and has been losing vigor, probably due to being somewhat inbred. Furthermore, there are no commercial red corn varieties adapted to the upper Midwest. Farmers in the southern parts of the Midwest are using a red Mexican flour corn to supply the needs of processors. There is also a demand for large seeded, white flour corn and there are no good cultivars for the Upper Midwest. Grain was selling at $16/bu in 1998. Furthermore, there is a growing market for white corn with normal seed size at a lower price advantage relative to the hybrids. All commercial white-seeded hybrids are late season and are unsuited for production above the border of Illinois and Wisconsin as well as for other regions of the Upper Midwest.

There is a growing interest among Japanese importers of corn for high quality characteristics including nutritional factors. We have been breeding corn for quality nutrition, trying to combine high oil, protein, lysine, vitamin E and carotene content. Vitamin E and carotenoids are anti-oxidants, and their use in feeds is expected to increase longevity and quality of meat and to transfer to health benefits for consumers. If we can produce varieties or varietal hybrids with acceptable agronomic characteristics there may be a market to ensure their use.

Kurilich and Juvik (1999) tested numerous corn inbreds for their content of carotenoids and tocopherols. The yellow dent inbreds that were tested ranged in their carotenoid content from 6 to 31 µg/g; the high quality Illinois inbreds R802a and R806 had 31 and 17 µg/g. The yellow dent inbreds ranged from 25 to 47 µg/g of total tocopherols with the highest content for the Illinois inbreds R802a and R806 (40 and 47 µg/g , respectively). In conjunction with Dr. Jack Juvick, University of Illinois, Urbana, Dept. of Natural Resources, we evaluated several of our own dent populations MF 8+14, MF 10, MF-GE, MF-LE, MF-SS, and MF-1819). The MF population 1819 is our high quality population. In general our populations had total carotenoid contents of 5 to 8 µg/g. This is higher than the 2.5 µg/g reported by Weaver (1987) as characteristic of hybrids, but lower than for two inbreds from Illinois, R802a and R806. The MFAI populations had tocopherol levels ranging between 22 to 30 µg/g. An exception to this is MF 1819. It had the highest total content ever recorded to our knowledge of 97 µg/g. Therefore it seemed expedient to continue to cross MF 1819 with R802a and R806 to try to combine characteristics for high carotenoid contents, high protein, oil, and lysine into one population.

Objectives of this project:

Our original objective was: to improve the agronomic and market acceptability of open-pollinated corn populations for organic farmers through breeding. We stayed with this objective. There were some changes in how we did the project relative to our original intentions and these are outlined in the results section with a justification for the changes.

Materials and Methods:

Two nurseries were managed about 700 feet apart on the Goldstein farm. This farm was certified as a Demeter farm located on a hill several miles away from neighboring corn fields. On one site (about 1/4 acre) corn was grown in 2000 in a rotation of six years of pasture (1998)-vegetables (1999). Manure compost was applied at 40 tons/acre. The second nursery was one acre in size. Corn followed after a two year stand of alfalfa + grass. Manure compost was applied at the rate of 10 tons/acre. In general standard practices were used for crossing corn using tassel bags and silk bags. Varieties were planted out in blocks with staggered dates to stagger the load of pollinating by hand.

On the one-acre plot an experiment was set out with three reps of a randomized block design to test ear to row plantings of 46 different ears with 3 replicate plots per ear. Ears used were of the high lysine and oil populations and mostly from 1819. The first replicate was intended for use as a nursery, for cross pollination of lines. The second and third replicates were combine-harvested for yield and moisture. Plots were 20 feet long and two rows wide with 3 feet between rows. Plants were seeded at 24,000 plants per acre. This is unusually low (usual rate 27,000-29,000 plants/acre), but spring promised to be a drought and I was afraid of planting at too high of a density. Every fourth two rows was planted with a mixture of seed from all the ears which were to be utilized as pollen donors for the plants in the middle. It did not turn out to be feasible to use this scheme. Flooding conditions thinned out the stands so that we did not trust these intended pollen donor stands to adequately pollinate the plants. Therefore we fell back to individual plant selection throughout the stand of the first replicate to select those plants that would be allowed to be' pollen donors 'in order to ensure adequate pollen distribution.

