2006 NCCC167 Annual Report from North Dakota State University (NDSU)

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Mission of unit:

The goal of the corn-breeding program at NDSU is to conduct research in basic and applied corn breeding for the northern Corn Belt emphasizing germplasm adaptation and improvement, inbred line and population development, and hybrid testing as well as training the next generation of plant breeders. Specific objectives are:
1) Identify elite exotic genetic materials for adaptation
2) Maximize genetic improvement of corn germplasm adapted to North Dakota
3) Develop early maturing maize inbred lines and populations for northern U.S.
4) Coordinate hybrid maize performance testing trials
5) Assess profitable alternatives (e.g. corn-ethanol relationship)
6) Train the next generation of breeders

NDSU has over 75 years of corn breeding research with a large tradition on research and utilization of its products. The NDSU corn breeding program is unique because it is the only U.S. North American public program that develops very early maturing drought tolerant (with drying costs rising) corn lines and hybrids while actively training the next generation of breeders (MS and Ph.D. Graduates). The NDSU corn breeding goals relative to ND producers are early maturity and yield/moisture performance index (identifying those early-maturing hybrids that outperform late-maturing ones), above average lodging resistance and test weight, excellent drought and heat tolerance and stability across locations, good emergence in cool soils, early seedling vigor, disease and pest Resistance (e.g. including GMOs), and value-added traits (e.g. quality and bio-fuels).

The NDSU corn breeding program has grown to a record of 20,000 plots across 15 locations and our products have extensively been requested by industry. In 2006 we continued a nursery for drought tolerant research, maintained our large cooperation with industry, and increased our testing efforts maintaining two winter nurseries (on site cooperation for two seasons per year), one greenhouse (three seasons per year), one disease nursery, and one shared molecular and quality lab with the potential and target of testing quality samples for the whole breeding program currently at 20% (~4-5,000 plots).

Breeding for Local Adaptation

Local adaptation is essential for ND environmental challenges. These environmental challenges are mainly the short period between killing frosts, the limited heat supply, and the limited rainfall. Therefore, grain quality, test weight, drought tolerance, cold tolerance, early seedling vigor, uniform emergence in cold soils, dry down, and early maturity are very important characteristics essential to a ND hybrid (as evident as grain yield). Our program has focused toward these farmer goals especially in 2006. We develop elite populations, inbreds, and their respective hybrids. We had about 40 requests for germplasm from other public and private programs last year, mainly inbred lines due to fast dry down, early maturity, good performance and quality, and because of new sources of genetic diversity within early maturing germplasm. Ethanol plants will only utilize ND corn hybrids if they are early maturing with above average drought tolerant, grain quality, and stand ability

Germplasm Adaptation and Improvement

Adaptation and germplasm improvement efforts have continued due to our long-term cooperation with the USDA-GEM program and our efforts on intra and inter-population recurrent selection programs. We currently have four full-sib reciprocal recurrent selection programs that address the creation of new heterotic patterns for the region and are a consequence of the extensive testing performed for choice of germplasm. NDBSK(HI-M)C3, NDBS11(FR-M)C3, and NDBS1011 were adapted and released as

improved germplasm sources for development of inbred parents for early maturity and high yielding corn hybrids and as elite parents for early maturing maize population hybrids (see 2007 NCCC167 release note). Other tropical and late temperate elite populations are under adaptation and extensive testing as well. In 2006, we continued our research devoted to germplasm adaptation with GEM material in the northern Corn Belt. AR16026:S17-66-1-B (coded as GEM21) derived lines, adapted through the incorporation of elite early-maturing line ND2000, were test crossed to LH176 and to a coded Bt commercial tester from Syngenta representing the Iodent heterotic group. Six-year efforts of adaptation are yielding several adapted lines with better yield and agronomic performance than popular hybrid Pioneer 39D82. During this season, we have maintained our four full-sib reciprocal recurrent selection programs involving BS21, BS22, NDSAB, Leaming, CGSS, and CGL derived early-maturing populations after creating new heterotic patterns. We have continued our intra-population recurrent selection efforts for germplasm improvement on populations that have demonstrated good potential for inbred line development.

