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

**General topic:** Weed management in organic corn; seed breeding

**Project Title:**

# *Methods to breed field corn that competes better with weeds on organic farms*

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## 1. Project Summary

Researchers at the Michael Fields Agricultural Institute (MFAI) tested methods for evaluating corn for its ability to compete with weeds using corn that was bred under organic conditions and conventional conditions. Corn was grown in two experiments with three adjacent replications on an organic farm. A parallel study took place on a conventional farm.

The first experiment contained 181 varietal entries. This included many varieties which had been selected multiple years under organic conditions, crosses between these varieties (varietal hybrids), crosses between these varieties and commercial inbreds (topcrosses), and hybrids made by crossing inbreds that were bred under conventional conditions. Many of these same varieties and crosses were also grown on a conventional site using herbicides and mineral N fertilizer by USDA cooperators. The second experiment contained 104 entries including 4 conventionally bred hybrids and varietal hybrids made by crossing numerous lines of three corn varieties that are in a reciprocal recurrent selection program under organic management.

We applied customary weed control practices (harrow, rotary hoe, inter-row cultivation) used under organic farming conditions to control weeds on the organic sites. On those sites three additional treatments were applied to each plot. They consisted of 1) hand weeding a meter-long strip in the plot when the corn was approximately 6 inches tall; 2) hand weeding a second meter-long strip and planting sunflowers between the corn plants; 3) allowing whatever weeds were there to grow on the rest of the plot without additional control measures. Weeds were visually scored in September as % of total green in the lower 1 m height of the canopy in the unweeded portions of the plot. Dry matter of the sunflowers was also measured in the fall as a response variable. Grain yield was determined by hand harvesting meter-long subplots and by harvesting the rest of the plot afterwards with a plot combine.

Unusually wet conditions affected plots along the periphery of the field. Attempts made to analyze the data with analysis of variance programs that correct for geographic factors did not produce adequate results. We intend to continue to try to remedy this problem in the near future. However, for an initial examination of the existing valid data we discarded data from areas where there were contiguous low yields between neighboring plots. Means were calculated for the rest of the plots. Results with grain yields and weed growth were as follows:

Crosses between MFAI populations and commercial inbreds (topcrosses) yielded very similar to commercial organic hybrids from Blue River Hybrids/NC+.
Single cross hybrids from Ohio State University, which had been bred under conventional conditions, appeared to produce the highest yields on average.
Crosses between populations (varietal hybrids) generally averaged somewhat lower yields than the topcrosses or commercial hybrids. However, some varietal hybrids produced similar yields to the highest yielding commercial hybrids.
The amount of hybrid vigor for grain yield that was found by crossing populations averaged only 10% in the first experiment and less in the second experiment (mid-parent heterosis).
The ranking of yield performance for different hybrids appeared to differ strongly according to whether the corn was grown under conventional conditions, organic conditions without weeds, or organic with weeds. Therefore, it is probably best to test

varieties for organic production in organic fields where there are moderate populations of weeds because those are conditions that are most realistic.

In 2006 the ability of the populations that were bred under organic conditions to compete with weeds appeared to be superior to commercial organic hybrids. Weed foliage density scores were 2-3 times higher for commercial organic hybrids than for hybrids selected under organic conditions, and sunflowers grew twice as heavy in mixture with the commercial hybrids than with the MFAI hybrids.

Both scoring and utilization of sunflowers as a test weed appeared to be a practical method for assessing the competitiveness of corn entries. Growing the sunflowers had the advantage of providing a uniform "weed" in areas where native weeds produced patchy irregular stands.

The ability of the MFAI varieties and varietal hybrids to compete with weeds has improved over time as the populations were selected multiple years under organic conditions. Breeding corn under organic conditions (with weeds) seems to result in plants that compete better with weeds.