Selection was practiced before anthesis on high lysine and oil and on yellow corn populations with white cobs. Plants were inspected on a daily basis at the time around anthesis and tested for stalk flexibility by pushing on the plant (plants that whipped around were detassled because we suspected that they would have poorer root, development and would be, susceptible to root lodging at harvest). A hand held penetrometer was used to test rind strength at nodes below the ear . Rind strength is a good indicator of stalk strength. Only approximately 1/4 to 1/7 of the plants in the high lysine/oil stand were allowed to contribute pollen based on these criteria. Selection at harvest took into consideration overall plant height and standing ability; height of the ear, size and apparent moisture content of the ear, lack of disease or physical defects, response to shaking the stalk (did it resist shaking?), and squeezing the stalk to get an idea of rind strength.

The same method which I used on test plots was taught to farmers for on-farm selection. However, the majority of farmers did not select before pollination but rather only mass selected at harvest. Farmers were encouraged to gather a minimum of 100 ears for seed in order to maintain stocks with adequate genetic diversity and to avoid inbreeding.

Project Results:

It is -difficult to discuss results from a long-term breeding program as anything but progress in the context of a process.

Breeding blue and red corn: We had blue and red seeded corn populations. In the past, our open-pollinated blue and red corn populations stood relatively well and have yielded on a field basis at 80-120 bu/acre when planted at 27,000 plants/acre. But there are two problems with these populations. First, both populations have a narrow genetic base. The blue population has been progressively showing signs of being somewhat inbred by losing its vigor. The red population is presently very vigorous, but its constitution is probably also narrow. Also, our blue and red corns had some white but mainly yellow endosperms. Lloyd Rooney, corn quality specialist from Texas A&M University, informed us in the spring of 2000 that his latest baking trials showed that only blue or red seeded corn that possessed white endosperms would keep their color in chips. With all this in mind we changed plans this year. We had planned to self-pollinate red and white plants in order to further fix and select for qualitative characteristics. Instead we made numerous crosses between our red and white populations and between our blue and white populations. White seed have white endosperms, and we, need to obtain this under a red or blue seed coat. Next year's grow-out will be self-pollinated in order to isolate plants with blue aleurones or red pericarps and white endosperms. Of the crosses made, ears from 280 plants were field selected for further multiplication. Seed from these plants will be grown in 2001, self-pollinated, and further selected for red or blue seed with white endosperms.

The white and blue or red corn varieties that we have crossed are derived from populations of different origin. We expect that we may see high yields from these crosses, due to heterosis ("hybrid vigor"). It is important to evaluate this in 2001, because if the yield increases are large, it might mean that we should consider developing varieties that could be crossed to give very high yields. Results from USDA corn breeders in Iowa suggest that varietal hybrids can produce yields that, are practically equivalent to yields of hybrids that are based on crossing inbreds. The making of varietal hybrids, rather than producting hybrid seed from crossing inbred populations, is relatively easy for farmers to do. This is because inbred lines are difficult to grow without herbicides, due to their relatively weak growth and lack of competitivity with weeds. Our varieties are quite vigorous and relatively competitive with weeds. We think it is probable that in the long-run organic farmers could easily grow their own varietal hybrids and still maintain independence, quality, and yield.

Breeding yellow corn: An additional effort was made to breed "food-grade" yellow corn with white cobs, but we did not have great success. Our varieties already have the hard yellow endosperms that are desired, but they have a mix of white and pink cobs. The pink cobs are not acceptable because their pink glumes make spots on chips and tortillas. White-cobbed plants from four populations were mass selected in 1999. Seed from these plants were not genetically fixed in this trait. In the spring of 2000 this seed was planted out in test plots with strips for each of the four populations. Unfortunately, flooding on the site reduced the stands and led to a delay of date of pollination. We were unable to self-pollinate individual plants because these plots needed to be pollinated at the same time as the blue and red corn. Therefore, we decided to base our program this year only on mass selection, with some minor bi-parental control of pollinators for agronomic characteristics. Out of four populations, seed from 488 white-cobbed plants were selected for further grow outs in 2001. This seed will be planted out and. self pollinated in order to establish, select, and thereby fix the white-cobbed trait in these four populations.

Breeding large seeded white flour corn: We continued to breed our population of large seeded white flour corn. This population was first developed from Tuscarora Indian corn that was backcrossed twice with our populations in order to increase stalk strength, standability, and disease and insect resistance. This year lines of this population, some of which had been self-pollinated in 1999, were inter-mated in order to broaden the genetic base of the population. We are concerned about avoiding future bottlenecks in yield due to inbreeding depression as we continue to select this population for agronomic characteristics and large seed size. We selected individual plants from each of the lines hard for standing ability and stalk strength with a penetrometer before flowering and only used pollen from the best plants for crossing. At harvest we selected 125 of the best plants for standing ability, plant health, and seed moisture content. Seed from these plants was further selected on the basis of seed size and the flour seed trait.

