

Development of Early Maturing GEM lines with Value Added Traits: Moving U.S. Corn Belt GEM Germplasm Northward

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Introduction:

The NDSU corn breeding program has 80 years of existence focused on the development of early maturing (65-95RM) corn. It is currently the most northern public breeding program in North America what is unique and essential for the development of new and genetically diverse early maturing lines.

The NDSU 'EarlyGEM' is the continuous effort to incorporate GEM germplasm into the northern U.S. Corn Belt with the purpose to increase the genetic diversity of short-season corn. The program started to move elite GEM tropical and temperate corn northward and westward as a source of new and unique elite products.

The NDSU corn-breeding program is one of the few public programs that can still offer a strong emphasis on germplasm adaptation and improvement, inbred line development, and training of applied plant breeders. The NDSU corn breeding program has become a GEM cooperator in 1999 and since then a long-term program has been initiated to increase the genetic diversity of hybrids in the U.S. Northern Corn Belt.

Justification:

North Dakota (ND) producers planted over 2 million acres of corn in 2009. However, industry hybrids are still late maturing, lack stress tolerance, are slow driers, and often end up with poor quality. One of the main reasons is that North Dakota commercial hybrids are mostly bred elsewhere (e.g. southern MN) making their adaptation to short-seasons challenging. Also, the lack of early-maturing industry testers limit the expansion of corn production to the northern U.S. Corn often needs to be harvested at moisture levels too high for safe storage and must be artificially dried for storage and transport. This is still happening as I am writing this report on Nov 17, 2009.

The purpose of this research is to develop early maturing high quality GEM lines for utilization in the northern U.S. Corn Belt. Our hypothesis is that early maturing recovered versions of GEM lines can be obtained retaining grain yield and agronomic and quality traits with the advantage of maintaining useful genetic diversity. New NDSU EarlyGEM lines carry, on average, 12.5 % of the exotic germplasm from GEM.

General Objective:

The long-term goal of the 'NDSU EarlyGEM' program is to increase the genetic diversity of early maturing hybrids through the incorporation of exotic useful germplasm. The purpose of this research is to develop early maturing (90RM) high quality GEM-derived lines for utilization in the northern U.S. Corn Belt.