## 2. Introduction to topic

Corn is the highest producing cereal in most parts of the Midwest and Eastern US, and its use is having increasing significance for organic meat production. On organic farms weeds can be a major problem in growing field corn, especially in cool wet springs when weeds in the row are not controlled on time. When weeds get out of hand they can reduce corn yields and their seed bank can assure higher weed pressure in subsequent years. Surveys of organic farmers in the Upper Midwest suggested that there was a need to develop corn varieties that compete better with weeds. There is little evidence in the scientific literature that it is possible to breed corn with that capability. However, it is commonly thought that corn varieties that develop a tall, dense canopy shade the most and should be the most competitive. In the season of 2002 we gained some evidence that by breeding under organic farming conditions, researchers at MFAI may have unintentionally selected corn with an enhanced ability to suppress weeds. Our evidence also suggests that this competitive ability may be caused more by what is going on in the soil than by the canopy, and that the ability to suppress weeds can be inherited.

## 3. Objectives Statement

Our overall objective is to breed high quality, high yielding corn for organic farmers that suppresses weeds and is relatively unaffected in yield by weed competition. Specific project objectives set out in our proposal were to: 1) develop *practical* ways to select corn both for the ability to suppress weeds and for resisting the yield reduction associated with the presence of weeds; 2) select corn for these abilities from two populations that yield well when crossed together.

These objectives were expanded in that we tested corn from a larger set of our breeding varieties and hybrids than we had initially planned. We adjusted our methods as well. Subplots that were hand weeded were smaller than originally intended. Also, we inserted a new treatment: planting sunflowers into the growing corn and measuring sunflower dry weight in the fall. We did this because weed pressure was uneven and we needed to have a uniform response variable measuring corn competitiveness.

## 4. Materials and Methods

These experiments were carried out in Southeastern Wisconsin at the MFAI North Farm in Elhorn. The farm and its soils were developed on a typical mixture of forested, prairie, and oak Savannah soils. The site receives approximately 32 inches of precipitation per year and is characterized by a continental climate with a cold winter and a warm summer.

The farm has been under organic certification since the 1990's and is currently certified by Stellar Services as an organic farm. The soil where the trials took place is a Sebewa silt loam (mollisol, mixed, mesic).

We carried out two side-by-side experiments. The first experiment was intended to evaluate different varieties we have been developing and their hybrids. These populations were classified on the basis of their pedigrees into two "heterotic groups." The populations AR21M, AR21B, AR1635, AR35B, BS28, CGSS, FS, FS97, and UR05B are considered to belong to the "stiff stalk heterotic group." The populations AR26M, AR56M, BS29, CH5M2, GQN2, PascoM2, UR1M1, and UR85N2 are considered to belong to the "non-stiff stalk heterotic group." We made crosses between these two heterotic groups because they are regarded as complementary, resulting in hybrid vigor and yield increase over parental yields per se.

The 181 varietal entries are listed in Appendix 1, Expt. 1 entries. On that list are many varieties, crosses between varieties (varietal hybrids), crosses between our varieties and commercial inbreds (topcrosses), and hybrids bred under conventional conditions. The varieties listed were mostly bred at MFAI for 4 to 6 years. Many crosses were with Nokomis Gold (NG) which has been under selection for 16 years. Many of these same varieties and crosses were also grown on a conventional site using herbicides and mineral N fertilizer by USDA-ARS cooperators in 2006 on the Brunk Farm near Eldora, Iowa, using the same techniques to plant plots but only two replications.