Non-transgenic Approaches to Drought Tolerance

Even though the ethanol industry is expanding in western ND, corn is still limited in its west extension due to significant environmental challenges, mainly drought. The main economic benefit to the farmer and industry in this state continues to be the current availability of productive early-maturing lines with high starch under abiotic stresses, a priority within the NDSU corn breeding program. Results so far indicate that over 700 ND lines (out of 3,500) have a large potential of transmitting drought tolerance to their hybrids and these were produced in our 2006 summer nursery. Efforts have been initiated to understand the mechanisms of polygenic effects involved in drought tolerance by annually testing over 4,000 genotypes (early generation inbreds and hybrids) through non-transgenic approaches, a complementary approach to industry. This has been made possible by increasing our drought management in winter nurseries and extending our testing efforts.

Grain Quality

Following an award from the state Agricultural Products Utilization Commission (APUC) we have initiated the screening of germplasm for grain quality traits for the development of corn hybrids specific for processing and ethanol utilization. Cooperation with industry has been essential. Our germplasm has shown a great variation for grain quality components. Currently, 20% of our germplasm is being evaluated for grain quality with a long-term target to evaluate all of it. Our corn breeding program has continued its focus on the development of very early-maturing inbred lines reducing the risks associated with late planting, early frost, and low grain quality. Extensive testing across locations have shown that some early-maturing hybrids (in cooperation with certain industries) are similar in grain yield and lodging performance, above average test weight (~3 lb/Bu) and below average grain moisture at harvest (~40 g kg^{-1}) compared to dominant commercial corn hybrids available in ND. Mating design studies including reciprocal crosses have evaluated not only combining ability effects but also maternal and reciprocal effects. Most traits, including endosperm-related traits, have not shown significant maternal and reciprocal effects. In cooperation with industry, we are planning studies for understanding the genetics of test weight and dry down.

Disease Resistance

Two segregating populations ($F_{2:3}$ families) derived from the crosses of ND284 (susceptible) x B100 (resistant) and ND284 x B37 (resistant) were evaluated. A total of 22 QTL(s) were discovered for eyespot resistance across all maize chromosomes (with major effects on chromosome 8) except chromosome 9. The total percentage of the phenotypic variation explained for eyespot resistance differed among traits and populations ranging from 16.1 to 70.1%. This specific study confirms the complexity of this trait and validates our efforts of phenotypic selection for eyespot resistance in our inbred line development process. This research shows the difficulty of the practical significance of performing marker-assisted selection of QTL(s) and real quantitative traits with minor effects, especially those QTL(s) that were not repeatable across populations. Standard errors, false positives, and power of QTL detection have limited our efforts on QTL studies.

Product Development for Short-Season Environments

Inbred Line Development

NDSU supports our major component of inbred line development for research and training purposes. Extensive data was generated from the 2006 field tests across 15 locations with the purpose to determine the relative effectiveness of selection studies for developing new early-maturing genotypes that can be used either in hybrids or as germplasm in pedigree selection programs. These lines are the result of an extensive pedigree selection methodology including thousands of lines and over four years of nursery line screening as well as early and late generation hybrid testing across locations, years, and industry testers. In my judgment, two of the new inbred lines seem promising for use as parents for 70 to 85RM hybrids while four new inbred lines seem promising for use as parents for 85 to 95RM hybrids (See NCCC-167 release note). Our early maturing hybrid trials included 10 experiments grown at three to 15 locations testing over 1,000 ND hybrids at early and late generation stages for yield, maturity, stand ability, and test weight performance. Twenty-three new and early maturing ND experimental lines are at final stages for potential release in the fall of 2008. These lines were sent to Puerto Rico for hybrid seed production each with six commercial inbred lines in cooperation with AgReliant. Meanwhile, 65 new and early ND experimental lines were selected for further testing and release potential in 2009.