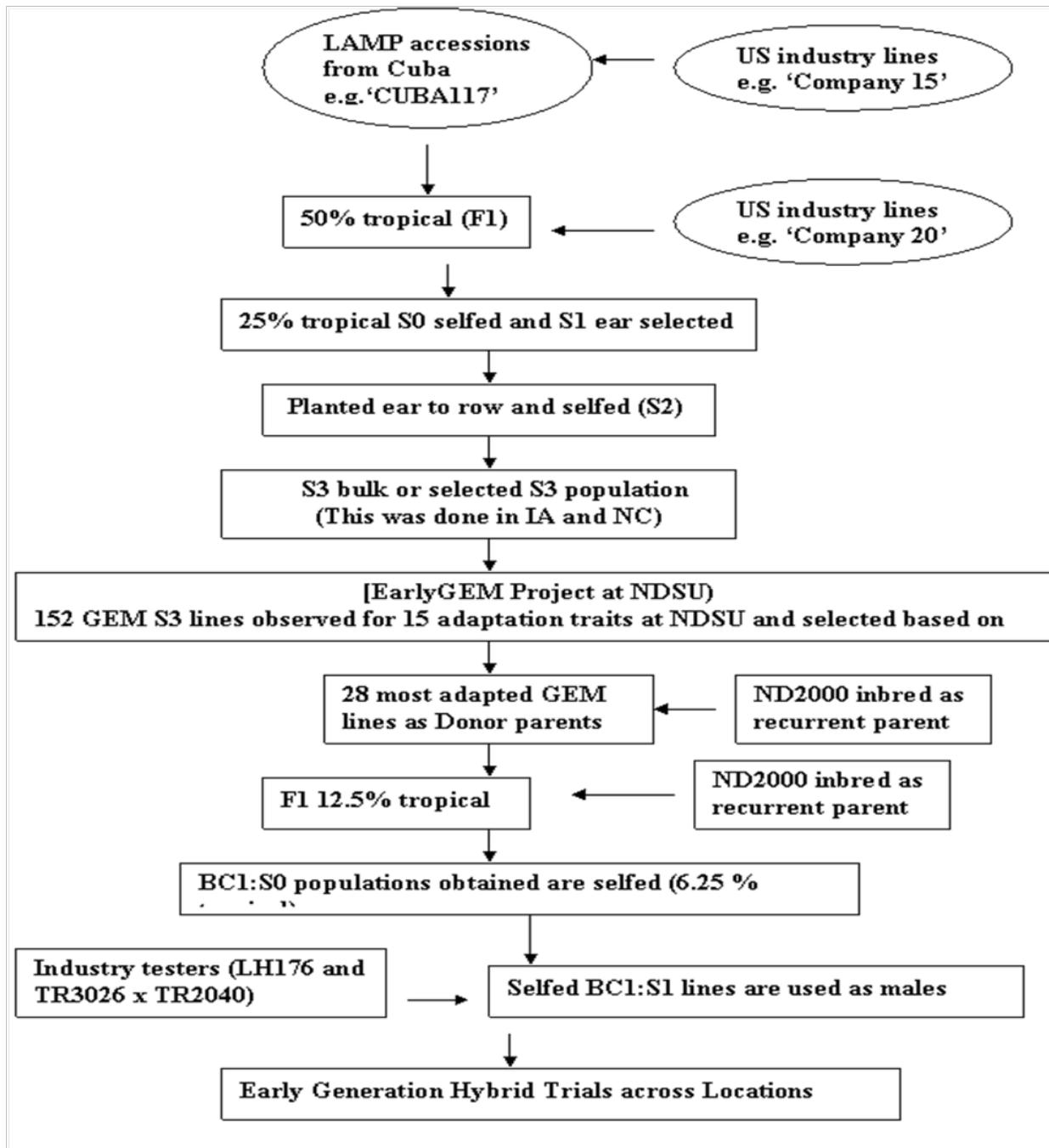
Specific Objectives:

- 1) Incorporate GEM germplasm as donor for high quality and genetic diversity.
- 2) Adapt GEM germplasm to short-season environments.
- 3) Develop new early maturing NDSU EarlyGEM unique lines competitive for industry use.

Germplasm Development

A backcross breeding program was initiated including GEM and ND elite lines to move U.S. Corn Belt GEM germplasm northward and westward. The inspiration of this long-term adaptation program was the backcross breeding program initiated by Dr. Pinnell at University of Minnesota (Rinke and Sentz, 1961) that yielded successful early maturing lines. However, the difference is that our program utilizes early maturing parents as recurrent ones and that only one backcross generation is produced without self-pollination. In 2001 we observed 152 GEM S3 lines from released GEM sets A, B, and C, for fifteen adaptation traits. The most adapted (based on earliness and agronomic data in Fargo, ND) and top yielding genotypes (based on central U.S. Corn Belt GEM trials) were selected and crossed to ND inbred lines. As expected, only 28 early maturing GEM lines were used to develop new populations from late by early crosses (less than 20% of the original GEM lines had potential to be utilized under ND conditions). Early maturing lines were planted at three different planting times in order to have successful seed production. F1 generations were backcrossed to early-maturing lines only once. Later flowering plants were discarded. Also, later maturing F1 generations and others were discarded based on agronomic deficiencies (poor stands, low seedling vigor under cold stress, drought stress, lodging, insect and disease susceptibility, height, and relative maturity). A second round of screening was conducted in BC1:S0 generations. Rows were screened for seedling vigor and checked for uniformity. Plants with below average agronomic characteristics were discarded. Only nine populations were kept to produce BC1:S1 [e.g. (GEMxND2000) x ND2000] elite early maturing lines with approximately 25% GEM germplasm (approximately 12.5% if we also consider industry germplasm used in original GEM crosses). These were selected for inbred line development.