The second experiment was meant to test the competitiveness of hybrids that have been developed through a half-sib reciprocal recurrent selection technique in which we test which lines of each variety do best in combination with a bulk combination of the other lines and then recombine the best the next year to complete a cycle of selection. NG has been found to make high yielding hybrids in crosses with two other populations (AR and FS). NG is a diverse population from our breeding program that has demonstrated the ability to compete well with weeds. AR is a population that has been developed by crossing Argentine 16021 (a very high yielding landrace from Argentina) with inbred B73. FS is a population developed by crossing Florida Synthetic 8AS with inbreds in the stiff stalk heterotic group. Both AR and FS are in their second cycle of being selected for their combining ability in hybrids with NG, and NG is in its second cycle of being selected for combining ability with AR or FS. Crosses between NG and AR yielded as well or close to yields of hybrid checks in 2004 in Wisconsin. Experiment 2 contained 104 entries and 3 replications (see Appendix 2, Expt. 2 entries). This included four conventionally bred hybrids and varietal hybrids made by crossing numerous lines of NG x AR, NG x FS, AR x NG, FS x NG.

Corn was planted on May 24, 2006, with a two-row plot planter. The two-row plots were spaced with 30 inches between rows. Plots were 17.5 feet in length and 30 seeds were planted in each row. We applied customary weed control practices (harrow, rotary hoe, inter-row cultivation) used under organic farming conditions to control weeds. Three additional treatments were applied to each plot. They consisted of 1) hand weeding a meter-long strip in the plot when the corn was approximately 15 cm tall; 2) hand weeding a second meter-long strip and planting sunflowers between the corn plants; 3) no additional weed control on the rest of the plot. Sunflowers were planted between corn plants; one sunflower was planted for every single corn plant in Experiment 1, but in Experiment 2, one sunflower was allowed to grow for every other corn plant. Weeds were visually scored in September by standing in the middle of each plot and estimating the percentage of total green in the lower 1 m height of the canopy in the unweeded portions of the plot that was due to weed biomass. Sunflower tops were harvested in the last week of August and dry matter of each entire sunflower plant was determined. Data were expressed as average dry weight/sunflower plant. Grain yield was determined by hand harvesting meter-long subplots by hand after grain had reached black layer (in the last week of September and into October), and by harvesting the rest of the plot afterwards with a plot combine. Moisture was determined at harvest, which took place on January 8$^{th}$-10$^{th}$, 2007. All grain yields were expressed at 15.5% moisture with a bushel weight of 56 lbs/bushel.

**5. Project Results**

The site chosen for the experiment was low lying and suffered from excessive moisture on its periphery. Plants in waterlogged areas were stunted and did not compete as well with sunflowers as those grown on drier ground. Charts of the grain yield results showed many contiguous areas with low yields that clearly related to wet areas (see Appendix 3, yield map).

Following a search for programs that could do analyses of variance and account for geographical variation, we attempted to analyze our data with a program developed by CIMMYT called ASReml. However, we were unsuccessful in achieving results that indicated that the program had compensated sufficiently for the correlated responses associated with waterlogging. Following on a suggestion by University of Wisconsin corn breeder James Coors, we decided to reject data from any plot that yielded less than 100 bushels per acre where there were two other adjacent plots that yielded the same. Means were calculated for the remaining data. Results are summarized in accompanying tables.

Table 1 shows the average yield and yield results obtained in Experiment 1, grouped into hybrids with similar breeding history.