Graduate Students

The demand for applied corn breeders is currently very high and training the next generation of breeders continues to be a priority within NDSU. In the past eight years the NDSU corn breeding program has trained an average of one student per year. All of them without exception were hired by industry (Monsanto, Pioneer), USDA, NDSU, and University of Delaware. Half of the Plant Science Ph.D. graduates in 2006 came from our program. Four graduate students (2 Ph.D. and 2 MS) and one visiting scientist (Corn Breeding Director at LAAS, Shenyang, China) were trained in our breeding program during 2006. One Ph.D. graduate was hired by the NDSU Canola Project and another was hired by NDSU as the dry bean breeder. One MS student has successfully defended his thesis and was hired as a Ph.D. corn breeding student at the University of Delaware. Graduate student theses and dissertations focused on molecular studies in disease resistance, conventional breeding approaches to cold tolerance and grain quality, as well as genetic effect estimation through quantitative genetic methods (e.g. mating designs). All graduates are applying what was learned at the NDSU corn breeding program. For instance, Clarissa Barata has expressed that our program has made easier her productivity and progress at Monsanto. Another example is that Juan Osorno has mentioned his willingness to change his dry bean trials to more efficient experimental designs based on his learning at NDSU corn breeding program. In addition to research and advising, I teach two graduate courses (Crop Breeding Techniques and Quantitative Genetics), serve as editor in Euphytica and Maydica, and serve as chair in the maize registration sub-committee of Crop Science Society of America.

Personnel during 2006

M. J. Carena	Project Leader
Duane Wanner	Research Specialist
McDonald Jumbo	MS Graduate (Mating Designs)
Marcelo Melani	Ph.D. Graduate (QTLs/Disease Resistance)
Juan Osorno	Ph.D. Graduate (Genetic Diversity/Quality Traits)
Bahadir Sezegen	MS Student (Cold Tolerance/Recurrent Selection)
Colins Eno	MS Student (Adaptation and Combining Ability)

Publications

Carena, M.J. 2007. Travels in the Genetically Modified Zone. By Mark L. Winston. Cambridge: Harvard University Press, 2005. 288 pp., ISBN 0-674-01529-0. Book review. Ag. Hist. 81:147-148.

Sonnino, A., M.J. Carena, E. Guimaraes 2006. Status of research and development of molecular markers in developing countries. FAO, Rome, IT. Book Chapter.

Carena, M.J. and Z.W. Wicks III. 2006. Maize population hybrids: an exploitation of U.S. temperate public genetic diversity in reserve. Maydica 51:1-8.

Barata, C. and M.J. Carena. 2006. Classification of ND maize inbred lines into heterotic groups based on molecular and testcross data. Euphytica 151:339-349.

Guimaraes, E.P., E. Kueneman, and M.J. Carena. 2006. Assessment of national plant breeding and biotechnology capacity in Africa and recommendations for future capacity building. Hort. Sci. 41:50-52.

Melani, M.D., and M.J. Carena. 2005. Alternative heterotic patterns for the northern Corn Belt. Crop Sci. 45:2186-2194.

Abstracts

Osorno, J., and M.J. Carena. 2006. Characterization of early maize populations based on grain quality traits. *In* Agronomy Abstracts [CD-ROM computer file]. ASA, Madison, WI.

Melani, M., and M.J. Carena. 2006. Identification of quantitative trait loci for resistance to eyespot in maize. *In* Agronomy Abstracts [CD-ROM computer file]. ASA, Madison, WI.

Carena, M.J. and A.R. Hallauer. 2006. Applied U.S. Public and Private Corn Breeding Efforts: Has Biotechnology Solved our Problems? *In* North Central Corn Breeding Research Committee Report. Guelph, ONT.

Editions

Carena, M.J., Lee, E., and Z.W. Wicks. 2006. Report of the sub-committee on uniform tests in the 100-300 maturity series. *In* K.L. Lamkey (Ed.). Report of the Minutes of the North Central Corn Breeding Research Committee (NCR167) Meetings. Minneapolis, MN.

Carena, M.J. and J. Ransom. 2006. North Dakota hybrid corn performance results 2005. (67^{th} Ed.). Circular A-793 (Revised). North Dakota Agric. Exp. Station and Ext. Service.

Field day speaking events

Corn Nursery tours to international scientists

1) 2006 Corn Nursery and trial tour to Syngenta
2) 2006 Corn Nursery and trial tour to Dow Agro Sciences/Mycogen
3) 2006 Minot Field Day (invited)
4) 2006 Sidney Field Day (invited)
5) 2006 Williston Field Day (invited)
6) 2006 Dickinson Centennial Field Day (invited)
7) 2006 Casselton Field Day (invited)
8) 2006 Mon-Dak Field Day (invited)
9) 2006 Mon-Dak Ethanol Workshop (invited)
10) 2006 Irrigation Workshop (invited)
11) 2006 ND Corn Council Utilization Workshop (invited)