The full procedure of adaptation was summarized by one of our students at the 2009 ASA meetings as:



Note most of our lines are 12.5 % GEM, only 6.25% would be in the final hybrid.

Inbred Line Development

The NDSU Early GEM program started with nine source populations that consist of three Stiff Stalk (SSS) and six non Stiff Stalk (NSS) populations. Stiff Stalk donors (CUBA117:S1520-388-1-B, CHIS775:S1911b-B-B, and AR16026:S17-66-1-B) and non-Stiff Stalk ones (BR52051:N04-70-1, SCR01:N1310-265-1-B-B, FS8B(T):N1802-35-1-B-B, UR13085:N215-11-1-B-B, CH05015:N15-184-1-B-B, and CH05015:N12-123-1-B-B) were advanced through modified pedigree selection with early and late generation hybrid testing across industry testers.

Funding limitations prevented us to evaluate all testcrosses in the same years. NDSU EarlyGEM efforts slowly increased through the years at a point they now represent 35% of NDSU inbred line development (see Figure 1). Thousands of NDSU EarlyGEM lines were planted across locations for early generation visual selection. These locations included breeding and disease nurseries which allowed us to select before flowering and to reduce the number of pollinations. In addition, winter nursery testing of inbreds and hybrids for drought tolerance in managed stress environments was conducted.

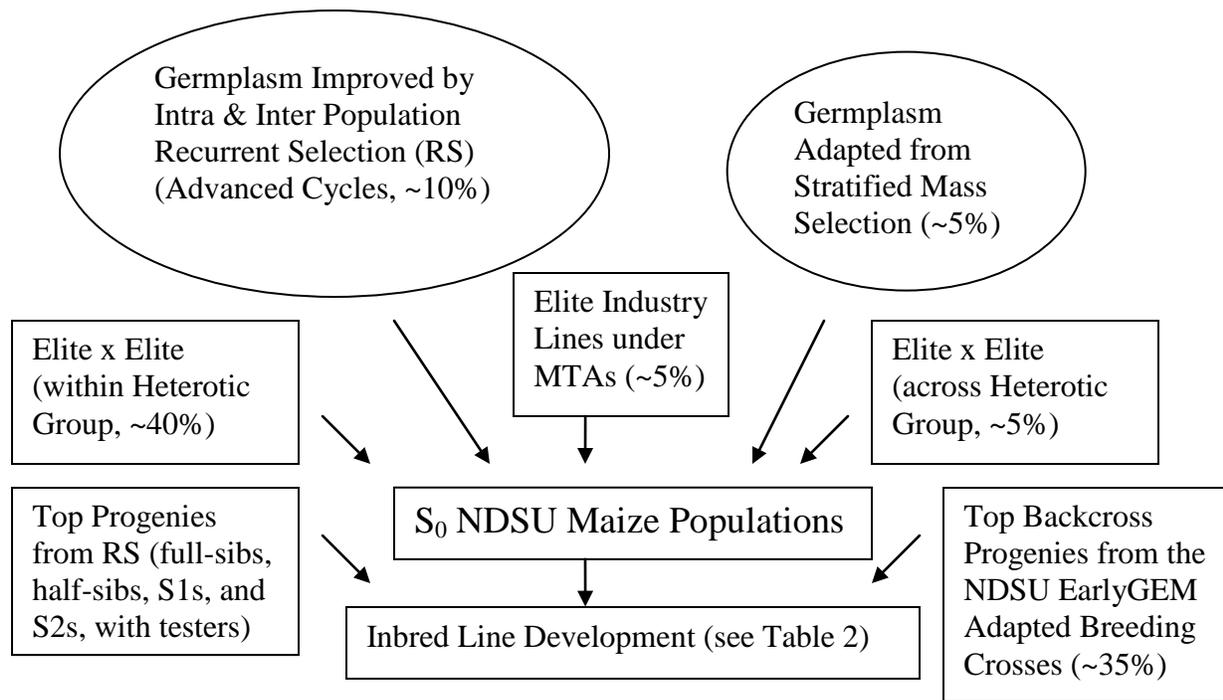


Figure 1. Germplasm pre-breeding sources for NDSU maize inbred line development (adapted from Carena et al., 2009).