**Table 1. Grain yield results from weed trial in 2006 at MFAI farm (Experiment 1).**

| | No. of crosses tested | average plot yield bu/a | highest yielding cross bu/a | lowest yielding cross bu/a | average grain moisture content % |
|---|---|---|---|---|---|
| ***Cross conventionally bred inbreds (single cross hybrids)*** | | | | | |
| Blue River hybrids | 4 | 138 | 147 | 132 | 16.6 |
| Ohio State Univ. test hybrids | 20 | 155 | 206 | 124 | 16.8 |
| ***Cross conventionally bred inbred with MF populations (topcrosses)*** | | | | | |
| LH185 x MF | 3 | 147 | 163 | 123 | 17.4 |
| LH198 x MF | 4 | 144 | 188 | 118 | 16.9 |
| FR1064 x MF | 8 | 136 | 149 | 119 | 17.2 |
| FR2108 x MF | 4 | 143 | 164 | 133 | 16.6 |
| FR3911 x MF | 7 | 137 | 159 | 110 | 16.7 |
| FR6943 x MF | 3 | 115 | 135 | 101 | 16.8 |
| ***Cross conventionally bred population x MF populations (varietal hybrids)*** | | | | | |
| CGSS x MF | 8 | 112 | 138 | 101 | 16.6 |
| HPALC x MF | 7 | 126 | 139 | 113 | 16.6 |
| ***Cross between MF populations (varietal hybrids)*** | | | | | |
| BS28 x MF | 9 | 122 | 131 | 108 | 17.1 |
| AR1635 x MF | 8 | 127 | 135 | 118 | 18.0 |
| AR21 x MF | 7 | 119 | 137 | 99 | 16.9 |
| FS97 x MF | 9 | 121 | 145 | 108 | 17.2 |
| AR21B x MF | 11 | 127 | 151 | 110 | 17.7 |
| AR35B x MF | 9 | 125 | 140 | 111 | 16.9 |
| FS x MF | 8 | 124 | 133 | 114 | 17.0 |
| UR05B x MF | 9 | 128 | 144 | 111 | 16.9 |
| NG x MF | 18 | 120 | 141 | 112 | **16.9** |

Single cross hybrids from Ohio State University, which had been bred under conventional conditions, appeared to produce the highest yields on average. Crosses between MFAI populations and commercial inbreds (topcrosses) yielded very similar to commercial organic hybrids from Blue River Hybrids. Crosses between populations (varietal hybrids) generally averaged somewhat lower yields than the topcrosses or commercial hybrids. However, some varietal hybrids produced similar yields to the highest yielding commercial hybrids. Table 2 shows the relationship between corn varieties, weed and sunflower growth, and corn yield for Experiment 1.

## Table 2. Weed trial in 2006 Experiment 1.

| | weed score % | weight grams/sunflower | grain yield hand weeded bu/a | grain yield with weeds bu/a |
|---|---|---|---|---|
| ***Cross conventionally bred inbreds (single cross hybrids)*** | | | | |
| Blue River hybrids | 24 | 2.2 | 168 | 130 |
| Ohio State Univ. test hybrids | 17 | 1.7 | 203 | 145 |
| ***average*** | **20** | **1.9** | **185** | **138** |
| ***Cross conventionally bred inbred with MF populations (topcrosses)*** | | | | |
| LH185 x MF | 4 | 1.6 | 196 | 137 |
| LH198 x MF | 16 | 0.6 | 184 | 138 |
| FR1064 x MF | 22 | 1.1 | 166 | 128 |
| FR2108 x MF | 12 | 1.0 | 182 | 136 |
| FR3911 x MF | 10 | 0.6 | 171 | 131 |
| FR6943 x MF | 13 | 0.8 | 152 | 107 |
| ***average*** | **13** | **0.9** | **175** | **129** |
| ***Cross conventionally bred population x MF populations (varietal hybrids)*** | | | | |
| CGSS x MF | 11 | 1.4 | 138 | 106 |
| HPALC x MF | 10 | 1.8 | 155 | 121 |
| ***average*** | **11** | **1.6** | **146** | **113** |
| ***Cross of MF population x MF populations (varietal hybrids)*** | | | | |
| BS28 x MF | 10 | 0.8 | 142 | 118 |
| AR1635 x MF | 10 | 1.5 | 155 | 122 |
| AR21 x MF | 8 | 1.7 | 155 | 112 |
| FS97 x MF | 9 | 0.3 | 136 | 116 |
| AR21B x MF | 7 | 1.0 | 148 | 121 |
| AR35B x MF | 7 | 1.3 | 166 | 115 |
| FS x MF | 12 | 1.1 | 142 | 120 |
| UR05B x MF | 9 | 1.5 | 156 | 123 |
| NG x MF | 8 | 0.9 | 149 | 113 |
| ***average*** | **9** | **1.1** | **150** | **118** |