Breeding white dent corn: Successful crosses were made with five white corn inbreds from South Dakota State University. These inbreds comprised a range of maturities. The offspring of these crosses should enable us to breed early lines for the Upper Midwest that presently are simply not available.

Breeding high oil and high lysine corn: Instead of the drought we expected we got a flood. The plots planted into the high lysine/oil corn were the wettest of all, though the nursery replicate was somewhat drier than the others and showed better growth. Corn was affected by intermittent flooded conditions during its germination and early growth.

Undoubtedly the greater proportion of nitrate in the soil was denitrified as the corn appeared to be deficient in N during the early part of the growing season. The variation in the field was large and could not fully be blocked out by the layout of the replicates. Differences between different lines were obscured by the high degree of variation associated with micro-sites and flooding. Yields were low. Previous years of experience have led us to expect yields of 80-120 bu/acre for this population. However, yields this year ranged between 17 and 104 bu/acre. The average yield, over all reps was 56.4 bu/acre. This is a yield which in our experience is generally achieved on this soil type when no fertilizer is applied and corn follows after crops that do not contribute large quantities of N. We suspect that a great deal of the N was made available out of soil organic matter and slower release forms of N from the manure and alfalfa. Nevertheless, the first replicate provided us with adequate chances for selection based on agronomic performance characteristics. A total of 667 individual ears were selected from test plots and seed from the top yielding ten varieties was sent away to the University of Minnesota for testing of lysine, oil, protein content. We have not yet received a report on the results.

Successful crosses were made between our high oil and lysine populations and Illinois inbreds R802a and R806, which have high oil, protein, vitamin E, and carotene content. Our seedstocks of these two inbred lines were very limited and they are both late maturing but we managed to make 50 successful crosses.

Conclusions and Discussion:

Due to the weather we had some setbacks but nevertheless we made progress in our breeding work. However, results must be seen in a larger context than a single year. We are getting an idea of what our first variety Nokomis Gold does for organic farmers. Yield estimates in bushels/acre for the Nokomis Gold on the farms were 110 for Pounder, 85 for Zinniker, 1 10 for Moora, 100 for Adams, 120 for Specht, not available for Adams, and 150 for Hartmann. In general this was 20 to 40 bu/acre less than for hybrids. We realize that our yield potential lags behind the hybrids. Catching up will be a long, uphill battle. We probably should do more work with varietal hybrids to evaluate whether our present populations, crossed with each other, might not give yields similar to those achieved by hybrids. Nevertheless, there is a growing interest in open pollinated corn in part because of perceived differences in quality. Protein contents for the open-pollinated corn has generally ranged between 9 and 11 % in previous years but we have not measured it yet this year. Generally hybrid seed has 8.5 to 9.5% protein.

A major question that confronts us now relates to the GMO issue. Is our corn free of GMO contamination? We don't know. It is probably possible to breed non-compatibility genes into our corn that would allow them to not accept pollination from hybrid dents. Two such genetic systems exist and I am presently exploring their potential.

Outreach:

Our progress with the open pollinated corn was highlighted at a field day held at Lakeland (Walworth County) farm on Sept. 22. The conference was attended by 35 people, mostly farmers. Afterwards, the farm of Walter Moora was toured to show a field planting of Nokomis Gold relative to a hybrid. (110 bu/acre for Nokomis Gold, 130 bu/acre for the hybrid). Four farmers were shown how to select corn from the stand and were allowed by Moora to harvest corn for their own use as seedcorn. Two field days were held on the farm of Mike Hartmann, Gibbon, Minnesota. About a dozen farmers attended the first (mid-July) and ten farmers attended the second (Sept. 30.). In the first workshop, farmers were shown how to make their own selections before flowering; in the second workshop they were shown how to make selections at harvest.

I carried out mass selection on several organic farms with the variety Nokomis Gold 98 under their normal field conditions. Farmers either did the selection themselves, were assisted by us in making selections, or I made selections for them. Cooperating farmers included John Pounder (Delavan, Wisconsin), Dick Zinniker (Elkhorn, Wisconsin), Walter Moora (East Troy, Wisconsin), Don Adams (Madrid, Iowa), Dan Specht (McGregor, IA), Steven Adams (Vrioqua, Wisconsin), and Mike Hartmann (Gibbon, Minnesota). The selected corn will be planted again in the following years and hopefully re-selected each year. Seed from each harvest will be kept and eventually grown out together to on farms to show whether we have made progress.

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