Evaluation of 2009 Experiments

a) (AR16026:S17-66-1-B x ND2000) x ND2000 derived NDSU EarlyGEM lines were advanced and testcrossed to four industry industry testers representing the nSS heterotic group in the 2008-2009 winter nursery. Experiments ranging from 64 to 121 entries (depending on testers) were arranged in partially balanced lattice designs with two replications per location. Popular known commercial hybrids were included as checks which they were utilized as criteria for different traits and benchmark for advancing pedigrees. As of Nov. 17, 2009 we have not harvested the experiments. Our plan is to continue advanced late generation testing in 2010 for release decision of first NDSU EarlyGEM lines.

b) Early generation trials of hybrids between industry testers and 400 SS and nSS BC₁:S₁ NDSU EarlyGEM lines were planted in experiments arranged in incomplete block designs. Also, no harvest of these experiments has been possible as of today. Our plan is to duplicate these trials in 2010.

c) Over 1,000 lines were advanced in the 2009 summer nurseries (a duplication of nurseries was made to assess early seedling vigor and emergence percentage across locations and at different planting dates, the more advanced ones with at least three rows per line). They were checked for uniformity and inbred characteristics. Top lines were included in inbred trials across locations and were sent to winter nursery for additional crossing and testing.

d) Three new synthetic varieties based on top NDSU EarlyGEM lines were developed: EarlyGEMa, EarlyGEMb, and EarlyGEMc. At least 500 rows were planted in the summer and winter nurseries for full-sib progeny production, recombination, and population maintenance.

e) 200 new rows were added to the 2009 summer nursery for 24 new early x late crosses between elite early hybrids and/or lines and new GEM breeding lines and crosses. These included:

AR13026:S1523-026-002-B
AR13026:S1523-049-001-B
AR13026:S1523-091-001-B
AR13026:S1523-094-001-B
AR13026:S1523-037-001-B
AR13026:S1523-014-001-B
AR13026:S1523-003-001-B
AR13026:S1523-088-001-B
AR13026:S1523-022-001-B

And populations:

UR11003:S17h49b
AR16021:N2149b
MBRC10:N1749b
CH05015:N4049a

Summary of Accomplishments

Earlier maturing versions of GEM-derived lines (NDSU EarlyGEM lines that are 12-20 days earlier) were produced. Recovered BC₁:S₁ lines (now near homozygosis) from one pedigree could retain yield at ND relative maturity in new hybrid combinations. Preliminary data show several experimental GEM-derived (12.5 % originally exotic) have, among other traits, not only better grain yield performance than popular industry hybrids at similar grain moisture at harvest but also highly significant better performance in grain quality traits and drought tolerance. GEM-derived lines showed over 101% of check mean yield in at least seven cases (second-year data) that were advanced to third year testing confirming unique germplasm with good general and specific combining abilities.

Extensive testing for agronomic traits and nutritional evaluation and analyses of hybrids has continued. We have extended this type of work to the other eight GEM-derived populations that are in need of extensive testing. Benchmarks have increased to 105 % of check mean yield and release decisions will follow. We have developed new early-maturing NDSU EarlyGEM populations to increase our efforts to identify alternative heterotic patterns for the northern U.S. Corn Belt. The new populations were included in a 16-parent diallel mating design produced in the 2009 summer nursery.

This is the first research devoted to <90RM germplasm enhancement with incorporation of tropical and late-temperate genetic materials for unique inbred line development. Winter nurseries with three generations per year are providing new lines in four years. As a consequence of long-term efforts we currently have early maturing NDSU EarlyGEM materials adapted to the northern U.S. Corn Belt which are competitive products for industry use.