In general the sunflowers did not grow well under the corn. The ability of the populations that were bred under organic conditions to compete with weeds appeared to be superior to commercial organic hybrids. Weed foliage density scores were 2-3 times higher for commercial organic hybrids from Blue River than for hybrids selected under organic conditions. Sunflowers grew twice as heavy in mixture with the commercial hybrids than with the MFAI hybrids. Some of the topcrosses between MFAI populations and commercial, conventionally bred inbreds

FR1064 and LH198 also had high weed scores. However, varietal hybrids consistently had both low weed scores and lower weights of sunflowers.

Inspection of the ranking of yield performance for different hybrids appeared to differ strongly according to whether the corn was grown under conventional conditions, organic conditions without weeds, or organic with weeds (see Appendix 4, Expt. 1 yields and Table 3 below). There were exceptions to this. In general, crosses with GQN2, FS97, and AR21B yielded relatively well on all sites while crosses with early varieties CGSS or AR21 did not. Furthermore, varieties that yielded the highest per se, such as NG or UR85N2 did not necessarily yield well in crosses.

The average data from this experiment are shown in Appendix 5, Expt. 1 yield list.

**Table 3. Ranking of varieties by heterotic group and highest yield in crosses on three sites for Experiment 1.**

| Brunk Farm Conventional | | | |
|---|---|---|---|
| | per se | in crosses | no crosses |
| **Non-stiff stalk group** | | | |
| GQN2 | 56 | 110 | 12 |
| AR56M | 73 | 108 | 12 |
| BS29 | 54 | 108 | 12 |
| AR26M | 59 | 105 | 12 |
| CH5M2 | 71 | 104 | 12 |
| UR85N2 | 88 | 102 | 12 |
| PascoM2 | 61 | 101 | 12 |
| UR1M1 | 32 | 98 | 12 |
| NG | 92 | | |
| | | | |
| **Stiff stalk group** | | | |
| FS97 | 89 | 121 | 8 |
| AR1635 | 103 | 113 | 8 |
| BS28 | 82 | 112 | 8 |
| AR21B | 88 | 110 | 8 |
| NG | 92 | 108 | 8 |
| AR35B | 80 | 108 | 8 |
| FS | 49 | 107 | 8 |
| UR05B | 96 | 102 | 8 |
| AR21 | 73 | 101 | 8 |
| CGSS | 71 | 75 | 8 |

| MFAI hand weeded | | | |
|---|---|---|---|
| | per se | in crosses | no crosses |
| **Non-stiff stalk group** | | | |
| GQN2 | 154 | 162 | 8 |
| PascoM2 | 121 | 158 | 8 |
| NG | 163 | 157 | 6 |
| UR1M1 | 130 | 157 | 8 |
| AR26M | 150 | 155 | 8 |
| AR56M | 135 | 155 | 8 |
| CH5M2 | 122 | 152 | 8 |
| UR85N2 | 182 | 150 | 8 |
| BS29 | 145 | 142 | 7 |
| | | | |
| **Stiff stalk group** | | | |
| AR35B | 141 | 164 | 9 |
| AR21B | 139 | 156 | 9 |
| FS97 | 116 | 155 | 9 |
| AR1635 | 145 | 154 | 9 |
| UR05B | 152 | 153 | 8 |
| BS28 | 119 | 153 | 8 |
| AR21 | 112 | 149 | 9 |
| NG | 163 | 149 | 8 |
| FS | 148 | 145 | 6 |
| CGSS | 133 | 134 | 7 |

| MFAI with weeds | | | |
|---|---|---|---|
| | per se | in crosses | no crosses |
| **Non-stiff stalk group** | | | |
| GQN2 | 128 | 129 | 9 |
| BS29 | 98 | 123 | 7 |
| UR1M1 | 124 | 123 | 9 |
| CH5M2 | | 120 | 9 |
| PascoM2 | 137 | 116 | 8 |
| NG | 119 | 114 | 7 |
| AR26M | 117 | 113 | 8 |
| UR85N2 | 128 | 111 | 8 |
| AR56M | 94 | 111 | 9 |
| | | | |
| **Stiff stalk group** | | | |
| UR05B | 117 | 127 | 9 |
| AR21B | 105 | 122 | 8 |
| FS97 | 83 | 121 | 9 |
| AR1635 | | 121 | 8 |
| FS | 121 | 120 | 7 |
| BS28 | 113 | 119 | 8 |
| NG | 119 | 114 | 7 |
| AR21 | 95 | 112 | 6 |
| AR35B | 111 | 110 | 8 |
| CGSS | 112 | 109 | 8 |

Results with Experiment 2 were similar to those obtained with Experiment 1 (see Table 4). The commercial hybrids averaged higher yields under weed free conditions but many of the varietal hybrid combinations averaged as well under conditions where weeds were present. Furthermore, there were higher ranging yields for individual combinations of MF hybrids than for the commercial hybrids.

Similar to Experiment 1, the MFAI hybrids showed 2-3 times lower weed scores and much lower sunflower weights than did the commercial Blue River organic hybrids.

The amount of hybrid vigor for grain yield that was found by crossing populations averaged only 10% in the first experiment and less in the second experiment (mid-parent heterosis).

**Table 4. Weed scores, sunflower dry weight, and corn yields from Experiment 2.**

| No. var | variety | weed score in % of green canopy | dry weight in grams/ sunflower | Grain moisture content % | Corn yield grown + sunflowers bu/a | corn yield hand weeded bu/a | Corn yield + weeds bu/a | overall yield entire plot bu/a |
|---|---|---|---|---|---|---|---|---|
| 1 | AR pool | 15 | 2.8 | 17.2 | 162 | 112 | 106 | 112 |
| 1 | FS pool | 12 | 0.3 | 16.9 | 148 | 183 | 113 | 123 |
| 1 | NG pool (AR) | 3 | 0.9 | 17.1 | 174 | 138 | 125 | 131 |
| 1 | NG pool (FS) | 2 | 2.5 | 17.1 | 166 | 152 | 123 | 130 |
| 26 | AR/NG crosses | 8 | 1.2 | 17.2 | 153 | 153 | 119 | 125 |
| 19 | FS/NG crosses | 9 | 1.8 | 17.0 | 146 | 157 | 111 | 119 |
| 25 | NG/AR crosses | 8 | 1.4 | 17.0 | 147 | 150 | 113 | 119 |
| 18 | NG/FS crosses | 10 | 0.9 | 16.9 | 146 | 155 | 118 | 124 |
| 3 | NG/HQ crosses | 7 | 1.0 | 17.0 | 165 | 139 | 115 | 122 |
| 4 | Hybrid Checks | 22 | 4.0 | 16.7 | 194 | 178 | 124 | 136 |
|  | Weighted Average | 10 | 1.6 | 17.0 | 154 | 156 | 118 | 125 |

**6. Conclusions and Discussion**

The results presented here are preliminary. It still may prove possible to obtain a better estimate of means that include discarded data using special computer programs, and we will pursue that avenue.

However, results suggest that some of the MFAI hybrids are competitive for yield under organic conditions where weeds are present. As was mentioned above, the ranking of yield performance for different hybrids appeared to differ strongly according to whether the corn was grown under conventional conditions, organic conditions without weeds, or organic with weeds. It is probably best to test varieties for organic production in organic fields where there are moderate populations of weeds because those are conditions that are most realistic.

There are large differences in weed control in favor of corn that has been bred under organic conditions. These results are similar to those achieved in competition trials carried out with Nokomis Gold and giant ragweed in 2002. Here is what we wrote about that experience:

*Giant ragweed has an unusual ability to shade crops. Due to this it has proved to be the most competitive weed with corn in our area and on some fields has precluded organic farmers from being able to grow corn. In 2002 on a second organic farm, we grew large, replicated plots of different corn populations or hybrids on rich farm soil with a severe infestation of giant ragweed. Within each plot we had mini plots containing weeded plots and plots that contained* *equal numbers of corn and giant ragweed plants. Weed biomass and grain yield were determined on the mini plots and large plots. We measured light interception in the canopy of corn twice during the growing season with a fleck photometer in the weeded areas to determine if shading characteristics of the corn canopy were key for suppressing ragweed. The corn we grew included:*

> *a variety called Nokomis Gold which was bred by MFAI under organic conditions and has been released for organic farmers;*
> *seven hybrids between Latin American corn and public inbreds B73, and 11 hybrids between Latin American corn and Mo17. B73 and Mo17 represent the two most common heterotic groups ('Stiffstalk' and 'Lancaster') that are used by breeders to breed corn;*
> *crosses between Nokomis Gold and the above hybrids.*

*Results were as follows:*

> *Nokomis Gold suppressed weeds more than the hybrids. At harvest, Nokomis Gold had 1/3 less weed biomass than did the hybrids between Latin American corn and B73 and 39% less weed biomass than the hybrids with Mo17. Crossing Nokomis Gold with the hybrids that contained B73 or Mo17 reduced weed biomass by an average of 14% and 33% respectively. Obviously, Nokomis Gold could suppress weeds and convey some of this ability to its offspring. Furthermore, some of the hybrids with Nokomis Gold were competitive in yield with check plots of hybrids.*
> *There was no significant relationship between light interception by the canopy of the corn and the ability of the corn to suppress giant ragweed. This suggests but does not prove that interactions in the soil may be associated with the ability of Nokomis Gold to suppress weeds.*

The varieties that were crossed with Nokomis Gold in 2002 were continuously selected under organic conditions in that year and the following years. In 2006 they were grown by themselves and in crosses for the sixth season under organic conditions in the experiments we presented above. It appears that over time they have become more competitive with weeds and thereby similar to Nokomis Gold. (For data on individual cultivars see Appendix 5, Expt. 1 yield list.) In 2006 the average percent score for weediness was 7% for 17 varieties grown without crossing, and the average weight of sunflowers was 1.7 grams. For Nokomis Gold these values were 8% and 0.9 grams, respectively. For the four Blue River (NC+) Hybrids, the values were 24% and 2.2 grams. Crosses between MFAI varieties often had lower sunflower yields than did the parental varieties (see Table 2).

In general there was a substantial decrease in yield associated with the presence of weeds. The yields of some high yielding hybrids responded very negatively to the presence of weeds whereas some of our hybrids did not. Our technique was not good enough to know for sure whether the effects we saw due to weeds might not have been confounded with selection of the best parts of the plots for hand weeding and sunflower response subplots.

The study was useful and applicable to other organic farms. Problems encountered during the trial had mainly to do with waterlogging. A larger set of our corn breeding stocks were tested than we had initially planned. Our project identified which corn varieties compete best with weeds, and developed new methods for accessing competition. Next steps would include 1) looking at a small set of cultivars and attempting to understand the nature of the competitive mechanism; 2) refining our methods for selecting corn so as to improve its ability to compete with weeds; and 3) applying such methods to breed corn with high yield potential that is very competitive with weeds, and is little affected by them in terms of yield.

**Outreach:** Results were presented at a field day on Sept. 15, 2006, in East Troy, Wisconsin, where weed scores were presented, and at the annual meeting of the USDA/ARS-MFAI-Practical Farmers of Iowa project called 'Developing high quality corn for sustainable farming in the Upper Midwest' on Feb. 27, 2007. Results were also presented to a group of 200 organic farmers and advisors in Quebec at the beginning of December, 2006.